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CONTENTS

FOREWORD

The beginning of the scientific conferences in the field of descriptive geometry and engineering graphics dates back to 1953. For years, it has been a gathering place for leading experts in the field of geometry and graphics at which professional and scientific achievements in these fields have been presented. The scientific conferences for one of the professional activities of the association, primarily the Yugoslav Association for descriptive geometry and engineering graphics (JUNGIG until 1997), the Serbian Society for Geometry and Graphics (SUGIG from1997), which discussed the problems of education, human resource issues and the status of geometry and graphics in accordance with modern scientific and technological achievements.

The University of Niš is the host of the XXVII Counseling and the IV International Scientific Conference "moNGeometrija 2014", which is taking place from 20th to 22nd June at Vlasina. The main organizer of the event is the Faculty of Civil Engineering and Architecture and the co-organizers are the Faculty of Mechanical Engineering, the Faculty of Occupational Safety and the College of Applied Technical Sciences in Niš. It gathers scholars from over ten countries and it is supported by SUGIG. The global development of technologies and the availability of information have contributed to better connecting of experts. The tendency of development of moNGeometrija is the inclusion of university centers from other countries in organizing this gathering.

Geometry, one of the oldest scientific disciplines, has been applied in various areas of technology, medicine and the arts. The importance of geometry is great, which is confirmed by its application, actuality and possibility of connection with other areas of modern, multi-disciplinary science. Scientific and professional papers published in recent years have shown an increasing tendency of research with the possibility of direct application in practice. Modern scientific achievements in geometry are applied to computer graphics and the precise visualization of objects from technical practice. The global development of modern digital technology conditioned the development of young professionals whose elementary knowledge is computer technology. Their ideas, substantiated by the knowledge of geometry, are applied in various fields of modern science and represent the future of the development of applicable, multidisciplinary geometry.

We thank the participants of this event and the members of the Scientific Committee from the country and abroad, for their cooperation and support. The great number of works with different topics of geometry and computer technology application confirms the importance of the multidisciplinary approach to researches presented in the Proceedings from the Conference "moNGeometrija 2014".

GEOMETRY AND GRAPHICS APPLIED IN ENGINEERING AND ARCHITECTURE

GEOMETRIC 3D MODELS OF SPIRAL STRUCTURES INSPIRED BY CONTEMPORARY ARCHITECTURE

Luka Kilibarda[1], Milica Milošević[2], Ljubica Tica[3] and Magdalena Dragović[4]

Abstract

This geometric research is inspired by numerous magnificent structures-buildings around the world, which applied spiral geometry. Here we will present some of these architectural wonders and their basic geometric concepts.

The intention of our work is to present the palette of 3D structures modeled in engineering software Auto CAD, where 3D operations with solids were available.

Our concept concerning modeling of spiral building structures follows the basic geometric principles of simultaneous rotating and translating of an element along given geometric axis. The simple geometric shapes of circle, square, triangle and hexagon were combined in order to create the basic unit of spiral structure. We employed repetition of the basic unit, with variations and the moving option in zigzag direction, around the central core (imaginary or real). Fake spiral concept is also included.

As the result, we presented five types of spiral 3D models - structures with their geometric characteristics.

Key words*: contemporary architecture, spiral structure, 3D model, basic structural unit.*

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1. INTRODUCTION

In the last decade, the contemporary architecture characterizes specific and sophisticated spiral geometry, where screw, twisted, swirling, or wrapped shapes of buildings appear. Their interesting structure, elegancy, uniqueness and beauty affects on the observers eye. A lot of interesting buildings in such manner were built around the world: Evolution Tower (in Moscow-Russia), Spiral Tower (in Nagoya-Japan), The Turning Torso (in Malmo-Sweden), Revolution Tower (in Panama City-Panama), etc. All of them surmount great heights and all kinds of influences including gravity, torsion, wind, etc.

Spiral-twisted shapes, or models are the matter of interest and research in various areas, closely connected to architecture and design, like: patent for twisted building construction [3], innovative architectural forms and technologies [5], characteristics of tall building structures [2] etc. Numerous famous architects were challenged by "spiral" design task [1].

Spiral architecture, in our case, was an inspiration for 3D modeling imaginative task: to create 3D structures based on predefined style – 5 geometrical "inspirations". We chose five building structures (some of them are built, while the others are in the design phase, different in geometric concept. The main geometric characteristics were analyzed and applied on new structures. The variations on each type of model are also presented.

2. FIVE 3D GEOMETRIC MODELS WITH "INSPIRATIONS"

Each modeled 3D structure, presented in our research is associated with specific term and geometry, and accordingly named by it: "Two in One", "Fan", "Propeller", "Star" and "Lego". The models were created in engineering software Auto CAD and modeler 3D SketchUp. The dimensions of the geometric shapes were in the second plan, but proportions were emphasized.

2.1 The inspiration No 1.- Two in One

The Mode Gakuen Spiral Tower in Nagoya (design by N. Sekkei) is magnificent building with triple - "wings", tapering towards the top of the building (Fig. 1)[6], which initiated the creative association to the “wrapping” of the central cylindrical core with spiral surfaces.

Figure 1. *Mode Gakuen Spiral Tower in Nagoya; inspiration – "Two in One"*

1. The cylindric corpus of the structure No. 1 is spiraly cut. The basic shape - a circle is cut with two rectangles (Fig.2a). The spiral rotation of the basic unit, along the vertical axis, enables the interfering of both spiral surfaces (outside) and empty space (inside).

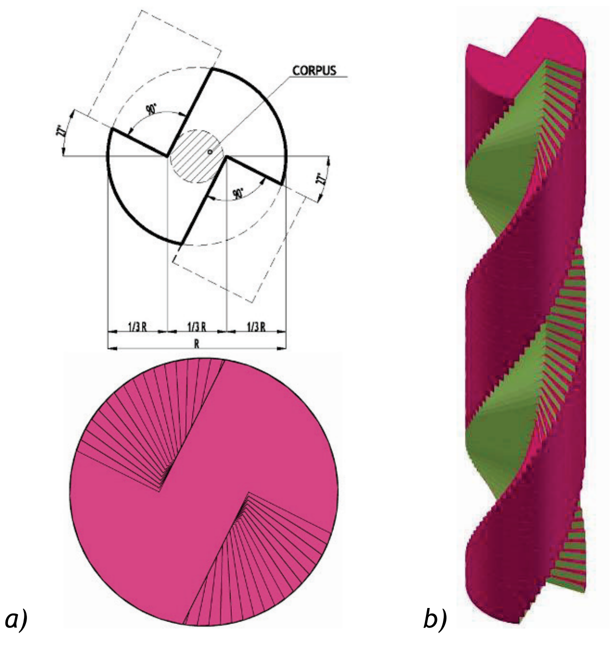


Figure 2. *Structure No.1: a) Floor plan; top view b)3D model*

2.2 The inspiration No 2. – The Fan

2. The idea of central core wrapped with spiral sequence of basic units, like staircase, where the observer clearly distinguishes core from the wrapper, appear in the proposition design for the skyscraper in Abu-Dhabi by Nabito Architects (Fig.3) [7].

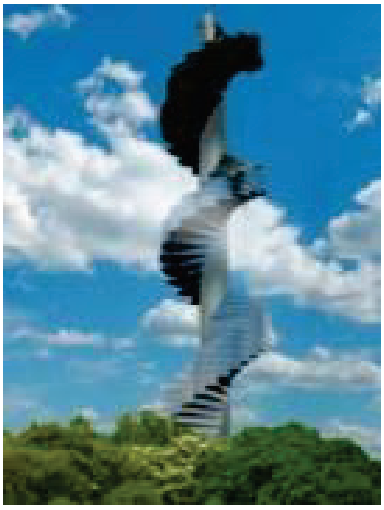
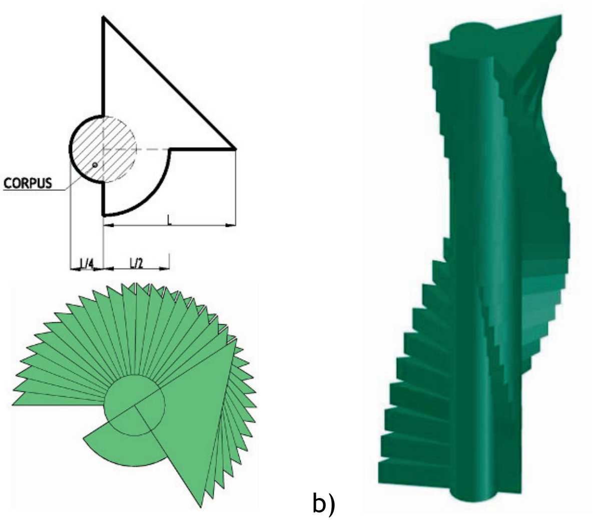


Figure 3.*The winner of New York contest for the design–Abu Dhabi skyscraper*

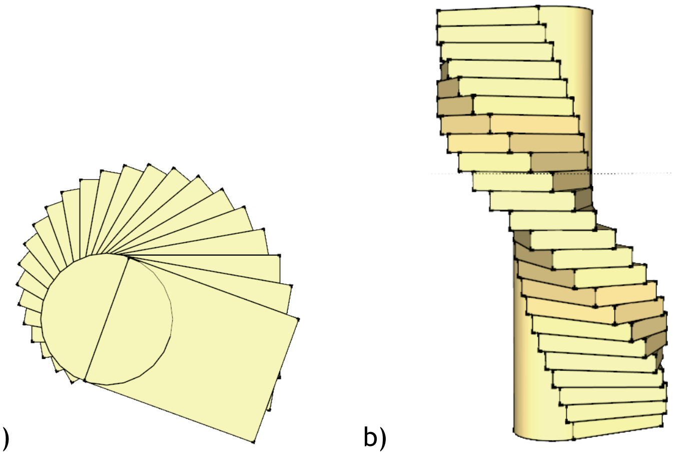
The geometric shape of the basic unit of model No. 2.1 is a union of a quarter circle, right-angled triangle and a smaller circle (Fig. 4a). The core, a cylinder, is wrapped with the spiral sequence of basic floor units (Fig. 4b).



a) b)

Figure 4. *Structure No. 2.1 – a) Floor plan; top view b) 3D model*

The variation structure No. 2.2 has a corpus of the structure like cylinder. The main floor unit is geometricaly union of a rectangle and a circle, which is uniformly rotated along the core (Fig.5).



a) b)

Figure 5. *Structure No. 2.2 – a)The base unit; b)3D model*

2.3 The inspiration No 3. – Propeller

3. The main core of a Diamond Tower is a cylinder with 3 additional elements (shape of propeller) which contionously rotate obtaining one spiral turn up to the top of the building 432m heigh. The

building is under construction since 2011., and planed to be finished in 2017.(Fig.6) [8].

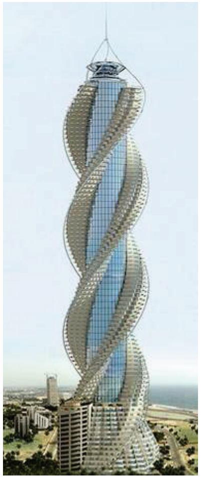


***Figure 6**. Diamond Tower, Jeddah, Saudi Arabia*

4. Central core of model No. 3.1 is a cylinder. Each floor unit has three satellites – circular in shape with the plug-in. The final structure has an association to the interlocking (Fig.7a).

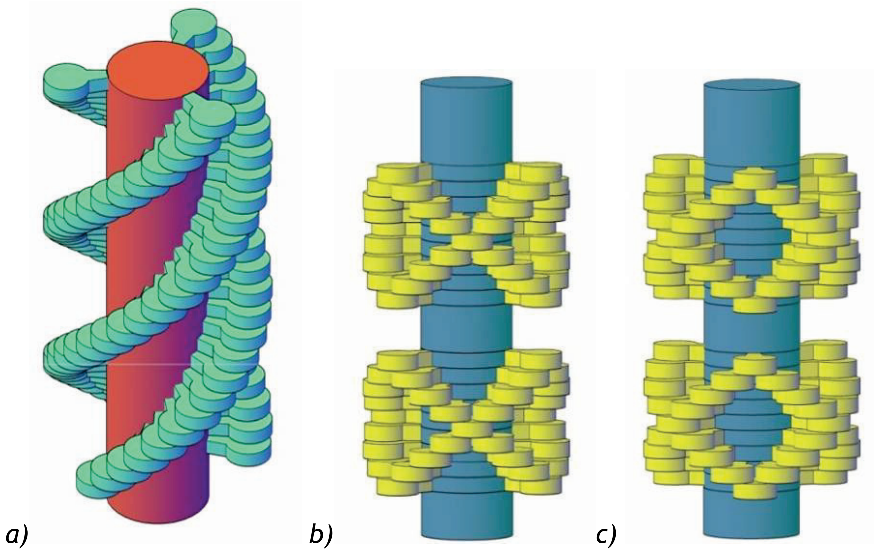
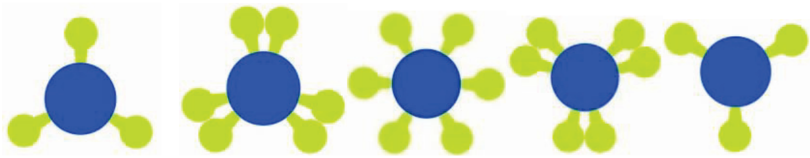


***Figure 7**. a)Structure No. 3.1 – 3D model;*
b)Structure No. 3.2 – 3D model-view 1; c) Structure No. 3.2 – view 2

5. The varition structure No. 3.2 has the same basic unit, but facade occurs in a different form, cosed by playing of the satellites. In the first tranzition satellites are duplicated (Fig.8), after which a spiral motion continues in two opposite directions. Hense, the two helical paths intersect in the middpoint (Fig.7 b,c). The same composition repeats after a „pause”.



Initial *the basis* *ultimate*

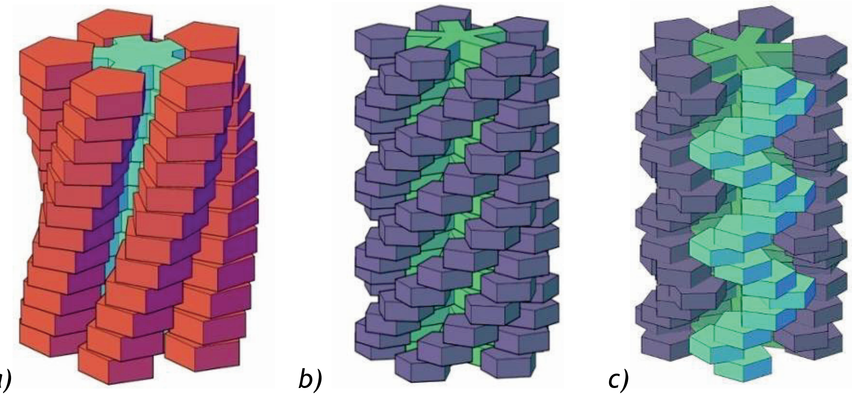
Figure 8. *Structure No. 3.2 – satellite variations in separate floors*

2.4 The inspiration No 4. – Star

Eco Skyscraper design concept for the city consists of two twisting towers connected by bridges. The interesting modeling approach complies with energy efficiency, planting, wind energy, etc. (Fig.9) [9].

Figure 9. *Eco Skyscraper, designed by V. Pawar, Noida - India*

Horizontal block unit of model No.4.1 is composed of a circular core and five radial satellites, pentagonaly shaped. Whole horizontal block continously rotates along the vertical axis and makes the final dynamic structure with terraces (Fig.10a).

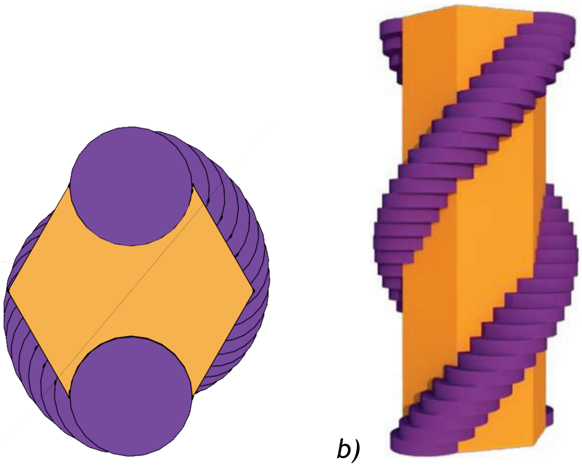


a) b) c)

Figure 10*.a)Structure No. 4.1– 3D model; b)Structure No. 4.2– 3D model; c)Structure No. 4.3 – 3D model*

The same disposition of five pentagonal satellites, without specific emphasis on the geometry of the core (model No.4.2) lightened previous massive structure (Fig.10b).Zig-zag motion of the pentagonal units on the fasade made interesting variation of the same concept (Fig. 10c).

The variation structure No. 4.4 is modeled with hexagonal core. The basic floor unit shape is a union of hexagon and two circles. The final structure proposed spiral movement of circular parts (Fig.11).



a) b)

Figure 11*. Structure No. 4.4– a)top view; b)3D model*

2.5 The inspiration No 5. – Lego

This modern structure offers a special concept of architecture. Changes on the façade (pixilated) made a dynamic, obtained with a cuboid-surfaced spiral cuts into the side of the building. This 77 store high building, in Bangkok is designed by architect O. Scheeren (Fig.12) [10].

Figure 12. *MahaNakhon Tower, designed by Ole Scheeren, Bangkok, Thailand*

Geometry of structure No. 5 is fake spiral. The hole - cube on each fasade's side moves diagonally, continuously changing the position in separate floor levels. This movement causes changes on each floor shape (Fig.13).

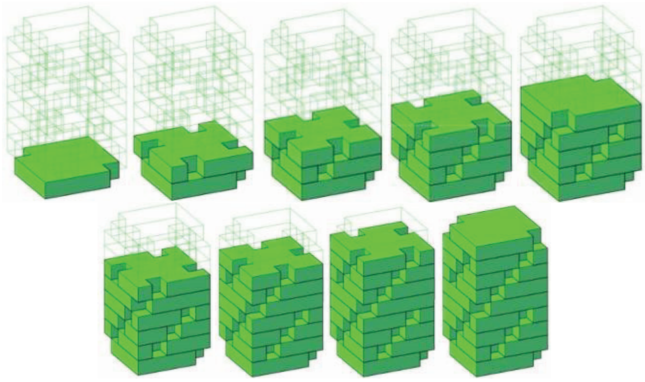


Figure 13. *Structure No. 5 – 3D model*

The main characteristics of 3D structures are emphasized in Table 1: geometry of the base unit, the fill rotation angle - φ/°, rotation "step" angle - s/ °, number of floors – n.

Table 1*. The overview of 3D structures with geometrical characteristics*

	Model	**Basic geometry**	φ	*s*	*n*
No. 1	*Two in one*	*Circle and rectangle*	*360*	*5*	*72*
No. 2.1	*The fan*	*Circle and triangle*	*147*	*7*	*22*
No. 2.2	*The fan*	*Circle and rectangle*	*240*	*10*	*24*
No. 3.1	*Propeller*	*Circle with satellites(circle)*	*225*	*7.5*	*34*
No. 3.2	*Propeller*	*Circle with satellites(circle)*	*60*	*7.5*	*30*
No. 4.1	*Star*	*Circle with satellites(pentagonal)*	*72*	*6*	*12*
No. 4.2	*Star*	*Rectangle and pentagonal*	*324*	*18*	*18*
No. 4.3	*Star*	*Rectangle and pentagonal*	*72*	*18*	*18*
No. 4.4	*Star*	*Hexagon with circle*	*310*	*10*	*22*

3. Conclusion

3D modeling of spiral structures is challanging and inspirative task for designers in a wide spectar of areas, whether scientific or practical. The architecture, as a living surroundings by its dynamics imitates the way of living, full of changes. Somehow, it seems that the spiral architecture also complies with this "concept", by taking care of implementing of eco design, energy efficiency (solar panels, wind turbines...), green architecture etc. Often they look like organic "sculptures" [4]. Such "inventions", built all over the world are astonishing both in technologies and imagery.

The basic geometric principles, presented in this research, were taken over from existing building structures, or designs, grouped in five diferent types. Based on concept of unit, or block, spiral movement they explore the combinations of circular and polygonal shapes. The variations are endless and rely on imagery of the designer.

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NATURAL PERSPECTIVE IMAGE FOR ARCHITECTURAL DESIGN REPRESENTATION

Ivana Bajšanski [1]
Vesna Stojaković [2]
Radovan Štulić [3]

Abstract

In architectural practice, floor plans, elevations and cross sections are obligatory parts of each project to present function, construction and form of one building. However, to be able to produce realistic image of buildings, architects use 3d models which are generated using digital tools. Although computer modeling is useful in the understanding of architectural form, digital tools do not always give fully adequate solution by means of its mode of generating perspective images. Perspective images (PI) play an important role to simulate the real space, but three point perspectives are sometimes inconvenient particularly when metrics and spatial relationships are to be detected from PI. Students often use software for 3d modeling in their courses which allow arbitrary angle between the direction of observation and the projection plane. This sometimes results in unnatural PI from which one can neither easily detect the spatial relationships nor calculate metrical properties. The problem in dealing with the skewed PI is that we cannot establish true and precise dimensions of the structures nor their true interrelationships.

When complex architectural composition are to be rendered, particularly in educational purposes, it would be useful if the restriction or a warning to a user appears, since students and non-professional 3D designers are often unaware that change of the vertical shift parameter can cause unnatural look of the final PI if it is not used carefully and just in specific cases for which that tool is designed.

Key words: *perspective image, students, architecture, education, 3d modeling software*

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[3] Radovan Štulić, PhD, Full professor, Faculty of Technical Sciences

1. PRESENTATION OF PERSPECTIVE IMAGES

There are many ways of representing one architectural scene. It depends on the part of the architectural scene that should be visible. When it comes to representing of 2D object, i.e. plan, elevation and section, that be easily and we manipulate with real dimension. From that draft we can precisely correlate part of object, define proportion, distance between two fragment, the angle, etc. Nevertheless, in order to make architectural object more realistic, architects used perspective projection as a way of presenting their design. With colored perspective view, eye can feel the depth of space, especially when shadow effects, textures and environment are turned on.

Computer vision, sometimes called image understanding, describes the automatic deduction of the structure and properties of a possibly dynamic three-dimensional world from either a single or multiple two-dimensional images of the world. The images may be monochromatic or colored, they may be captured by a single or multiple cameras, and each camera may be either stationary or mobile. The structure and properties of the three-dimensional world that we seek to deduce in computer vision include not only geometric properties, but also properties of the material and the lighting of the world. Examples of geometric properties are the shape, size, and location of object, and examples of material properties are the lightness or darkness of surfaces, their color, texture and material compositions [2].

Considering many different techniques used to create visual perspective, linear perspective is geometrically most interesting [1]. In final student's projects we usually meet color perspective, which is built in a program for 3D modeling, and sometimes consequence is that a parts of the scene in these images look very unnatural. Nevertheless, if we do reconstruction of that PI, we can derive some of elements these PI (vanishing points, position of the view point, position of the projection plane, focal length used in virtual camera, and if picture allows, determine accurate dimensions of the objects in the PI), and we can track the problem that causes unnaturally looking PI [3].

What means unnatural PI? That problem can be explained in two ways. First, if we have the object, placed on a plane, position of the view point should not be placed on that plane. Result would present PI in which objects seems to fall on the ground. Another type of unnatural PI is connected with software for 3D modeling. When parameters of the view point (camera) or projection plane are changed, picture is being stretched, distorted, and appear unnatural. (Fig. 1.)

This survey concerning programs for 3D modeling has aim to shown (dis)advantages in process of create PI.

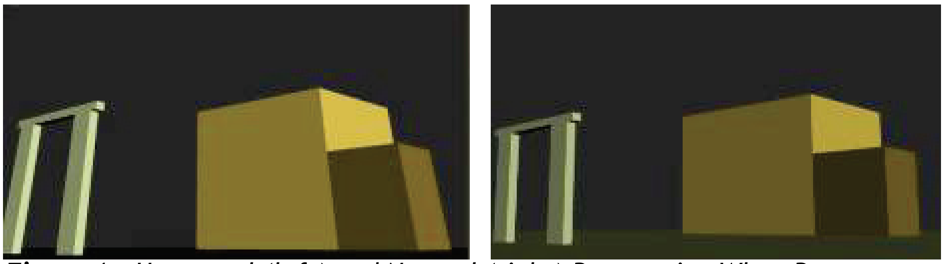

***Figure 1**. Unnatural (left) and Natural (right) Perspective When Parameters of Camera are Changed*

2. RECONSTRUCTION OF A STUDENT WORK

The process of creating final PI in programs for 3D modeling is called rendering. By placing the camera we get a frame of projection plane, i.e. part of the architectural scene that will be displayed and rendered. In the following example, in camera parameters vertical shift is changed by the student. Vertical shift is the parameter aimed to make analogous projection as vertical shift sensor in real camera used by photographers who shoot high buildings from short distance keeping the verticals vertical in the photo. However, same as in real camera, in virtual camera vertical shift should be carefully used. If the projection plane is not parallel with the verticals in the scene, PI will look very unnatural. In this example student's use of the vertical shift in totally inappropriate (height of the scene and relation to the scene verticals are not considered).

In order to explain digital tools used and their (dis)advantages, it is useful to introduce methods of single image reconstruction of the student's render. This procedure applies to already completed PI, and its main purpose is defining the basic elements of the scene in perspective.(Fig. 2.) These elements helped us to create orthogonal projections of the scene. As an example, we analyzed the student's render, based only on the geometrical and perspective projection rules. When vanishing points (N_a, N_b and N_n) are identified, some other values such as: position of view point (E',E'',E'''), focal length (distance-*ds*), angle of view and horizontal plane ($<N_nE_xH$) can easily be obtained.(Fig. 3.)

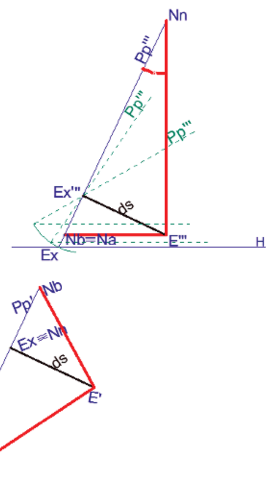

Figure 2*. Top view and bottom view - Relation Between Perspective Element*

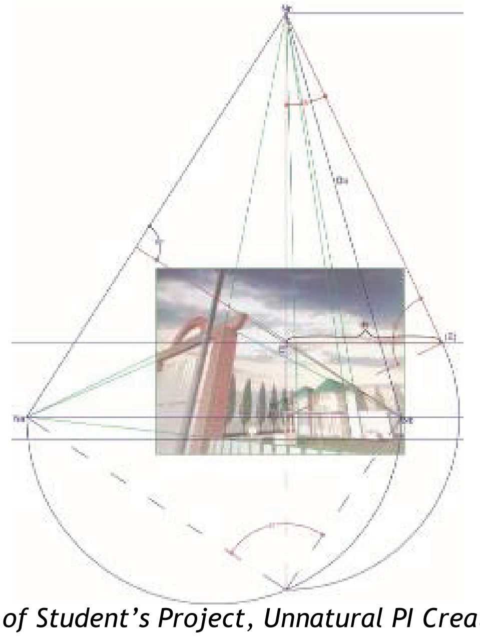

Figure 3*. Example of Student's Project, Unnatural PI Created With Programs for 3D Modeling*

This PI easily confuse human perception. It is difficult to conclude, which object is higher than the other or distance between the objects. The problem in dealing with the skewed PI is that we cannot establish true and precise dimensions of the structures nor their true interrelations.

To calculate some parameters from the analyzed PI we have to assume some relations. e.g. The garage is in the line with the gate. (Fig. 4.)

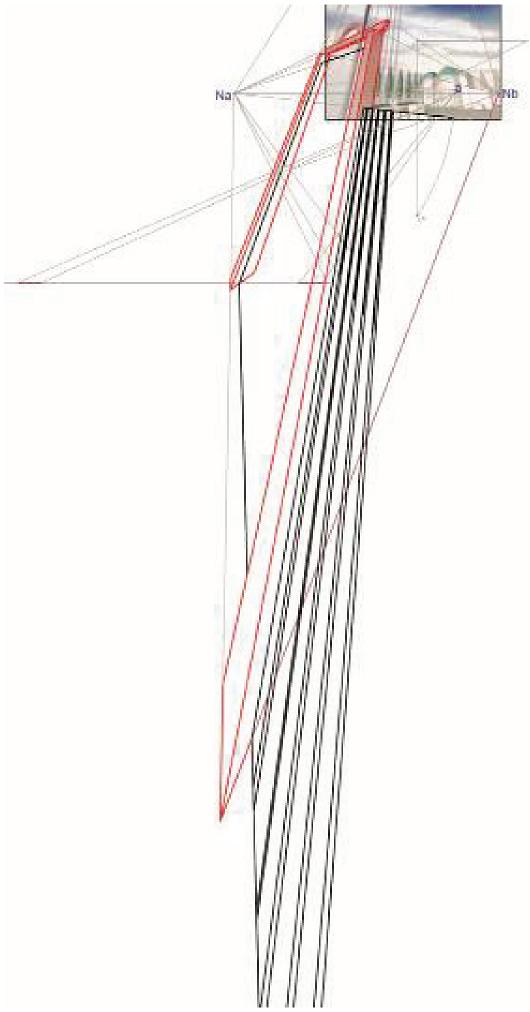

***Figure 4**. Possible reconstruction of Fence and Gate (supposed that is gate in the same line with garage)*

3. RELATION BETWEEN BASIC PERSPECTIVE ELEMENTS

The role of a camera in computer vision system is analogous to the role of the eye in the human visual system [2]. In linear perspective, we can see eye (camera) and projection plane (as a line), that conclude angle between direction of observation and projection plane. Cause of the deformed and unnatural images is arbitrary position of direction of observation in related on projection plane. When angle changed, PI is being more deformed. (Fig. 5.)

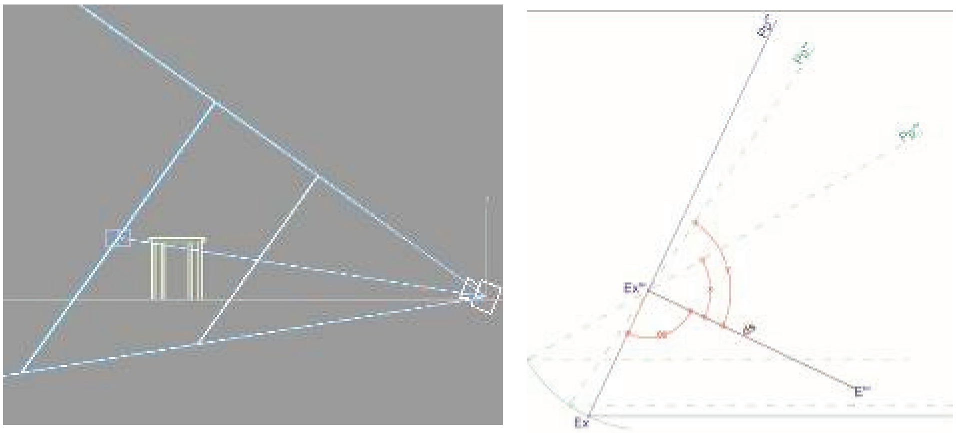

Figure 5. *Left view - Possible Relationships between the Projection Plane (Pp) and otical axes (Ds) (what program allowed (left), analysis of real image reconstruction (right))*

In geometrically and mathematically accurate PI right angle between the projection plane and direction of observation (optical axes) is presumed. However, programs for 3D modeling have options and digital tools which are used for PI creation, e.g. vertical shift. Some of these tools had options to change parameters, and influence final result, i.e. PI. Images are without deformations when these parameters are set to zero.

If parameter changes, either it takes positive or negative value, position of projection plane relative to the direction of observation also changes. Programs allow arbitrary and unnatural position of camera (E'''), and plus random position of projection plane (P_p'''). Product of playing with the program for 3D modeling is angle X and Y. The point is that programs not restricted to the natural perspective view, since the direction of observation and projection plane are not constrained. (Fig. 5.)

4. POSIBLE SOLUTION OF THE PROBLEM

One of the problems that occur when installing the camera, the impossibility of perceive the whole object. This is another reason why the tools are used for elongation pictures and why resort to changing parameters. Problem can be solved with one special kind of perspective which make it possible to view a scene or an object from multiple angles [5].

Multi-perspective images can depict, within a single context, details of a scene that are simultaneously inaccessible from a single view, yet easily interpretable by a viewer [6]. Setting up multiple cameras and forming 2D drawing looks much more natural and more logical. At all, a much better solution and a way to avoid changing the parameters and create an unnatural perspective images is to create a plug-in, for computer programs, which limits eye to be placed in the illogical position, and thereby enable to prevent parameter changes. Eye (camera) would be set about 1.80m height, and field of vision include angle of 60 degrees.

5. CONCLUSION

Consequences of advanced software for 3d modeling in addition to previous problems are, when creating animation, if the camera adjusts the unnatural, animation losing quality and there is no impression real depth and size of space, the human eye losing feel of dimension, whether the object is wider or longer.

Main advantage of control of the naturally looking PI in programs connected with 3d modeling would be simplicity and reality perspective view, efficient set up of the camera, the possibility of image reconstruction and determining the exact measurement and spatial relationships of the 2D image.

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REPRESENTATION OF MORPHOLOGICAL CHARACTERISTIC OF SPACE IN ARCHITECTURE AND URBANISM BY FLY-THROUGH ANIMATION AND SIMULATION

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Abstract

Representation of space in architecture and urban planning is one of the most important aspects of communication in building today it is essential for illustration of various concepts and ways of functioning of the facility. The amount of information that we receive by the visual presentation of space allows better communication between professionals, investors and the general public. The potentials of animation display in architecture and urban planning to enter the dimension of time gives the quality of visual presentation space. The most common form of animation used in the building practice is a fly-through animation, but there is a tendency for the emergence of other types animation display in the form of simulation. The introduction of dynamic aspect ratio of the object and its surrounding environment creates the conditions for a better understanding of the influential energies, such as the climate, which may influence the geometry of a building. In this paper the potential of fly-through animation and simulation/engineering animation is analyzed as a tool for analysis and evaluation of the interaction of physical characteristics and environment.

Key words: *architecture animation, fly-through, simulation*

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1. INTRODUCTION

Throughout the history of architecture the static display of structure in the form of 2D drawings or models was a dominant instrument of communicating ideas to the observer for centuries. Animation provides a dynamic overview of the process of design and the visual characteristics of space and also an insight into different processes that are intended to take place in the facility. The advantage of the dynamic display of planned space is the dimension of time in visualization of space and possibilities of different scenario visualization required by the investor or anticipated by the designer. According to Obradović, et. al. (2013) animation in Engineering is an integral process today and involves almost all areas of life. This enables the viewer who is not of the expert in the field of architecture to perceive and easily understand the project. Recent studies suggest that animations produce better learning and pattern recognition than static images (Höffler and Leutner 2007). In respect, these characteristics of animation has a great potential in the field of education in engineering and arts.

Initially, the development of CGI software including high-end animation and rendering tools have not been developed for the purpose of architectural design, some architect recognized them as a powerful tool in creating new emerging forms in architecture (Tepavčević, et. al., 2012). Animation is becoming a mainstream tool in project presentation in the greatest studios for architectural projects, such as Herzog & de Meuron, OMA, MVRDV, etc. The world's leading architects use animation as new form of project rendering, such as Zaha Hadid, Eric Owen Moss, Santiago Calatrava, etc. (Popkonstantinović et. al, 2012), as shown in the examples in figure 1.

The main goal of this paper is analyzing the possibility of using animation in the fields of architecture and urbanism, as well as the classification of animations in this area according to its use. When the term animation in this paper is used, its meaning will be limited to computer animation. There are different forms of animation that depends on the type of information that is presented to the viewer. The most common reason for using animation in architecture is the purpose of realistic presentation of architectural and urban works to people who are not experts in the field. Another type of animation is oriented toward the presentation of information specific to a particular field of expertise.

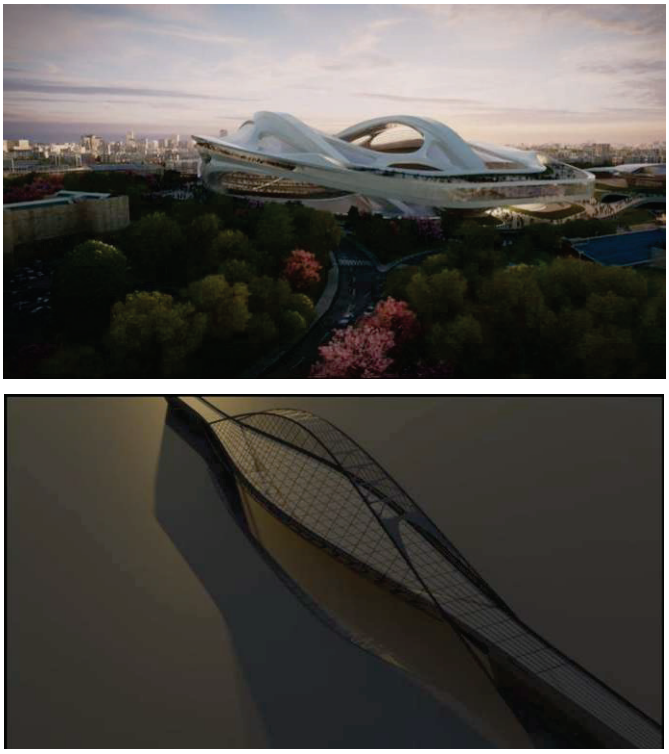

Figure 1*. Clips from architecture animations. Picture above is project of New national stadium of Japan by Zaha Hadid, picture below is Oudry Mesly Bridge by Santiago Calatrava*

Two basic types of animation in architectural practice are classified in this study. First stream is the Fly-through or Walk-through animation, and it is used to introduce the architectural form to the viewer imitating realistic surrounding environment. Another approach to animation refers to the fact that the time component can be used in research, most often through the use of simulation software tools. This form is intended for professionals in the field and it can contribute to decision support in the process of architectural and urban design. In the following part of the paper these two types of animation are analyzed as the tools of information visualization in different fields they are applied to.

2. FLY-THROUGH ANIMATION

In this chapter the approach to information visualization commonly known as walk-through or fly-through is analyzed. Fly-through and walk-through is the popular form of animation in architectural designing. It is also the simplest form of animation with only a camera animated (Parent, 2012). Typically in walkthrough animations, structural and environmental objects such as walls, columns, doorways, buildings, and trees remain stationary while the camera moves through the scene. Walk-through and fly-through differ in technique (Cory, et. al., 2001). A walk-through is used to show the actual point of view of a person walking through a scene and is generally shot at or slightly below eye level. Fly-through are not as narrowly structured as walkthroughs and can be made from any point of view desired and at any speed and camera angle. (Weishar, 1997).

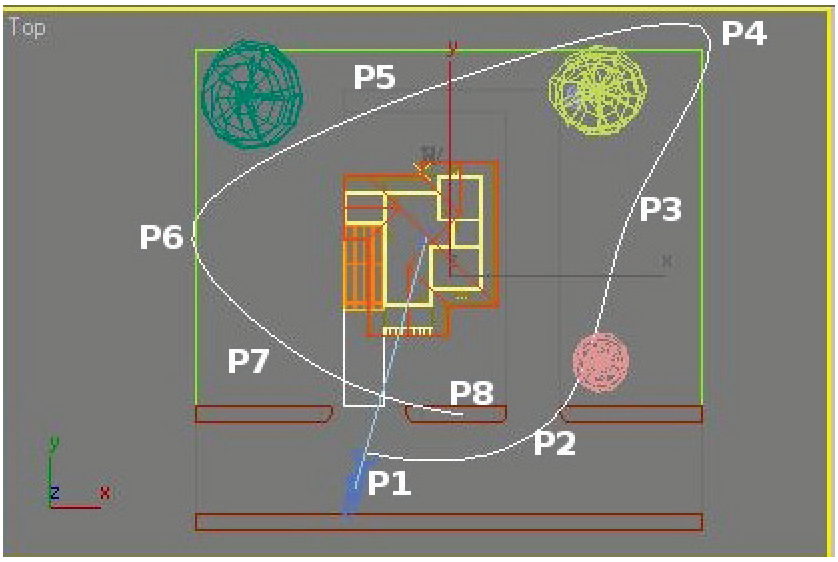

***Figure 2**. Orthographic layout of architectural structure and camera path for fly-through animation*

For example in the figure 2 the orthographic layout of architectural structure and camera path for fly-through animation is presented. This type of visualization is used in the final stage of designing and is made only when all the elements of the design are defined.

The most commonly used software for architectural animation are Autodesk 3ds Max, Autodesk Maya, Cinema 4D, Lumion, Artlantis... There are also software frequently used in the field that are not primarily oriented to complex visualization and often have limited tools sets for this type of simulation such as Autodesk AutoCAD, Graphisoft ArchiCAD and Trimble SketchUp.

The most common visual expression in this type of animation tend to photorealism as a defining quality. In recent years, architectural animation takes on a new dimension and becoming an artistic medium. Architectural Visualiser, Alex Roman for his short animation "The Third and The Seventh", and for the commercial named: "Above everything else," received great recognition in the field of art animation (Cannes Film Craft Gold Lion and Prix Ars Electronica - Computer Animation / Film / VFX prize). These awards confirm that animation in architecture is not only created for the investors or for presenting a project to the public, but also as a form of independent artistic expression.

***Figure 3**. Clip from film* "The Third & The Seventh" *by architecture Visualiser Alex Roman*

3. THE USE OF ANIMATION AS A RESEARCH TOOL

Current trends in the development of information and communication technologies have the direct impact to the majority of human activities. The possibility of creating virtual reality, based on software tools and integrated development environments available today in the domain of architectural and urban planning, becomes a challenge to urban planners as well as to the software designers. The use of animation as an integral part of the simulation is another aspect this paper analyses. Simulation is observed as the imitation of the operation of a real-world process or system over time (Banks, et. al., 2001). Inherent complexity, embedded in real world concepts, promotes modeling and simulations as the unavoidable mechanisms for preventive valorization of contemporary civil engineering and urban achievements. The special challenges lie in modeling and parametric simulation of space and architecture that enables the analysis of existing environments in order to gain its potential revitalization. Now a days there are several software tools that, in more or less effective way, enable the experimental approach in the domain of architectural design and urban planning. By the establishment of set of space attributes, as the basic element of architecture or urban environment structure, it is possible to simulate and experimentally valorize the different aspects of human-space relationship concerning up to date city building.

There are several software that can serve the purpose of animation in architecture and urban planning, but few of them have been made the purpose of use in these areas. The basic form of the use of animation as a means of parametric analysis of the architecture is given in plug-in for software Rhinoceros 3D, Grasshopper. This software allows the user to see the changes based on any of the analyzed parameters (which are in complex analysis associated with other parameters), a type of generated display of geometry over time. In this way, the user is able to choose the most appropriate design solution, with the help of dynamic parameterized animation. The figure 4 presents the dialogue from the software which sets the animation parameters within the hourly calculation of energy efficiency of the facade in one day.

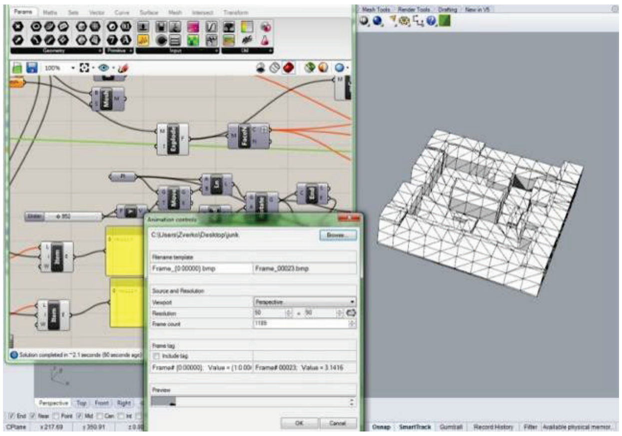

Figure 4*. The dialog for recording animation in software Rinoceros 3D and Grasshopper plug-in*

Daylight simulation is the most frequently used type of simulation used architecture. The parametric approach implies the use of weather data for the analyzed location in form of calculation of average brightness and position of the sun during the day, yearly. Some programs, such as Graphisoft ArchiCAD (figure 5) and Autodesk Ecotect offer complete solutions in which the animation shows the location of the shadows during the year, while other programs for visualization can adapt the parameters to the solution presented in the same way. This simulation can contribute to the improvement of architectural form making it efficient in terms of optimal daylight exposure of the facades.

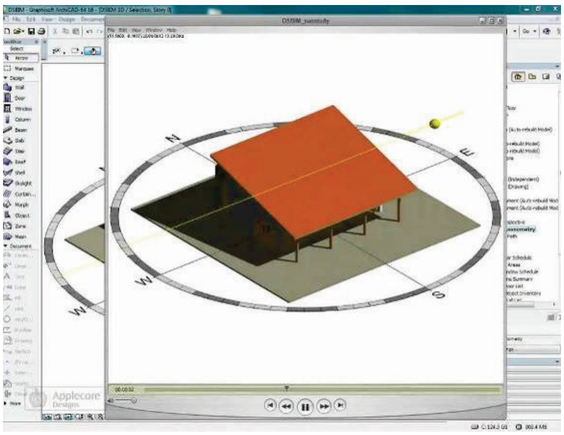

Figure 5*. Sun Study tool in ArchiCAD software*

Displaying simulation in a form of animation is also available in CFD software. They offer a possibility of wind tunnel particles simulation around the observed geometry of a structure, showing wind movement influenced by parameters defined The accurate results are gained by series of calculation, that show the interrelationship of wind movement and built environment geometry. Based on the results of this dynamic-parametric animation it is possible to make a conclusion about whether a form of the object is appropriate in terms of ventilation and wind safety regulations. The most commonly used software in this scientific domain are ANSYS and Autodesk Simulation CFD specialized for fluid dynamic engineering research. There are also affordable and user friendly software oriented toward the CFD simulation in the construction industry like Autodesk Project Falcon and Autodesk Project Vasari. The examples of interface for Autodesk Vasari and Autodesk Simulation CFD are shown in the figure 6.

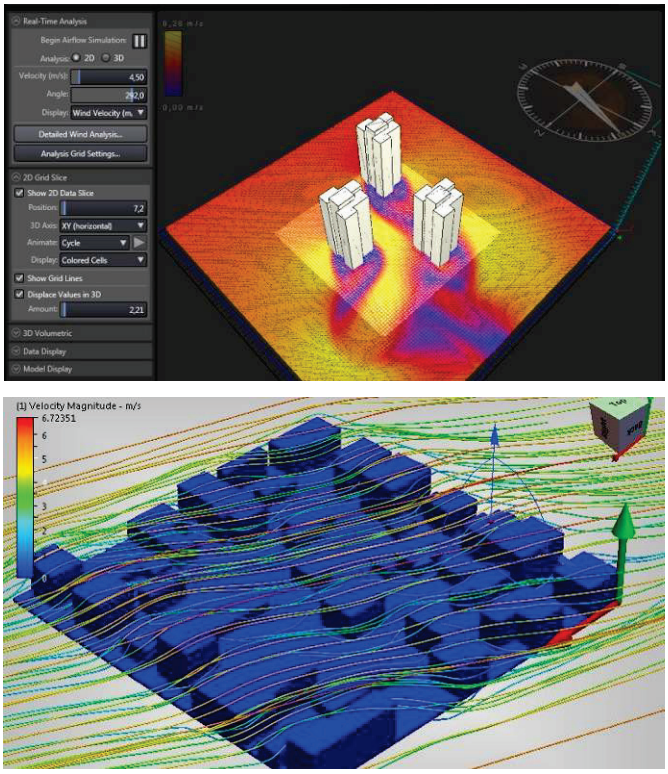

Figure 6. *Picture above-Autodesk Vasari interface example, picture below-Autodesk CFD Simulation interface example*

Animation, in the analyzed examples, is used to support the design process and can contribute to a better and more effective solution of geometry in planning, it is fast, easy-to-read, and gives highly precise results for the parameters analyzed.

4. CONCLUSION

This paper presents the main aspects of animation used as visualization tool in the architectural and urban design. The first part analyzes the use of animation in order to visualize the final product of architectural design, classified as animation postprocessor. The second type of animation is a computer simulation displaying dynamic relationships between the geometry of the structure (or example) and its environment used for the purpose of decision support and design improvement in all stages of planning. They are associated with participation in the process of designing architectural works and urban environments.

The differences between these two types of use of animation in architecture and urbanism is that the first approach has the artistic character and its development is in the field of artistic contribution to visualization, the second approach uses computer technology for the purpose of scientific research which aims to design buildings with better performance in terms of daylight accessibility, wind exposure and geometric parameterization of structures. Table 1 represents a comparative analysis of the two approaches in architectural animation.

Aliases	Fly-through, Walk-through	Simulation
Focus	Framing, texturing, camera movement	Defining the parameters for the analysis
Approach	Artistic	Scientific
Audience	General public, investor	Professionals
Main goal	Photorealistic visualization	Accuracy, engineering precision, data visualization

Table 1. *Fly-through/ Walk-through animation characteristics compared to animation in Simulation software*

The table shows that both methods have different focuses, approaches and purposes in the field applied to. Their results have different profiles and different professionals are required to improve the development of these fields. Also, the animation is a relatively new method in architecture, but as shown in this paper it has the great potential for evolving into a necessary tool for the visualization and analyses of design. The introduction of dynamic aspect ratio of the object and its surrounding environment creates the conditions for a better understanding of the influential energies, such as the climate, which may influence the geometry of a building. In this paper the potential of fly-through animation and simulation/engineering animation is analyzed as a tool for analysis and evaluation of the interaction of physical characteristics and environment. The development of both approaches is crucial for the architectural profession.

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THE ROLE OF 3D PRINTING IN THE MAKING OF MODELS FOR TACTILE PERCEPTION OF ARCHITECTURAL OBJECTS

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Bojana Anđelković [2]
Hristina Krstić[3]

Abstract

The topic of this paper is to review the contemporary possibilities of improving the making of models for tactile perception of architectural structures to help the blind and visually impaired people. The existing ways of making models of buildings and complexes are examined and compared to the new techniques of 3D printing. The traditional way of making a model for haptic perception that consists of making models in clay and their casting in bronze, is compared to the new method of creating 3D models in a CAD software and its printing on a 3D printer.

Key words: *tactile models, 3D printing, 3D modeling, haptic perception*

1. INTRODUCTION

People blind from birth, in average have the same test results in cognitive and intellectual processes, inductive and numerical reasoning, but scientific research confirmed that blind people have an enhanced sensitivity of some sensory functions, to compensate for their lack of eyesight[1]. This is often manifested through enhanced haptic perception, where using other senses the sensory information is translated into graphical representation of space, in the visual cortex of the brain. This special characteristic of spatial cognition can be

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used to inform blind people about their surroundings, and important historic buildings. Modern 3D printing technologies are creating new possibilities for the fabrication of tactile models. In this paper 3D printing is compared to the traditional method of bronze casting, used today for fabricating tactile models.

2. HAPTIC PERCEPTION

Haptic perception is a process in which a person perceives physical space and objects through touch. It is a complex process that combines information perceived through touch and kinesthesia. Haptic sense, or the sense of touch, is the most frequent in living beings and evolutionary oldest sense, that collects stimulations from the environment and consists of receptors on the skin. It reacts to temperature, pressure and pain. Sense of kinesthesia is the sense of movement of muscles and position of body parts in space[2]. Integrating these information the observer creates a mental picture about texture, shape, material, moving parts and the size of the perceived object. By using these two senses, haptic perception gives answers to "What" and "Where", and connects these two answers into one. The observer collects, interprets and organize these sensory data, processes them in his consciousness, and in creates the impression of the world around him[3].

It is widely accepted that the haptic perception is significantly different from visual perception in many aspects. Vision gives a very accurate visual perception of space and time, and haptic perception is extremely effective in sensing the different properties of materials and surfaces. Unlike visual perception, haptic has a very low resolution and detail. Touch can be active or passive, in this case we are interested in active because it relates to the touch that has the purpose to study the external environment and absorb the important information about an object and navigate in space.

2.1 Two-dimensional and three-dimensional haptic perception

The precision and efficiency of the haptic perception depends on the type of information to be interpreted. There are two types of haptic perception: two-dimensional haptic perception, that we use to interpret information presented in one plane, and three-dimensional haptic perception, used for interpreting a three-dimensional object. Two-dimensional information can be Braille or relief drawings, and three-dimensional information are scaled models and objects. Two-dimensional perception is appropriate and simple when it comes to reading using Braille, but when two-dimensional drawings or engravings are interpreted to find out the appearance of an object or area, it is a big problem for blind people. This problem occurs because the observer sequentially receives information and it is necessary to form a mental image out of sequences of information. In three-dimensional haptic perception the observer experiences the object starting with the whole to the details, and begins to form a rough mental image of the shape, its size and weight, and then touching he explores the details and quality of the surface, and the information is processed quickly and accurately[4].

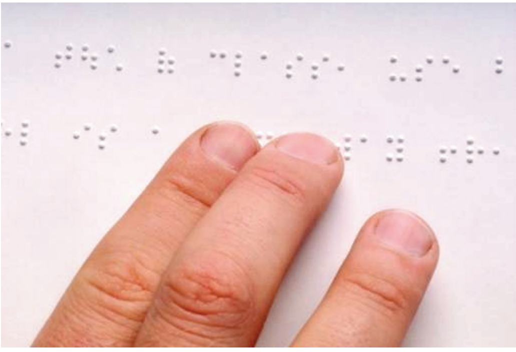

Figure 1*. 2D Braille text*

We can conclude that the presentation of architectural structures and complexes, for the easiest haptic perception of appearance, form and texture of surfaces, it is necessary to make scaled three-dimensional models of objects, not relief images of floor plans and perspectives. In this paper the topic is the exterior of buildings and complexes.

3. SCALED MODELS OF ARCHITECTURAL OBJECTS

Models of architectural objects, are a representation of architectural structures or complexes in a certain scale, and they are used in presentations to investors and clients, and also in education. In the last few years, the population of blind and visually impaired people received public attention, and many scale models of architectural object were made to present to them their form and appearance. Tactile models are not just for blind people, but also for all people because they offer the possibility of perceiving the object and its relationship with the environment from a different perspective.

Figure 2. *Scaled tactile model of the Jefferson Memorial, Washington, USA*

Many studies have been carried out in order to increase their quality and usefulness, the following recommendations were made:

• Surfaces should not be too smooth to order to prevent fingers from slipping, but neither too rough, to avoid the interference with the reading of Braille;

• The scale model has to have a certain degree of abstraction and simplification, in order to avoid too much tactile information;

• It is desirable that the model shows various textures in order to get an impression of the different materials applied to the object[5].

On the example of research carried out by the Smithsonian Institute[6], with a test group of visually impaired and blind people, the tactile models of the exhibition "Washington - a symbol of the city," came to the following conclusions:

• It is important that if more scale models are presented in one location, all models should have the same scale;

• The subjects felt the details that go beyond the basic shape of objects. On the model they noticed details such as inscriptions above the entrance to the facility, details of decorative elements on the facade, and even managed to distinguish different types of columns on the facade;

• If the exhibition includes more models from a site, it is desirable to present on the exhibition a smaller scale model of the site in order to identify relationships between the buildings.

3.1 Traditional bronze casting

Casting in bronze is the most popular method of making metal castings. Ancient civilizations such as the Greek and Chinese have used bronze in the preparation of the works of art, tools of weaponry, and the same technology is being used today. The casting process consists of six steps: making models out of clay, making of rubber mold, casting wax models, making a plaster mold, casting models in bronze and polishing.


***Figure 3**. (left) The process of casting bronze into plaster molds; **Figure 4**. (right) Bronze tactile model of the Ljubljana castle, Slovenia*

The process of casting models in bronze is an extremely expensive, complicated and outdated process that requires highly skilled workers, sculptors and a lot of time and work. The described process of casting is identical to that used in the world during the Renaissance. Today worldwide, tactile models are mainly manufactured in this manner[7].

As an example from the neighboring countries we can specify a tactile model in the Ljubljana castle in Slovenia, shown in fig. 4, set up in October 2013. The scale model cast in bronze represents the Ljubljana castle and surrounding terrain. On the base of the model there are inscriptions in Braille and Latin. The cost of producing this models with approximate dimensions 100x100x40 cm, is approximately 26 000 Euros[8]. In Graz, Austria, in front of the Kunsthaus museum of modern art, stands a tactile model of the object (fig. 5). The Museum is shown with the addition of adjacent structures to estimate their correlation. Due to the scale of the model, many elements of the building are simplified, but all the typical components such as windows of the neighboring building and openings on the museum roof can be perceived by touch. On the plates that are attached to the stand basic information about the building and street names are given in Braille.

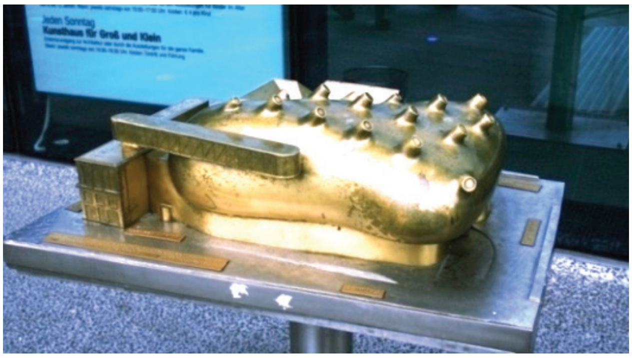

Figure 5. *Bronze tactile model of the Kunsthaus, Graz, Austria*

The advantages of making tactile models in bronze are that bronze is exceptionally strong and tough material so there is less risk of damage and theft of the model; bronze is resistant to outside influences, non corrosive and can last indefinitely. The disadvantages of this process are that it is a complicated, time consuming and outdated process of production and the high price of tactile models because of the expensive materials used and the need for highly trained workforce.

3.2 The use of 3D printing in the development of tactile model

The progress of computer technology in the last 20 years has enabled the appearance and spreading of digital 3D modeling. A wide range of required tools are now available to customers in the commercial and open source format, so that 3D modeling is done by more people.

Rapid prototyping (RP) is an automated production of physical 3D models based on previously prepared digital models. Application of RP varies from prototype models to final version of the product. Although there are numerous ways of making digital models (additive, subtractive, formative ...), most authors as the most suitable method accept the additive method which includes 3D printing and stereo lithography. Additive method of making 3D models represents successive addition of thin layers of molten material (extrusion) or hardening successive layers of powdered or liquid material (3DP). This method can produce any forms modeled for printing.

3.2.1 Method of 3D printing by extrusion

In this method of printing, also called "Selective deposition", the 3D printer lays successive layers of melted material through the print head. For the application in haptic models printing with extruded liquid plastic, which hardens upon deposit ,is applicable. The print head squeezes out the molten plastic into layers, which are horizontal cross-sections of the object, starting from the base, until it reaches the layer which is the highest point of the model.

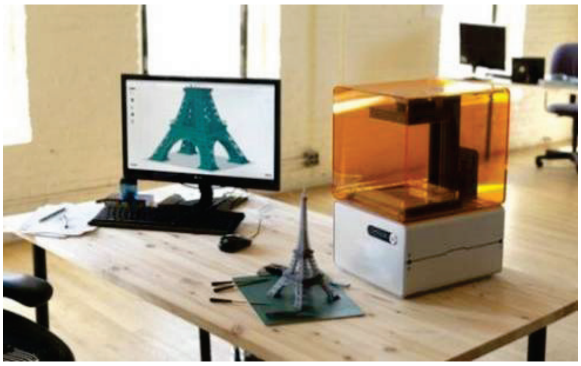

Figure 6. *3D printing by extrusion setup*

This printing technique has become exceptionally popular, because there are very low-cost, compact version of the printer, which everyone can use in their homes. Disadvantage of this 3D printer is that it creates a model that is sensitive to shocks and high temperatures, so it cannot be used outdoors as a tactile model.

3.2.2 3DP method of printing

The 3DP method of printing (Three-Dimensional Printing) uses technology designed in 1993. It is done by hardening thin layers of powder with a liquid binder. The powder material is evenly distributed on the platform by a mechanism of rollers for printing, then the print head, like a standard ink-jet printer, prints successively over each layer of powder to give the desired color and also binds it. The finished product is cleaned of residues of powder, and soaked in a liquid that is used to further harden the outer layer.

Figure 7. *3DP printing technology, cleaning the resulting model from powder residue*

The resulting model has relatively high strength and resistance to weathering, in what we can make sure by the example of "Distributed Defense", which was able to print with this method a functional automatic rifle. This printing technique allows printing in full color, unlike extrusion which gives monochrome models [10].

4. CONCLUSION

The characteristics of 3D printing mentioned in this paper provide great opportunities for making of tactile models, bringing a revolutionary change and progress. Although print speed is relatively slow, about 2 cm height for 1 h, depending on the technique and the printer, it is possible in one day to make a digital 3D model and immediately get a physical model, as opposed to the casting in bronze where the fabrication of a model it takes several weeks. As the cost of production of such models is becoming more affordable, application possibilities are immense. Level of detail of the model is possible to the extent that the surface can mimic different materials and textures, which is of great importance for the understanding of tactile models. With adequate insurance against vandalism models made by 3D printing can be placed in open space, which is important in order bring them closer to as many users as possible. Models made using extrusion could be placed indoors, because of the sensitivity to increased temperature and lower strength of the material. Current production models that could be set up outdoors are more than 10 times cheaper than making the same models in bronze, and the price with the appearance of new and less expensive 3D printers declines in time.

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TECHNICAL VIZUALIZATION IN THE PROCESS OF VEHICLE IDENTIFICATION USING AUGMENTED REALITY

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Abstract

The process of vehicle identification is an engineering procedure defined by national laws and regulations and EU Directives and conducted by national accredited technical service when vehicles are imported in the country or modified by the owner during exploitation. Although the procedure is strictly regulated by laws and regulations the actual execution of the identification process is based on the expertise and engineering knowledge of the personnel of the technical service. This paper presents a solution based on technical visualization using augmented reality. With that, the operators get a visual step-by-step guidance in the process of locating the appropriate data elements on the vehicle during the identification procedure. The solution provides the technical service to easily transfer knowledge, to increase the efficiency and improve the safety of the personnel.

Key words: *augmented reality, 3D objects, image tracking, and technical vizualization.*

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1. INTRODUCTION

The process of vehicle identification is an engineering procedure defined by national laws and regulations and EU Directives and conducted by national accredited technical service when vehicles are imported in the country or modified by the owner during exploitation. Although the procedure is strictly regulated by laws and regulations the actual execution of the identification process is based on the expertise and engineering knowledge of the personnel of the technical service. This paper presents a solution based on technical visualization using augmented reality. With that, the operators get a visual step-by-step guidance in the process of locating the appropriate data elements on the vehicle during the identification procedure. The solution provides the technical service to easily transfer knowledge, to increase the efficiency and improve the safety of the personnel.

2. AUGMENTED REALITY

Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. Ideally, it would appear to the user that the virtual and real objects coexisted in the same space. A more comprehensive definition of AR would be as a system that has the following characteristics: (1) combines real and virtual world, (2) interactive in real time and (3) registered in 3D [1]. Augmented Reality enhances a user's perception of and interaction with the real world. The virtual objects display information that the users cannot directly detect with their own senses. The information conveyed by the virtual objects helps a user perform real-world tasks.

Figure 1*. Milgram's Reality Reality - Virtuality continuum.*

Augmented Reality might apply to all senses, not just sight. So far, researchers have focused on blending real and virtual images and graphics. However, AR could be extended to include sound, smell or tactile. At this paper the focus is only on sight as a human sense that needs to be augmented in order to achieve enhancement of the students' ability to visualize space and objects in it.

A basic design decision in building an AR system is how to accomplish the combining of real and virtual. Two basic choices are available: optical and video technologies. Each has particular advantages and disadvantages.

In the optical case, the virtual image is projected at some distance away from the user. This distance may be adjustable, although it can be fixed if the display is mounted to the user. Therefore, while the real objects are at varying distances from the user, the virtual objects are all projected to the same distance. If the virtual and real distances are not matched for the particular objects that the user is looking at, it may not be possible to clearly view both simultaneously.

A key measure of AR systems is how realistically they integrate augmentations with the real world. The software must derive real world coordinates, independent from the camera, from camera images. That process is called image registration. Image registration is one of the most basic problems currently limiting Augmented Reality applications. The objects in the real and virtual worlds must be properly aligned with respect to each other, or the illusion that the two worlds coexist will be compromised. More seriously, many applications demand accurate registration. Without accurate registration, Augmented Reality will not be accepted in many applications. Registration errors are difficult to adequately control because of the high accuracy requirements and the numerous sources of error. These sources of error can be divided into two types: static and dynamic. Static errors are the ones that cause registration errors even when the user's viewpoint and the objects in the environment remain completely still. Dynamic errors are the ones that have no effect until either the viewpoint or the objects begin moving [2].

Image registration uses different methods of computer vision, mostly related to video-tracking. Many computer vision methods of augmented reality are inherited from visual odometry. Usually those methods consist of two parts. First detect interest points, or fiduciary markers, or optical flow in the camera images. First stage can use feature detection methods like corner detection, blob detection, edge detection or thresholding and/or other image processing methods.

The second stage restores a real world coordinate system from the data obtained in the first stage. Some methods assume objects with known geometry (or fiduciary markers) present in the scene. In some of those cases the scene 3D structure should be pre-calculated beforehand. If part of the scene is unknown simultaneous localization and mapping (SLAM) can map relative positions. If no information about scene geometry is available, structure from motion methods like bundle adjustment are used. Mathematical methods used in the second stage include projective (epipolar) geometry, geometric algebra, rotation representation with exponential map, Kalman and particle filters, nonlinear optimization, robust statistics.

However, video-based approaches can use image processing or computer vision techniques to aid registration. Since video-based AR systems have a digitized image of the real environment, it may be possible to detect features in the environment and use those to enforce registration. They call this a "closed-loop" approach, since the digitized image provides a mechanism for bringing feedback into the system. For example, in some AR applications it is acceptable to place stationaries in the environment. These stationaries may be LEDs or special markers. The locations or patterns of the stationaries are assumed to be known. Image processing detects the locations of the stationaries, and then those are used to make corrections that enforce proper registration [3].

3. AUGMENTED REALITY IN MOTOR VEHICLES

The application of augmented reality in the field of motor vehicles is a research topic in every major car manufacturing company. Right after this technology was made available, the research departments of the automotive companies presented concept ideas based on the use of the augmented reality.

In general, the use of augmented reality in the automotive industry can be grouped in three categories:

- Systems which provide safety improvements during driving the vehicles,

- Systems which provide entertainment and additional information for the driver and the passengers,
- Systems which provide facilitation in the process of vehicle maintenance.

Car manufacturers like BMW, Toyota, Mercedes and General Motors in the last years have presented prototypes with which augmented reality is being utilized in motor vehicles. For example, the Japanese car manufacturer Toyota, through its Department for development Kansei, in cooperation with the Institute for interactive design in Copenhagen (CID), in 2011 presented a prototype called "Window to the World" which provides interactive entertainment for the passengers on the back seats. This system enables the passengers to zoom in on parts of the surrounding and the passing objects during driving. In addition, the system provides an option to measure distances between points of interest or objects that are in the field of view or to simple doodle simple shapes and forms on the back window of the car [4].

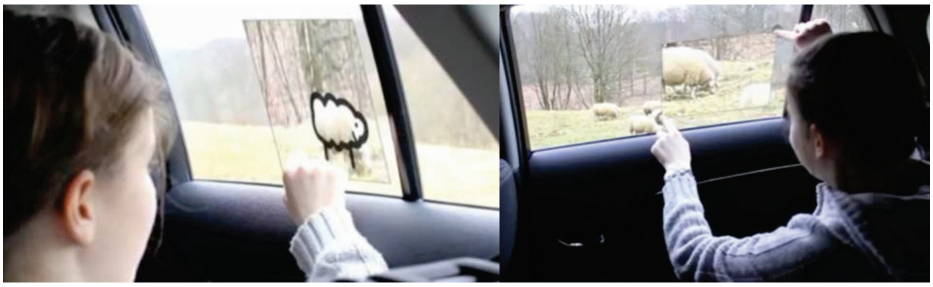

Figure 2. *Toyota's Window to the World.(Source: Toyota Motor Corporation)*

Another concept for utilization of augmented reality was presented by the American car manufacturer General Motors (GM), known as system for vision enhancing. The system consists of numerous sensors and cameras mounted inside and outside on the vehicle which monitor the vehicle's surrounding and the orientation of the driver's head and direction of sight. After that, this data is used to project additional information to the windshield regarding the condition of the road, navigation assistance or warnings for different danger elements that might appear. Also, this system provides the ability to mark the edges of the road with virtual lines on the windshield of the vehicle in harsh weather conditions or other cases of limited visibility of the road.

4. INSPECTION AND CONFORMITY ASSESMENT OF MOTOR VEHICLES

The current National and European legislation strictly defines the process of inspection and conformity assessment of motor vehicles. This process can be conducted only by accredited inspection body approved and assigned by the respective national authorities to conduct such activities – so called Technical services for vehicles. The Technical services may provide variety of services for conformity assessment and approval of vehicles which in general are of great importance to the country and play key role in maintain the safety of national and international traffic and protection of the environment.

The process of identification of vehicles is conducted in several steps, where one of the elements is to obtain the Vehicle Identification Number (VIN) and the engine number. The engine number is a unique mark placed by the manufacturer of the engine or by the manufacturer of the vehicle and it contains coded information regarding the year of manufacturing, the type of the engine, country of origin etc. By decoding the engine number through comparison to existing data bases all relevant properties of the engine can be determined.

The key issue in this activity is determination of the engine number position and accessing it. The issue is raised by the simple fact that there is no international standard or regulation on the exact position of the engine number. Meaning every car manufacturer or engine manufacturer can choose and place this key data element freely. This results in many variations. Today in the World exist around 282 different manufacturers of cars only, which results with huge variety on the location of the engine number. Even the same manufacturer for different engine types or for different model years uses different position.

5. TECHNICAL VIZUALIZATION IN THE PROCESS OF VEHICLE IDENTIFICATION USING AUGMENTED REALITY

The concept idea presented in this paper is to use augmented reality and develop a solution for technical visualization that will provide the inspectors with a step-by-step visual guide for determining and accessing the engine number on the specific vehicle. In order to do this, a system was designed for use of augmented reality on the basis of the existing software tools available on the market. The design of the system includes use of hardware like video camera and personal computer, than software applications for processing and combining the video signals, detection and tracking of markers, data base management and providing user interface to present the results on a computer screen.

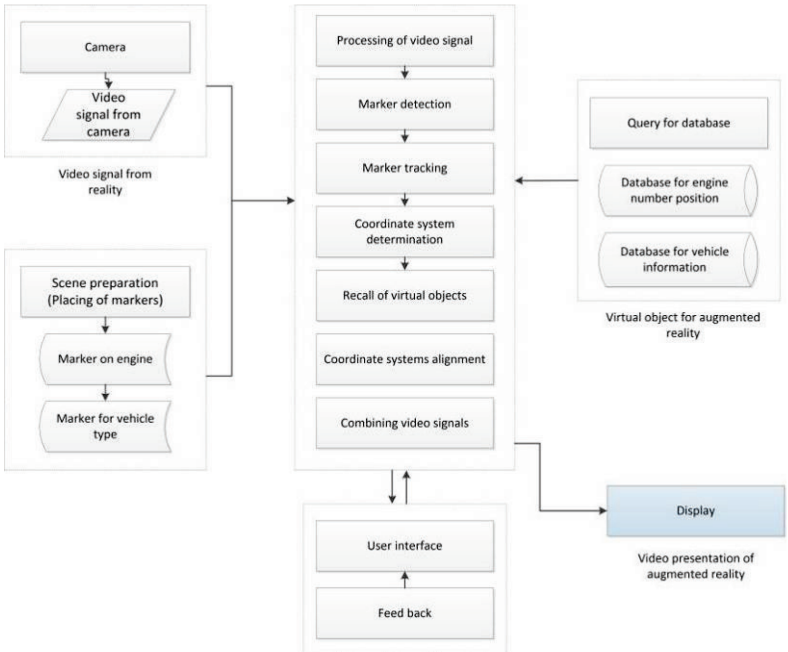

Figure 3. *Flow diagram of the concept idea for technical visualization*

Based on the flow diagram presented on Figure 3, a multi-relational data base was created mapping the data elements of the virtual 3D models of the engines with the general information about the vehicles. Information regarding the location of the engine number and ways to access it are extracted from the data base *Autodata Technical Database CDA-3*. Based on that, a 3D model of the engine with a virtual object as a corresponding marking that determines the location of the engine number were created. These models are than added to the multi-relational database.

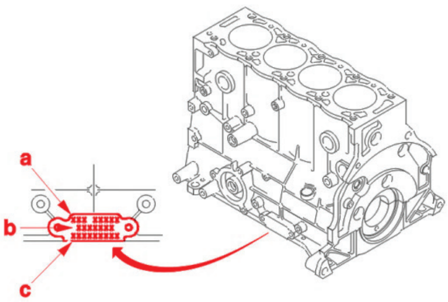

Figure 4*. Information on the location of the engine number provided in the Autodata database. (Source: Autodata)*

As most suitable software tools for completing this concept as designed, the BuildAR application from HITLabNZ and ARToolKitPlus were selected. BuildAR enables processing and combination of video signals, detection and tracking of markers, user interface and presentation of the results to a computer screen. For detection and tracking of the markers the software application uses the algorithm ARToolKitPlus [5]. This algorithm is robust and fast enough in the process of identification of fiducial markers with a consisting performance in various conditions. With this combination of software tools, the user is enabled to use more than one maker, to add virtual 3D models, 2D models, video, picture, sound or text [6].

In the concept presented in this paper, two markers are used. The first one has the task to define the location of the 3D model of the engine, and the second one to define the location of the general information about the vehicle (manufacturer, commercial mark, year of production, engine type, engine capacity, engine power, number of doors, number of seats, approved tire size). In that way, the inspector of the vehicle has the ability to check the information and compare it to the vehicle that is being inspected. This will provide additional control and eliminate mistakes in the inspection process.

In order to provide a step-by-step visual guide for the inspector, on the basis of the 3D model of the engine, together with the virtual elements that determine the location of the engine number an animation is created. This animation is later presented to the inspector's computer screen augmenting his real view of the vehicle's engine.

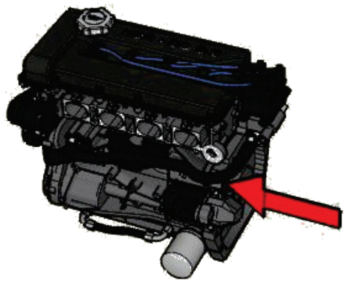

Figure 5. *3D virtual model of the engine with marking of the location of the engine number.*

Prior to activating the application for technical visualization it is necessary to prepare the scene. The vehicle must be positioned on to a defined location, that location has to be in the field of view of the camera, the lighting should not result in flashes or reflections from parts of the engine or front of the vehicle obstructing the video signal from the camera. In the end, the corresponding markers should be placed on the top of the engine.

Figure 6. *Vehicle for inspection with prepared scene for technical visualization using augmented reality.*

After that, the algorithm of ARToolKitPlus detects the markers in the video signal from the camera and is tracking their position and orientation continuously. Based on the data gathered through image recognition of the marker, the system connects to the corresponding virtual model in the database, loading the corresponding animation to the computer screen of the inspector. The two video signals are processed and matched accordingly, resulting in an augmented reality step-by-step guide. The same is done for the second marker, where instead of an animation, text as virtual object is presented.

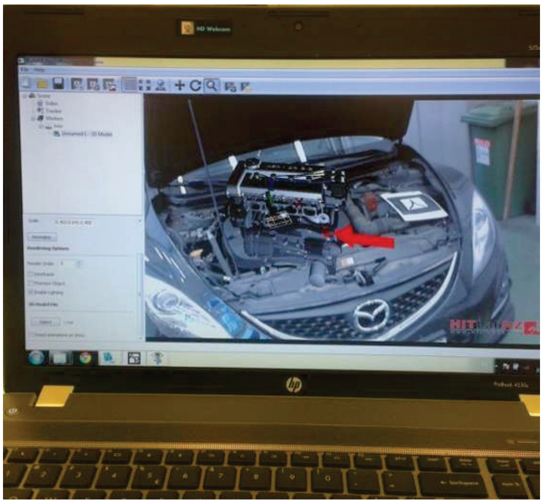

Figure 7*. Technical visualization using augmented reality – visual guide for determining engine number position.*

In that way, a clear visual guide for the inspector is presented on the screen out of which the position of the engine number and the necessary steps to reach it are clearly explained. The visual guide is presented in augmented reality, where the directly on the real image of the vehicle, the virtual instruction is presented in a form of a 3D model of the engine.

The augmentation achieved with this concept presents a successful application of augmented reality because the user is convinced that the real and virtual objects coexist. In addition, this application is a successful example because it contributes to simpler execution of activities related to inspection of vehicles in the process of approval.

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THE APPLICATION OF AR MEDIA PROGRAM FOR THE PRESENTATION OF A HOUSE OBJECT FROM THE 19TH CENTURY, THE FAMILY HOME IN JUGOVICEVA STREET, A CASE STUDY

Mila Cvetković [1]

Abstract

The technology development has enabled us to travel through different periods in the past. Our task is to make this journey as realistic, rich and interesting as possible. This project represents a case study of the 3D model object's production in Jugoviceva Street, by using Google Sketch-up and AR-Media program. Photogrammetry and the possibilities offered by augmented reality are presented here.

Key words: *presentation, augmented reality, old Nis, AR media, Google Sketch-up.*

1. INTRODUCTION

Photogrammetry represents the skill of obtaining reliable and quality information about physical objects. The object's dimensions are based on measuring, analysis and interpretation of photos and scenes. This skill is as old as modern photography. Photogrammetry is applied in various areas, such as topographic creation, architecture, engineering, police, geodesy...

On the other hand, augmented reality enables us to perceive the world around us from a different perspective, in the way we have never believed it would be possible by using a program, such as AR Media. Precisely this possibility was used in this scientific project.

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Modern technology enabled us to recreate objects that had not existed for years. In the following passages, we will talk about the way the object in Jugoviceva Street was built, as well as about the programs which enabled that.

2. CREATION OF THE 3D MODEL

The house object in Jugoviceva Street was created for residential purposes. After Naumovic family's arrival from Greece, they built the house at the end of the 19th century (we are not quite sure about the exact year). The object was demolished in 2007. Today, there is a residential and commercial complex at the same place.

The entire dimensions of the building were gained from the family photos in the possession of their heirs (7 photographs were used). The most important issue was to adjust indefinite perspectives, which later became the main spatial directions (Fig 1)

Figure 1*. adjusting of perspectives*

Based on these photographs we draw contours in order to obtain the shape of the object, later used for a detailed presentation of its former state.

The photography which is used for drawing of the north front is old and textures are not visible enough, so it was necessary to use the other photographs in order to present the materials used during the building of this object in a better and more realistic way.

Figure2.*Final appearance of the north front*

Different photos for doors and windows were used depending on the visibility of textures. By joining complete SKETCHUP files, the final appearance the north fasade of the object was obtained (Figure 2).

Figure 3. *Final appearance of the south front*

The south façade was more difficult to obtain, because we did not have any photographs that could have been used for complete drawings, so it was drawn in parts and the final parts were combined.

3. ARGUMENTED REALITY

The technology development provided us with the programs for 3D reality and various virtual worlds we have not even dreamed about. One group of such programs deals with augmented reality, that is, it allows us to see things beyond the limits of our own eyes. This type of program was used in AR-media research and in this case, it allowed us to create the means to return to the past by viewing the objects from the old Nish as if they were in front of us.

Everything that is necessary for a journey like this je a complete 3D model, that is, an addition in Google Sketch-Up. The program does all the rest by itself. It is also necessary to upload and print the marker from the Internet which will serve as a stand to our object.

Figure 4. *Display and use of the marker*

For the presentation of the model, free AR Media Plugin for Sketch-Up was used. It is only necessary to install Plugin for the program in which 3d model was made, that is, Google Sketch-Up in this case. After the installation, a new descendant menu will appear in the program that enables the opening of the model like AR Media files. If we save model like AR Media file, the icon will appear on the desktop. If we left click on it, we open AR Media Player that automatically plugs in the little camera on our installation and searches for the marker.

After the marker's identification, the model is linked to it, and we are able to see our object literally standing on the marker on the screen.

4. CONCLUSION

This paper represents the successful project of making 3D model of the object in Jugoviceva Street by using Google Sketch-Up and AR Media program. These programs are easily applied and can be installed in any device (mobile phone, tablets, laptop or desktop computer) which has the access to Internet. The easiest way of making models, as well as the possibilities that augmented reality offers are presented in this research. The technology development has enabled us to travel through different periods in the past. Our task is to make this journey as realistic, rich and interesting as possible.

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AR MEDIA PRESENTATION OF A NO LONGER EXTANT OBJECT - HOTEL "ORIJENT" IN NIS, SERBIA

Andjela Djokic[1]

Abstract

This paper presents a creating process of "no longer extant historic objects" presentation. The entire process has been presented through a case study about hotel "Orijent" which was built in the late 19th century at the Square of King Milan (downtown of Nis, Serbia). Today, hotel "Ambasador" stands in its place. Using the principles of photogrammetry, only one photograph and SketchUp and Photoshop computer tools, this old facility of the city of Nis was created and presented via AR Media software (Augmented Reality Media Software).

Keywords: *augmented reality, photogrammetry, hotel "Orijent", SketchUp, AR Media*

1. INTRODUCTION

Virtual modeling and 3D reconstruction are common tools used to imagine and analyze cultural heritage of both small and large facilities. Various technologies can be used for that matter, and one of them is Augmented Reality (AR).

Augmented Reality is a type of technology which combines real world information with computer-generated pictures and contents.

[1] Andjela Djokic, a second year student of Civil Engineering and Architecture, University of Nis

When united, these elements can be shown on the screen of a computer, cell phone, tablet, as well as on special kinds of goggles and contact lenses.

In this manner, user's view of the world is being augmented with additional information [1]. AR can be used for the purposes of education, archeology, architecture, art, medicine, computer games development, television, as well as for everyday life.

Everything we need as material is a 3D model made with one of the above mentioned tools, which will then, in combination with AR Media, be computer-processed in front of us. In order to make this possible, it is also necessary to print a marker on which the model will be presented.

Using the AR Media tool, facilities of ancient Nis will be presented, thereby enhancing the impression of the city's cultural heritage and bringing the past closer to the present even more.

2. CREATION OF THE 3D MODEL

The hotel building (Figure 1.) was built in the late 19th century, probably in 1899, at the place where hotel "Ambasador" now stands. The building had one floor, a restaurant and a garden; it was the most contemporary object in the city. It is believed that the building was constructed according to the project of two architects, Cuk and Dikic, in Misovski international style with discreet, tiny mosaic on the façade. The hotel was taken down in 1960 with the idea to replace it with a gigantic Union Center. Due to the lack of means to complete the construction of the Union Center, the unfinished object stood as the city's mockery until the idea of building a hotel instead was presented. In this manner, the decision was made to assign one part of the unfinished object to the Workers' University, one to the shopping mall "Beograd", and one to the local catering facility "Srbija-Turist". The purpose of the catering facility was later changed and turned into hotel "Ambasador"in 1968.

Figure 1. *Hotel Orijent*

Due to the fact that the model is extracted from photographs, it is necessary to import them into the tool with which they will be further defined. In addition, immensities are marked (Figure 2.) with caution not to coincide the red and green discontinuous lines with the object’s edges. Caution is also taken not to coincide the same colors in the same mark.

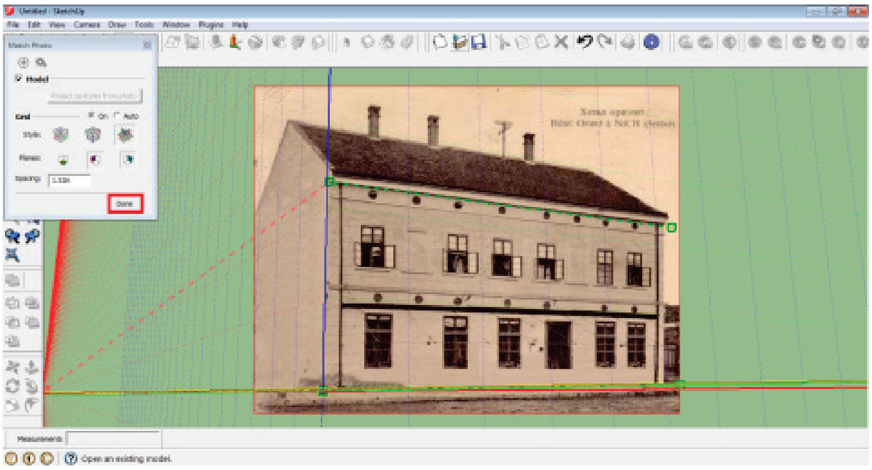

Figure 2. *Immensity Marking*

Standard SketchUp tools were used to obtain the outlines of the object. By making tridimensional shapes and adding and subtracting certain parts, the model was gradually shaped.

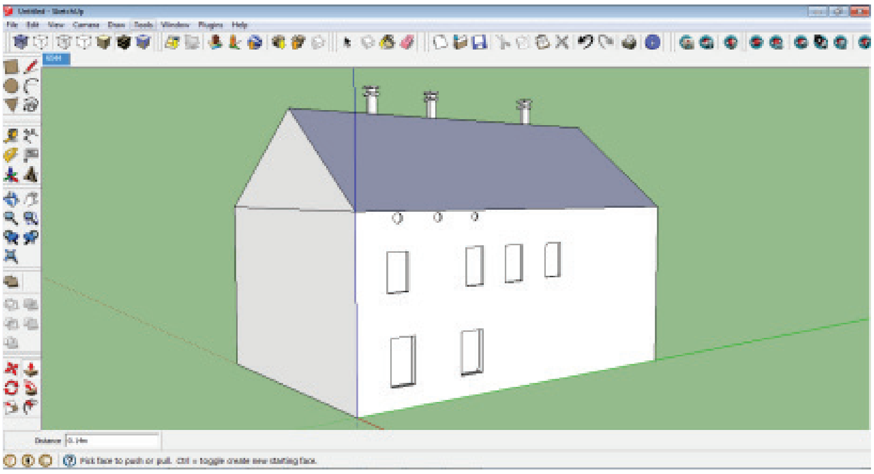

Figure 3. *The process of sketching the object*

Roughly sketched dimensions of the object (Figure 3.) were further shaped using the details on the object itself. Unfortunately, due to the lack of photographs, the object was shaped and modeled using improvisation, insights about symmetry of the object and internet search for the information about the style and the period the object was built in.

Figure 4. *Details which need to be removed*

It is necessary to apply the texture to the sketched object. Considering the fact that there are some environment details on the picture (Figure 4.), it is necessary to remove them using Photoshop or a similar photo processing tool in order to obtain only a clean texture of the façade.

Figure 5*. Final sketch of the model*

3. AUGMENTED REALITY PRESENTATION

In order to convert the tridimensional model and the presentation, AR Media plugin for SketchUp was used. Launching of the AR-Media Player activates the camera installed on the device. Once the desired marker is identified, the model connects with it and the object is displayed. By moving the marker, moving of the virtual model of the object is being done on the display, as well.

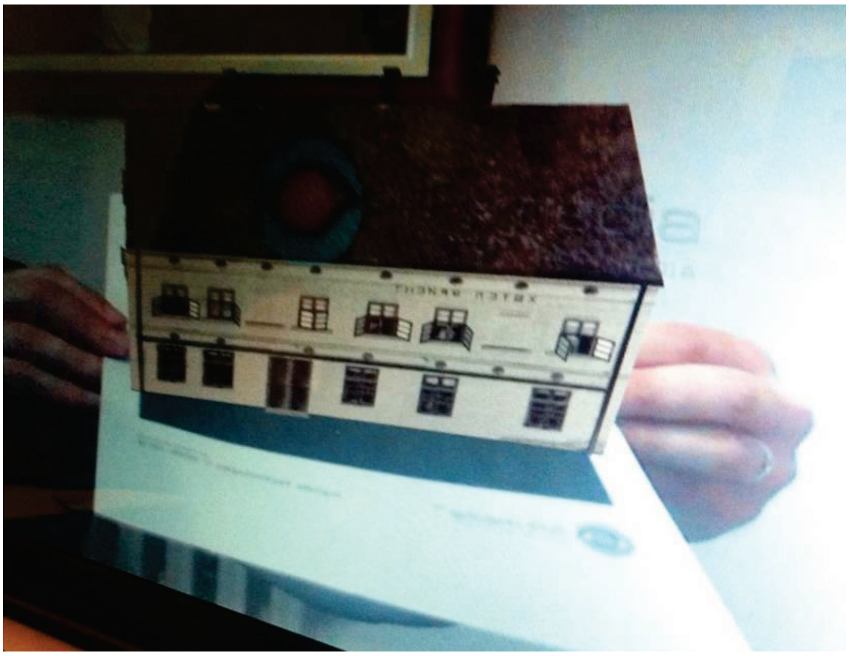

Figure 6. *Object display on the AR marker*

4. CONCLUSION

In this manner, we demonstrated how far the modern technology has progressed and how applicable it is in any area of life. This kind of presentation is very useful because it shows historical structures we are not able to see today in great details. It is very user-friendly due to simplicity of handling the tool itself and the devices we use every day. The process of creating the model is not that demanding as obtaining the photographs of no longer extant objects is. There is a lack of sources because technology only started to develop later. Augmented Reality Media presentation of no longer extant objects can be characterized as both educational and creative, and it is only as much interesting as much we are determined to explore.

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THE APPLICATION OF AUGMENTED REALITY IN THE PRESENTATION OF EXISTING ARCHITECTURAL FACILITIES

Petar Pejić [1]
Sonja Krasić [2]
Nenad Jovanović [3]

Abstract

The presentation of an existing architectural facility is most often done because of its historic significance or design values. Traditional methods of presentation imply the use of perspective images and videos. Contemporary methods of presentation use the development of hardware, software and the Internet for this purpose. This paper presents a comparative analysis of the methods of presentation of existing architectural facilities using: perspective images, videos, 3D web and augmented reality. The complete analysis has been illustrated by the case study of the presentation of the "Salon 77", the former Bali Bey Mosque in Niš.

Key words: *presentation of existing architectural facilities, augmented reality, 3D Web, perspective image, video*

1. INTRODUCTION

Augmented reality (AR) is an emerging computer technology where the perception of the user is enhanced by the seamless blending between a realistic environment and computer-generated virtual

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objects coexisting in the same space [1]. The resulting mixture supplements reality, rather than replacing it [2]. The evolution of modern microprocessors and computer memories during the past decade has made the acquisition, recording and manipulation of virtual 3D data technically affordable, even with standard personal computers [3] and handheld devices.

Augmented reality technology has been proven to have great potential in many different areas, such as education, entertainment, medicine or the arts [3]. However, researches in the field of architecture are very rare and usually have limited applicability, such as to the presentation of facilities of architectural heritage.

The presentation of a particular architectural facility is most often done because of its significance and attractiveness. The following things are promoted through the presentation of a particular facility:

- cultural and historical significance and the tradition of a city or a region where it is located or
- contemporary architectural design values of its location

Traditional methods of presentation imply 2D photos of the facility or 3D animations and video clips. Technology development has enabled web 3D view of the models of facilities even for users with basic computer literacy. Three-dimensional models of existing architectural facilities are presented in an intuitive way with the application of augmented reality. This paper has comparatively analyzed the methods of the Bali Bey Mosque presentation in Nis, by comparing the traditional methods (photos and videos) and the contemporary methods (3D web presentation and augmented reality).

2. MATERIALS AND METHODS

The complete analysis in this paper has been conducted on the former Bali Bey Mosque, currently “Salon 77,” in Niš. It is located in the central part of the fortress in Niš and it represents the endowment of Bali Bey. The first mention of the mosque can be found in the Ottoman census defter (register) from the period 1521 – 1523. The facility had suffered damage over time. Therefore, it was completely reconstructed in the period 1976 – 1977. It has a square base and an area of 64m2 with 16 windows, and a dome on pendentives, 12 meters high. Although this facility is one of the two preserved mosques in Niš from the Ottoman period, it is not used for religious purposes instead serving as an exhibition area and a gallery called "Pavilion 77" [6].

Free software packages and data available on the Internet have been used in order to carry out a comparative analysis of the traditional and the contemporary methods of presentation of existing facilities. We used the video material from the internet portal “Youtube”, and the Internet services "3D Warehouse", "Sketchfab" and "Google Earth" for a three-dimensional model presentation; whereas for the presentation of the model using augmented reality we used the software package "Augment".

3. TRADITIONAL METHODS OF PRESENTATION

Traditional methods of presentation of existing facilities imply a perspective image representation and a presentation using video.

Figure 1*. Facility photo*

Figure 2*. Digital Perspective Image*

3.1 Perspective image

The perspective image presentation can be on a paper or in a digital form. It implies a facility representation from a specific angle predefined by the author. Perspective images can be:

- photos, which show the realistic facility appearance from specific angles (Fig 1),
- photorealistic digital perspective images of the facility-model presentation (Fig 2)

3.2 Video

The video presentation of existing architectural structures can be analog or digital. It implies the representation of an object from specific angles along a path, predefined by the author of the video. The video can be:

- a video clip of a real facility [8](Fig 3),
- an animation of a 3D facility model [7](Fig 4).

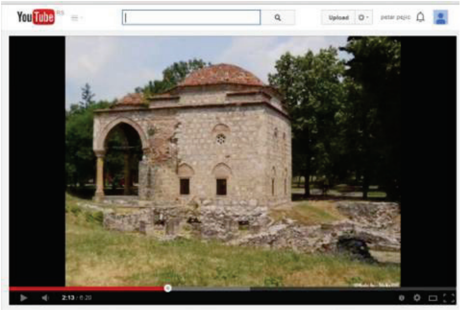
***Figure 3**. Video clip*

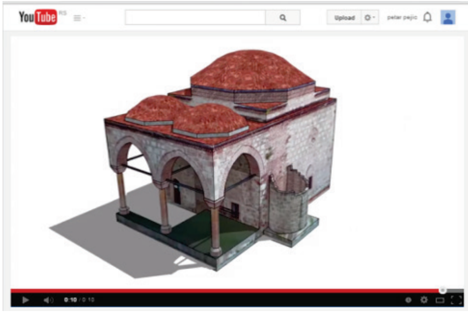
***Figure 4**. 3D model animation*

4. CONTEMPORARY METHODS OF PRESENTATION

The contemporary methods of presentation of existing facilities covered in this paper are: 3D web presentation and augmented reality. These methods of presentation are directly related to the development of contemporary microprocessors and software. They have been used for research purposes for several decades. However, it was not until a few years ago did they become widely applied.

4.1 3D Web

Web 3D presentation is the possibility to view a three-dimensional digital model by using a web browser without installing additional software and without downloading any files. With a basic knowledge of using the Internet, the 3D model of an existing facility can be seen from any angle chosen by the user himself. We distinguish between two basic types of these services:

- the presentation of 3D model, web services such as 3D warehouse [9] (Fig 5) i Sketchfab [10] (Fig 6),
- the presentation of geo located 3D models, web services such as Google Earth (Fig 7).

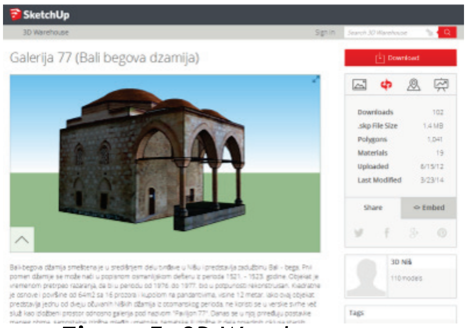

Figure 5. 3D Warehouse

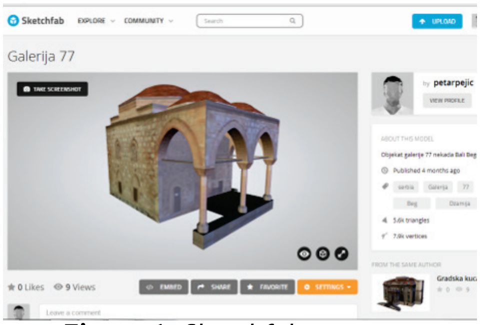

Figure 6. Sketchfab

4.2 Augmented Reality

The augmented reality presentation of existing facilities involves use of an appropriate hardware (a computer, a tablet, a mobile phone), software (Augmented, AR Media...) and markers (2D graphics). It offers the possibility to see 3D models in a realistic environment, just like a scale model does (where by physically moving and rotating a marker you move and rotate the facility, looking at it from the perspective chosen by the user (Fig 8)). This enables an intuitive view of the 3D facility model and it is more suitable for users with no experience in the manipulation of three-dimensional digital facilities.

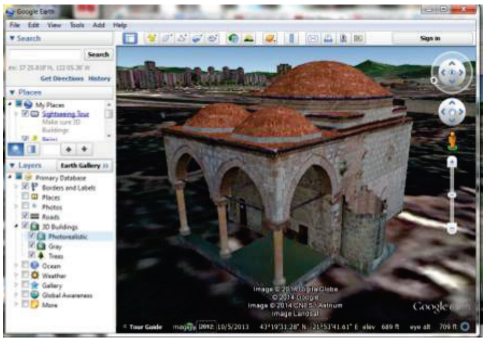

Figure 7. Google Earth

Figure 8. Augment Reality

5. THE RESULTS OF DISCUSSIONS

The assumption in this study is that the user, the observer of the presentation of the existing facility, has basic computer literacy, as well as that his/her only task is to review the previously prepared presentations. Based on these assumptions, the analysis of the positive

(+) and negative (-) factors of the facilities presentation was conducted (table 1).

Table 1*. The positive and negative factors of presentations*

Factors\presentation	Persp.Image	Video	3D Web	AR
Application availability	+	+	+	+
Necessary hardware	+	+	+/-	-
Review start	+	+	+	+
The complexity of use	+	+	+/-	+
Representation elaborateness	-	-	+	+
Representation stability	+	+	+/-	-

Applications for viewing the presentations of existing facilities are widely available and there are free versions. All portable devices and computers have sufficient hardware to view perspective images and videos. Higher-quality hardware is required and an Internet connection is mandatory in 3D Web presentation because of the manipulation of 3D content. The most demanding hardware is necessary in presentation using augmented reality. Besides the basic components it must have at least a camera, whereas it is desirable, because of the presentation stability, that it additionally has a gyroscope, an accelerometer and an electronic compass. The complexity and elaborateness of 3D models directly affect the complexity of the necessary calculations and the need for hardware with higher processing power.

Basic knowledge of the use of applications on computers and portable devices is enough to view each of the covered methods of presentation. The use of applications for viewing perspective images and videos is extremely simple, because it is the part of the basic IT culture. The requirement that the user has some experience in manipulating 3D content is negative when viewing 3D Web presentation; whereas the use of AR applications is reduced to the intuitive movement of markers or a mobile device in order to view the model.

The presentation of existing facilities using traditional methods is limited compared to the contemporary ones in terms of the freedom to choose the viewing angle. In perspective images and videos the angles predetermined by the author are displayed and there is no possibility for the user to change them. Therefore, it is often impossible to view the entire facility from all angles and in particular to view the most interesting details. With 3D Web presentation and augmented reality the user has a three-dimensional model of the entire facility and the possibility to choose viewing angles.

The representation stability of perspective images and videos is constant and does not depend on external conditions; and most of today's hardware enables stable work of their applications. The representation stability of 3D Web presentations are influenced by the internet speed, and there might be difficulties in presentation with hardware with lower processing power. The stability of an AR presentation is influenced by numerous factors. The complexity of a 3D model which is presented must be supported by hardware of the appropriate power. The model representation is done based on the detected position of the marker. The quality of representation depends on the quality of the camera which detects the marker, as well as on external conditions of the marker illumination. Insufficient light makes it difficult to detect the marker, thus influencing the representation stability. If the camera does not detect the marker, the representation stops unless the device has an accelerometer, gyroscope and compass.

6. CONCLUSION

The traditional methods of presentation, perspective images and videos, are characterized by stable performance and simple use. However, they are limited in terms of freedom of viewing content. The user often sees only parts of the facility which is presented. With this method of presentation, it is not possible to show all the facility details interesting to the user.

The contemporary methods of presentation 3D Web and Augmented Reality can have problems with the work stability, especially on devices with lower processing power. The biggest problems with the stability of the applications used for presentation occur in augmented reality due to the complexity of its work and the involvement of different hardware.

Unlike the traditional methods of presentation, the contemporary ones enable viewing the entire facility. The choice of the viewing angle and keeping an eye on the specific details is up to the user, which greatly improves the presentation principle. The contemporary methods of presentation in relation to the traditional ones, regardless of the complicating hardware calculations, do not increase the complexity of use. On the contrary, in augmented reality we have a simplification which is reflected in the intuitive use of display devices.

It could be said that augmented reality transforms mobile devices into a magical frame through which one can see the models of facilities. The development of contemporary hardware accompanied with Augmented Reality presentations development represents an evolutionary development of the method of existing facilities presentation. With further hardware development current disadvantages regarding the usability and functionality of these applications will be eliminated.

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APPLICATION OF AUGMENTED REALITY IN INTERIOR DESIGN

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Bojana Anđelković [3]

Abstract

The augmented reality represents a contemporary technology which has been finding increasing application in various fields of life. As it allows mixing of presentation of actual and virtual worlds, it is very suitable for presenting of different architectonic ideas. The basic problem encountered by the architects while designing the interior is the physical arrangement of the existing space. The contemporary interior designs comprise production of 3D space models and their presentation. By virtue of that, the principles of augmented reality are applicable in the area of design and interior arrangement. This paper analyzes and classifies the currently available software packages and augmented reality principles applied in the field of interior arrangement.

Key words: *Augmented reality, Interior design, Architecture, Visualization*

1. INTRODUCTION

Augmented reality is the technology by which the users' perception of the real world is complemented with virtual objects[1].

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This technology augments the real environment with computer generated images, 3d models, text or sound. The augmented reality does not change reality like the virtual reality, but enriches it with digital data, making the virtual and actual object coexist in the same space[2].

The augmented reality system is very complex, and in general it must allow:

- Tracking and locating the real world,
- Display of virtual information
- Alignment and superposing of virtual data on the actual environment image.

In general, the augmented reality system must be equipped by the: screen, tracking device, graphic device and adequate software[2]. Head-Mounted Displays (figure 1a) represent one of once most popular approaches to the development of mobile augmented reality. The biggest problem is the weight of the system, dimensions of used hardware and social unacceptability of the users' appearance.

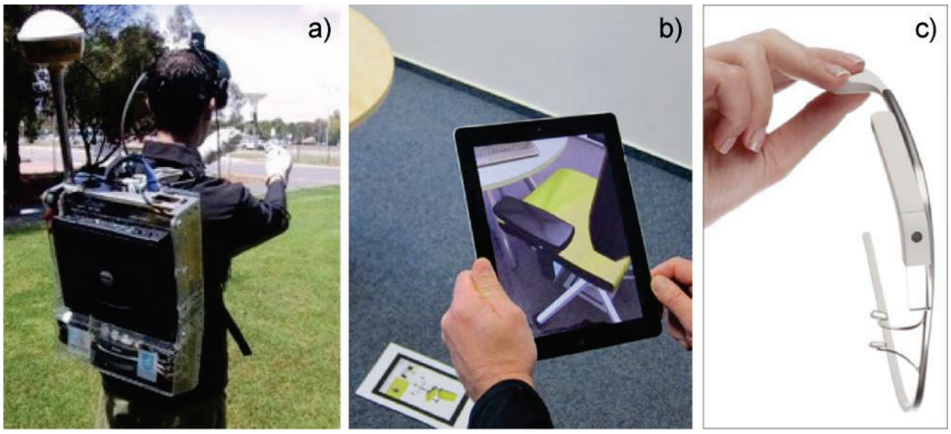

***Figure 1**. development of augmented reality system: a) Traditional Head-Mounted System, b) handled devices, c) Future of Head-Mounted System,*

Development of technology allowed reduction of size of necessary components of an augmented reality system[3]. Contemporary portable devices, (figure 1b) such as the smart phones and tablets have all the necessary sensors (proximity, gyroscope, accelerometers, GPS), making them very suitable for development of augmented reality systems. However, current global development trends of mobile technologies are oriented to integration of technology of smart portable devices into new Head-Mounted Systems (figure 1c) such as the "Google glass" project[4], which overcome all the insufficiencies of the previous systems of the same type.

Every interior space has a certain design, some simple and some complex. The design is created for the purpose of coordination with the rules and technical regulations on construction on one hand, and esthetic appearances on the other. The interior design is a trade dealing with creative and technical aspects of creation of arranged interior space[5]. The generally accepted method of presentation of architectonic design of interior comprises production of a design, which contains the 3D presentation of space. As architecture is dealing with modeling of the actual world, the augmented reality is becoming an increasingly used method of design presentation.

The application of augmented reality in the interior design can be with the goal of:

- finished design presentation or
- creation of design in real time.

Both cases of application of augmented reality in the interior design can be performed in two ways:

- in a small scale (the user can use the model of space).
- In a 1:1 scale (the user is in the space being treated),

The goal of this paper is the comparative analysis of the methods of presentation and creation of interior design using augmented reality on the portable devices. A special attention will be paid to the necessary level of foreknowledge for using of these systems, and of their limitation and advantages in respect to the classical approach of the interior design.

2. INTERIOR DESIGN PRESENTATION

Architectonic interior space design in the traditional terms comprises production of 2D drawings and 3D models. Presentation of 3D models comprises a photorealistic display of space in the form of photographs or video. In such method of space presentation, an architect determines the display angles, so the user (commissioner of the design) cannot have the overview of the complete space.

As opposed to the traditional display of the interior, the contemporary methods of augmented reality, provide an opportunity to view the entire space, in an entirely intuitive way and from all the angles.

The interior design using augmented reality can be viewed in a smaller scale as a model (Figure 2a). For such display, on needs a 3D model o the interior, portable device, appropriate software and a marker (most often a 2D sign). By starting the software on the portable device, a camera displaying the real world is activated. If the software, detects a marker by camera, it displays a model of the interior in its place. By changing the angle of the marker in relation to the portable device, the view angle changes in real time. In case the software does not detect the marker, the interior model position is determined by the portable device sensors (gyroscope, compass...).

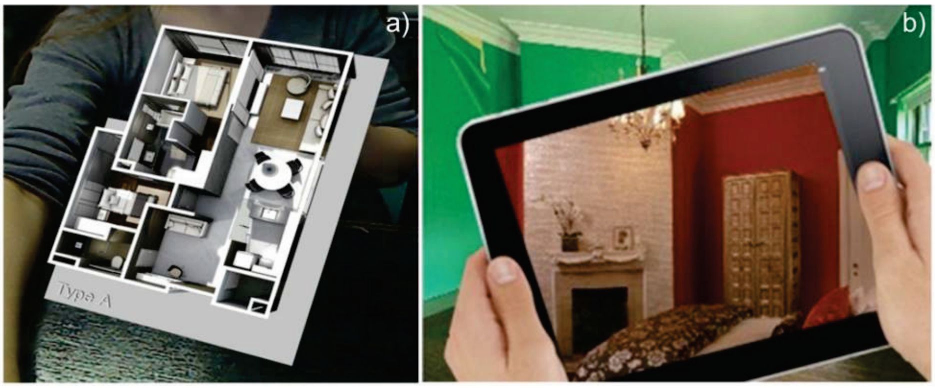

***Figure 2**. display of interior design: a) small scale, b) 1:1 scale*

The interior design using the augmented reality can be viewed in the 1:1 scale inside the actual space being arranged (Figure 2b). For such display, 3D interior model, portable device, corresponding software and the marker (most frequently a 2D sign) or GPS locating. It is necessary that the user is inside the space being arranged. By starting the software on the portable device, the camera displaying the real space is activated. If the program detects a marker via the camera, it will display the newly design elements of the interior on the predetermined place. By changing the position of the device in respect to the fixed marker, the view angle in real time also changes. In the event the software does not detect the marker, the determination of ht interior model position is taken over by the portable device sensors (gyroscope, compass...). The second method of presentation is via the

GPS usage. For such presentation, it is necessary the 3D model is precisely geo-located, so that it could be positioned in the appropriate place. Rotation and change of view angle are detected owing to the sensors (gyroscope, compass…) while the change of the user position is detected through the change of GPS coordinates. Rotation and change of view angle are detected owing to the sensors (gyroscope, compass...), while the change of the user position is detected through the change of GPS coordinates.

3. INTERIOR DESIGN IN REAL TIME

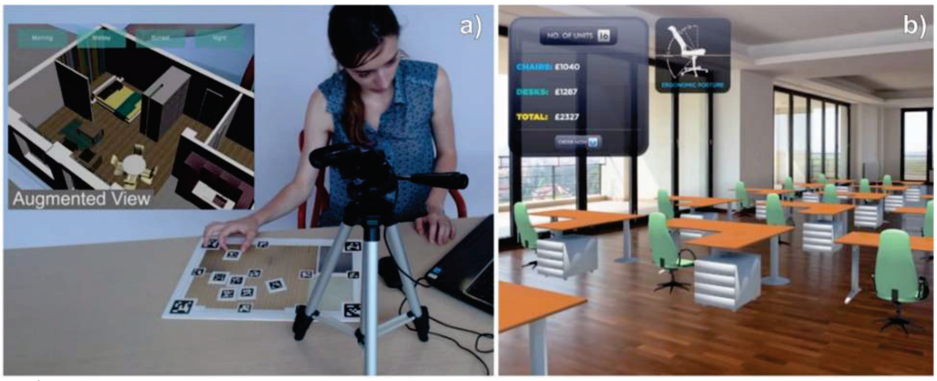

Figure 3. *real-time interior design: a) small scale (model), b) 1:1 scale (in the real space)*

When arranging interior, an architect would suggest and test the design of certain interior space. The problem occurring in this process is that this may require a lot of work and time. If the user is not satisfied with the appearance of the space, the architect must rearrange the plan, and this calls for the additional time and cost. A partial solution of this problem can be usage of the augmented reality.

Development of digital technologies contributed so that many manufacturers of the home furniture offer 3D models of high quality for free. This is an excellent basis for production and presentation of space in the augmented reality. In order to solve the potential deliberations of the clients, regarding the choice of furniture, as efficiently as possible, the augmented reality enables their inclusion in the designing phase.

The design of the interior, using augmented reality can be viewed in a small scale, in the form of a model. For such display, one requires a 3D model of the interior walls, 3D models of furniture, portable device, adequate software and markers. With such approach, the architect creates the wall design, while the choice of furniture and its arrangement is agreed with clients in real time. In this approach, several 2D markers placed on a flat surface are used. Each of them represents a certain piece of furniture (Figure 3a). Movement of markers on the screen is reflected by the movement of furniture.

The interior design using augmented reality can be viewed in the 1:1 scale inside the real space being arranged (Figure 3b). For such display, one requires a 3D model with the changes of the interior walls, 3D models of furniture, portable device, adequate software and markers (most often a 2D sign).

It is necessary that the user is inside the space being arranged. By starting the software on the portable device, the camera displaying the real space is activated. If the program detects a marker via the camera, it will display the newly design elements of the interior on the predetermined place. By changing the position of the device in respect to the fixed marker, the view angle in real time also changes. In the event the software does not detect the marker, the determination of ht interior model position is taken over by the portable device sensors (gyroscope, compass...). Many companies dealing with the manufacturing of furniture offer their software packages based on the augmented reality for the selection of furniture. In the software, apart from the choice of various pieces of furniture and their viewing in real space there is a possibility to order them and analyze the total cost of procurement.

4. RESULTS AND DISCUSSION

By comparative analysis of presented ways and the method of application of augmented reality in the process of interior design, table 1 with positive and negative factors is obtained.

For interior design presentations, it is necessary to produce a complete 3D model of interior space, for which one must possess a foreknowledge of modeling. On the other hand, in the real time design, the architect's task boils down to creation of the model of changes on the existing walls. The existing applications, many of which are free, provide intuitive usage by the users. Because of the implementation of sensors, (gyroscope, compass…) and hardware performances of portable devices, applications tend to be very functional. The only problem occurs in the usage of GPS modules because of the enclosed spaces shutting out the GPS signals.

Table 1 Positive and negative factors of AR application in the interior

Interior	**Design presentation**		**Real time design**	
Scale	Small	Actual	Small	Actual
3D model	-	-	+/-	+/-
Foreknowledge of modeling	-	-	+/-	+/-
Complexity of usage	+	+	+	+
Software accessibility	+	+	+	+
Functioning	+	+/-	+	+

5. CONCLUSION

Application of augmented reality in architecture and interior represents the presentation method becoming increasingly used. Such presentation method transforms the portable device into a "magical window" which converts the 2D medium into the 3D presentation of the interior design.

From the client standpoint, in the traditional way of interior design presentation, the display of space was predetermined by the architect. As opposed to that, the augmented reality method allow viewing of all the parts of space chosen by the client. Usage of portable devices enable the client to fully view the design in a more natural way.

From the architect standpoint, both methods require conceiving of arrangement and production of 3D model for the purpose presenting an idea of interior design. The next phase of the traditional approach requires production of a photorealistic presentation in the form of images or animations. This phase requires knowledge of the work in software packages for this purpose, and investment of considerable time. In the presentations using the augmented reality methods, the

3D model can be converted into an adequate format and started using the appropriate software. In comparison to the traditional procedures, this approach does not require foreknowledge nor is time-consuming.

Owing to the development of offer of the companies dealing with the manufacturing of furniture, their 3D models became available to everyone. Thus inclusion of the clients in the designing phase, using augmented reality, contributes to the efficiency of design creation.

The main shortcoming of the interior presentation using augmented reality is the lack of capacity for photorealistic presentation, because of hardware limitations and complexity of calculations performed so that it could work.

Augmented reality is definitely future of visualization of architectonic designs. The principles of its functioning and application in the domain of design and presentation of interior are at a higher level than traditional. The further development and improvement of the technology will surely contribute to the better quality and photorealism of presentation.

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BIO-INTERFACES:
STUDIES IN BIONICS AND SPACE STRUCTURES DESIGN

Jelena Milošević [1]
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Abstract

This paper explores the concept of bio-appropriation as a problem-solving methodology for production of designs based on principles derived from nature. In specific, the effectiveness of this approach was tested through generative design process for bio-inspired space structures. A source of inspiration were interface surfaces forming a common boundary among two different phases of matter, or in the case of organisms bio-interfaces formed between a biomaterial and another material. Design potentials of the functions that govern interface processes and interactions were re-viewed. Identified patterns were re-evaluated, re-fined and used for creation of formal solutions and their dynamic transformations.

Key words: *Generative Design, Bio-appropriation, Bio-interface, Structural Systems, Space Structures, Space Metamorphosis*

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1. INTRODUCTION

The development of innovative technological approaches in the field of biology generated cultural, aesthetical and technical implications. This paper reviews impact of these emerging and progressive biological advances upon architectural design, and illustrates its potential through a design experiment that utilizes bio-appropriation as a method to explore and manipulate designed matter. Implementation of nature derived relations facilitated implantation of novel space structure design(s) within its environment. Intention was to generate design concept that in terms of form, structure, function and materialization complements, extends and upgrades its context. In this set context comprises combination of two basic influence factors - place (constrained spatial conditions) and time (defined dynamic relations).

Development of information theories and related technologies, accomplishments in the fields of Artificial intelligence and Cybernetics influenced that the notion of architectural performance basically gets associated to the ability of a given system to exchange information with its environment, and take actions that will maximize its chance of success. Increased computational capabilities affected arrangement in which projects are converging toward a unique environment wherein architecture and many types of knowledge-based expertise continuously crossover, exchange, analyze and produce information of all kinds. The expression of this condition is exemplified by the transformation of design studio into a design laboratory where designers experiment by acquiring terms and practicing discourses often borrowed from other disciplines. In that respect, introduction of terms from the biological sciences vocabulary, such as *morphogenesis*, *homeostasis*, *self-organization*, *self-assembly*, *self-replication*, *regeneration*, *adaption*, etc., has etymological implications upon architectural language and our way of understanding of architecture. Embracing these concepts, appropriating and borrowing elements and procedures or using processes and methods form nature, stands in the light of a phenomenon that is referred in [3] as the *biologicalisation of architecture*.

As the strict boundaries of design practice are increasingly questioned, broadened, and blurred, technology development and application, as well as incorporation of overlapping patterns, emerge as an essential vehicles for design exploration and assessment in controlled but indeterministic generative design processes, characterized by application of artificial and to some extant autonomous production systems. Though any system that possesses generative capacity could be used for these creation processes, application of computational systems is prevailing. Respectively, S. Krish notes: *Generative Design is the transformation of computational energy into creative exploration energy empowering human designers to explore greater number of design possibilities within modifiable constrains* [9]. In a certain way exceeding role of plain tool generative systems actively participate in creation and to some extent shape designers process of reflection, opening possibilities for unanticipated outcomes.

2. BIONITERFACE CONSTRUCT

In this study bio-appropriation was exploited as a problem-solving methodology and bio-interface was subjugated as stimulus for conception of spatial design.

2.1 Bio-appropriation

Bio-appropriation represents creation strategy that uses techniques such as re-vision, re-evaluation, variation, interpretation, imitation, approximation, supplement, increment, paraphrase, mimicry, allusion, intertextuality, etc. for derivation and implementation of design principles taken from nature. By evolving problem solutions from the natural processes, Nature becomes mentor, model, system, setting a new standards for design[1]. The modes of transposition of identified natural laws in the fields of science, engineering or art could be in the form from literal coping of shape to a more abstract derivation of principles and systematic resolutions. The aim is realization of optimal solutions which have a certain desirable attributes of biological systems.

[1] The clear distinction should be made between nature as a source of explanation and source of inspiration. While in the first case, in the context of natural sciences, it is essentially important that analogy is valid, in the case when it is used as a starting point for design experiment weaker form of analogy is tolerable and according to Frazer [4] even misunderstand or heretic ideas could be stimulating.

Biological systems are frequent inspiration for generative methods. According to C. Soddu: *Generative Design is a morphogenetic process using algorithms structured as not-linear systems for endless unique and un-repeatable results performed by an idea-code, as in Nature* [12]. Generally, strategies inspired by nature applied in generative processes could be summarized by three key notions: *mapping*, *collectivity* and *evolution*, that are directly related with procedures of *representation*, *composition* and *variation* of information fundamental for design creation [13]. With the remark that generative design basically always represents evolution of data.

In architecture, the morphogenetic projects deal with the mathematical nature of form and its capacity to translate desires, environmental constraints and technical limits into integrated morphological solutions. The observations from the nature have been greatly used as foundation of form-finding strategies exemplified in structural design experiments from F. Otto and B. Fuller to contemporary digital avant-garde applications of digital media generative tools - *digital morphogenesis*. In a way comparing an object to a living organism, *a form of artificial life* [4] morphogenetic approach seeks ways to create an architectural condition by which the object *adapts*, *reacts* and *mutates* according to the external environmental and internal parameters of the designed systems.

2.2 Bio-interface design pattern

In this study physical and symbolic gist of the bio-interfaces were assigned to the parameters that represent basis for the computational design exploration. The computation was preceded by identification and abstraction of patterns from the nature and formulation of generative system for production of optimized design solutions and their pulsating variations. Common properties and performances of the natural interfaces was studied, and outcomes were processed and instrumentalized in order to determine formal, structural, material and functional constraints. Re-evaluated and re-fined properties of bio-interfaces were transferred in design context by taking advantage of structural and evolutionary processes.

An interface represents a surface forming a common boundary among two different phases of matter, such as an insoluble solid and a liquid, two immiscible liquids, a liquid and an insoluble gas, a liquid and vacuum, or in the case of organisms boundary formed between a cell, a biological tissue or a biomaterial with another material. Interfaces have predominant importance in the systems with big area to volume ratios, such as colloids. In the light of this study particularly interesting were gas liquid interface exhibited between aerosols and other atmospheric molecules. And in specific liquid foams that could constitute a convenient model system for exploration of structural surfaces. Soap-film experiments conducted by F. Otto and his team at the Institute of Lightweight Structures at the University of Stuttgart illustrate feasibility of this form-finding method. Soap-films represent uniformly stressed minimum energy systems that naturally minimize the surface between given boundary conditions[1]. In the case when film acts as pressurized membrane obtained bubble shapes may be used for rigid shells or pneumatic structural systems.

Surface tension is the function which rules interface processes involving liquids. The soap molecules are salts ionized in water, which orientation gives rise to a force along the macroscopically thin surface layer. For any soap-film that acts as a boundary between volumes of liquid and gas, the excess pressure needed to contain the liquid is the product of surface tension f and the sum of the principle curvatures $K_1 = 1/R_1$ and $K_2 = 1/R_2$. The uniform and constant surface tension in the soap-film implies that the sum of the principle curvatures has to equal zero - the typical geometric property of all minimal surfaces [1]. Foam rheology researches demonstrate that in the absence of external forcing such systems are trapped in metastable configurations. As a consequence, they exhibit a fine yield stress below which the material responds elastically. When a large stress is imposed, it triggers a series of plastic events which release the applied stress, yielding a macroscopic flow [2].

In design exploration our task was to simulate system that consists of monolayer bubbles configured within predefined boundary. Properties of dynamism and fluidity that create distinctive configurations of bio-interfaces were transferred in the design context. Though interdependent dynamism and fluidity are different concepts. Dynamism is produced by the force fields which influence cohesion (coagulation/attraction) and adhesion (dispersion/separation) of the interface. It could be precisely defined and controlled by parameters.

[1] Since the energy embedded in soap film is the product of the total surface tension present and the area of the film, the state of minimal energy is only achieved with minimal surface area between a given boundary condition [1].

In this set the constrained design environment affected and characterized bubble-scale dynamics of motion and deformation during shearing processes, exhibiting shear-banding instability. The research of dynamic adhesion properties could be conducted by varying distances between *bubbles*. On the other hand, fluidity represents lightness, liquidness, gaseous, everything marked by easy motion transfer and constant changes enabled by its form, composition and structure. Fluidity provides softness, imagination, as well as possibility to demarcate all indefinable by parameters, to be transferred and explained in symbolic manner. And in symbolical terms surface structure should envelope new complement contents. Accordingly, methodological frame is compatible with rational view of interaction in which design is engaged in dialogue with its context, emphasizing partition between novel and existing forms and blurring distinctions/mutability between novel and existing contents.

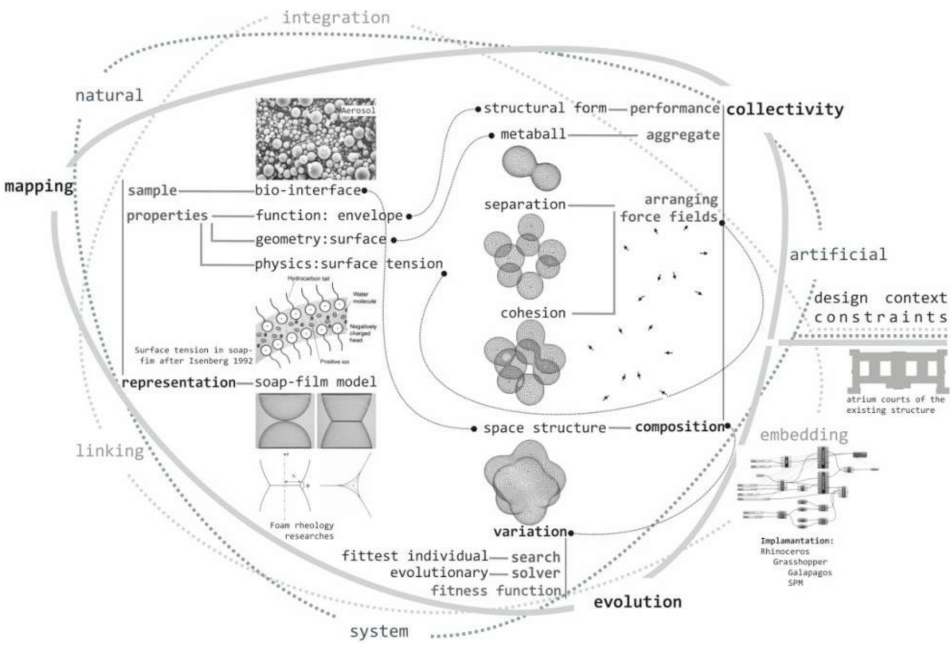

Figure 1. *Design diagram*

Instead of form proposition, the focus of morphogenetic design process was definition of generative system (exploration construct) which intermediates production, control and selection of form(s). In this set the essence was to regulate and control relations between design object, rules (specifications) and conditions (constraints).

Without any intention for linearization, the design process was conducted by abstracting definition of design problem, formulation of the rules, conditions and constraints relevant for the search process and their transformation into the exploration system/construct, and then creation of instrument for production of design variations and selection of desired results which are applied for design production. By parallel monitoring of all the rules object emerges by crossover of solutions and system response. Out of this complex, dynamic, nonlinear process intricate and variable forms emerged.

3. DESIGN PATTERN IMPLEMENTATION

Within this study, generative role of digital technologies was realized by manipulation of following computer constructs: isomorphic fields (for modeling of isomorphic ploysurfaces) and evolutionary strategies (for solution search).

3.1 Generic algorithm

The generative system was implemented by application of 3D graphical program Rhinoceros®, its plug-in for parametric design Grasshopper, SPM Vector Components plug-in for vector field simulations [8], and built-in evolutionary solver Galapagos [11]. Two types of parameters were used to determine design constraints. Static parameters based on boundary conditions formed by the existing structure and variable parameters based on bio-interface characteristics, which produce dynamism and changeability of design.

Shape was modeled by organic-looking objects - metaballs with the centers in spatially distributed points. Generally, these geometries represent implicitly defined isosurfaces through some scalar energy field, where the center of each metaball could be considered as energy source with a fallof in the level of energy by distancing from the point. In this set the meatball surface could be considered as representation of all the points within that energy field that have a particular energy value. Since Grasshopper implementation of metaballs provides component to generate curves which represent flat 2D slice through the set of metaballs, 3D form was created by generating number of these curves on different planes.

The manipulation of variables in the search for the solution(s) that best fit set conditional relation between cohesion and separation

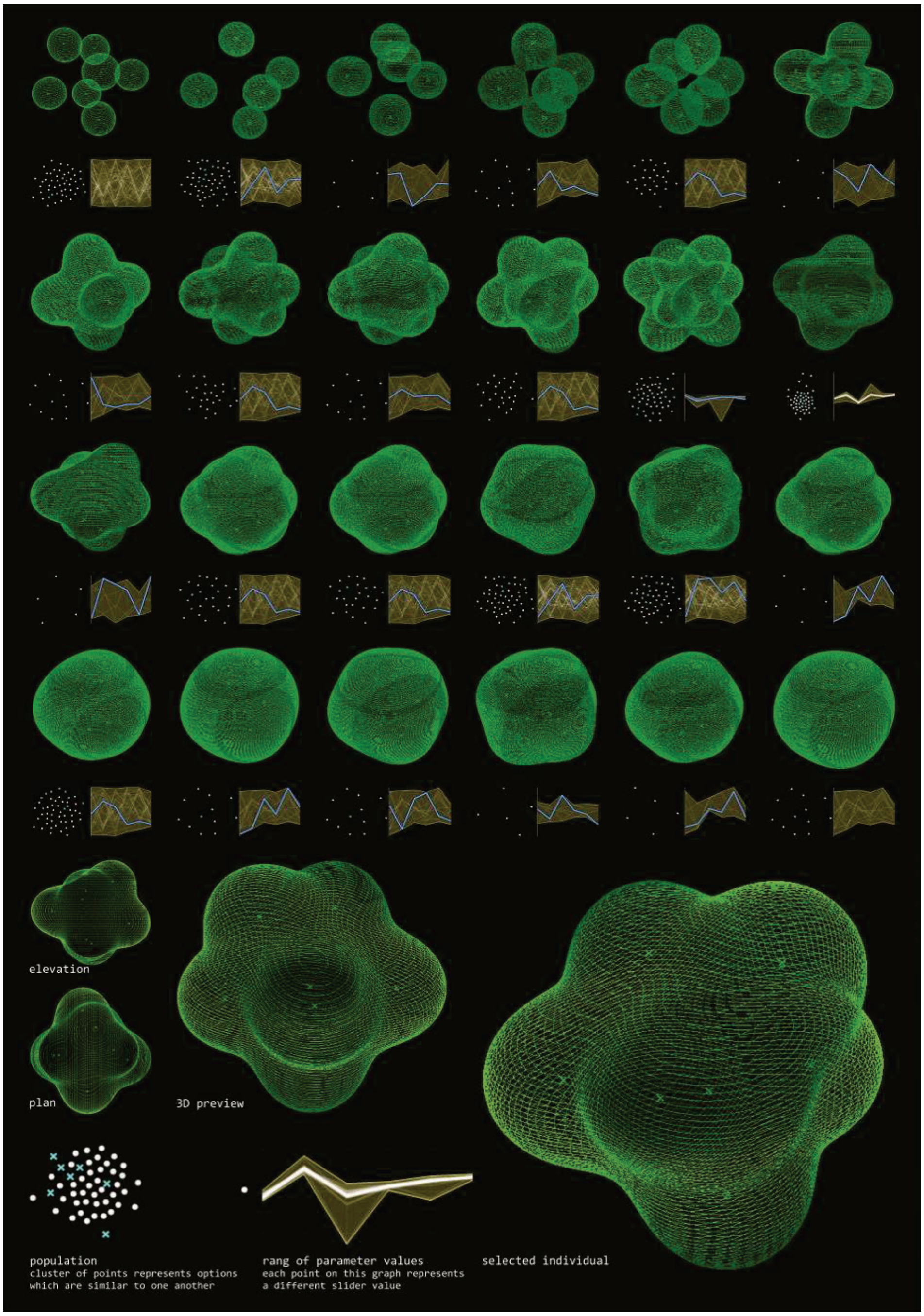

Figure 2. *Design variations*

vector fields was conducted by application of evolutionary solver. Bio-inspired evolutionary algorithms, described in [5], are expressed by the set of generative rules that manage digital morphogenesis. Genes, coded by DNA standards, determine genesis and form of entities. Variations are obtained by gene crossover and mutation. In short characteristics of evolutionary algorithm are following: they operate with coded scripts of analyzed quantities - chromosomes; they conduct search using population of possible solutions; they need fitness function for evaluation of chromosomes and they are based on probabilistic transition rules, i.e. they use randomized genetic operators. Any precisely defined adaptive problem could be genetically formulated and solved by determining representation scheme, evaluation criteria, parameters and variables which control algorithm, determination of results and termination criteria.

3.2 Outcomes

More than derived from scaled-up analogies between biological conditions and large scale constructs (architecture), this design approach implies organic design entity. Term organic here denotes system connection and coordination of parts within composite whole. The combination of functional interdependences and structural unity enables transformations of elements and transitions between them. The presented design, more than being organism or assemblages (typically digitally driven geometric system), is bio-inspired architectural composite that emerges as *naturifical*[1] entity, constructed unstable composite which tends to de-compose and re-compose in different ways, oscillating in-between unique and un-limited variations of form, un-claiming definitive identity.

4. CONCLUSION

Like nature architecture is also based on organization and materialization, deals with morphology and structure, represents composite of individual functional elements that act as a whole. Bio-mimetic approach to architecture requires application of consistent design methodology, in which form is thought in-separately from function, structure and material, and is not considered as a fixed entity but as a sort of reactive, *semi-organic* system. More complex

[1] natural + artificial = naturificial

computational means for exploration, expression and production of form fashioned aesthetics of intricacy and variation on the one hand and on the other hand functional performances and constructional logics of designed systems. The optimality of architectural form represents derivative of parameters which facilitate precisely informing inexact yet rigorous process. The effectiveness of discussed concepts was tested through bio-inspired space structure designs, that reference the relationships between bio-interface and its environment, characterized by the notions of distribution, configuration, connectivity, partitioning, dispersion, suspension, fluidity, dynamics, etc. Outcome of described design process constructs different interactions with surrounding approaching figuration that is flexible, adjustable, and free.

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ALGORITHMIC APPROACH TO ORIGAMI PATTERN APPLICATION IN ARCHITECTURAL DESIGN

Marko Jovanović [1]

Abstract

The new paradigm in architecture tends to lean towards real time adaptability, interactivity and performance optimization. Myriad of techniques are utilized to procure such solutions, mainly focusing on mechanical adaptation of one form into another. The element most prone to application is the facade, as a mediating agent between the interior and the exterior. Origami folding patterns present an approach, where by manipulating elements, the facade can change its function, opaqueness, performance etc. In this research an algorithm is designed that utilizes origami patterns as changeable facade elements. The manner of manipulating and generating real life conditions for simulation and analysis purposes is achieved by applying both a geometric and mathematical approach and comparing it.

Key words: *origami pattern, algorithm, folding, facade performance*

1. INTRODUCTION

Contemporary approach to architectural and urban design involves utilization of algorithms and computation in order to optimize the building's performance and/or design [1,4]. In order to account for changing variables in the building's surrounding, and to factor in

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interactivity between the building and the users, real time adaptability has presented itself as an adequate approach. Application of several adaptability and interactivity techniques, mostly visual and mechanical, has already been researched in previous work [2]. Use of motors, as most common mechanical actuators, is restricted by it size and hence dictates the size of actuating elements. Origami patterns present a manner of planar and spatial tessellation, exhibit changeability and will be researched further on, as adaptive facade elements. Origami is a modern art form, following the basic principle of folding a flat piece of paper, without the use of glue or cutting tools, and transforming it into a spatial form. Since the interconnected layout of mountain and valley folds allows for such tessellation, origami pattern application in architecture opens up great opportunities [3]. Problems can occur when rotating multiple folds, or axes, around one point, since the possibility of generating a real joint to account for this presents a challenge. Also, the thickness of the elements can present an issue during rotation, since paper based origami is thin and allows for such creases and folds to be made [5]. This paper will research an origami based element that manipulates the opaqueness of the facade by opening and closing appropriately. The goal is to limit or control the sunlight exposure. The manner of achieving desired or predetermined state of the origami element will be researched twofold - from a geometrical and mathematical point of view.

2. METHODOLOGY

This research will explore a single equilateral triangle, whose edges are going to fold up towards the orthocenter.

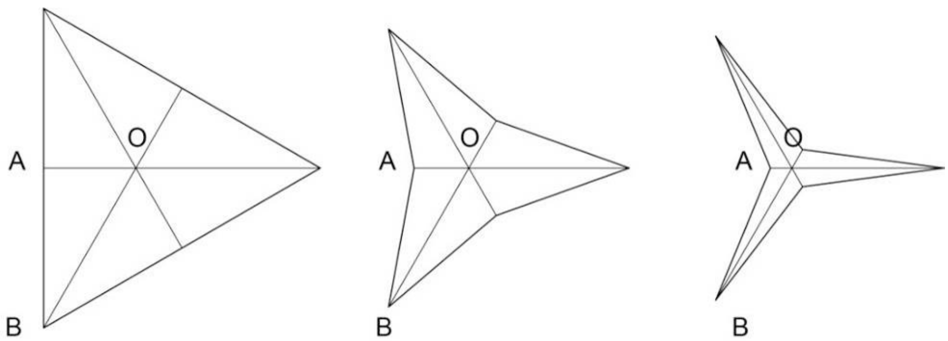

Figure 1. *Stages in folding the equilateral triangle*

That way, the exposed surface area will decrease and allow for adequate sunlight exposure. This principle will be applied to all triangles that form the facade envelope and thus generate an opaqueness manipulating system. The triangle is divided into 6 equal triangles, all similar to the triangle OAB (Figure 1). This triangle's process from the state of being fully closed to the state of being fully open can be simulated twofold - geometrically or mathematically. Geometrical approach takes into account one edge, OA, its angle of rotation, α, and uses basic principles of geometry to find the position of the other two edges, OB and AB, for a specified value of α. The mathematical approach generates a formula of interdependency, between the rotational angle of the edge OB and the edge OA, respectively. Detailed process of generating the missing elements will be described further on.

3. WORKFLOW

Before both manners of simulating the folding process are described, several facts are introduced. The orthocenter is fixed and does not move during the folding process. Only one rotational angle is given that defines the entire folding process in both cases, respectively. The triangle OAB remains planar through the entire process. Edges OA and OB remain in the vertical planes and rotate around the orthocenter, respectively. The orthocenter remains fixed for each equilateral triangle, in order to enable positioning such elements on a rigid structure.

3.1 Geometrical Approach

This manner of simulating the folding process is based on finding the rotated point B, referred to as point Br, dependent on the rotational angle of the edge OA, α. Rotational angle, α, ranges from 0 to 90 degrees, in order to procure a valid folding process. Anything below 0 degrees would close the triangle upwards, and above 90 degrees would lead to self intersection. Since the triangle OAB remains planar, the right angle in the rotated point A, Ar, remains the same. Therefore, it is possible to construct a circle with the center in point Ar, perpendicular to the edge OAr, with the length of AB and intersect it with an arc defining the rotation of the point B, referred to as point Br (Figure 2).

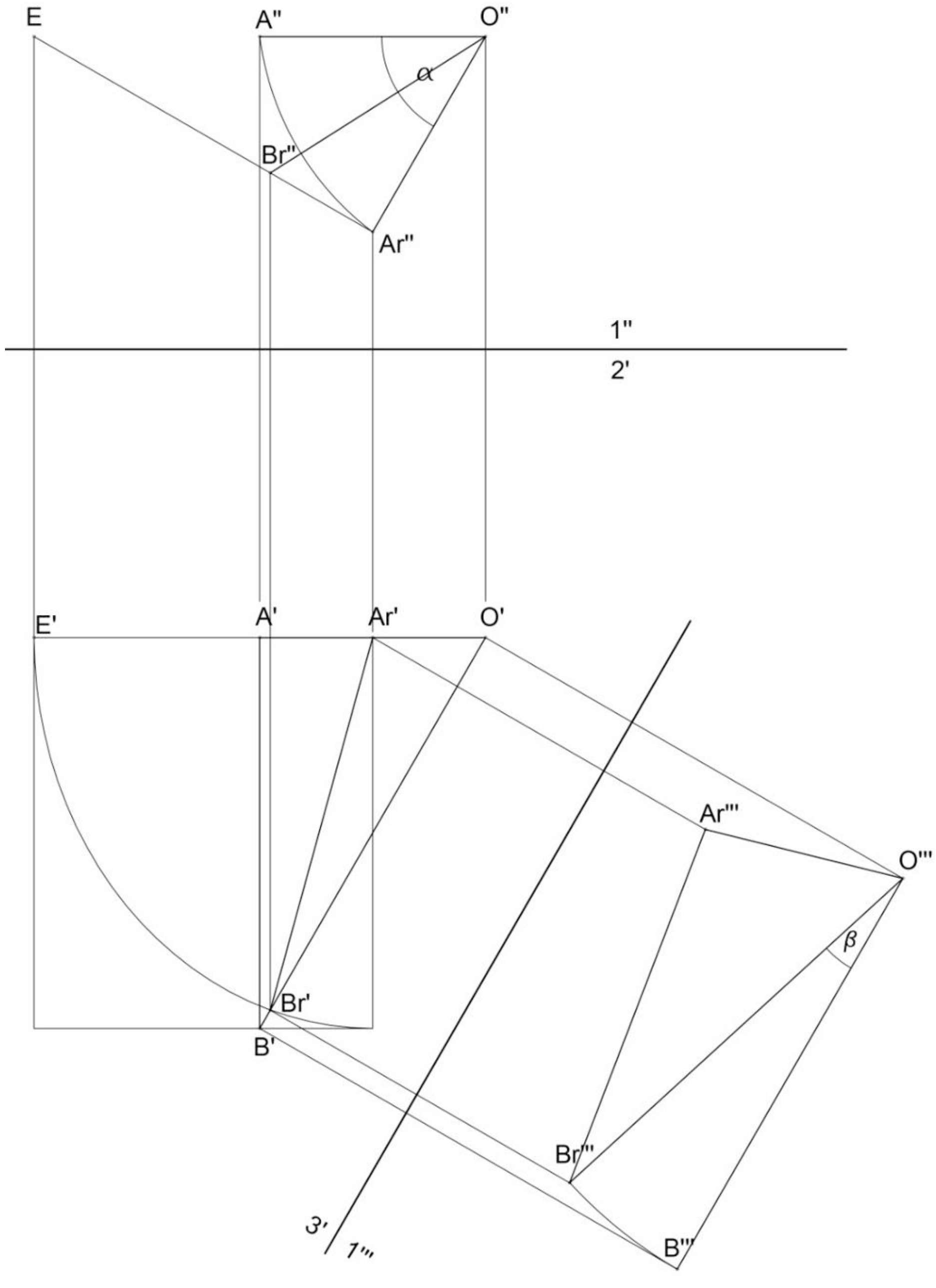

Figure 2. *Finding the edge ArBr and OBr using geometry principles*

The arc has an angle of 30 degrees, since that is the last valid position of the point Br and the length of two thirds of the height of the triangle, which is the circumscribed circle's radius. Intersection generates the point Br, a valid point which is used to generate the missing edges. For very small values of angle α, two points are generated, out of which, the one closest to the orthocenter in the vertical direction is chosen. The need for this filter makes this approach somewhat unreliable, as opposed to the mathematical approach.

3.2 Mathematical Approach

Mathematical approach entitles defining the rotational angle of one edge based on known rotational angle of the other. In this case, the known rotational angle is the one referenced to the edge OBr, angle β. It ranges from 0 to 30 degree. The rotational angle of the edge OAr, angle α, which ranges from 0 to 90 degrees, is defined by using the angle β. Mere multiplication of the angle β by three will give approximate values of the angle α, which leads to discrepancies in edge length. Since this approach is not precise and accurate, another method is chosen. The method of generating the equation is based on referencing the edge lengths from two projections, two views, as seen in Figure 3. In the first projection, edge ArBr, named c, is defined via Pythagoras's theorem as:

$$c^2 = d^2 + e^2 \quad (1).$$

Value e is calculated as cos30*cosβ*OBr, where OBr is the circumscribed circle's radius of the equilateral triangle, as mentioned previously. Value d cannot be calculated, but is instead defined by the unknown angle as:

$$\sin 30 \cdot \cos\beta \cdot Obr - \cos\alpha \cdot OAr \quad (2),$$

where OAr is the inscribed circle's radius.

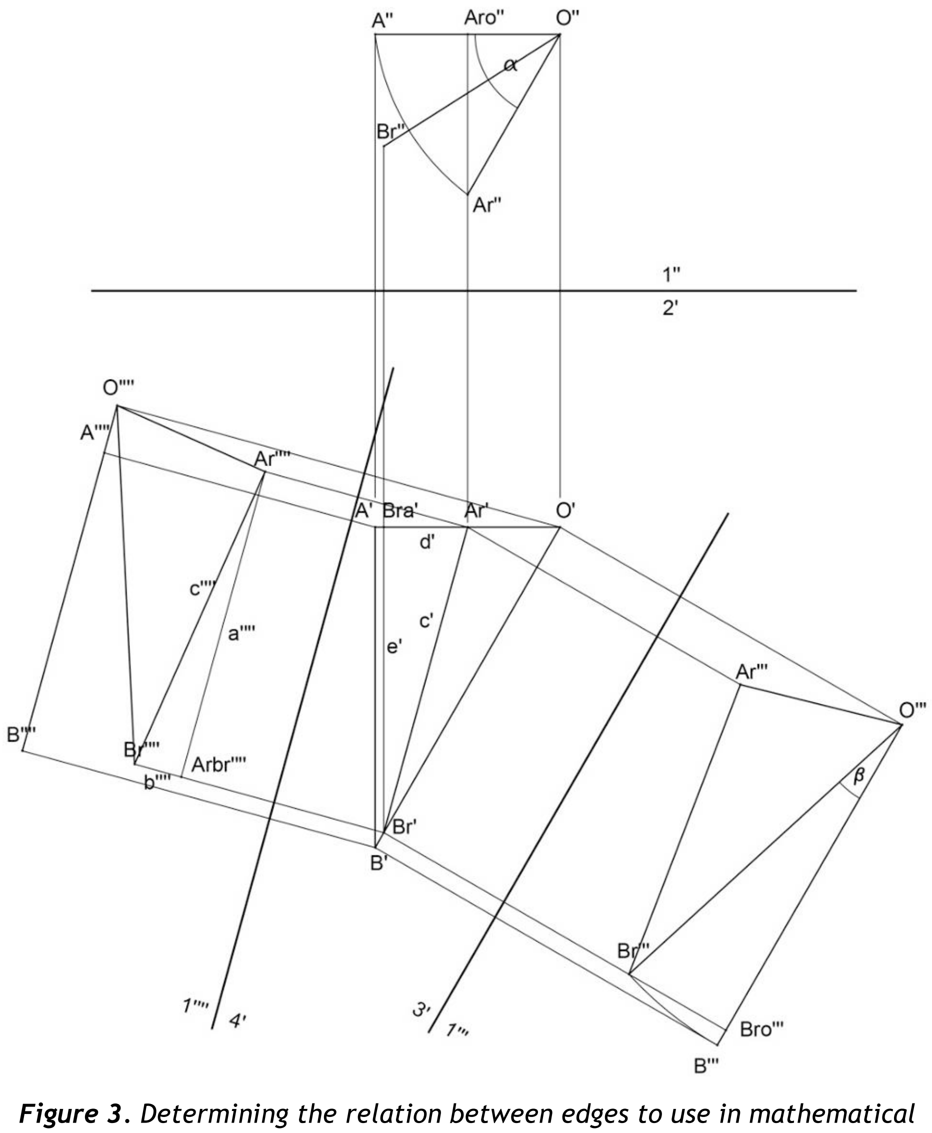

Figure 3*. Determining the relation between edges to use in mathematical calculus*

In the fourth projection, the same line length is defined via Pythagoras's theorem as:

$$a^2 = c^2 - b^2 \quad (3)$$

Value c, which represents the actual length of the edge ArBr is defined as half of the equilateral triangle's edge, or the length of the edge AB. Value b represents the difference between descending of the points Ar and Br, respectively. Therefore it is also defined by one unknown variable, the angle α as:

$$\sin\alpha * OAr - \sin\beta * OBr \quad (4)$$

Since values a"" and c' have the same length, equation (1) and (3) can be joined and expressed as:

$$(\sin 30 * \cos\beta * Obr - \cos\alpha * OAr)^2 + (\cos 30 * \cos\beta * OBr)^2 =$$
$$(ArBr)^2 - (\sin\alpha * OAr - \sin\beta * OBr)^2 \quad (5)$$

By replacing the known values of the edges, and by simplifying the expression, it can be written as:

$$\cos\beta\cos\alpha + 2\sin\alpha\sin\beta = 1 \quad (6)$$

Even though this equation has only one unknown variable, the angle α, the fact is that it is used in both sinus and cosines expression, and hence impossible to calculate in current form. By introducing a known trigonometric relation:

$$\sin^2\alpha + \cos^2\alpha = 1 \quad (7)$$

sinα can be defined as:

$$\sin\alpha = \pm\sqrt{1 - cos^2\alpha} \ (8).$$

By combining equations (6) and (8) angle α can be written as:

$$\alpha = \arccos\left(\frac{cos\beta}{cos^2\beta + 4sin^2\beta} - \sqrt{\frac{1}{cos^2\beta + 4sin^2\beta}\left(4sin^2\beta - 1 + \frac{cos^2\beta}{cos^2\beta + 4sin^2\beta}\right)}\right) \quad (9)$$

In this manner, by changing the value of the angle β, angle α can be calculated accordingly. By doing so, end points Ar and Br are defined for a certain value of β and the edge ArBr can be constructed. An algorithm is designed to accommodate for all of these variable and geometry, which will be defined in the next section.

4. RESULTS

Both of these approaches provide the same end result in terms of generating the geometry. By implementing the mathematical approach, the folding manipulation process is somewhat facilitated, since the edge rotation is defined by numbers, instead of being geometrically constructed. By using a visual programming language in the program Grasshopper, an algorithm is designed that can generate this geometry and animate it, for specific values of the angle β. Input values are the edges of all the triangles similar to the triangle OAB and their respective vertical rotational planes. Since mathematical approach is chosen for the folding process, equation (9) is introduced into the algorithm. By changing the β value, thus rotating the edge OBr, equation (9) is providing the α value, thus rotating the edge OAr. Since the edge ArBr is dependent on these two points, Ar and Br, it can now be drawn as a two point line accordingly. During the process of folding, the edge length is kept unchanged and consistent, which verifies this approach throughout the entire range from 0 to 30 degrees (Figure 4).

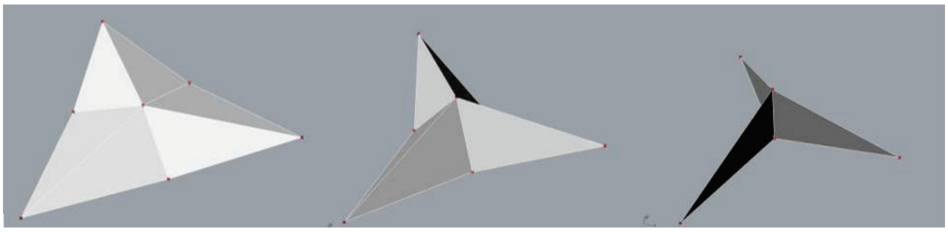

***Figure 4**. Stages in triangle's folding for β values of 5, 15 and 30 from left to right*

Since the edge length is kept unchanged, the same principle can be applied to all the elements on the facade surface, which is tessellated by equilateral triangular elements. The facade surface researched here is a planar one. By applying this principle on the facade elements, each element can fold according to predetermined criteria for performance optimization (Figure 5).

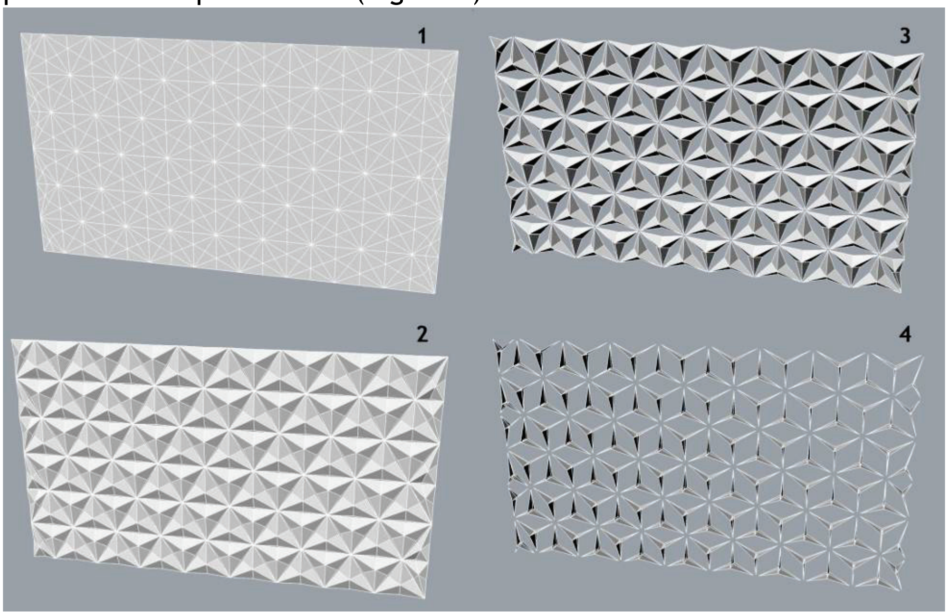

***Figure 5**. Folding triangle application on a planar facade surface. 1 - Fully closed, 2 - 5 degrees open, 3 - 15 degrees open, 4 - Fully open*

Similar method is applied to the Al Bahar Towers project in Abu Dhabi by Aedas Architects, for the purposes of reducing and controlling sunlight exposure, with the exception of applying this method to a double curved surface. Such a surface is tessellated to form planar equilateral triangles on the entire surface, so it can use the same principle.

5. FUTURE WORK

Based on this algorithm, a performance optimization algorithm can also be added to control sunlight exposure. This implies generating a section of the algorithm that awards β values for each triangle, instead of manipulating it manually.

6. CONCLUSION

In this paper, an origami pattern is applied to a facade element in order to control opaqueness, by increasing and decreasing surface area. Manner of simulating the folding process is researched through two approaches, geometrical and mathematical. For real life purposes, it is determined that a mathematical approach is better, since it generates rotational angles for the edges, which would be connected to the actuating motors. The utilization of mathematical approach circumvents potential errors that can occur in geometrical approach, as is described in paper.

7. ACKNOWLEDGEMENT

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GEOMETRY OF INTERIOR SPACE OF CHURCH BUILDINGS OF MEDIEVAL SERBIAN ARCHITECTURE

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Dušan Ranđelović[3]
Hristina Krstić[4]

Abstract

Geometry of internal space of contemporary architectonics structures is free of norms and formalism, especially in case of the structures of specific and special purpose, is divergent from the sculptural visual expression which can theoretically be defined as archisculpture. In this context, the temporary church architecture, stimulated by the new technical-technological potential, represents a sort of a revolution in expression of geometrical forms. The study of the characteristics and mutual relationship of geometrical forms of the interior space of church buildings, predetermined by their structural, formal and esthetic development, is presented in this paper through the geometrical analysis of style groups of church buildings of medieval Serbian architecture. By decomposing the architectonic form of the interior of church buildings to primary geometrical forms, using the computer models generated according to the planimetric data for the specified style group, it will be analyzed how their quantity and mutual relationship affect the form and

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architectonic expression of such spaces. Inspired by the thesis that the characteristics of the geometrical form of interior space of church structures is articulated by the complexity of the geometrical simplicity of their space, by comparing the defined criteria, potential quantitative-geometrical classification of the representative sample of medieval church buildings of the certain style group will be analyzed and presented.

Key words: *geometry, primary forms, interior space, church structures, style group*

1. INTRODUCTION

Consideration of the issue of form-shape and structure of interior space of churches is an everlasting interest of their builders-architects, not only for the sole need to create physical space, but because of simplicity of interior spatial contents, where architectonic space serves to discover and interpret the spirituality in its own way [1].

The form can be observed as product of and as condensation of geometrical forms, but it is not only a mathematical value. It can be observed as fragmented, composed of small primary parts of some other forms, it can be obtained by repetition of the same forms, or is per se indivisible and compact. From the point of view of form, composition of spatial forms is based primarily on finding, observation and definition of mutual relationships of geometrical element and solids in two-dimensional (planimetric) and three-dimensional (stereometric) space. The broadest area of archetypal forms (primary geometrical forms) are those which are generalized in terms of shape gender. Shape gender in the theory of form defines the status of formal characteristics of form. Formal characteristics of general form of church buildings of a certain style group, for the purpose of defining their three-dimensional – stereometric representation of the spatial model, using singled out primary geometrical forms (cube, cylinder and sphere) is based on [2]:

- dimensional transformation,
- subtractive transformation and
- additive transformation.

2. TYPIFICATION OF THE SHAPE OF THE CHURCH STRUCTURES LAYOUT AND ADOPTION OF GEOMETRY CRITERIA ANALSYS

The conducted proportional analysis of idealized horizontal and vertical plan of the interior space [3], rendered possible the formation of the general structure of architectonic layout of the building. The further procedure, decomposition of the architectonic form of the interior of church structures to the primary geometrical forms, generates their approximate preferential spatial models. The method used for analysis of the selected church structures of a certain style group, was derived for the purpose of defining the basic global parameters, that is, further spatial-geometrical evaluation according to the adopted preferential criteria:

A. Criterion of approximate proportional relationship A : B, which defines the global parameters:

- Rational and irrational proportional relationship of the floor plan structure – horizontal plan Fig.1.
- Rational and irrational proportional relationship of the cross section structure - vertical plan Fig.2.

B. Criterion of typological-style and formal-geometrical properties defining the general appearance of the idealized structure of the floor plan and cross section of the church – horizontal and vertical plan, which determines:

- Style group – belonging to a certain style group of church buildings (RSG, BSG and MSG).
- Formal type – belonging to a certain type of the floor plan (TA, TB1 and TB2).
- Formal type – Belonging to a certain style structural floor plan (RS-1 to RS-4, BS-1 to BS-4 and MS-1 to MS-4).

C. Criterion of primary forms, which determines:

- Quantitative and qualitative category of implemented primary (original) forms according to the status of applied geometrical elements and their derivations.

The basis used for establishment and adoption of the analysis criteria is primarily based on the typological classification of the structural floor plane, which provides the essential character to the structure. In this way, even though multiple style forms of structural layouts in the architecture of the medieval Serbia are included, two most frequently used types of structural floor plans are recognizable:

I) <u>Type A</u>:

A single bay building, covered with longitudinal semi-cylindrical vault, without a dome (small structures) or with a dome (some of the largest legacies).

II) <u>Type B</u>:

Buildings with the floor plan in the form of an "inscribed cross", where the dome is at the intersection of two semi-cylindrical vaults, but the structural layout is not left to constitute the cross, but the "cross" is enclosed by the massive walls into a rectangle [4].

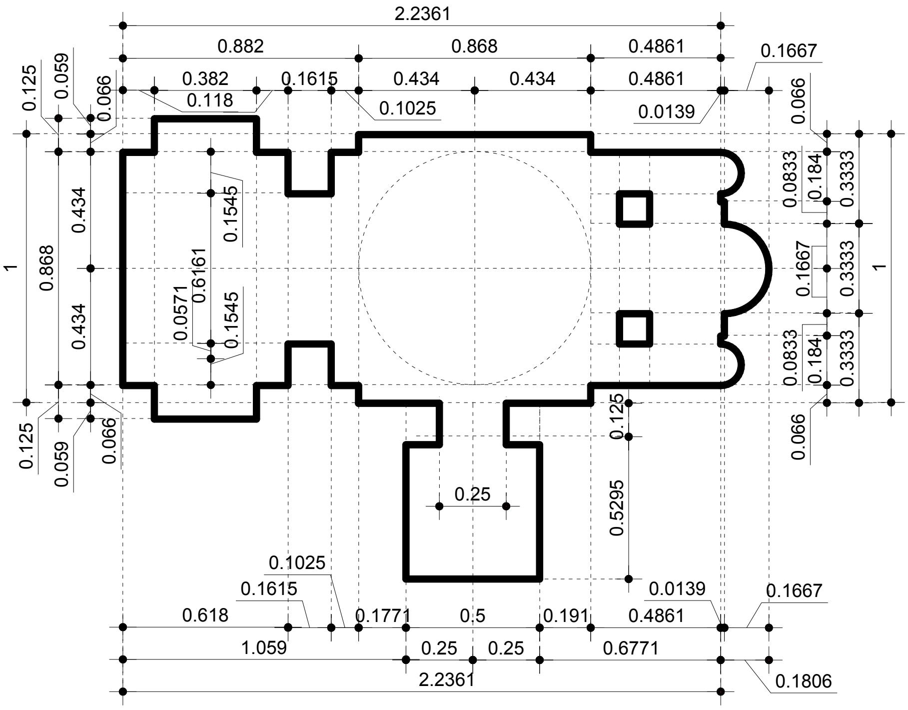

Figure 1*. Idealized horizontal floor plan – structural layout of Sv. NIKOLA Church near Kursumlija*

For all the structures of the first type (Type A), of those which have a dome, the dome is supported by four pilasters, four columns resting against longitudinal walls. As opposed to this, in the buildings of the second type (Type B) the dome is supported in two variants:

II-a) Type B.1:

Developed form of the "inscribed cross" – is formed in the case when the nave of the building is sufficiently wide, the crosswise arms of the cross is sufficiently long so that the columns are completely free (the so called “development type”).

II-2) Tip B.2:

Condensed form of the "inscribed cross" – is formed in the case when the nave of the building is narrow, and the crosswise arms of the cross are short, so that the columns are integrated in the lateral walls (the so called “condensed type”).

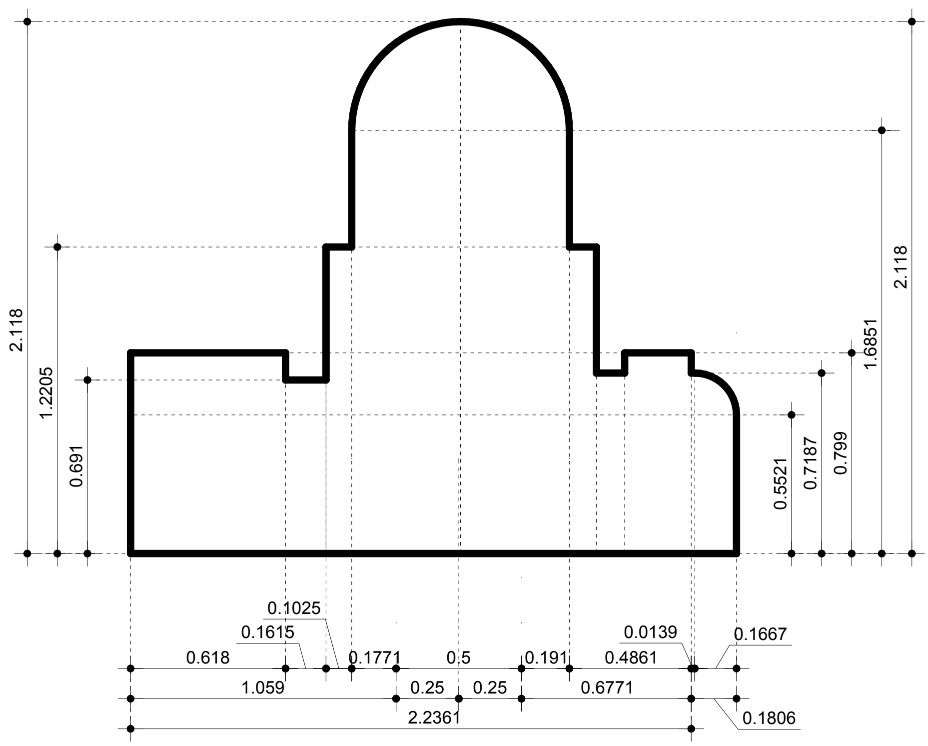

Figure 2*. Idealized vertical plan – cross section of Sv. NIKOLA Church near Kursumlija*

Apart from the listed characteristics there is one style-architectonic characteristic which is common both for one and for the other type of church buildings. This characteristic is determined by the specific form of formation of the floor plan known under the name of “triconch”. Triconch represents the form of the floor layout which apart from the altar apse (conch), there are two conches of same form, but placed on the northern and southern ends of the central nave.

The presented floor plans are determined by the way of their formation and they can be characterized as the most used forms of Serbian medieval church buildings. A more comprehensive formal analysis would show that they cannot be proclaimed the only ones. It would demonstrate that apart from these most frequently used and most regular church buildings, there are numerous departures and variants in their formation, which in essence represents one of these two basic types.

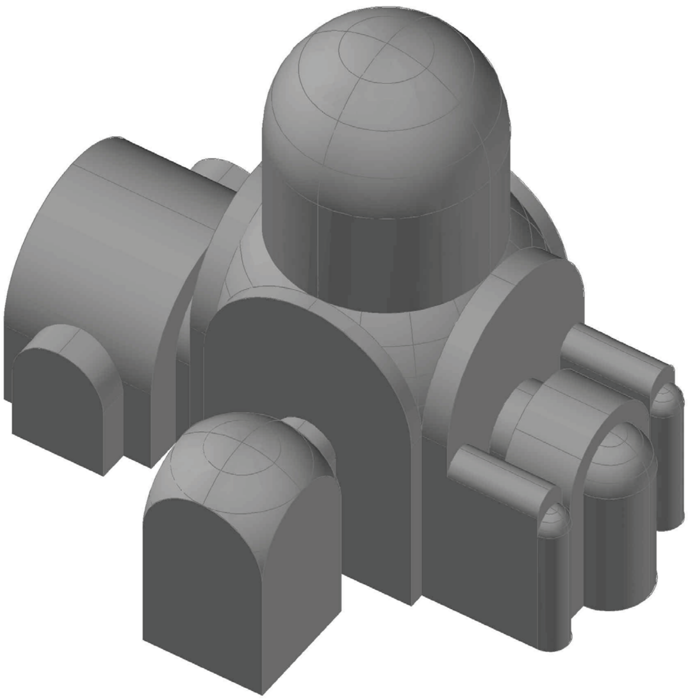

***Figure 3**. Spatial model of the interior of Sv. NIKOLA Church near Kursumlija*

3. PRESENTATION OF THE RESULTS OF THE PROPORTIONAL AND QUALITATIVE-GEOMETRICAL ANALYSIS

According to the previous criteria, a total of 36 churches have been analyzed. By grouping by similarity, 14 typical churches (5 RSG, 6 VSG i 3 MSG) were studied, and quantitative and qualitative changes of the used primary forms (original forms) of geometrical elements and their derivations according to the status of application were observed. Articulation of spatial forms of orthodox churches, reflects in the fact that there is a constant, almost universal type of applied elements of geometrical forms. Three out of five primal forms are recognized as universal geometrical elements. Thus the global form of interior space of churches is formed by: cube, cylinder and sphere and their dimensional, subtractive and additive derivations [5].

3.1. Raska style groups

Church of Sv. Nikola – Basis global parameters of the idealized spatial model of the interior of the church of the Sv. Nikola were presented in Table 1. According to their characteristics, the church St. Nikola belongs to the Raska style group (RSG), first type of churches (TA) and Raska structural layout of the floor plan (RS-3), with the descriptive model designation (RSG.TA.RS-3).

Tabela 1. Review of basic global parameters - type of church RSG.TA.RS-3

Criterion of evaluating A		Nave widht (A)	Nave lenght (B)
Global proportions ratio A : B	RATIONAL	1	2,236
	IRRATIONAL	1	√5

Criterion of evaluating B		**Criterion of evaluating C**				
Style group **RSG** Formative typ **TA.RS-3**	applied geometric element or derivative	cube	cylinder	½ cylinder	½ sphere	¼ sphere
	status of element application	yes	yes	yes	yes	yes
	number of applied elements	20	1	18	1	3

3.2. Byzantin style groups

Church of monastery Gracanica – Basis global parameters of the idealized spatial model of the interior of the church Gracanica were presented in Table 2. According to their characteristics, Gracanica belongs to the Byzantin style group (BSG), second type of churches (TB1) and Byzantin structural layout of the floor plan (BS-4), with the descriptive model designation (BSG.TB1.BS-4).

Tabela 2. Review of basic global parameters - type of church BSG-TB1.BS-4

Criterion of evaluating A		Nave widht (A)	Nave lenght (B)
Global proportions ratio A : B	RATIONAL	1	2,118
	IRRATIONAL	1	1+√5/2

Criterion of evaluating B		**Criterion of evaluating C**				
Style group **BSG** Formative typ **TB1.BS-4**	applied geometric element or derivative	cube	cylinder	½ cylinder	½ sphere	¼ sphere
	status of element application	yes	yes	yes	yes	yes
	number of applied elements	30	3	30	4	1

3.3. Moravian style groups

Church of monastery Veluca – Basis global parameters of the idealized spatial model of the interior of the church of the monastery Veluca were presented in Table 3. According to their characteristics, the church of the monastery Veluca to the Moravian style group (MSG), first type of churches (TB2) and Moravian structural layout of the floor plan (MS-2), with the descriptive model designation (MSG-TB2.MS-2).

Tabela 3. Review of basic global parameters - type of church MSG-TB2.MS-2

Criterion of evaluating A		Nave widht (A)	Nave lenght (B)
Global proportions ratio A : B	RATIONAL	1	1,559
	IRRATIONAL	1	1+√5/4

Criterion of evaluating B		Criterion of evaluating C				
Style group **MSG** Formative typ **TB2.MS-2**	applied geometric element or derivative	cube	cylinder	½ cylinder	½ sphere	¼ sphere
	status of element application	yes	yes	yes	yes	yes
	number of applied elements	14	1	18	1	5

4. CONCLUSION

The result of the applied methods of transformations represents geometrical volumetric-spatial model articulated in selected and formulated primary geometrical forms, that is, their derivatives obtained by division and decomposition. Such presentation of church buildings, by approximation of the spatial forms, is applied in practice especially as a method for formation of experimental basis of software.

Therefore, this kind of analysis, apart from providing a general overview into the geometrical status of spatial models of interior space of church buildings, in a way allows functional observation of the change of geometrical form of a certain style group for the different purposes of analyses according to the various comfort parameters, such as: acoustic quality and comfort of the interior space of the churches, influence of the shape factor on the energy efficiency, influence of the spatial geometry on the light comfort, but also various forms of numerical, dimensional and geometrical analysis.

In this paper, due to space limitations, analysis procedure shown only in one example of each of the stylistic group. Having that in mind, this paper presents only one aspect of discourse analysis and starts debate the importance of detailed geometric analysis of numerous buildings that belong to the category of buildings of special cultural and historical significance.

Ultimately, the result of this analysis of geometry of internal space of church buildings of medieval Serbian architecture is, that the basic primary forms-geometry elements of all church buildings are: cube-prism; cylinder; 1/2 of cylinder ; 1/2 of sphere and 1/4 of sphere.

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DETERMINIG THE SPEED OF HYDRAULIC EXCAVATOR CHARACTERISTIC POINTS

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Abstract

Studying complex mechanics problems, such as movement of a complex construction consisting of many bodies and connections between them, requires applying multidisciplinary approach where Constructive Geometry takes its respected place. For determining the movement of a construction as a whole, where movements of its individual parts within their coordinate systems are known, it is necessary to make transitions from one coordinate system to another. We use transformation matrices to resolve this problem. This paper presents determining the speed of hydraulic excavator movement points based on setting up and transforming several coordinate systems.

Key words: *coordinate system, hydraulic excavator, position vectors, speed of movement*

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1. INTRODUCTION

Dynamic behaviour of hydraulic excavators is their construction feature. In order to make it better, it is necessary to do some testings, analysis and synthesis of the construction itself. To make it possible to do all necessary calculations and analysis to this end, there has to be made a dynamic – mathematical model based on the created hydraulic excavator physical form. The analysis is done by means of a selected analytical or numerical method that gradually leads to a ''step by step''improvement until the desired goals are achieved. The analysis itself is practically the stage of collecting data – frequency and amplitude, oscillations, deformations, maximum dynamic forces, etc. – enabling the correction of the construction solutions, in other words, the evolution of the existing constructions. In that way, it is possible to do some corrections of the dynamic parametres of an excavator, such as the mass, the inertia moments, rigidity, damping, the movement regime, the material and alike. With well selected dynamic paramteres, the excavator will be ready to work in accordance with the requested operating regime with the tolerable degree of oscillations of its parts or the construction as a whole. When preparing the mathematical model used for describing hydraulic excavator behaviour, it is essential to be familiar with the speeds of the excavator characteristic points. All these issues have been described in this paper together with the procedure of determining the speeds.

2. HYDRAULIC EXCAVATOR CONSTRUCTION AND PERFORMANCE

The construction of a hydraulic excavator (fig. 1) consists of the undercarriage part (1), revolving part (platform) (2) and the manipulating part (3, 4, 5). The revolving part contains power and signal transmitting subsystems. The selection of both excavating and unloading planes is done on the basis of rotating the revolving part in relation to the basic undercarriage part. These two parts are connected with a joint shaped as radial – axial bearing forming the base of excavator. For earth excavation, regardless of the excavator size, we use a three-part kinematic chain manipulator plane configuration: the arrow (3), the arm (4) and the bucket (5). The last part of the chain is the bucket of certain shape and volume. The manipulator chain parts form kinematic pairs i.e. revolving joints.

Kinematic pairs segments are, directly or indirectly, connencted with hydraulic actutators: revovlving platform drive hydromotor C_2 and manipulator drive hydrocylinders C_3, C_4, C_5. The position and the process of excavating itself are determined by activating the manupulator. Figure 1 shows the model and a photo of BTH-600 excavator together with its basic parts.

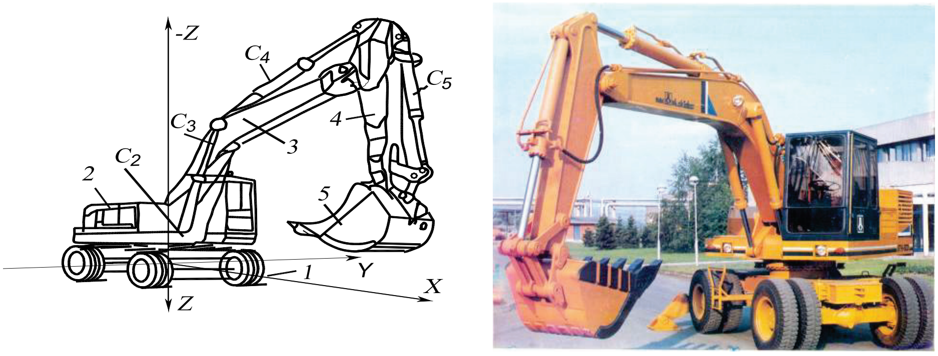

Figure 1 *The mechanical model of BTH - 600 excavator: 1 - undercarriage part (pneumatics), 2 - revolving part (platform), 3 - arrow, 4 - arm (handle) 5 - bucket*

3. COORDINATE SYSTEMS

Excavator position is defined in relation to the immobile (absolute) coordinate system $Oxyz$. The coordinate starting point *O* of the absolute system is in the center of the undercarriage section mass for the whole system. Axis Ox is directed to the longitudinal, and axis Oy to the cross main central inertia axis in the position of the whole system static equilibrium, while axis Oz is directed vertically downwards. Local coordinate systems are established for determining the position of the parts of kinematic excavator chain, described in the paper [1] (Fig. 2):

1. $O_1x_1y_1z_1$ - mobile coordinate system adopted for the mass center O_1 of the undercarriage section. Axis Ox_1 overlaps the longitudinal, and axis Oy_1 the cross main central inertia axis of the undercarriage section

in the equilibrium position while axis Oz_1 is directed vertically downwards;

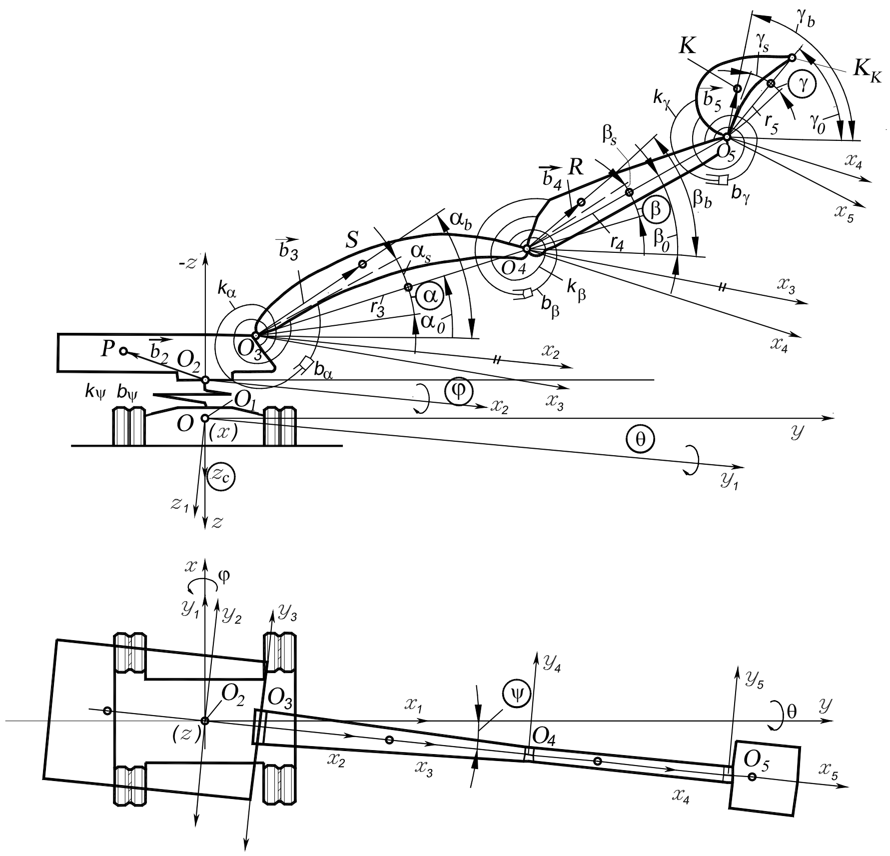

Figure 2 *Dinamic model of the hydraulic excavator. The platform and the kinematic chain rotated by the angle* $\psi = 90^0$

2. $O_2x_2y_2z_2$ - mobile coordinate system connected to the center of axial bearing ***O***$_2$;

3. $O_3x_3y_3z_3$ - coordinate system connected to the joint centre O_3 and rotated by the generated coordinate α in relation to the coordinate system $O_2x_2y_2z_2$;

4. $O_4x_4y_4z_4$ - coordinate system connected to the joint centre O_4 and rotated by the generated coordinate β in relation to the coordinate system $O_3x_3y_3z_3$ and

5. $O_5x_5y_5z_5$ - coordinate system connected to the joint centre O_5 and rotated by the generated coordinate γ in relation to the coordinate system $O_4x_4y_4z_4$.

4. TRANSFORMATION MATRICES

Characteristic points speeds for such complex mechanical systems are determined by applying the method based on setting up and transforming corresponding mobile coordinate systems. This method was applied in paper [3].

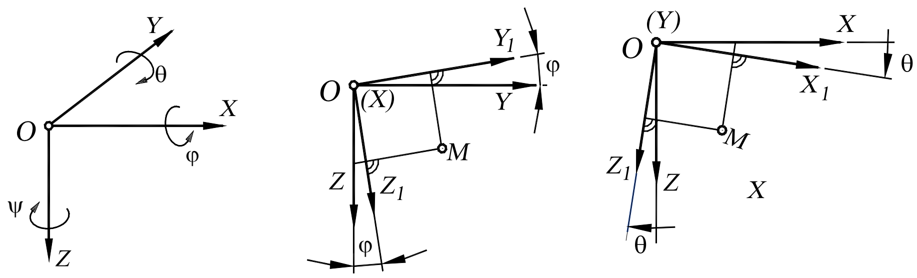

Figure 3 *System axis position, rotation around axis Ox for the angle φ and rotation around axis Oy for the angle θ*

$$\mathbf{T_x}(\varphi)=\begin{bmatrix}1 & 0 & 0\\ 0 & \cos\varphi & -\sin\varphi\\ 0 & \sin\varphi & \cos\varphi\end{bmatrix} \qquad \mathbf{T_y}(\theta)=\begin{bmatrix}\cos\theta & 0 & \sin\theta\\ 0 & 1 & 0\\ -\sin\theta & 0 & \cos\theta\end{bmatrix}$$

$\mathbf{T_x}(\varphi)$ is the matrix of elementary rotations around axis Ox for the angle φ and $\mathbf{T_y}(\theta)$ is the matrix of elementary rotations around axis Oy for the angle θ.

Since there are two rotations around axes Ox and Oy for the nagles φ and θ, the matrix of transforming immobile system $Oxyz$ into mobile

$O_1x_1y_1z_1$ (taking into account the rule of right hand coordinate axes direction) equals:

$$\mathbf{T_{10}} = \mathbf{T_y}(\theta)\cdot\mathbf{T_x}(\varphi) = \begin{bmatrix} 1 & \theta\varphi & \theta \\ 0 & 1 & -\varphi \\ -\theta & \varphi & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & \theta \\ 0 & 1 & -\varphi \\ -\theta & \varphi & 1 \end{bmatrix} \quad (1)$$

The matrix of transforming immobile coordinate system $Oxyz$ into another mobile system relating to $O_2x_2y_2z_2$ equals:

$$\mathbf{T_{20}} = \mathbf{T_{10}}\cdot\mathbf{T_{21}} = \begin{bmatrix} \cos\theta & \sin\theta\sin\varphi & \sin\theta\cos\varphi \\ 0 & \cos\varphi & -\sin\varphi \\ -\sin\theta & \cos\theta\sin\varphi & \cos\theta\cos\varphi \end{bmatrix} = \begin{bmatrix} 1 & 0 & \theta \\ 0 & 1 & -\varphi \\ -\theta & \varphi & 1 \end{bmatrix} = \mathbf{T_{10}} \quad (2)$$

where: $\mathbf{T_{21}} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \mathbf{E}$

E is matrix equation of transition from one mobile system $O_1x_1y_1z_1$ to another mobile system $O_2x_2y_2z_2$ because systems ''1'' and ''2'' are parallel and the connection is rigid. When determining the transformation matrix from immobile coordinate system $Oxyz$ to a new mobile coordinate system $O_3x_3y_3z_3$, it is necessary to determine the third rotation. So the matrix for elementary rotations around the third axis, that is for angle ψ around axis Oz is (Fig. 4):

$\mathbf{T_z}(\psi)$ is the matrix of elementary rotations around axis Oz for the angle ψ. Since there are three rotations around axes Ox, Oy and *Oz* for the angles φ, θ and ψ, the transformation matrix (taking into account the rule of right hand coordinate axes direction) equals (Fig. 3 and 4):

$$\mathbf{T_z}(\psi)=\begin{bmatrix}\cos\psi & -\sin\psi & 0\\ \sin\psi & \cos\psi & 0\\ 0 & 0 & 1\end{bmatrix}$$

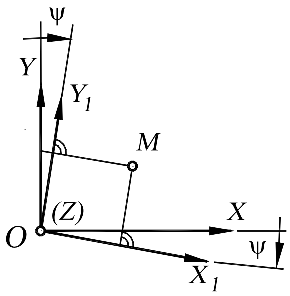

Figure 4 *Rotation around axis Oz for the angle ψ*

$$\mathbf{T_{30}}=\mathbf{T_y}(\theta)\cdot\mathbf{T_x}(\varphi)\cdot\mathbf{T_z}(\psi)$$

The matrix of transforming immobile coordinate system $Oxyz$ to the third mobile system $O_3x_3y_3z_3$ (Fig. 2.1 and 3.2) equals:

$$\mathbf{T_{30}}=\mathbf{T_{20}}\cdot\mathbf{T_{32}}=\begin{bmatrix}\cos\psi & -\sin\psi & \theta\\ \sin\psi & \cos\psi & -\varphi\\ -\theta\cos\psi+\varphi\sin\psi & \theta\sin\psi+\varphi\cos\psi & 1\end{bmatrix} \tag{3}$$

Where $\mathbf{T_{32}}$ is the matrix of transition from the second mobile system $O_2x_2y_2z_2$ to the third mobile system $O_3x_3y_3z_3$.

$$\mathbf{T_{32}}=\begin{bmatrix}\cos\psi & -\sin\psi & 0\\ \sin\psi & \cos\psi & 0\\ 0 & 0 & 1\end{bmatrix}$$

The matrix of of transforming the immobile coorinate system $Oxyz$ to the fourth mobile coordinate system $O_4x_4y_4z_4$ (Fig. 2) is:

$$\mathbf{T_{40}}=\mathbf{T_{30}}\cdot\mathbf{T_{43}}=\begin{bmatrix}\cos\psi & -\sin\psi & \alpha\cdot\cos\psi+\theta\\ \sin\psi & \cos\psi & \alpha\sin\psi-\varphi\\ -\theta\cos\psi+\varphi\sin\psi-\alpha & \theta\sin\psi+\varphi\cos\psi & 1\end{bmatrix} \tag{4}$$

The matrix of of transforming the immobile coordinate system $Oxyz$ to the fifth mobile coordinate system $O_5x_5y_5z_5$ (Fig. 2) is:

$$\mathbf{T_{50}} = \mathbf{T_{40}} \cdot \mathbf{T_{54}}$$

$$\mathbf{T_{50}} = \begin{bmatrix} \cos\psi & -\sin\psi & \beta\cos\psi + \alpha\cos\psi + \theta \\ \sin\psi & \cos\psi & \beta\sin\psi + \alpha\sin\psi - \varphi \\ -\theta\cos\psi + \varphi\sin\psi - \alpha - \beta & \theta\sin\psi + \varphi\cos\psi & 1 \end{bmatrix} \quad (5)$$

Where:

$$\mathbf{T_{54}} = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix}$$

Since φ and θ are small it is possible to apply the approximation denoted with $\sin\theta \approx \theta$, $\cos\theta \approx 1$, $\sin\varphi \approx \varphi$ and $\cos\varphi \approx 1$, as shown in previous formulas.

5. MASS CENTER POSITION VECTORS OF EXCAVATOR PARTS IN RELATION TO THE ABSOLUTE COORDINATE SYSTEM

Calculating kinetic energy means calculating mass center speeds of certain hydraulic excavator parts. That is why we need characteristic system points position vectors (Fig. 5). Absolute coordinate system accompanied by the undercarriage section coordinate system and its mass center are at one point - $O = O_1$:

$\mathbf{r_{10}}$ - is deformation vector of the model excavator base support, that is, the mass center movement vector of the undercarriage section in relation to the absolute coordinate system.

$\mathbf{r}_j$ - is the mass center position vector of the joint in relation to the previous joint O_{j-1}.
Vector intensity represents the length of the excavator chain part.

$$\mathbf{r_{10}} = \begin{bmatrix} 0 \\ 0 \\ z_c \end{bmatrix}, \ \mathbf{r_1} = \begin{bmatrix} 0 \\ 0 \\ -r_{1z} \end{bmatrix}, \ \mathbf{r_2} = \begin{bmatrix} r_{2x} \\ 0 \\ -r_{2z} \end{bmatrix}, \ \mathbf{r_3} = \begin{bmatrix} r_3 \cos\alpha_0 \\ 0 \\ -r_3 \sin\alpha_0 \end{bmatrix}, \ \mathbf{r_4} = \begin{bmatrix} r_4 \cos\beta_0 \\ 0 \\ -r_4 \sin\beta_0 \end{bmatrix},$$

and $\mathbf{r_5} = \begin{bmatrix} r_5 \cos\gamma_0 \\ 0 \\ -r_5 \sin\gamma_0 \end{bmatrix}$.

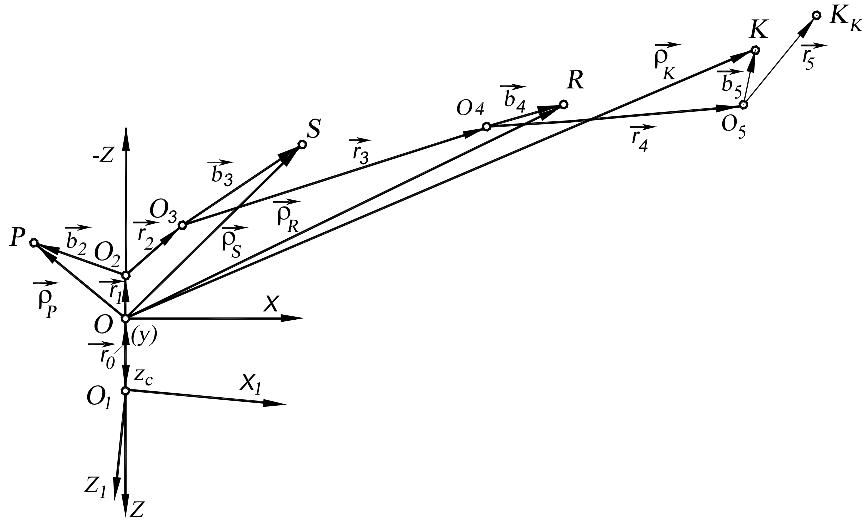

Figure 5 *Radius vectors of hydraulic excavator characteristic points*

Vectors b_i are mass center position vectors L_i in relation to the joint center O_i.

$$\mathbf{b_1} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \ \mathbf{b_2} = \begin{bmatrix} -b_{2x} \\ 0 \\ -b_{2z} \end{bmatrix}, \ \mathbf{b_3} = \begin{bmatrix} b_3 \cos\alpha_b \\ 0 \\ -b_3 \sin\alpha_b \end{bmatrix}, \ \mathbf{b_4} = \begin{bmatrix} b_4 \cos\beta_b \\ 0 \\ -b_4 \sin\beta_b \end{bmatrix} \text{ and}$$

$$\mathbf{b}_5 = \begin{bmatrix} b_5 \cos\gamma_b \\ 0 \\ -b_5 \sin\gamma_b \end{bmatrix}$$

Where α_0, β_0 and γ_0 are position angles of the manipulator arrow, arm and bucket in static equilibrium; α_s, β_s and γ_s are static deflections (caused by their own weights) of arrow torsion springs, the arm and the bucket; α_b, β_b γ_b are vector angles of the arrow, arm and bucket mass center position. Mass center position vectors $\vec{\rho}_i$ of the excavator parts in relation to the absoulute coordinate system can be expressed as the following matrix form:

$$\boldsymbol{\rho}_\mathbf{i} = \mathbf{r}_\mathbf{0} + \sum_{\mathbf{j=1}}^{\mathbf{i-1}} \mathbf{T}_{\mathbf{0j}}\mathbf{r}_\mathbf{i} + \mathbf{T}_{\mathbf{0i}}\mathbf{b}_\mathbf{i} \tag{6}$$

Vectors $\vec{\rho}_i$ connect the absolute coordinate system and mass centers (P platform mass center, S arrow mass center, R arm mass center and K bucket mass center). Angles α_b, β_b and γ_b can be expressed in dynamic operation regime as:

$$\alpha_b = \alpha_0 + \alpha_s + \alpha \text{ ;}$$
$$\beta_b = \beta_0 + \beta_s + \beta \text{ and } \gamma_b = \gamma_0 + \gamma_s + \gamma \tag{7}$$

This is going to be of great importance when deriving excavtor parts' mass center position vectors.

6. SPEEDS OF SYSTEM CHARACTERISTIC POPINTS

Matrix forms of speeds were described in paper [4]:

$$\mathbf{v}_{n0} = \dot{\boldsymbol{\rho}}_{n0} = \dot{\mathbf{r}}_{10} + \sum_{k=1}^{n-1} \mathbf{T}_{k0} \cdot \dot{\mathbf{r}}_k + \sum_{k=1}^{n-1} \dot{\mathbf{T}}_{k0} \cdot \mathbf{r}_k \text{ .} \tag{8}$$

Hydraulic excavator characteristic points are:

Undercarriage section mass center speed (point $O_1 = C$) is

$$\mathbf{v}_C = \mathbf{v}_1 = \dot{z}_C \tag{9}$$

Platform mass center speed (point *P*) is

$$\mathbf{v}_P = \dot{\mathbf{r}}_{10} + \dot{\mathbf{T}}_{10} \cdot \mathbf{r}_1 + \mathbf{T}_{10} \cdot \dot{\mathbf{r}}_1 + \dot{\mathbf{T}}_{20} \cdot \mathbf{b}_2 + \mathbf{T}_{20} \cdot \dot{\mathbf{b}}_2 \tag{10}$$

$$\mathbf{v}_P = \begin{bmatrix} 0 \\ 0 \\ \dot{z}_c \end{bmatrix} + \begin{bmatrix} -\dot{\theta} r_{1z} \\ \dot{\varphi} r_{1z} \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} -\dot{\theta} b_{2z} \\ \dot{\varphi} b_{2z} \\ \dot{\theta} b_{2x} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -\dot{\theta} r_{1z} - \dot{\theta} b_{2z} \\ \dot{\varphi} r_{1z} + \dot{\varphi} b_{2z} \\ \dot{z}_c + \dot{\theta} b_{2x} \end{bmatrix}. \tag{11}$$

Arrow mass center speed (point *S*) is

$$\mathbf{v}_S = \dot{\mathbf{r}}_{10} + \dot{\mathbf{T}}_{10} \cdot \mathbf{r}_1 + \mathbf{T}_{10} \cdot \dot{\mathbf{r}}_1 + \dot{\mathbf{T}}_{20} \cdot \mathbf{r}_2 + \mathbf{T}_{20} \cdot \dot{\mathbf{r}}_2 + \dot{\mathbf{T}}_{30} \cdot \mathbf{b}_3 + \mathbf{T}_{30} \cdot \dot{\mathbf{b}}_3 \tag{12}$$

$$\mathbf{v}_S = \begin{bmatrix} -\dot{\theta} r_{1z} - \dot{\theta} r_{2z} - \dot{\theta} b_3 \sin\alpha_\mathrm{b} - \dot{\alpha} b_3 \cos\psi \sin\alpha_\mathrm{b} - \dot{\alpha}\theta b_3 \cos\alpha_\mathrm{b} \\ \dot{\varphi} \mathrm{r}_{1\mathrm{z}} + \dot{\varphi} \mathrm{r}_{2\mathrm{z}} + \dot{\varphi} b_3 \sin\alpha_\mathrm{b} - \dot{\alpha} b_3 \sin\psi \sin\alpha_\mathrm{b} + \dot{\alpha}\varphi b_3 \cos\alpha_\mathrm{b} \\ \dot{z}_C - \dot{\theta} \mathrm{r}_{2\mathrm{x}} + (-\dot{\theta}\cos\psi + \dot{\varphi}\sin\psi) b_3 \cos\alpha_\mathrm{b} - \dot{\alpha}(-\theta\cos\psi + \varphi\sin\psi) b_3 \sin\alpha_\mathrm{b} - \dot{\alpha} b_3 \cos\alpha_\mathrm{b} \end{bmatrix} \tag{13}$$

Arm mass center speed (point *R*) is

$$\mathbf{v}_R = \dot{\mathbf{r}}_{10} + \dot{\mathbf{T}}_{10} \cdot \mathbf{r}_1 + \mathbf{T}_{10} \cdot \dot{\mathbf{r}}_1 + \dot{\mathbf{T}}_{20} \cdot \mathbf{r}_2 + \mathbf{T}_{20} \cdot \dot{\mathbf{r}}_2 + \dot{\mathbf{T}}_{30} \cdot \mathbf{r}_3 + \mathbf{T}_{30} \cdot \dot{\mathbf{r}}_3 + \dot{\mathbf{T}}_{40} \cdot \mathbf{b}_4 + \mathbf{T}_{40} \cdot \dot{\mathbf{b}}_4 \tag{14}$$

$$\mathbf{v}_R = \begin{bmatrix} v_{xR} \\ v_{yR} \\ v_{zR} \end{bmatrix} \tag{15}$$

$$\begin{aligned} v_{xR} = & -\dot{\theta} r_{1z} - \dot{\theta} r_{2z} - \dot{\theta} r_3 \sin\alpha_0 - \dot{\alpha} r_3 \cos\psi \sin\alpha_0 - \dot{\alpha}\theta r_3 \cos\alpha_0 - \\ & (\dot{\alpha}\cos\psi + \dot{\theta}) b_4 \sin\beta_\mathrm{b} - \dot{\beta} b_4 \cos\psi \sin\beta_b - \dot{\beta}(\alpha\cos\psi + \theta) b_4 \cos\beta_b \end{aligned}$$

$$v_{yR} = \dot{\varphi} r_{1z} + \dot{\varphi} \mathrm{r}_{2z} + \dot{\varphi} \mathrm{r}_3 \sin\alpha_0 - \dot{\alpha} r_3 \sin\psi \sin\alpha_0 + \dot{\alpha}\varphi r_3 \cos\alpha_0 -$$
$$(\dot{\alpha}\sin\psi - \dot{\varphi}) b_4 \sin\beta_\mathrm{b} - \dot{\beta} b_4 \sin\psi \sin\beta_b - \dot{\beta}(\alpha\sin\psi - \varphi) b_4 \cos\beta_b$$

$$v_{zR} = \dot{\mathrm{z}}_\mathrm{C} - \dot{\theta} \mathrm{r}_{2\mathrm{x}} + (-\dot{\theta}\cos\psi + \dot{\varphi}\sin\psi) \mathrm{r}_3 \cos\alpha_0 - \dot{\alpha}\left(-\theta\cos\psi + \varphi\sin\psi\right) r_3 \sin\alpha_0 -$$
$$\dot{\alpha} r_3 \cos\alpha_0 + (-\dot{\theta}\cos\psi + \dot{\varphi}\sin\psi - \dot{\alpha}) b_4 \cos\beta_\mathrm{b} + \dot{\beta}(\theta\cos\psi - \varphi\sin\psi + \alpha) \cdot$$
$$b_4 \sin\beta_b - \dot{\beta} b_4 \cos\beta_b$$

Bucket mass center speed (point *K*) is

$$\mathbf{v}_K = \dot{\mathbf{r}}_{10} + \dot{\mathbf{T}}_{10} \cdot \mathbf{r}_1 + \mathbf{T}_{10} \cdot \dot{\mathbf{r}}_1 + \dot{\mathbf{T}}_{20} \cdot \mathbf{r}_2 + \mathbf{T}_{20} \cdot \dot{\mathbf{r}}_2 + \dot{\mathbf{T}}_{30} \cdot \mathbf{r}_3 +$$
$$\mathbf{T}_{30} \cdot \dot{\mathbf{r}}_3 + \dot{\mathbf{T}}_{40} \cdot \mathbf{r}_4 + \mathbf{T}_{40} \cdot \dot{\mathbf{r}}_4 + \dot{\mathbf{T}}_{50} \cdot \mathbf{b}_5 + \mathbf{T}_{50} \cdot \dot{\mathbf{b}}_5 \qquad (16)$$

$$\mathbf{v}_K = \begin{bmatrix} v_{xK} \\ v_{yK} \\ v_{zK} \end{bmatrix} \qquad (17)$$

$$v_{xK} = -\dot{\theta} \mathrm{r}_{1\mathrm{z}} - \dot{\theta} \mathrm{r}_{2\mathrm{z}} - \dot{\theta} \mathrm{r}_3 \sin\alpha_0 - \dot{\alpha} r_3 \cos\psi \sin\alpha_0 - \dot{\alpha}\theta r_3 \cos\alpha_0 - (\dot{\alpha}\cos\psi +$$
$$\dot{\theta}) r_4 \sin\beta_0 - \dot{\beta} r_4 \cos\psi \sin\beta_0 - \dot{\beta}(\alpha\cos\psi + \theta) r_4 \cos\beta_0 - (\dot{\beta}\cos\psi +$$
$$\dot{\alpha}\cos\psi + \dot{\theta}) b_5 \sin\gamma_\mathrm{b} - \dot{\gamma} b_5 \cos\psi \sin\gamma_b - \dot{\gamma}(\beta\cos\psi + \alpha\cos\psi + \theta) b_5 \cos\gamma_b$$

$$v_{yK} = \dot{\varphi} r_{1z} + \dot{\varphi} r_{2z} + \dot{\varphi} r_3 \sin\alpha_0 - \dot{\alpha} r_3 \sin\psi \sin\alpha_0 + \dot{\alpha}\varphi r_3 \cos\alpha_0 -$$
$$(\dot{\alpha}\sin\psi - \dot{\varphi}) r_4 \sin\beta_0 - \dot{\beta} r_4 \sin\psi \sin\beta_0 - \dot{\beta}(\alpha\sin\psi - \varphi) r_4 \cos\beta_0 -$$
$$(\dot{\beta}\sin\psi + \dot{\alpha}\sin\psi - \dot{\varphi}) b_5 \sin\gamma_\mathrm{b} - \dot{\gamma} b_5 \sin\psi \sin\gamma_b - \dot{\gamma}(\beta\sin\psi +$$
$$\alpha\sin\psi - \varphi) b_5 \cos\gamma_b$$

$$v_{zK} = \dot{\mathrm{z}}_\mathrm{C} - \dot{\theta} r_{2x} + (-\dot{\theta}\cos\psi + \dot{\varphi}\sin\psi) r_3 \cos\alpha_0 - \dot{\alpha}\left(-\theta\cos\psi + \varphi\sin\psi\right) \cdot$$
$$r_3 \sin\alpha_0 - \dot{\alpha} r_3 \cos\alpha_0 + (-\dot{\theta}\cos\psi + \dot{\varphi}\sin\psi - \dot{\alpha}) r_4 \cos\beta_0 + \dot{\beta}(\theta\cos\psi -$$
$$\varphi\sin\psi + \alpha) r_4 \sin\beta_0 - \dot{\beta} r_4 \cos\beta_0 + (-\dot{\theta}\cos\psi + \dot{\varphi}\sin\psi - \dot{\alpha} - \dot{\beta}) b_5 \cos\lambda_\mathrm{b} -$$
$$\dot{\gamma}(-\theta\cos\psi + \varphi\sin\psi - \alpha - \beta) b_5 \sin\gamma_b - \dot{\gamma} b_5 \cos\gamma_b$$

7. CONCLUSION

Determining hydraulic excavator characteristic points necessitates setting up an immobile (absolute) coordinate system both for the excavator as a whole and for its parts. The absolute coordinate system is transformed to each of the mobile coordinate systems. Transformation matrices meet the needs of this. Speeds calculations are worked out on the basis of excavator characteristic points position vectors. The characteristic points speeds determined in this way make it possible to calculate hydraulic excavator kinetic energy.

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SIGNIFICANCE OF THE SPECIMENS GEOMETRY IN SCC TESTS

Dušan Petković [1]
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Abstract

Stress corrosion cracking (SCC) occurs during the simultaneously action both static tension stress and corrosion environment. SCC is most often rapid and unpredictable process. Failure can occur in a short time as a few hours or take years and decades to happen. Most alloys are liable to SCC in one or more environments requiring careful consideration of alloy type in component design. It has been developed a lot of methods for measuring SCC susceptibility of materials due to provide better overview of the materials behavior in the corrosion environments. In this paper, basic types of specimens which used for SCC tests are shown.

Key words: *stress corrosion cracking (SCC), specimen, SCC test,*

1. INTRODUCTION

Stress corrosion cracking (SCC) is a phenomenon that engineers should always keep in mind during the structure design, particularly in the case of pressure vessels. SCC is a stress assisted anodic process as a result of synergistic action of ions, such as Cl^- and H_2S, and oxidants like elemental sulfur present in the solution. It can produce dangerous

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failure mode resulting from synergistic actions of mechanical stress, susceptible material, and specific corrosive environment [12]. In other words, SCC can be responsible for the sudden catastrophic failure of an alloy with otherwise excellent mechanical properties at stresses far below the material's yield strength. Such failures are induced by exposure of the alloy to specific environments while subjected to sustained stresses [3].

The undesired effect of sensitization of material is the increased susceptibility to corrosion and, for structures in operation, stress corrosion cracking. For SCC to take place, three conditions are required: a susceptible material, a corrosive environment, and a tensile stress; their mutual dependence is shown in Figure 1. If any of these three conditions are removed, SCC will not occur. SCC in structure components depends on the material, its associated exposure environment, and the sources of stress [8].

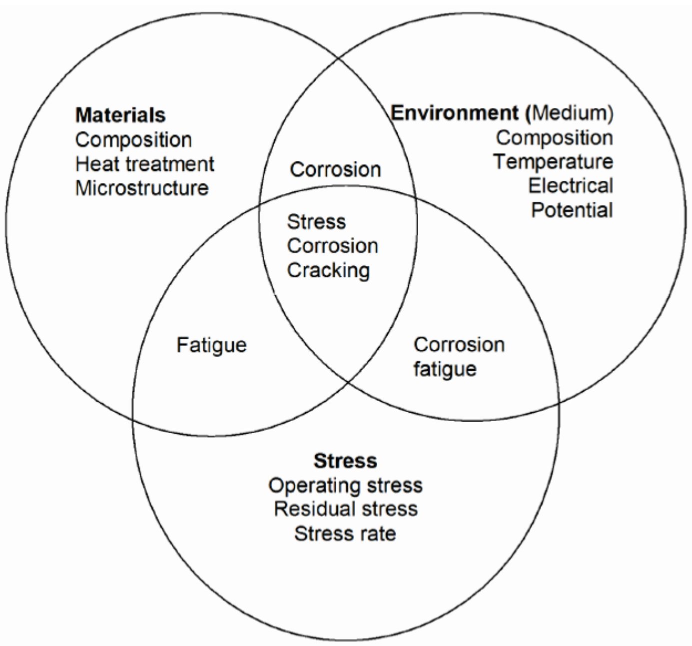

***Figure 1**. factors affecting SCC*

Stainless steels, nickel alloys, and aluminum alloys are especially susceptible to SCC [9]. Cracks appear and grow through the material as the effect of SCC. Those cracks usually propagate perpendicular to the direction of tension, generating inter-crystal or trans-crystal fracture mode. SCC growth is highly dependent on the presence of mechanical/thermal stress in the component.

The susceptibility to SCC is influenced by factors like environmental condition, temperature, hardness of the material, level of applied stress and microstructure of the material. The stress could be due to residual stress generated during manufacturing process or could be due to applied loading. For example, high residual stresses are generated during welding of dissimilar metal joints. Similarly, high residual stresses are generated in steam generator tubes U-bends during its forming process. Stress corrosion cracking is a major issue for reactor cooling system pipes particularly in the weld regions where it is connected to nozzles through safe ends. Also, SCC is a major issue for steam generator tube integrity in many power plants.

It has been developed a lot of methods for measuring stress corrosion cracking susceptibility of materials due to provide as better as possible view of material behavior in the corrosion environments [10]. In the last time, scientists have developed the rapid laboratory tests, which provides results in the short time interval [11].

Mainly used test methods are:

- Static tests of the smooth specimens,
- Slow strain-rate deformation method,
- Tests based on the fracture mechanics method,
- Potentiodynamic tests [2].

The most of these tests are standardized (ISO, ASTM, NACE, BS), but some methods (chemical and electrochemical) are applied only for research. SCC tests can be divided in several ways [1]. There are two general categories according to type of the specimens as follows:

- Tests of the smooth specimens and
- Tests on the specimens with undercut or pre-cracked specimens.

In this paper different geometry and its important on the SCC test specimens are considered. The authors aim to review basic types of specimens which used in SCC test. Within this short review, significance of the specimens' geometry is highlighted.

2. SMOOTH SPECIMENS LOADED WITHIN ELASTIC STRESS AREA

The purpose of the application of these tests is to define the critical stress by using as small as possible number of the specimens. Testing usually starts at load 50 % of the yield stress and increases gradually up to occurrence of the first crack. Criteria for assessment stress-corrosion cracking susceptibility is the time to occurrence of the first crack at a certain value of the constant strain/stress.

Strain of the specimens is usually limited to the elastic area in order to perform the test at exactly defined tensile stresses. Then, the value of the applied stress can be calculated based on the measured deflections and the elasticity modulus of the material tested. When the test performs at a constant stress, its amount usually can be measured directly.

Smooth specimens most frequently used are listed below:

- "C rings",
- Bending of specimens in two points,
- Bending of specimens in three points,
- Bending of specimens in four points,
- Specimens with constant bending moment.

2.1. "C ring" specimens

"C – rings" are commonly used specimens in order to define susceptibility to SCC, shown in Figure 2. They are particularly suitable for testing of pipelines. Their size can vary, but not recommended testing of specimens with outer diameter less than 16 mm. The reasons are difficulty in manufacturing and reduced load accuracy. These tests are usually performed at a constant strain, Figure 2 a) and c). A constant stress method, provided by means the calibrated spring, can be used too, Figure 2 b). Maximum accuracy of deformation measured can be achieved by using the strain gauges [6].

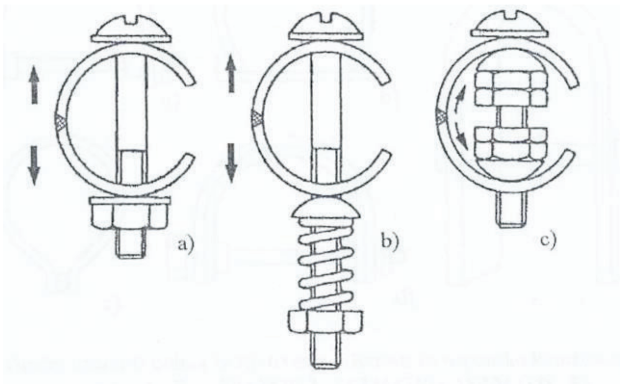

Figure 2*. schematic presentation of "C – rings"*

2.2. Specimens for bending tests

Specimens for bending tests are commonly used for testing sheets, plates, welds, cast materials, wires, rods, etc. Some of the specimens in this category are shown in Figure 3, and ones may be applied for any test within the material elasticity area [4].

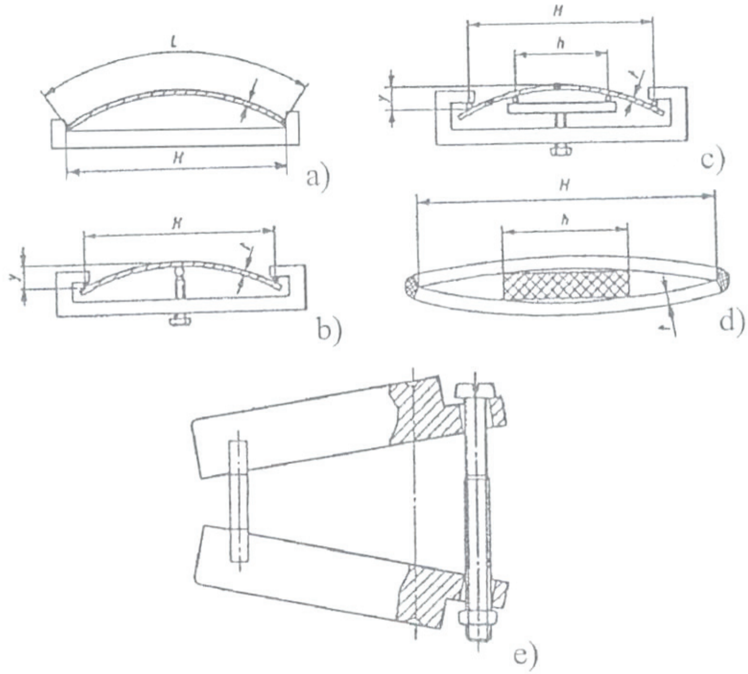

Figure 3*. Schematic presentation of the bent-beam specimens*

3. SMOOTH SPECIMENS LOADED WITHIN PLASTIC STRESS AREA

Specimens of this group have unknown level of stress before the test, although it is known that they have suffered high both elastic and plastic deformation [5]. The tests based on such specimens often use for rapid detection of materials prone to stress corrosion cracking, Figure 4. “U – specimens” are the most commonly used.

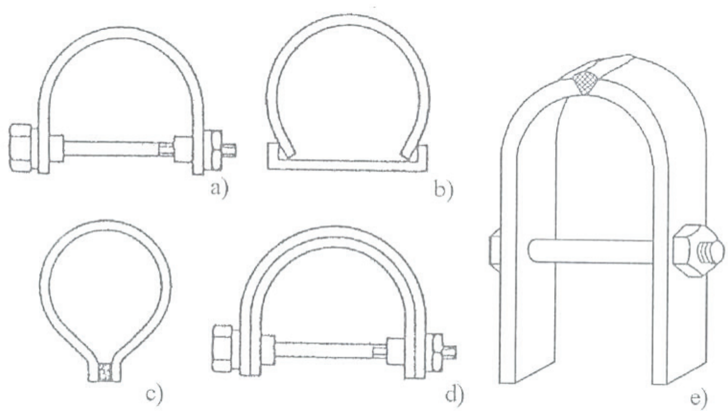

Figure 4. *Schematic presentation of the “U specimens”*

The main advantage of this test is its simplicity and the ability to test of the specimens in all possible operating conditions during the test period. A lack of these tests is reflected in the fact that the stress which initiates a crack may not be accurately determined.

4. PRE-CRACKED SPECIMENS

For monitoring the behavior of materials with pre-cracked specimens, which are exposed to external stresses and corrosive environment at the same time, classical stress analysis is not enough reliable. Therefore, the methods based on the fracture mechanic are used as the most reliable.

It is foreseen the use of specimens loaded with tensile or bending stress, for testing of stress-corrosion cracking using fracture mechanic methods. Detailed description of the procedure to perform tests and the dimensions of the specimens that are used for testing are defined and shown in Figure 5 [7].

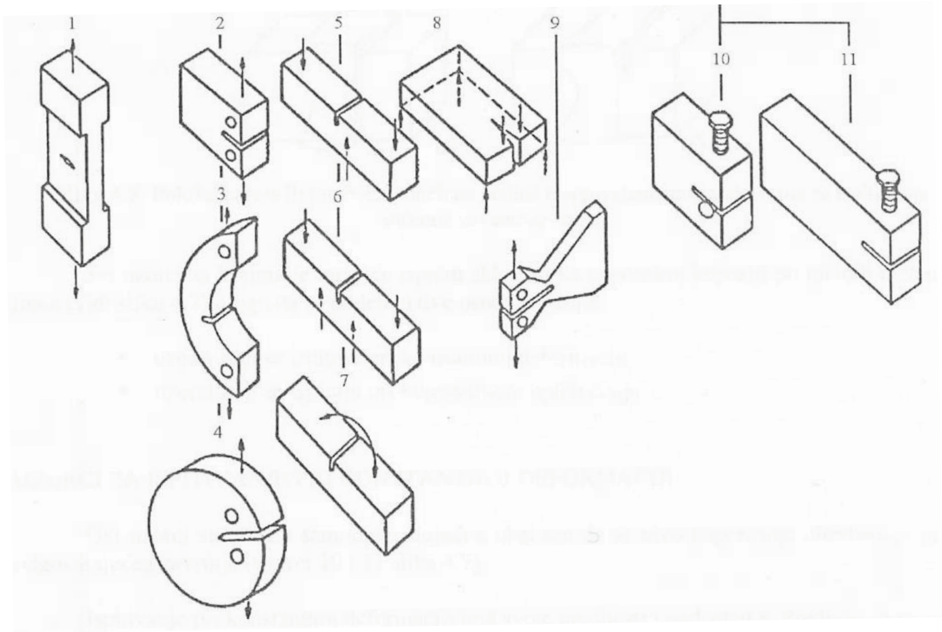

Figure 5*. pre-cracked specimens for SCC testing*

In previous figure different specimens geometry was presented. The specimens are classified as follows: 1 – Centre cracked plate; 2 – Compact tension specimen; 3 – C – shaped; 4 – Disk; 5 and 6 – 4-point bend specimen; 7 – Cantilever bend; 8 – Double torsion plate; 9 – Contoured double cantilever beam; 10 – T –type wedge opening loaded specimen; 11 – Double cantilever beam.

5. CONCLUSION

Based on the aforesaid it can be concluded that SCC is a complex physical phenomenon that appears on the sensitive material loaded with tension stress which operate in the aggressive environment. Since it is unavoidable in many cases, it is necessary to determine/estimate the lifetime of the structure based on the known parameters. For this purpose the SCC tests are used. The tests as an output usually assess the material susceptibility to SCC initiation and growth. Selection of the type of the test and the shape of the specimen depends on both function and environment of the structure which needs to be tested. Appropriate geometry is a factor that significantly affects test results. The choice of the specimen geometry depends on the shape, purpose of the structure/element to be tested as well as its technological capabilities.

6. ACKNOWLEDGEMENT

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SYNTHESIS, SOLID MODELING AND WORKING SIMULATION OF MOON PHASE CLOCK MECHANISM

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Ratko Obradović[2]
Zorana Jeli[3]
Slobodan Mišić[4]

Abstract

This paper presents the method and kinematical principles by which the synthesis of the Moon phase clock mechanism can be accomplished. This mechanism computes the duration of the synodic month and displays the proper lunar phases with the systematic error less than thirteen seconds per year. Moreover, 3D solid model and working simulation of this mechanism are also described and disclosed in the paper. The method uses the best rational approximation to the speed ratio, based on the continued fraction finite expansion of the real number.

Key words: *clock, continued fraction, mechanism, Moon phase,*

1. INTRODUCTION

A synodic month is defined [6] as the time interval between two consecutive occurrences of a particular phase as seen by an observer

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on Earth. The mean length of the synodic month is 29.5305879814815 days (29 days, 12 hours, 44 minutes, 2.8016 seconds). Due to the eccentricity of the lunar orbit around Earth (and to a lesser degree, the Earth's elliptical orbit around the Sun), the length of a synodic month can vary periodically by up to seven hours. Moon phases during June 2014 are shown on Fig. 1, as an example.

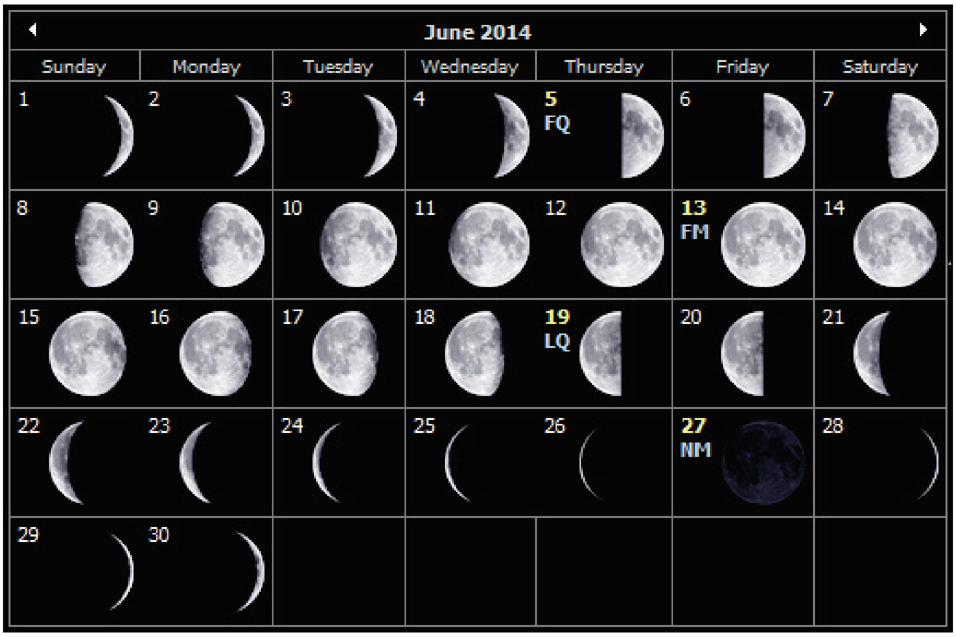

***Figure1**. June 2014 Moon phases calendar*

Almost all Astronomical clocks (Fig. 2.), many large Grandfather's (Fig. 3) and wall clocks, as well as some high end, luxury watches [4] (Fig. 3) display the Moon phases. These clocks and watches have a special kind of mechanism by which a synodic month is calculated and a special kind of dial (clock or watch faces) on which lunar phases are displayed [1]. Several types of Moon phase dials can be designed and applied. Strictly correct visual presentation of all lunar phases can be obtained only by a globe (Fig 4), half white half black, rotating on an axis in the plane of the dial in a circular hole which diameter is equal to the diameter of a globe [1]. Other Moon dial types are flat (Fig 4) and therefore can not display the shape of all lunar phases exactly. To emphasize the differences between them, we can say that 3D lunar phase presentation by the globe is strictly correct and 2D flat Moon dials are more practical.

Figure 2. *Prague astronomical clock*

Since all timekeepers (clocks and watches) already display minutes and hours, the essential problem of the synthesis of the Moon phase mechanism is the question how to obtain the specific speed ratio R = (2∢29.5305879814815) : 1 between angular velocities of the hour hand arbor and Moon phase arbor. This paper presents and explains the method by which that specific problem, and problems similar to them, can be solved. In addition, 3D solid model and working simulation of the Moon phase mechanism are also described and disclosed in the paper.

Figure 3. *Moon dials: Grandfather's clock and luxury watch*

Figure 4. *3D and 2D lunar phase presentation*

2. BEST RATIONAL APPROXIMATIONS AND CONTINUED FRACTIONS

It was already emphasized that a Moon phase clock mechanism, which computes the synodic month and displays the proper lunar phases, has to reduce the angular velocity of the hour hand arbor to the angular velocity of the Moon phase arbor by the very specific ratio R = (2∢29.5305879814815) : 1. Since that is always done by the set of meshing gears (gear trains), the speed ratio R can not be realized exactly but only approximately, with a limited level of accuracy. In other words, the speed ratio R must be approximated by a rational number and it is wise to choose the best rational approximation among all possible. Therefore, some important conclusions derived from the well known mathematical theory of real number rational approximations will be considered and disclosed firstly.

Russian mathematician Khinchin (Алекса́ндр Я́ковлевич Хи́нчин) [5] introduced two following definitions of the best rational approximation to a real number:

1. Rational number p/q (q>0) is the best rational approximation of the first kind to the given real number α if and only if the next inequality is satisfied:

$$\left|\alpha - \frac{p}{q}\right| < \left|\alpha - \frac{r}{s}\right|, \text{for all fractions } \frac{r}{s} \neq \frac{p}{q}, \text{ and } 0 < s \leq q \tag{1}$$

2. Rational number p/q (q>0) is the best rational approximation of the second kind to the given real number α if and only if the next inequality is satisfied:

$$|q \cdot \alpha - p| < |s \cdot \alpha - r|, \text{ for all fractions } \frac{r}{s} \neq \frac{p}{q}, \text{ and } 0 < s \leq q \tag{2}$$

Theorem 1: The best rational approximation of the second kind is always the best rational approximation of the first kind. The opposite statement is not necessarily true.

It was Russian mathematician Khinchin who discovered an important and essential role of continued fractions in rational approximation to a real number [5]. Initial segments of an infinite continued fraction representation for a given real number provide excellent rational approximations to that number. Regarding these facts, it is necessary to reveal and emphasize some important terms, definitions and statements on continued fractions [2].

A continued fraction is an expression of the form:

$$a_0 + \cfrac{b_1}{a_1 + \cfrac{b_2}{a_2 + \cfrac{b_3}{\ddots}}}$$, where a_i and b_i are integers

(3)

If b_i = 1 for all *i* the expression is called a simple continued fraction (4). In all further considerations in this paper, only the simple continued fractions (4) will be used and applied.

$$a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{\ddots}}}$$, where a_i are integers

(4)

If the expression contains a finite number of terms, it is called a finite continued fraction. Otherwise, expression is called infinite continued fraction. Integers a_0, a_1, a_2, etc., are called the coefficients or terms of the continued fraction (4). The limit continued fraction can be abbreviated by the notation [a_0; a_1, a_2 … a_n] and it can be always transformed to a simple fraction p/q in which both the numerator p and the denominator q are whole numbers. The coefficients of the continued fraction can be determined by the well known Euclidian algorithm. Let us describe the calculating process of those coefficients for a given rational number α. Coefficient a_0 is the integer part of $\alpha = \alpha_0$ and all other coefficients are determined by the expressions:

$$a_0 = [\alpha],\ \alpha_k = \frac{1}{a_{k-1} - \alpha_{k-1}},\ a_k = [\alpha_k],\ k = 1,2,...n;$$

(5)

The calculating process is finished when α_n becomes an integer.

The continued fraction [a_0; a_1, a_2, … a_n] represent the rational number p_n/q_n, which numerator p_n and denominator q_n can be determined by the following recurrent formulae and initial values:

$$p_n = p_{n-1} \cdot a_n + p_{n-2},\ q_n = q_{n-1} \cdot a_n + q_{n-2},\ p_0 = a_0,\ p_1 = a_0 \cdot a_1 + 1,$$
$$q_0 = 1,\ q_1 = a_1$$

(7)

For a given continued fraction [a_0; a_1 a_2, … a_n] representation to a rational number α, the expressions (5) defines the sequence of fractions p_0/q_0, p_1/q_1, … p_n/q_n, which are called the convergents or the continued fraction approximations of those number α.

It was Khinchin who proved and disclosed the two following theorems:

Theorem 2: Rational number p/q is the best rational approximation of the second kind to a given real number alpha if and only if that rational number is the convergent of the continued fraction [a_0; a_1, a_2, … a_n] representation to that real number α.

Theorem 3: For a given real number α, its finite continued fraction representations are the best rational approximations of the first kind. The opposite statement is not necessarily true.

If p_{n-2}/q_{n-2}, p_{n-1}/q_{n-1} and p_n/q_n are tree successive convergents, then any fraction of the form:

$$\frac{p_{n-2} + k \cdot p_{n-1}}{q_{n-2} + k \cdot q_{n-1}}, \; k \in \{1, a_{n-1}\}$$
(10)

are called semiconvergents or secondary convergents and formed the sequence of semiconvergents for the continued fractions p_{n-2}/q_{n-2} and p_n/q_n. Khinchin also discovered, proved and disclosed the following theorem 4:

Theorem 4: Rational number p/q is the best rational approximation of the first kind to a given real number α if and only if that rational number is the convergent or semiconvergent of the continued fraction [a_0; a_1 a_2, … a_n] representation to that real number α.

Theorem 4 plays the most significant role in the method exposed in this paper by which the best rational approximation of the synodic month can be determined.

3. RATIONAL APPROXIMATIONS OF THE SYNODIC MONTH

According to the theorem 4, the best rational approximation to the synodic month value and speed ratio R = (2 ∢ 29.5305879814815): 1 will be tracked and found between convergents and semiconvergents of the continued fraction representations of those numbers. But this condition is not sufficient since the specific speed ratio *R* will be realized by the set of meshing gears with limited numbers of teeth [9]. More precisely, some numerators and denominators prime factors of the speed ratio *R* convergents and semiconvergents are so large that ratio *R* can not be practically realized by the set of meshing gears. This limitation proceeds from the fact that gears with a big number of teeth have either unacceptably large diameters or exceedingly small dimensions of teeth. Consequently, the magnitude of above mentioned numerators and denominators prime factors [8] will be the critical selection criterion of the continued fraction representations of the speed ratio R.

Now, the complete procedure for the best rational approximation of the synodic month value and consequently for the speed ratio *R* = (2 ∢ 29.5305879814815): 1 will be explained and disclosed in this chapter. All important numerical data are placed in the Table 1. First of all, the value of the syndic Moon 29.5305879814815 days is rounded to 23.5306, and this rounded value is approximated by the set of its continued fraction convergents and semiconvergents [3]. The rounding way is very important since it has the high influence to the process of continued fraction convergence. Namely, different rounded values of the synodic month and speed ratio *R* will produce different values of convergents and semiconvergents. Moreover, most of them could not be practically realized and obtained by the meshing gears if the prime factors [8] magnitudes of their numerators and denominators are extremely large. The rounded value 23.5306 of synodic month will lead to the applicable solutions. This rounded value 23.5306 is approximated by all convergents and semiconvergents of its continued fraction representation and the results are placed in the Table 1.

***Table 1**. Rational approximations of the synodic month*

No.	Continued fraction abbreviation	Decimal presentation	Rational presentation	Enumerator / denominator prime factors	±
1	[29;]	29.0	29/1	29/1	+
2	[30;]	30.0	30/1	(2∢3∢5)/1	+

3	[29; 2]	29.5	59/2	59/2	+
4*	[29; 1, 1, 4]	29.(5)	266/9	(2⋖7⋖19)/3^2	+
5*	[29; 1, 1, 5]	29.(54)	325/11	(5^2⋖13)/11	+
6*	[29; 1, 1, 6]	29.(538461)	384/13	(2^7⋖3)/13	+
7	[29; 1, 1, 7]	29.5(3)	443/15	443/(3⋖5)	-
8	[29; 1, 1, 8]	29.52941176	502/17	(2⋖251)/17	-
9*	[29; 1, 1, 7, 2]	29.53125	945/32	(3^3⋖5⋖7)/2^5	+
10	[29; 1, 1, 7, 1, 2]	29.53061224	1447/49	1447/7^2	-
11*	[29; 1, 1, 7, 1, 2, 17]	29.53058823	25101/850	(3^2⋖2789)/(2⋖5^2⋖17)	-
12*	[29; 1, 1, 7, 1, 2, 18]	29.53058954	26548/899	(2^2⋖6637)/(29⋖31)	-
13*	[29; 1, 1, 7, 1, 2, 19]	29.53059078	27995/948	(5⋖11⋖509)/(2^2⋖3⋖79)	-
14*	[29; 1, 1, 7, 1, 2, 20]	29.53059177	29442/997	(2⋖3⋖7⋖701)/997	-
15*	[29; 1, 1, 7, 1, 2, 28]	29.53059755	41018/1389	(2⋖20509)/(3⋖463)	-
16*	[29; 1, 1, 7, 1, 2, 29]	29.53059805	42465/1438	(3⋖5⋖19⋖149)/(2⋖719)	-
17*	[29; 1, 1, 7, 1, 2, 30]	29.53059852	43912/1487	(2^3⋖11⋖499) /1487	-
18*	[29; 1, 1, 7, 1, 2, 31]	29.53059896	45359/1536	67⋖677/(2^9⋖3)	-
19*	[29; 1, 1, 7, 1, 2, 32]	29.53059937	46806/1585	2⋖3⋖29⋖269 /(5⋖317)	-
20	[29; 1, 1, 7, 1, 2, 33]	29.53059976	48253/1634	(73⋖661)/(2⋖19⋖43)	-
21	[29; 1, 1, 7, 1, 2, 34]	29.53060012	49700/1683	(2^2⋖5^2⋖7⋖71)/(3^2⋖11⋖17)	+
22*	[29; 1, 1, 7, 1, 2, 33, 2]	29.53059994	97953/3317	(3⋖103⋖317)/(31⋖107)	-
23	[29; 1, 1, 7, 1, 2, 33, 1, 2]	29.5306	147653/5000	(11⋖31⋖433)/(2^3⋖5^4)	-

Let us analyze the results shown in Table 1. Semiconvergents are indicated by asterisk mark (*) placed behind the ordinal numbers of the rows in the first column. Regarding the limitation value of teeth gear numbers, which is assumed to be 100 in this paper, the last column indicates if the solution is acceptable or not. For instance, the convergent number 7 is not acceptable because its numerator is 443. Other solutions which transgress the limitation value of teeth gear number are enumerated by: 8, 10-20, 22 and 23. Only suitable continued fraction approximations are denoted by numbers: 1-6, 9, and 21. Since the first two solutions between first 6 have very high error of approximation, they are used rarely. The third convergent 59/2 is accurate enough just for the visual presentation of the lunation and consequently is applied in many Moon phase ordinary watches and grandfathers clocks (Fig. 3). This approximation generates positive systematic error of one day of lunation in 2.6433 years (2 years and 235 days). Next practically valuable semiconvergent is number 9* which approximates the synodic Moon to the value of 29.53125 days, with positive systematic error of only one day of lunation in 122 years and 42 days. It is applied in very expensive high end watch Patek Phillipe - Grand Complication Perpetual Calendar Moonphase Chronograph [4]. Other acceptable solutions enumerated by 5* and 6* are applied rarely since they require the same numbers of meshing gears as the better approximation denoted by number 9*.

The best possible and practically applicable solution is the convergent enumerated by 21. It approximates the synodic month to the value of 29.53060012 days, with positive systematic error of 1.0487 seconds per lunation, or 12.97 seconds per year. This means that error of only one day of lunation will be accumulated after exceptionally long period of 6661.425 years, or 6661 years and 155 days. This continued fraction approximation of the synodic month is the original discovery of the paper authors and it will be applied for the synthesis of the Moon phase clock mechanism.

4. SYNTHESIS OF THE MOON PHASE MECHANISM

At the very beginning of the synthesis of the Moon phase mechanism it is important to emphasize all numerator and denominator prime factors [8] of the rational presentation of the 21st convergent, shown in Table 1.

$$\frac{49700}{1683}=\frac{2^2\cdot5^2\cdot7\cdot71}{3^2\cdot11\cdot17}$$
(11)

The Moon phase mechanism will be accomplished by the set of meshing gears (gear or wheel train) with the approximated value of the speed ratio R = (2∢49700/1683) : 1 between angular velocities of the hour hand arbor and Moon phase arbor. Therefore, the numerator and denominator of the fraction (2∢49700/1683) should be expressed in the form (12) which better represents the teeth gear numbers.

$$\frac{2\cdot49700}{1683}=\frac{2^3\cdot5^2\cdot7\cdot71}{3^2\cdot11\cdot17}=\frac{35\cdot40\cdot71}{9\cdot11\cdot17}$$
(12)

Respecting the expression (12), the gear train with the speed ratio R =
(2∢49700/1683) : 1 can be accomplished by tree pairs of gears. As is shown on Fig. 5, the pinion (smaller gear) P_1 with Z_{P1} = 9 teeth, mounted on the arbor A_1, meshes with the wheel (large gear) W_1 with Z_{W1} = 35 teeth. The pinion P_2 with Z_{P2} = 11 teeth meshes with the wheel W_2 with Z_{W2} = 40 teeth. The pinion P_3 with Z_{P3} = 17 teeth meshes with the wheel W_3 with Z_{W3} = 71 teeth. The pinion P_2 and wheel W_1 are mounted on the same arbor A_2. The pinion P_3 and wheel W_2 have the same arbor A_3, while the wheel W_3 is mounted on the separate arbor A_4. The input angular velocity of the arbor A_1 and pinion P_1 is 2 rotations per day, while the output angular velocity of the arbor A_4 and the wheel W_3 is 1683/49700 rotations

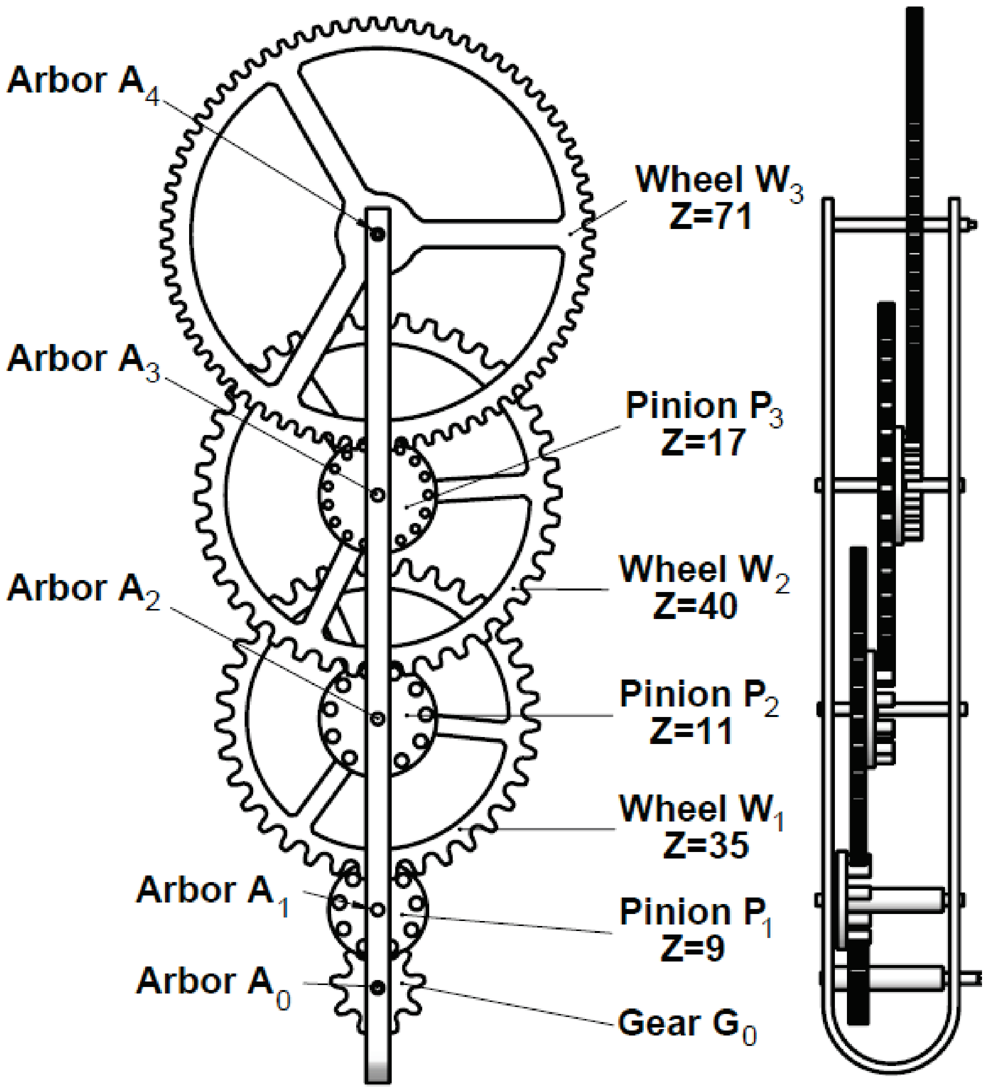

Figure 5. *Gear train of the Moon phase mechanism*

per day. More precisely, if the input arbor A_1 makes 2∢49700/1683 rotations, the output arbor A_4 will make 1 complete rotation [8]. The gear G_0 on the arbor A_0 is used just to reverse the rotation direction of the pinion P_1 with the speed ration 1:1. Consequently, the arbor A_0 can hold the hour hand and rotates in the same direction as the arbor A_4 on which the Moon phase indicator is mounted.

All pinions are lantern gears (*Der Triebstockverzahnung*) and they have cylindrical rods for teeth, parallel to the axle and arranged in a circle around its axle. According to the fundamental law of gearing, the teeth profiles of all large wheels, which are meshed with the pinions, represent cycloid curves [8].

5. MOON PHASE DIAL

Among several possible types of Moon phase dials, the flat 2D dial is chosen, and its proper form designed and exposed in this paper. As is shown on Fig. 6, this dial consists of 3 following parts: the immovable mask, the movable Moon plate and the sliding scale. The central part of the immovable mask is the oval, egg shaped cover which contour is composed of two semi ellipses. This oval mask is especially designed to exhibit the proper Moon phase by the overlapping the movable Moon disk. Moreover, the egg shaped cover has the scale by which the complete lunation is divided on 16 equal parts. On this division, four principal lunar phases are particularly accented by the longest tick marks. The movable Moon plate is centrally mounted to the arbor A_4 on which the Moon disk and the Moon tick mark is engraved. The sliding scale division is weeks, days and 12 hours, and is used to measure time intervals between current and any other Moon phase. It is important to emphasize again that this 2D flat dial can not exhibit the shape of all lunar phases exactly. But, since it is equipped with especially designed and arranged scales, this Moon phase dial can display the proper Moon age in correctly measured weeks and days. Besides the parts of the Moon phase dial assembly, the presentation of eight characteristic and successive lunar phases [6] (New Moon, Waxing Crescent, First Quarter, Waxing Gibbous, Full Moon, Waning Gibbous, Last Quarter and Waning Crescent) are also given on Fig. 6.

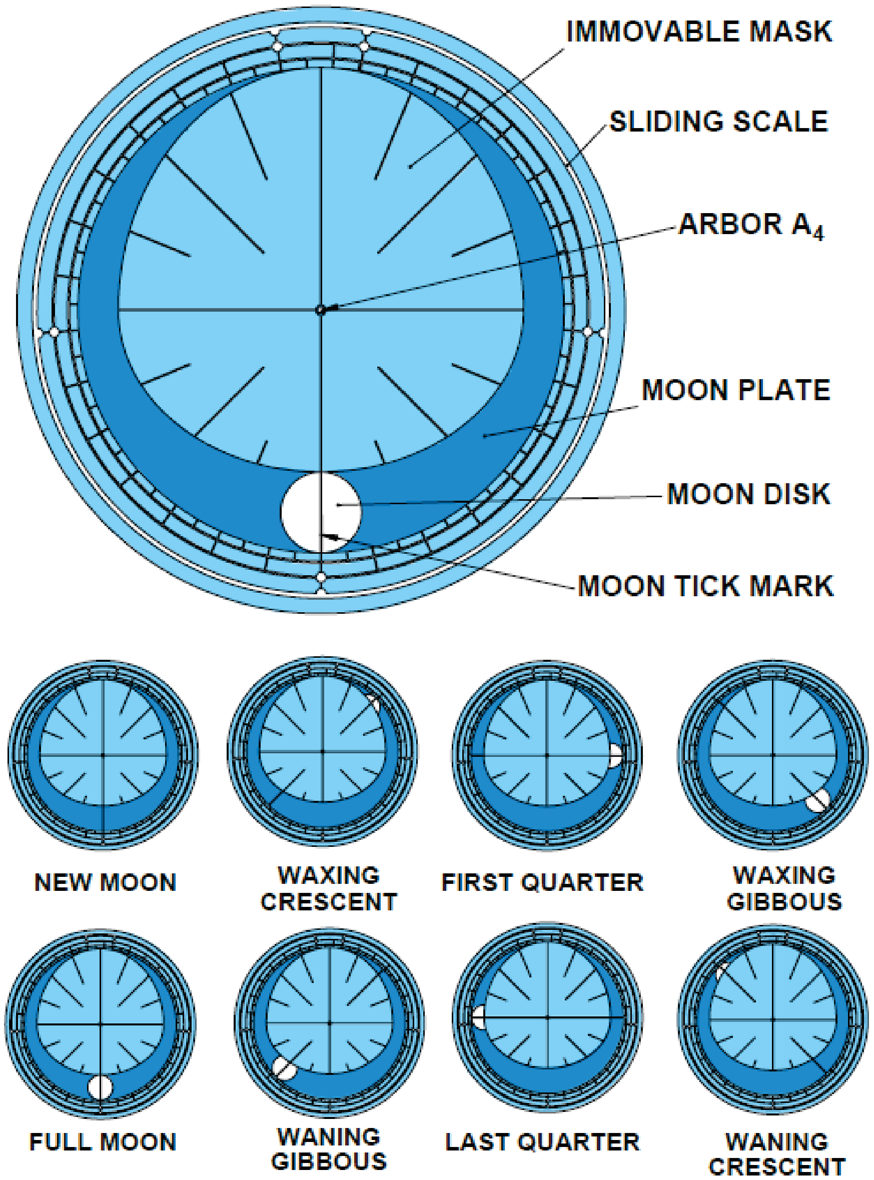

Figure 6. *Parts of the Moon dial assembly and 8 characteristic and successive lunar phases presented on the Moon dial*

The Moon phase dial should be adjusted properly. The method of Moon phase clock adjustment will be explained on one example. On July the 12th 2014, Moon is full in the sky of Serbia at 13:25. This data can be found in a Moon phase calendar on Internet [7] or any other astronomical almanac. On that datum, shortly before 13:25, the clock must be stopped, hour and minute hands set to show 13:25 and Moon disk rotated to the position in which it displays the full Moon. On that datum, exactly at 13:25, the clock mechanism must be started. Now, it will display the lunar phases correctly, with the systematic error of a little bit more than one second per month. The sliding scale can be set to the proper position only at 00:00 or 12:00. While the clock is running, the suitable 00:00 tick mark on the sliding scale should be turned to overlap the Moon tick mark exactly at midnight. Instead of this, the chosen 12:00 tick mark on the sliding scale should be turned to overlap the Moon tick mark at noon. Now, it is possible to measure and thus predict the next particular lunar phase with the error less than ±6 hours. Instead to use the data for a full Moon, the Moon phase dial can be similarly adjusted by the using of a data for any other suitable, usually principal lunar phase, if such a phase is given in astronomical almanac [7].

6. FINAL REMARKS AND CONCLUSION

This paper discloses one possible method by which the best rational approximation of a real (irrational) speed ration of a gear train can be found. The method uses a continued fraction representation to a given real number by a sequence of convergents and semiconvegents which serve as continued fraction approximations of that real number. This method can be applied in many different fields of mechanical engineering, especially in machines design and in the synthesis of clock and watch mechanisms. Thus, the synthesis of the Moon phase clock mechanism which computes the duration of the synodic month mean value and displays the proper lunar phases with the systematic error less than thirteen seconds per year is accomplished and presented in this paper. Moreover, 3D solid model, 2D Moon phase dial and working simulation of this mechanism are also realized by the using of Solid Works 2012 computer application.

Since the apparent length of the synodic month varies almost harmonically from its mean value up to seven hours [6], [10], the presented mechanism can be modified to display lunar phases more precise. This can be obtained by the synthesis of a special computational mechanism which will generate and add one or more harmonic components to the mean value angular velocity of the Moon orbital revolution. That will be the task for some future research.

Acknowledgement: Research is supported by the Ministry of Science and Education of the Republic of Serbia, Grant No. III 44006.

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COMPUTATIONAL MODELING AND SIMULATION OF WALKING MECHANISM

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Abstract

This paper explains the basic principles on which the walker mechanism for the rehabilitation of injured people is functioning. This paper presents the mechanism geometry, kinematics of its work as well as the appropriate model and simulation obtained by the software package SolidWorks. This work can be applied to the design of medical devices for the rehabilitation of persons with injured spine, paraplegics or those who have difficulties in walking due to cerebral apoplexy.

Keywords: *mechanism, walker, simulation, medical aid*

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1. INTRODUCTION

Consideration, analysis and synthesis of various types of walking mechanisms can be important at least in two different fields of science. First, this study offers the contribution to the theory of kinematics, mechanisms, machines and similar fields of science and techniques. And secondly, but not of less importance, this research can be applied to the design and practical construction of walking and standing mechanisms by which the walking rehabilitation and training in the treatment of spinal cord injured (SCI) patients can be obtained. Moreover, various types of mechanical walkers and walker systems can be applied for establishing the standing and walking assistance functions for elderly and temporarily or permanently disabled people.

The problem of synthesis and design of different categories of mechanical walking mechanisms represent the respectable subject of research in modern science and technique. Modern methods are CAD with the special software for analysis processing, which can simulate not only the motion of the mechanism, but can define the position, velocity, acceleration, forces, moments and other parameters at every moment of time, but verification and mechanics laws understanding are necessary. The exposed methods are significant for the motion simulation, and analysis of kinematical characteristics of the mechanical walker model accomplished in this paper by CAD application. Authors emphasized that main features for the proposed biped machine are low-cost design and easy-operation in terms of compactness, light weight, and reduced number of degrees of freedom (DOFs). During a pilot clinical test, a hemiplegics patient could use the suggested gait rehabilitation robot with a slow walking speed. The rehabilitation plan was also suggested for the patient and the possible therapeutic effects of the suggested rehabilitation robot system are discussed. The implementation of mechanism for the reconfigurable quadruped/biped walking robot is described and its application is discussed. In [2], Takeshi et al proposed a new mechanical gravity compensation mechanism suitable for the wearable lower limb rehabilitation system. The gravity compensation ability of the proposed mechanism and the effectiveness of the proposed system as a lower limb rehabilitation system are examined by some computer simulations and experiment using the actual equipment. Authors claimed that the proposed gravity compensation systems are safer than previous ones since the proposed mechanisms which generate gravity compensation torques are totally embedded to the body link. In [4], Yong et al generated a conceptual design for a prosthetic ankle-foot mechanism that can automatically adapt to the slope of the walking surface. The mechanism simulates the behavior of the physiologic foot and ankle complex by having low impedance in the early stance phase and then switching to higher impedance once foot-flat is reached.

In [5], Veg et al presented an improved planar biomechanical model of a human leg which comprises three body segments and two joints. Model was developed to investigate automatic control for functional electrical stimulation.

This paper describes the synthesis and principal kinematical analysis of mechanically established walking and standing mechanism. Moreover, design and motion simulation of mechanical walker 3D model is shown, elaborated and documented by various kinematical diagrams.

2. THE MECHANICAL WALKER MECHANISM

The curved sliding mechanism OABC, with special parameters, extended with dyad CC' and DC' is the fundamental mechanism of the model of the mechanical walker (Fig. 1)

Since the point A of a crank OA of the leading link has a circular trajectory SA, the point C of the link AC, of the leaded member moves over the trajectory SC,, the symmetrical 6th order curve (1) with special characteristic are of interest for application.

By transforming of the curved sliding mechanism on the equivalent four bar linkage [6] it is possible to synthesize the six member joint mechanism. One of the members has the curve translation law of motion, which can be described by the law of motion of the point C of link of the curved sliding mechanism [7], [8]. Because the link and the moving link of the equivalent four bar linkage are infinite, its practical application is inconvenient. This fact improves the use of the quasi equivalent joint four bar linkage with the members of infinite length. The law of motion of the point C of the quasi equivalent mechanism is close to the law of motion of the point C of the link of the curved sliding mechanism [8].

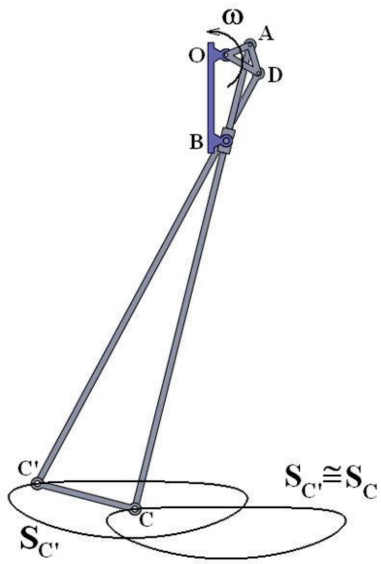

***Figure 1**. The fundamental mechanism of mechanical walker model*

By applying the Robert-Chebyshev theorem on the quasi equivalent joint four bar linkage it is possible to obtain the parameters of the added dyad, in which one of the members does the curve translation [7], [8].

By the invention of curves sliding mechanism extended with the dyad, whose one member do the close to translation, it is possible to treat it as an four bar linkage CADC' with the added link OB and slider B (Fig. 2).

Two of such identical six member mechanisms, placed in two parallel planes, with the common crank phasic shifted for 1800, able to rotate around the point C, forms the fundamental structure of the mechanical walker (Fig. 3). The members CC', the feet, has the floor contacts with the unmoving ground, one after the other. The trajectory SOb of the translatory moving couple of the walker is to be obtained by assembling of the upper parts of the trajectory SB, from a to b (Fig. 2), that is from a1 to b1 in a continual curve in the sagittal plane (Fig. 4). Details of the walker mechanism are shown in Fig. 5.

The mechanical walker, synthesized by the use of mentioned method, does not imitate the human pattern of walking. The conditions necessary for motion stability are based on the explained mechanical structure. Because of the low walking speed of the walker, the static stability is of the main interest, the dynamical influence of the stability is of the second order [3].

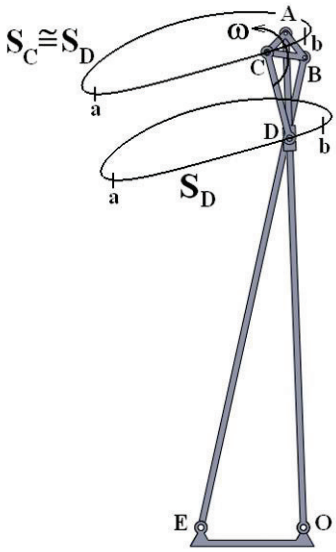

Figure 2*. Four bar linkage CADC' with the added link OB and slider B*

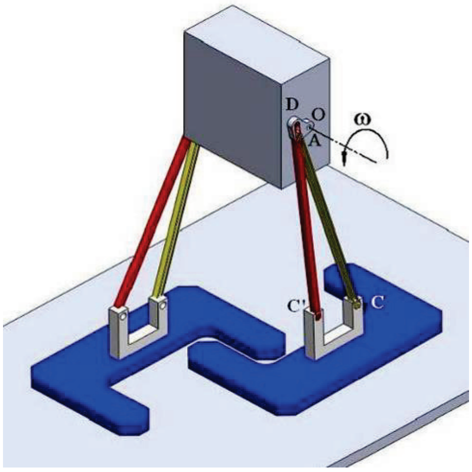

Figure 3*. The fundamental structure of the mechanical walker*

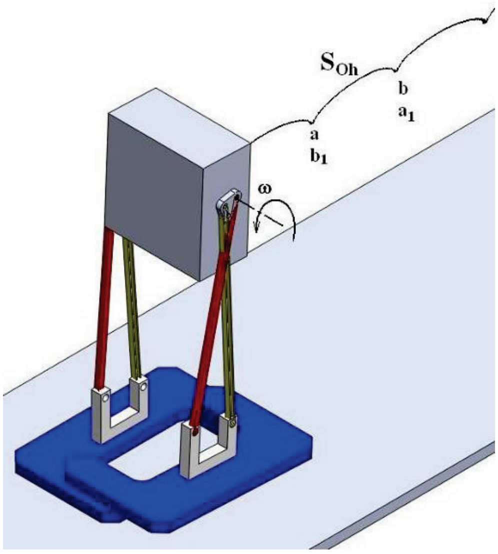

Figure 4. *The trajectory of the translator moving couple of the walker*

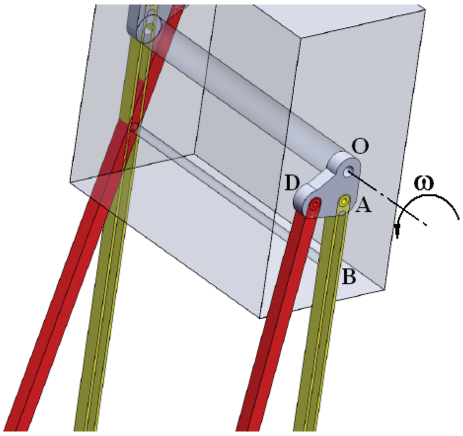

Figure 5. *Details of the walker mechanism*

By analyzing of the human walk [2] it could be concluded that the head and shoulders are moving approximately uniform, with a constant velocity during walk cycle. Comparing the trajectories of the mechanical walker (Fig. 2) and man's head it is to be pointed out that it is necessary in first approximation to build in the horizontal moving component to the point of the seat (predicted for the handicapped person) OB, for obtaining close to constant velocity during walking.

This is possible to realize by harmonic mechanism, with the initiating angular velocity ω1, doubled to the angular rate of the fundamental mechanism ω2 = -2ω. Superposition of the motion laws of the fundamental mechanism and the harmonic one result that the moving of the seat of the walker is obtained with the close to constant velocity.

3. EVALUATION AND VERIFICATION OF THE SOLUTION

Since the mechanical walker, proposed in this paper, is expected to be used for walking rehabilitation and training in the treatment of spinal cord injured patients, its kinematical characteristics should be compared with the kinematical characteristics of human walk. That comparative evaluation can offer the verification of mechanical walker as a useful medical tool for the purpose of walking rehabilitation.

The positions set of the mass center of the walking man is obtained by corresponding anthropometric measurements and are graphically exposed on Fig. 6 by the series of dots. The trajectory of one chosen point on the 3D model of mechanical walker is shown on the same Fig. 6 by the continuous red curve. This 3D model is created by the using of CAD [7] (SolidWorks) application and the trajectory is generated by the motion simulation tools of the same CAD application. The comparative consideration of this trajectory and the positions of the walking man center of mass represented by the series of dots shows significant fitting, i.e. almost trivial differences. Thus, it can be regarded that designed mechanical walker is a practical and beneficial medical device for walking rehabilitation

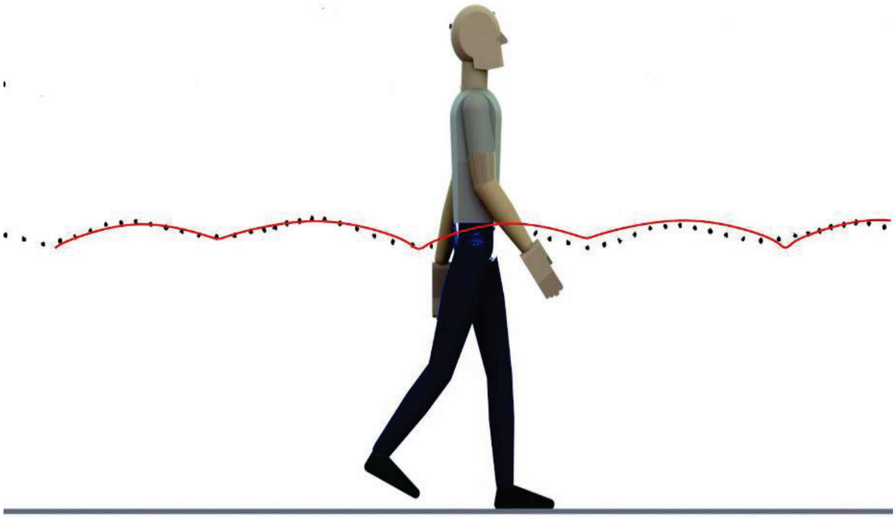

Figure 6. *The mechanical walker trajectory (red curve) and the positions of the walking man's center of mass (black dots)*

4. CONCLUSIONS

This paper describes a novel walker with mechanically established walking and standing mechanism. Described synthesis of mechanism of the mechanical walker can be compared with the similar solution, the tripod walking robot, based on mechanism composed of 8 linkages, [8], whereas our mechanical walker comprises just 6 elements. Moreover, the fulcrum of the walker described in this paper, is the structural member of the mechanism, while the tripod walking robot rests upon the surface in singular points. Finally, tripod walker has larger overall dimensions than mechanism proposed here. Since both mechanisms generates similar walking path, it can be concluded that the design exposed in this work is more practical and reliable, as well as less expensive.

In further establishment, it is possible to develop new mechanisms, function generators, which will take into account horizontal component, as well as the vertical one. It is of interest to correct the vertical component of the velocity of the seat of the mechanical walker. The goal for the correction is to obtain better coincidence of the motion laws of the walker to the walking patterns described in gate analysis [4].

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SIMULATION OF MACHINES FOR MECHANICAL OPERATION OF GRAPES IN WINERY

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Abstract

This paper presents the mechanical operations in the processing of grapes in wine-making process. In the software package SolidWorks modeling was performed for certain machines used in wineries and then performed a simulation of these machines. Based on the simulation of machines and harmonizing the operating parameters of the designed model it creates a base and determins all relevant parameters for the final construction of machinery. This procedure reduced the time of making final technical documentation.

Keywords: *wine, machinery, SolidWorks, simulation, technical documentation*

2. INTRODUCTION

Serbia has a great potential in wine making industry, especially in area of small family wineries. Several regions are famous for their wines but lack of proper equipment force many winemakers to buy machines that are expensive and oversized. In order to make accessible but quality machines for mechanical operation of grapes

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during wine making process in 2012, we started a national project "Serbian mini winery" in which was defined most of equipment for small scale wineries. These wineries should have area under vineyards no more than 5 ha [1], which is the most common case in small family wineries. During the period of project it was defined a technology and process of making wine and grape treatment and basic plan how the winery should look like (figure 1).

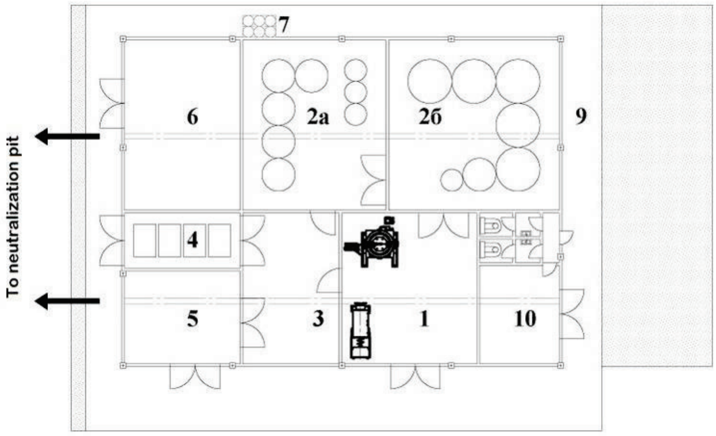

***Figure1**. Basic plan for small scale winery*

First, the grapes are brought from vineyard on the handling porch (9) mostly in crates. All grapes go to machines that are called crusher and press (1). There are few differences in making white or red wine [5] and one of these differences is that grapes for white wine goes on crusher and right after that on the press and juice is filled in tanks (2a). A grape for red wine goes into the crusher and then it goes in special tank for process called maceration. After maceration pomace goes to press and grape juice goes to tanks (2b). Depending of technological terms, after fermentation wine goes for bottling and is ready to go into the market (3). Rests of the winery are storages, worker rooms and cooling system [4].

In this paper will be described two machines that were mentioned before: grape crusher-destemmer and press. It will be shown also their 3D models and principals of work.

3. CRUSHER DESTEMMER

Crushing grapes is a first step that we start a production of wine from grapes. We are crushing grapes in order to extract grape juice with its berries. This task should be executed in that way that we don't damage the solid part's of grape (like seed inside a berry) but just hard enough to that grape berry skin breaks and juice gets out. This procedure is very important so it allows yeast to come in contact with a grape juice and do alcohol fermentation. Also by crushing grape we are making it easier for press to separate a liquid part and solid part of grape berries (berry skin and seeds) [6].

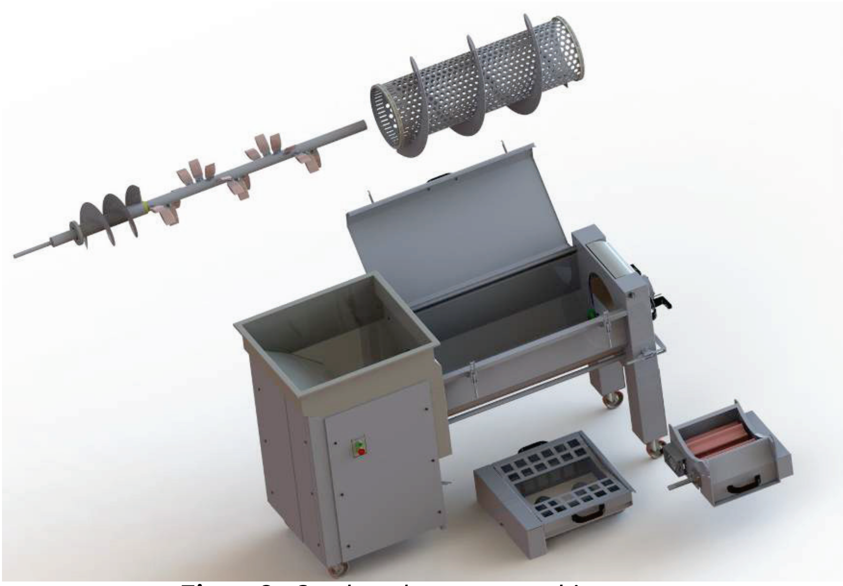

Figure2. *Crusher destemmer whit parts*

Crusher destemmer (Figure 2) is a machine that is using to separate the grapes themselves from the stems and then to split open the grape in order to get at the sugary juice inside that is going to be fermented.

Operating principle goes throw several phases. Grapes are going throw hopper to screw conveyer which has a function as dozer for amount of grapes to transport to shaft with arms and paddles. Destemmers comprise a perforated cylinder, with a shaft equipped with paddle-like arms running through its center. When the shaft turns, it draws in the grape clusters and expels the stems out the other end. The juice, pulp and grape skins pass through the perforations. A quality destemmer should not leave any berries attached to the stem. Reciprocally, the stem should not be impregnated with juice. The stem should also be entirely eliminated, with no broken fragments remaining. To accomplish wanted goal working parts of destemmer have a specific geometry (figure 3 and figure 4) [2].

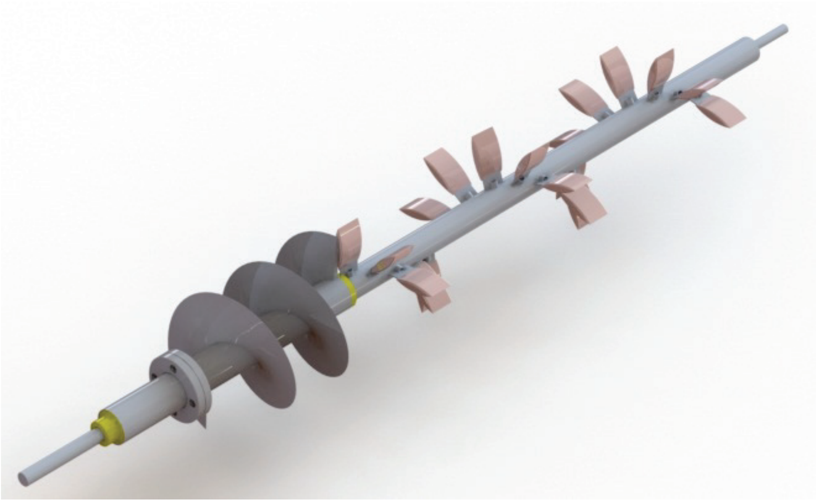

Figure 3. *Shaft with arms and paddles*

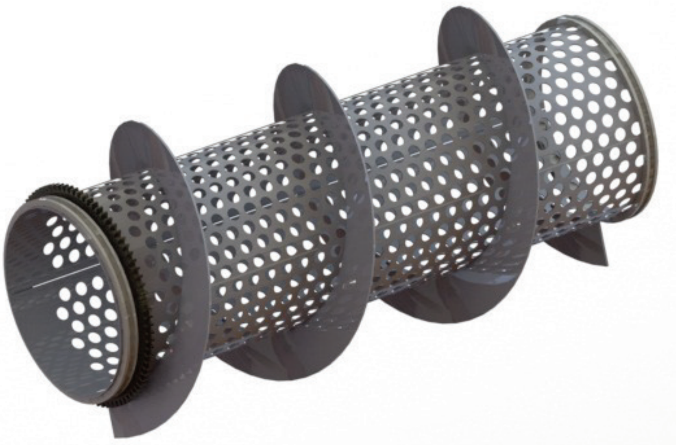

Figure 4. *Perforated drum*

As it was said, destemming grapes is done by two rotating elements: drum (figure 3) and shaft with arms and paddles (figure 4). Inside element (shaft) rotating in mathematically positive direction while outside element (drum) is rotates in opposite direction. On shaft first we have a screw conveyer that is used to dose amount of grapes before it goes to arms with paddles which separate grape and stalk. This is an example of how geometrically different elements are used for current function.

Outside element (figure 4) have a spiral plate around perforated drum which has a function to move grape berries back for further processing. Throw perforated drum grape berries are going to rolls and stem are going outside. With this characteristic geometry of these two elements we have gain accurate destemming which has as a result a better wine quality.

4. PRESS

Wine press (figure 3.) constructed for small winery has a unique design that makes it cheaper to made and easier to handle. It consists of:

1) Support structure
2) Head of press
3) Protection shield
4) Tank

Basic principle of operation of this specific press is that when tank is placed pumping three rubber tires head of press is moving down for a 350 mm. After that head is getting back up and released a dissenter that presses the grapes for more 300 mm more. Whole pressing path of head is about 650 mm or less depending of type of grapes and quantity of dry mater in the tank. After grape is pressed juice is going to tank for storage for fermentation [3].

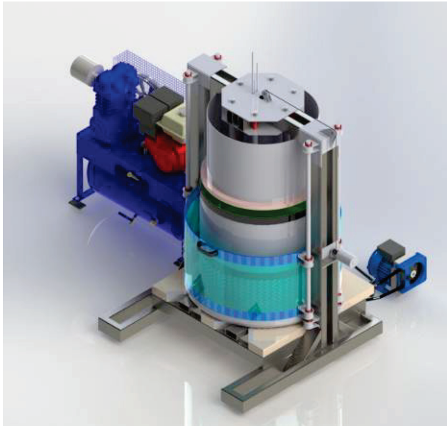

Figure5*. Wine press*

5. FINAL REMARKS AND CONCLUSION

For all machines described above there are made models in program called Solidworks and it has been simulated their work. As a practical result of these models, for example, we have a kinematic scheme of grape crusher-destemmer (figure 5) on which we can see all rotating speeds of all moving parts.

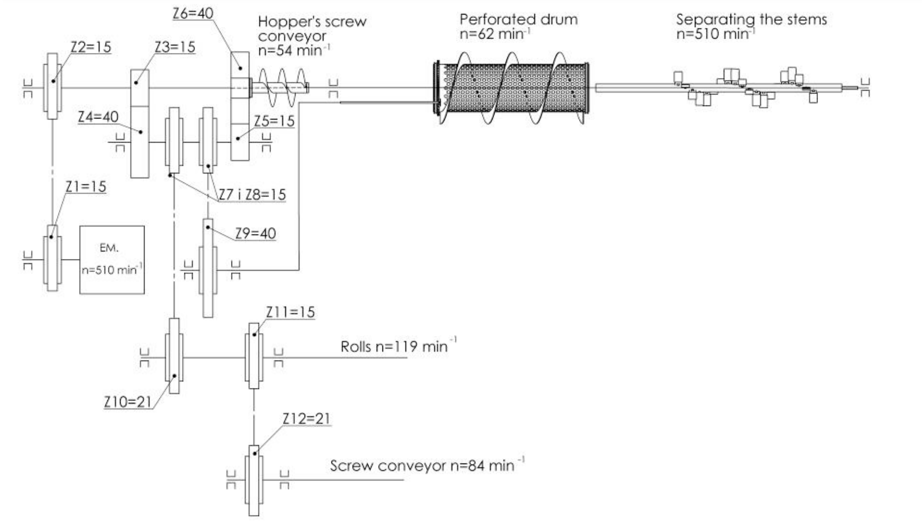

Figure 6*. Kinematic scheme of grape crusher-destemmer*

This paper present a good example how to use theoretical knowledge, in this case, in field of Descriptive geometry, and thus to solve a practical problem. Solution we explain in this paper is elegant, but very efficient.
In oral presentation it will be shown simulation in which is very clearly shown how these machines work and their assembling from parts.

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GEOMETRICAL CHARACTERISTICS AND SOLID MODELING OF THE GRASSHOPPER ESCAPEMENT MECHANISM

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Ljubomir Miladinović[2]
Marija Obradović[3]
Miša Stojićević[4]

Abstract

This paper presents the geometrical properties of one special type of escapement mechanism – the grasshopper escapement, by which the first marine chronometers were equipped. The most important and distinguish mechanical feature of this escapement is also disclosed that contact surfaces between pallets and escapement teeth do not need lubrication. In addition, paper presents the escapement 3D solid model and explains briefly its operational cycle.

Key words: *clock, escapement, grasshopper, Harrison, mechanism,*

1. INTRODUCTION

It was already disclosed [1], [7], and emphasized that an escapement is a part of every clock and watch which serves as a mechanical regulator with two different functions: the locking and the impulse function. The angular velocity of the clock and watch

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mechanism is regulated by the locking function while the dissipation of the oscillator energy is recompensed by the action of the impulse function [7]. Grasshopper escapement [3] is a recoil escapement for pendulum clocks invented by British carpenter and clockmaker John Harrison (Fig. 1) around 1722 [4]. Harrison used this escapement in his regulator and turret clocks, and also in the first three of his marine chronometers, H1 - H3, by which the famous problem of Longitude was finally solved. The term "grasshopper" describes the specific skipping and kicking action of the pallets and it first appears in The Horological Journal in the late 19th century.

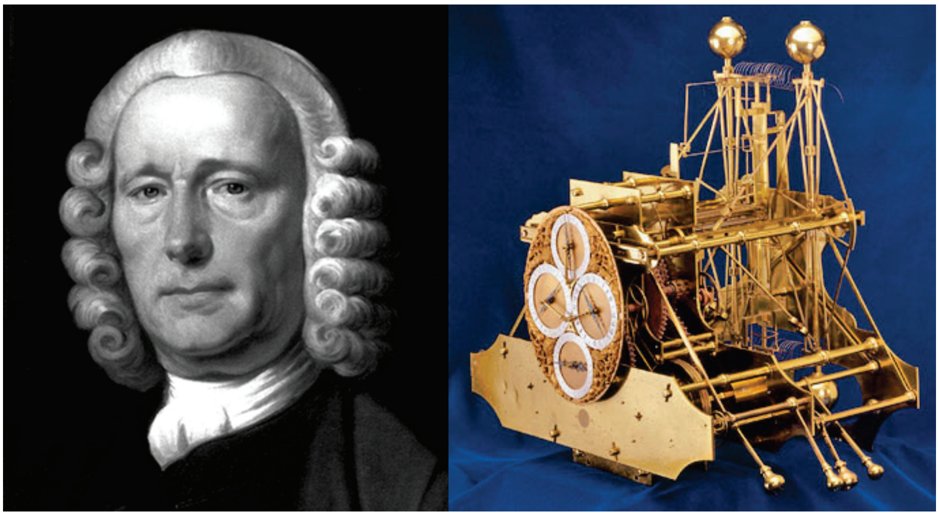

***Figure1**. John Harrison and the first marine chronometer H1 equipped with a grasshopper escapement*

Grasshopper escapement shares all characteristics with any other recoil anchor escapement except one: the contact surfaces between pallets and escapement teeth do not need lubrication. This is an important advantage because the clocks equipped with grasshopper escapement do not need to be stopped frequently for cleaning, oiling and adjusting. Moreover, those “grasshopper” clocks are more accurate and reliable than others since the deterioration of lubricant, which is highly detrimental to the clock rate stability, is completely eliminated from the pallets of the grasshopper escapement.

2. GEOMETRICAL PROPERTIES OF THE GRASSHOPPER ESCAPEMENT

The design of the grasshopper escapement can be perceived and comprehended as the modification of an ordinary anchor escapement [2]. This modification was invented and accomplished by John Harrison to eliminate the need for lubrication of the escapement pallet contact surfaces. That distinguish mechanical property of the grasshopper escapement is the direct consequence of its geometrical characteristics.

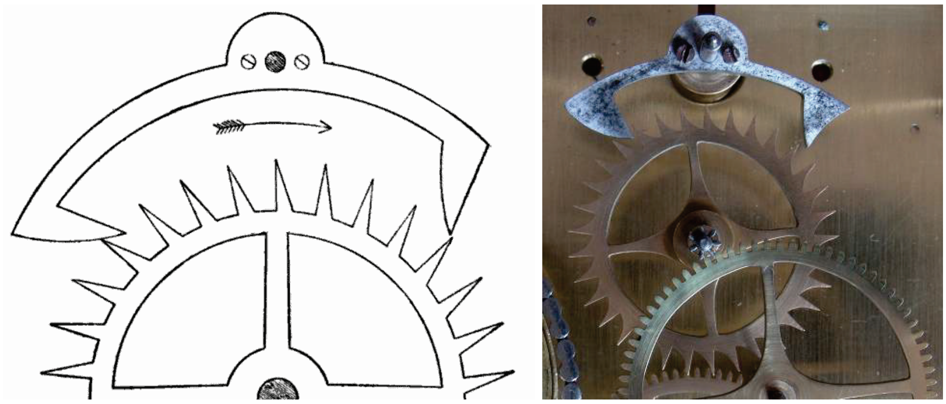

Figure2. *Anchor recoil escapement*

At the very beginning of this discussion, the simple anchor escapement [2], whose design was accounted for by an English clockmaker William Clement and British scientist Robert Hook in 1670, will be analyzed briefly. This recoil escapement given on Fig.2 interacts with oscillator permanently. The effect of sliding friction moment of force is tachy - chronous overall [7], which means that every increase of the driving moment leads to diminished oscillation period of a pendulum and acceleration of the clock rate [8]. The sliding friction can be reduced by pallets surfaces lubrication but since lubricant degrades during the time, the problem persists. One possible and very smart solution to this clockmaker's puzzle is to replace the sliding motion with rotation of a pallet around its fulcrum on an escapement tooth [6]. This kinematical replacement can be achieved only if escapement pallets are not fixed on, but able to rotate around their joints with escapement crank arms.

Fig. 3 discloses the basic geometrical properties of the grasshopper escapement [3]. Escapement wheel is presented by the escapement circle e whit the diameter *De*, and the center in the point *O*. Pallet arms *HA* and *JB* are pivoted to the pallet cranks *GH* and *GJ* in the points *H* and *J*. Since crank arms GH and GJ have the same length, points *H* and *J* belong to the same circle perimeter *c* with the center in the point *G*. Pallet arms *HA* and *JB* are connected to the perimeter of the escapement circle *e* in the points *A* and *B* respectively. The angle *AOB* = σ is the pallet span angle. The entry pallet arm *HA* is the mutual tangent to the escapement circle *e* in the point *A* and a crank circle *c* in the point *H*, while the exit pallet arm *JB* is the mutual tangent to the escapement circle *e* in the point *B* and a crank circle *c* in the point *J*. This "mutual tangents" geometrical characteristic is the essential concept of the grasshopper escapement design. The linkage motion, as carried on the small arcs, is analogous to the motion of two pulley wheels coupled together one half of the time by a common loop belt so as to rotate in the same direction. The other half of the time they are coupled together with the crossed belt and they rotate in an opposite sense with respect to each other. Since pallet arms are the mutual tangents to the escapement and crank circle, the directions of escapement impulse forces are always collinear with the pallet arms. Consequently, the relative sliding motion between contact surfaces of pallets and escapement teeth is eliminated, and thus the sliding friction and the need for the surfaces lubrication [6].

3. 3D SOLID MODEL OF GRASSHOPPER ESCAPEMENT

At the very beginning of the 3D solid modeling of the grasshopper escapement, some parameters must be assumed and others are determined regarding the geometrical properties of this escapement shown on Fig. 2. The pendulum (oscillator) period is *T* = 2 s (clock rate is 0.5 Hz) and the escapement wheel has *Z* = 30 teeth. Thus, the angular velocity of the escapement wheel is one revolution per 60 seconds. It is assumed that diameter of the escapement circle *e* is *De* = 170 mm, and the number of teeth spanned by pallets *N* = 9. Other dimensions are determined by a simple calculation and results are placed in Table 1.

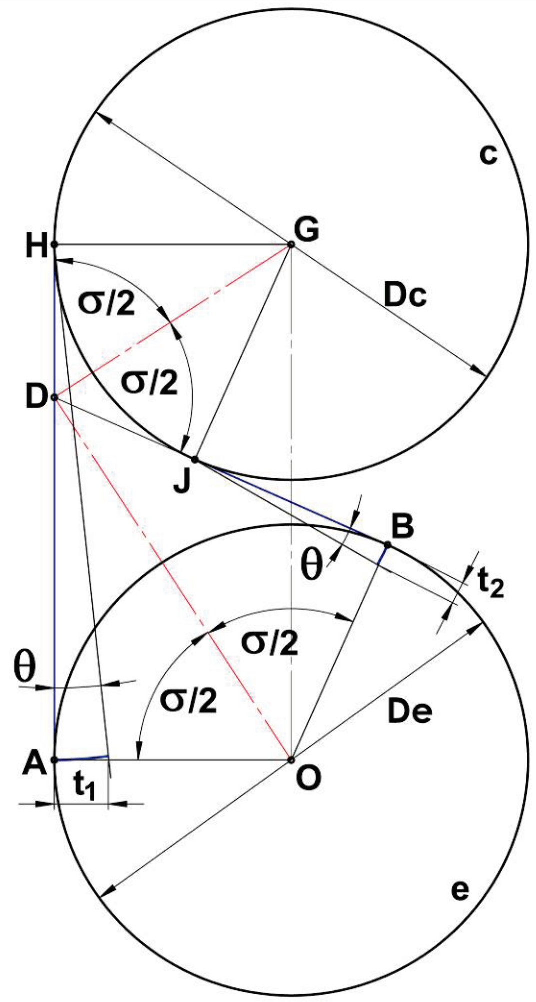

***Figure 3**. Geometrical properties of grasshopper escapement*

__Table 1__: Geometrical parameters of the grasshopper escapement

Parameter name	Formula	Value
Number of toot pitches spanned by pallets p	$p = N + 0.5; N \in \mathbf{N}$	9.5
Pallet span angle σ	$\sigma = 360^0 \cdot p / Z$	114^0
GH, GJ pallet cranks length	$GH = GJ = D_e / 2$	85.00 mm
AD, BD	$AD = BD = GH \cdot tg(\sigma / 2)$	130.89 mm
DO	$DO = \dfrac{D_e}{2\cos(\sigma / 2)}$	156.07 mm
DG	$DG = \dfrac{D_e}{2\sin(\sigma / 2)}$	101.35 mm
OG centers distance	$OG = \sqrt{DO^2 + DG^2}$	186.09 mm
DJ, DH	$DJ = DH = \dfrac{D_e}{2tg(\sigma / 2)}$	55.20 mm
Entry pallet arm length AH	$AH = AD + DH$	186.09 mm
Exit pallet arm length BJ	$BJ = BD - DJ$	75.69 mm
Pendulum arc θ	$\theta = 180^0 / Z$	6^0
Pendulum amplitude α	$\alpha = \theta / 2$	3^0
Entry pallet nib length t_1	$t_1 = AH \cdot \pi \cdot \theta / 180^0$	19.49 mm
Exit pallet nib length t_2	BJ pi theta / 180	7.93 mm

Since the entry and exit pallet intermittently and alternately engages and disengages the escapement's teeth, the pallet arms must be capable to skip out of the way of the escapement wheel spontaneously whenever the pallet nib is not resting on the escapement's tooth. This kinematical behavior can be accomplished either by a spring or gravity force. The solution based on the gravity force is used in this case and is practically realized by the tail heavy pallet arms.

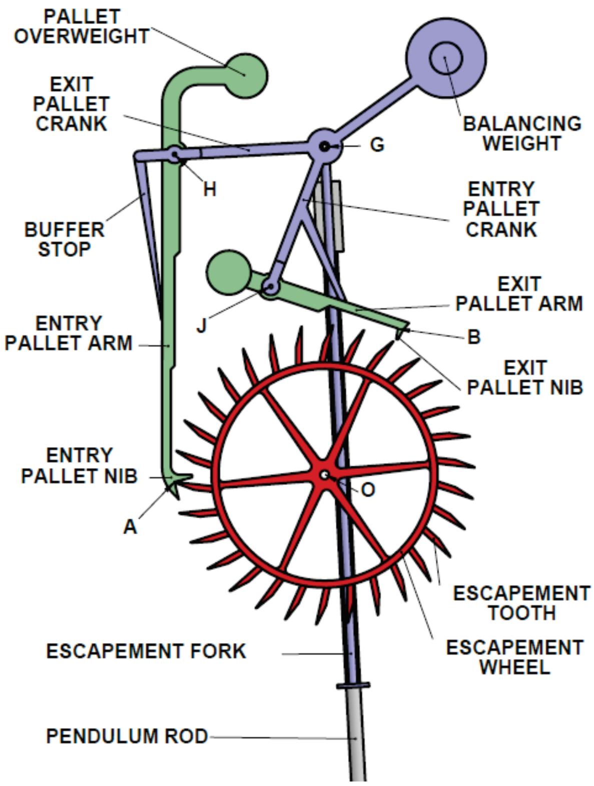

Figure 4. *3D model of the grasshopper escapement*

Respecting all geometrical parameters determined in previous chapter, the complete 3D solid model of the grasshopper escapement is accomplished and given on Fig 4. Since this paper does not expose the simulation and motion study of the escapement working cycle, the escapement operation is explained just briefly.

The constant momentum of force acts on the escapement wheel in the clockwise direction. When the pendulum is swinging from right to left, the nib of the entry pallet rests upon the escapement tooth; the escapement wheel rotates clockwise and the escapement fork delivers the impulse force to the pendulum. Just before the pendulum reaches the left amplitude position, the nib of the exit pallet enters the space between escapement teeth, engages the tooth and locks the further clockwise rotation of the escapement wheel. However, the pendulum, having momentum of inertia, continues its swing to the left, and the buffer stop on the crank arm continues to poll the exit pallet and the locked tooth to the left. This action forces the escapement wheel to recoil a small amount and thus to release the nib of the entry pallet from the engagement with the escapement tooth. Since tail heavy, the unlocked entry pallet jumps out of the way of the escapement wheel almost immediately and rests upon the buffer stop. Now, the pendulum starts to swing from left to right, the nib of the exit pallet rests upon the escapement tooth; the escapement wheel rotates clockwise and the fork delivers the impulse force to the pendulum. This working cycle will repeat as long as momentum of force is applied on the escapement wheel.

4. FINAL REMARKS AND CONCLUSION

This paper exposes the basic geometrical characteristics of the grasshopper escapement and explains how these characteristics influence its mechanical properties. The most important and distinguish mechanical feature of the grasshopper escapement is disclosed and emphasized that contact surfaces between pallets and escapement teeth do not need lubrication.

Respecting its geometrical parameters, the complete 3D solid model, as well as the motion study and animation of the grasshopper escapement, is accomplished by the using of the “Solid Works 2012” computer application. The escapement operational cycle has been considered and explained just briefly and visualized by the short movie [5].

Besides specified mechanical advantage, this type of escapement has several unfavorable features. First of all, since grasshopper escapement belongs to the group of anchor, recoil escapements, it makes permanent disturbing influences to the pendulum harmonic oscillations. Secondly, the grasshopper pallets tendency to jump out of the way of the escapement wheel has some serious defective consequences. For instance, whenever the clock’s going train is stopped or interrupted by winding, the grasshopper escapement will become temporarily inoperable because its pallets miss the contact with the escapement teeth. Nevertheless, this escapement mechanism remains today a unique, ingenious and admirable clockmaker’s invention.

Acknowledgement: Research is supported by the Ministry of Science and Education of the Republic of Serbia, Grant No. III 44006.

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COMPUTATIONAL STUDY OF FLOW AROUND THE FRONT WING OF A RACE CAR

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George Gherghina [3]
Dragos Popa [4]

Abstract

This paper aims at investigating aerodynamics of a race car, measuring airflow around the front wing. There are two methods to measure the drag, the first is by simulating the air flow with computational fluid dynamics (CFD) suite, and the second is by using a wind tunnel experiment. This study includes comprehensive computational approaches in order to characterize the complex flow structures in the front wing of the car. The continuous evolution in the automotive world demands the use of Computational Fluid Dynamic analysis and simulation to maximize down force and minimize drag during high speed manoeuvres. The front wing orientation was modified to enhance down force and lessen drag for maximum stability and control during race.

Key words: *automotive aerodynamics, design optimization, complex flow, race car.*

1. INTRODUCTION

The evolution of vehicles, in the last years, has been extremely fast because of increased competition between the car companies. Nowadays, the aerodynamics of vehicles has improved greatly. State-of-the-art automobiles exhibit a well-designed exterior with an

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intelligent flow interaction [1]. It is generally accepted that external flows have significant effects on the final aerodynamic performance of an automobile and that the amount of aerodynamic drag and the speed of an automobile are proportional to its square. The major goal of automobile aerodynamics research is to improve the fuel efficiency of a car by analyzing and controlling the external flows to reduce the aerodynamic drag [4]. As the top tier of racing, Formula One is an accumulation of high performance technology to maximize speed and control, while also ensuring the safety of the driver. Formula One car frequently race at speeds of up to 220 mph and are capable of a lateral acceleration nearing 5g. High-speed stability and control for these extreme manoeuvres are provided by precise aerodynamic calculations, finely tuned hard suspensions and tight grip tires [3]. Computational fluid dynamics (CFD) is extensively used in the racing industry to predict the down force and drag race cars would experience at high velocities. CFD provides numerical solutions to the governing equations of fluid dynamics throughout the desired flow region. It allows for complex problems to be solved without losing the integrity of the problem due to over-simplification. It is this ability to solve large problems that makes CFD an excellent tool for the automotive industry. CFD allows engineers to examine the airflow over an automobile or a particular part such as a wing or hood, and see the aerodynamic effect of changing the geometry of any particular area of the vehicle. Not only does the automotive industry use CFD to study the airflow external to the car, but now also employs CFD in mapping airflow through the engine, and even within the car to predict the behaviour of thermal comfort systems and the efficiency of cooling systems [6]. Different comparisons between wind tunnels and track measurements were included to show the validity of the CFD simulations. Using Navier-Stokes equations was simulated the heat transfer, compressibility, and different rotating reference frames that have grid resolutions approaching 100 million cells. These difficult simulations require dedicated computational resources for simulations as well for pre and post processing. At Sauber Petronas all the Navier-Stokes analyses were done with Fluent. The simulations can give valuable information's and insights not easily obtained from old wind tunnel measurements. Despite these complex models in practice cannot be used integrally due to the variations of roll and steer angles, yaw and wing settings. However CFD simulations can give information's to various concepts to be further exploited in the wind tunnel. In the near future these CFD simulations will reduce the number of hours spent in the wind tunnel [2]. These results obtained from CFD simulations can provide boundary and initial conditions to use smaller sub-models. These simulations can decrease the turn-around times and to allow for more design iterations to be realized within a given time frame without scarifying too much simulation accuracy.

2. MATERIALS AND COMPUTATIONAL PROCEDURE

In this study, aerodynamic analyses of a CAD model have been done using CFD to validate and correlate aerodynamic parameters established by car manufacturers. The model presented below is at 1:1 scale and follows the regulations of FIA of 2010. The model was conceived and built in Solidworks (Fig.1).

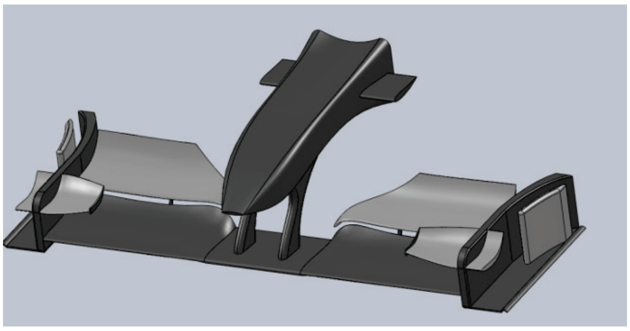

Figure 1. *CAD model of a front wing race car*

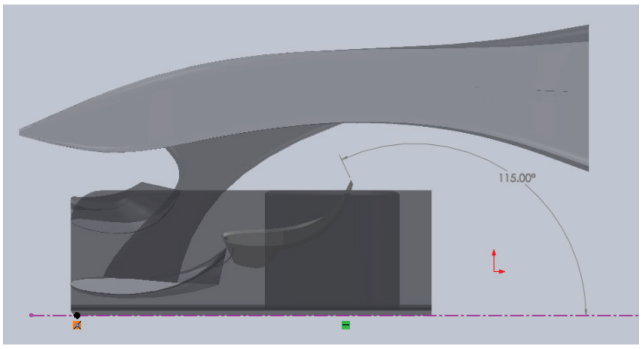

Figure 2. *Inclination angle of the main wing of the car*

On this basis, the CAD geometry models of the car are aerodynamically optimized and enhanced via various alterations in bodywork design and comparatively analyzed. This study is performed with an inclination angle of 115° degree of main wing of the front car

(Fig.2). The CFD simulations were carried out with an epsilon standard wall function turbulence model due to its iterative stability and commercial versatility. Different meshing strategies were tested to determine the effect of the grid on the convergence of iterative calculations. The model computation was done with an I5 core processor with a time of four hours.

3. RESULTS AND DISCUSSIONS

The front wing shape is one of the most important elements of the formula one car. The influence of the front wing system to the aerodynamics is an important factor in its development and optimisation. CFD use has an advantage by producing numerous flow fields and surface data that are hard to obtain from real experiments. The simulation give valuable information’s on the flow field downstream of the wing. According to the surface data obtained was collected information’s about load distribution of the wing, pressure distributions, Mach number, velocity and vortices. Such value leads to the understanding of interactions of the aerodynamic parts with the overall aerodynamics of the car.

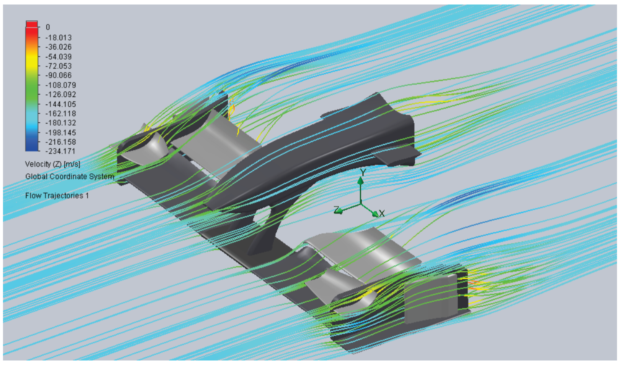

Figure 3. *Velocity distribution over the front wing*

The analysis was focused on visual observations of the principal properties of interest such as vortices, Mach number, and pressure contours that are difficult to obtain from wind tunnel experiments. Combined with experimental data if is possible the simulation can give the best profile of the front wing. The inclination of the main stabilization wing set to 115° degree produce down force on the front end of the car.

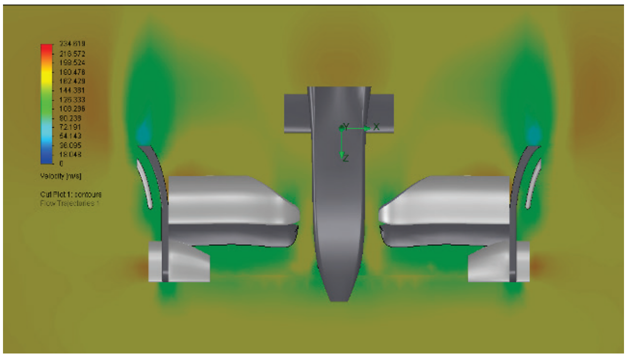

Figure 4. *Cut plots of velocity field on the wing*

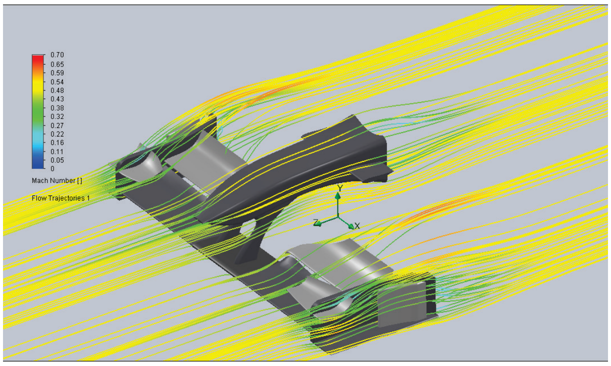

Figure 5. *Mach number field distribution the front wing*

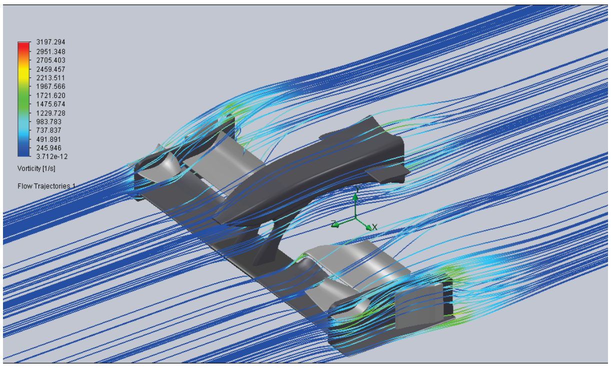

Figure 6. *Sample image of vorticity flow visualization*

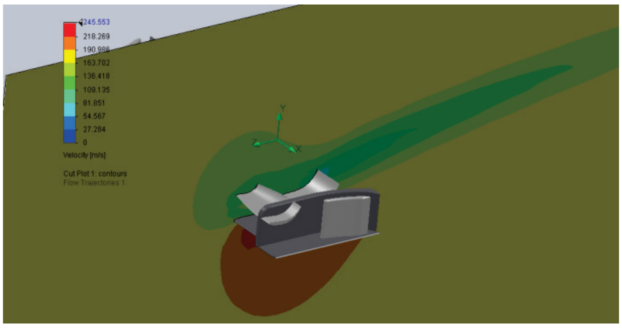

Figure 7*. Cut plots of vorticity on the main stabilization wing*

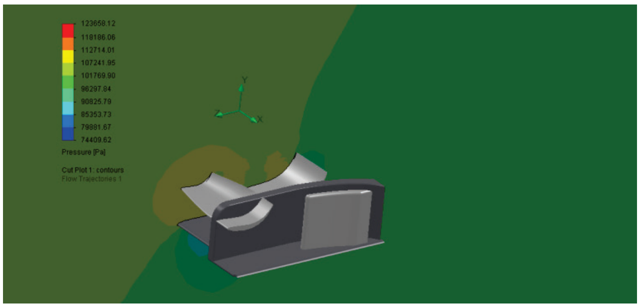

Figure 8*. Cut plots of pressure on the main stabilization wing*

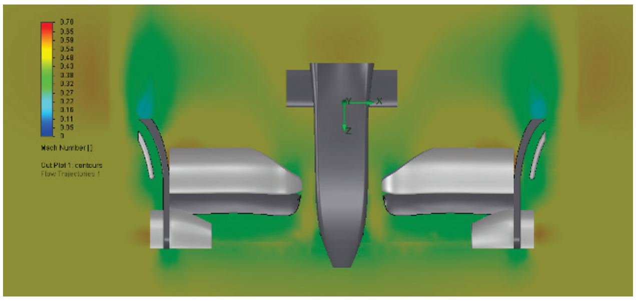

Figure 9*. Cut plots of Mach number*

The wing also function as an adjustable counterbalance for the rear wing load. Although Mach number is considered irrelevant in vehicle aerodynamics due to the fact that the regime is subsonic this parameter starts to be used in consideration in racing car. Mach number is dependent especially by the medium composition and local condition such as temperature and pressure. Due to this down force production can influence the downstream flow field which affects the potential aerodynamic shape of the rest of the car. The pressure when the flows accelerate over the top of the wing creating an unwanted lift creating a decrease of the normal force. Also beside its complex role in the overall aerodynamics of the car, the limitations imposed by the FIA technical regulation add more challenges in the development of the front wing.

4. CONCLUSION

Running simulations on the race car wing provided valuable insight on how the car would react during high-speed runs. Through this study, the performance of the front wing was analyzed, its aerodynamics evaluated, and necessary recommendations and suggestions provided. The front wing was designed from an aero-dynamical perspective to study the streamlines and pressure paths for high speeds. This study showed the capabilities of aerodynamic and CFD analysis to be used in aerodynamic performance of the cars in all its ramifications either on the circuit or on the road as the case may be.

ACKNOWLEDGEMENT

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THE METHODS AND TECHNIQUES USED FOR THE HUMAN BONES VIRTUAL RE-CONSTRUCTION

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Abstract

To understand the problems, which appear in every human joint, it is very important to know the anatomy and morphology of the human bones and the way in which the components are working together to realize a normal functionality.

For this purpose was used a CAD parametric software which permits to define models with a high degree of difficulty. First, it was used a CT or MRI device to obtain the parallel sections in every studied component bone. A 3D scanner can be used only for the outer geometry. In the second step the images were transferred to a 2D CAD software, as AutoCAD, where the outer and inner contours of the bone were approximate to polygonal lines composed by many segments. After this, the contours were transferred to a 3D CAD software, as SolidWorks, where, step by step, and section by section, was defined the virtual bone component. The primary sections can be directly unified in shapes, as Loft geometrical shape, to define the base of the bone. Additionally to this shape can be attached other Loft, Round or Dome shapes. For some components, as vertebrae, mandible or skull

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bones, it can be used a preliminary model obtained by parallel sections. Starting from this, the model can be defined using the main 3D curves for final virtual solid model.

Key words: *virtual bone, complex 3D shapes, virtual prototyping, virtual human skeleton*

1. INTRODUCTION

The subject of this paper permits the cooperation between many researchers activating in different fields, which have the capacity to develop informational methods and technologies to solve difficult problems given by the complexity of the scientifically target. Using computer aided design (CAD) and dynamic simulation programs can be developed a virtual model of the human skeleton that can includes the main muscle groups simulated by springs with dynamic parameters, nonlinear and variable. Also, on this virtual model can be studied the main types of movements as walking for the lower limbs, flexion-extension and pronation-supination for upper limbs or lateral bending (left-right), rotation and flexion-extension movements for cervical spine. On the same model can be analyzed the pathological, surgical or post-surgical situations or can be tested different types of implants or prosthesis [1].

2. MEDICAL IMAGING CT OR MRI SCAN SCHEMES OF THE MAIN BONES

To obtain CT images of bone components were used main bones of the human knee, elbow and cervical spine joints. The experiment was conducted using CT installed at Emergency County Hospital Craiova. Tomography machine allows the user to obtain images in DicomWorks format, specialized software for CT or MRI images and their management. To obtain the tomographical images of the three bone components (humerus, cubitus and radius) were used two scanning schemes. First, was completed a complete scanning operation for 5 mm distances having the results 147 images. After that, had been obtaining cross section images at the distance of 1.25 mm for the ends of the bones and the elbow joint area [1]. For the femur and tibia bone were used two scanning schemes at 1 and 3 mm.

To obtain the virtual components of the human cervical spine were analyzed 284 computer tomography images obtained in different planes. There are three schemes used for scanning: scanning with cross-sectional planes parallel with distance of 10 mm, a scanning plane parallel to the front with the distance of 1.7 mm, a scanning plane parallel to the sagittal distance with 1.1 mm.

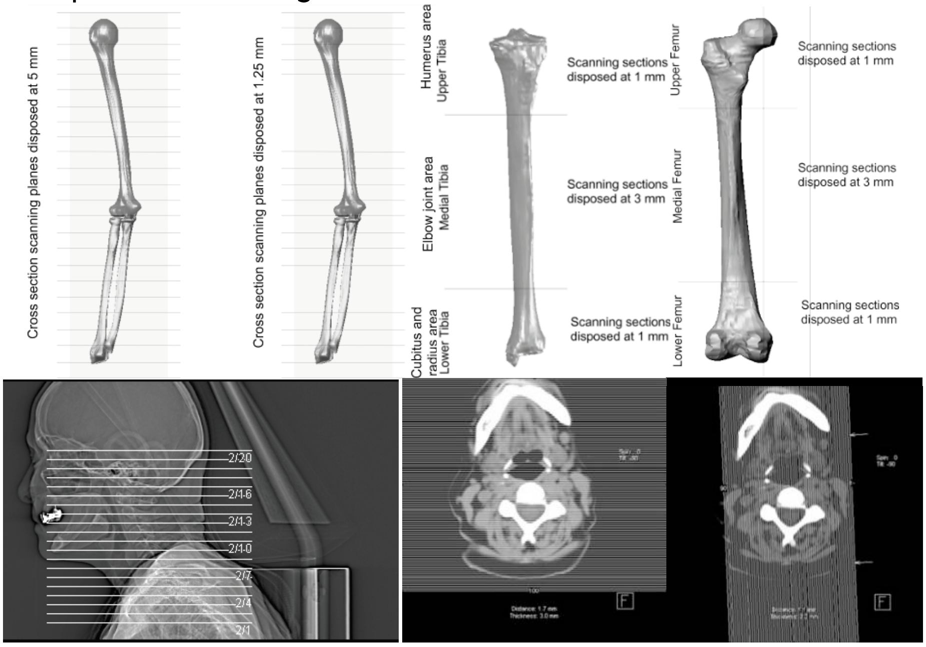

Figure 1. *The CT scan schemes used for elbow, knee, skull and cervical spine*

For the knee bones were initially obtained 26 file folders, and after a careful selection, were used for three-dimensional modeling only 14, 3 for each component as tibia, fibula, femur and the bones of the foot, one for pelvis and one for patella. For example, Figure 2 summarizes six key images of the tibia.

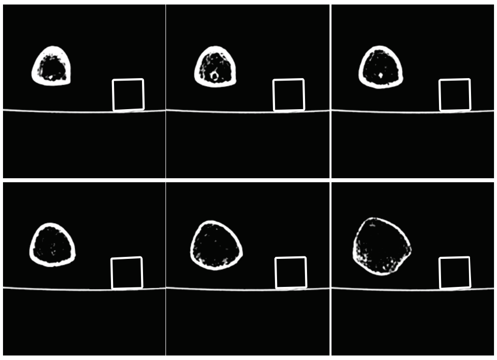

Figure 2. *Six images of tibia CT scan*

These images, compatible with most Windows-based files, were loaded one-by-one in AutoCAD. The computer aided design software allows defining two-dimensional non-parametric models. First, the images were loaded into the program to determine the geometric scale made by computer tomography. Because each CT image contains a fixed benchmark (a plastic rod with square section with sides of 20 mm) comparing the square on the images with real section was determined the scale of these images and these were loaded into AutoCAD, so images appear to the natural scale 1:1. For the beginning, over loaded image in AutoCAD and properly scaled to the natural size, were drawn inner and outer contours of the bone and a square with sides of 20 mm corresponding to bar section used as a fixed reference (Figure 3).

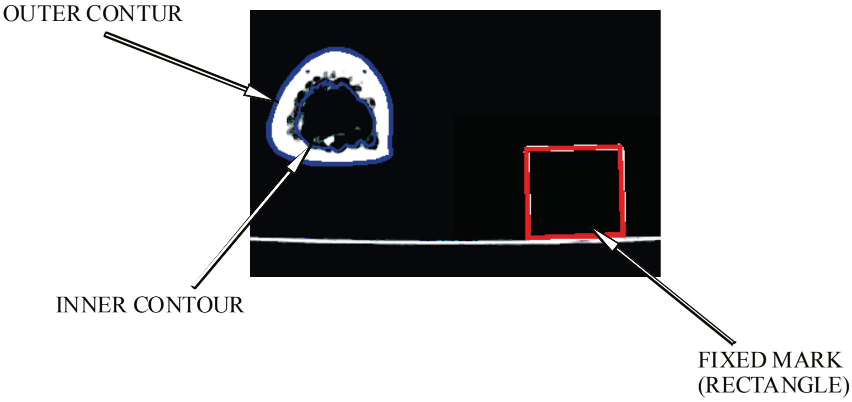

Figure 3. *The 2D elements drawn in AutoCAD over the imported CT image.*

These contours were transferred successively into a three-dimensional parametric design program as SolidWorks, used in mechanical engineering. In this program, were initially defined several parallel planes at a distance of 1 mm or 3 mm, according to the scheme used for CT operation. This operation of defining the contours and transfer to SolidWorks was repeated for each CT scan. In Figure 4 are shown, three sections transferred to different planes. To obtain a parametric solid were "unified" the outer contours in a loft type form. For example, to generate the inner channel of the virtual bone were used the 3 inner sections and a feature like CUT-LOFT type. The steps and the result of this operation is shown in Figure 4.

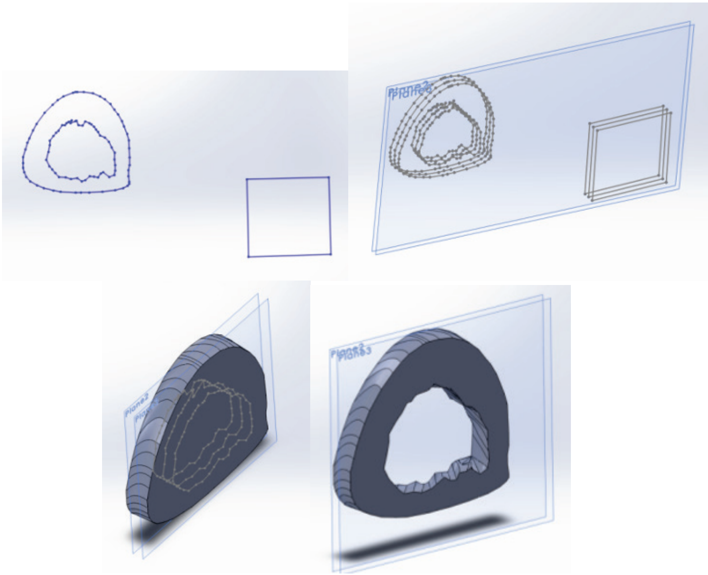

Figure 4. *The 2D elements drawn imported in SolidWorks [4].*

Using the CT sections of the vertebrae, for defining the cervical spine model, were generate, in the first stage, the primitive curves for each vertebra as in the Figure 5.

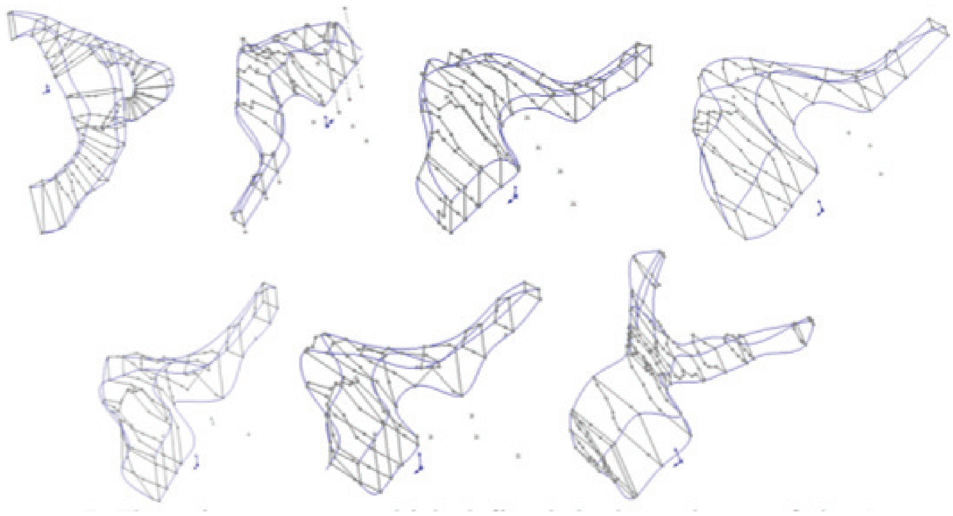

Figure 5. *The primary curves which defined the base shapes of the C1-C7 vertebrae.*

3. VISUAL ANALYSIS OF THE PRIMITIVE GEOMETRIC SHAPES MADE ON REAL BONES

Simultaneously with the CT scan of the human bones were studied bones of a human adult (teaching materials of the University of Medicine and Pharmacy of Craiova) for analysis of the geometric forms as was shown in Figure 6.

Figure 6*. The real bones studied to determine the primitive shapes.*

4. VIRTUAL MODELS OF THE HUMAN BONES

SolidWorks allows for getting a solid model by merging cross sections in parallel or oblique planes. To "solidify" these sections was used, as called Loft shape, which is based on these sections and a guiding curve defined automatically by the program. For example, Figure 7 presents the Loft defining scheme for C1 vertebra.

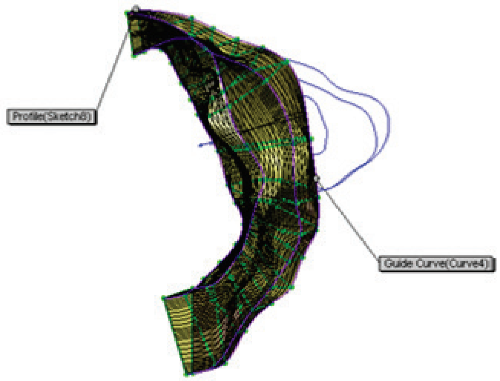

Figure 7. *The definining Loft shape for C1 vertebra.*

Using similar operations in the virtual parametric software were defined femur, tibia, fibula, humerus, cubitus, radius, C1-C7 vertebrae, cervical spine and human head-neck system (Figure 8) [2,3,4].

Figure 8. *The virtual human bones defined in SolidWorks [7].*

5. VIRTUAL HUMAN BONE SYSTEMS USED IN DIFFERENT SIMULATION

Using the model of the human elbow joint were developed different simulations as flexion-extension, pronation-supination kinematic simulations and was analyzed, using finite element method, the behavior of different implants or elbow prosthesis. In Figure 9 were presented different results obtained on virtual human elbow joint [7].

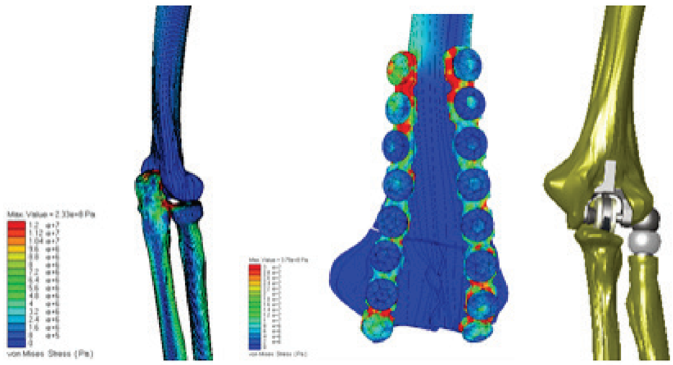

***Figure 9**. The results obtained on virtual human elbow joint.*

Similar simulations were obtained on virtual knee joint or on its components (Figure 10).

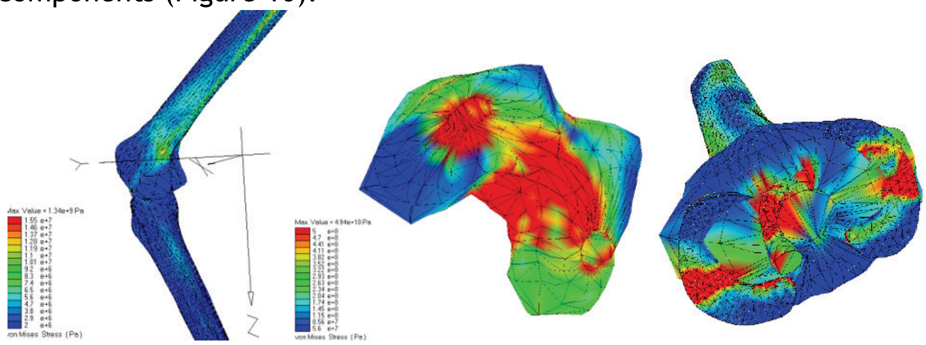

***Figure 10**. The results obtained on virtual human knee joint.*

Also, were developed simulations for the main head-neck human system as rotation, lateral bending, flexion-extension, mandible movements or implant behavior studies (Figure 11).

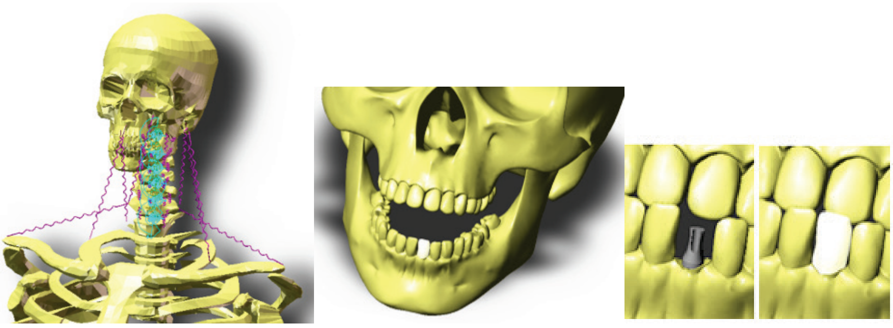

Figure 11. *Virtual simulations made on head-neck human system [6].*

6. CONCLUSIONS

The elbow is one of the most complex joint from the human body, but this paper proves the mechanical studies can be made starting from anatomical knowledges. The behavior of the virtual elbow can give the important informations which can be used in the fields of robotics, medicine sciences and medical robotics. Also, on the virtual elbow joint can be attached virtual prosthetic elements for virtual post-surgery simulations [2,3]. The obtained models were completed with the mass properties and the virtual bones had, in that moment, the same inertial characteristics as the real bones. Additionally, can be obtained different comparing diagrams for analysis and disscusions.

Also, on the virtual knee joint can be attached virtual prosthetic elements for virtual post-surgery simulations. The simulation program permits the obtaining of some kinematical, statically or dynamical results in a short time with a high precision. Thus, it can obtain the position, velocity and acceleration variation vs time for any biomechanical system. In the studied case, these variations permit the obtaining of other important function parameters.

It can be obtained the forces in joints, which could require an ample calculus or special equipment, permit the obtaining of some important parameters, which define the entire kinematical behavior [5]. These programs offers important databases for analysis with finite elements or processing simulation programs. The utilization of these programs is easy and, starting from a three-dimensional CAD model, permit the rapid obtaining of some results, which, usually, could require complex and expensive devices. In conclusion, the virtual bones that were studied can be used as prototype model for the studies regarding elbow, knee, head-neck system with applications in medical researches.

Acknowledgment

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3D GROUND TRUTH HEART MODELING AND VISUALIZATION BASED ON MANUALLY SEGMENTED 4D CT SLICES

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Abstract

4D CT is a new emerging medical imaging technology commonly used for heart visualization and monitoring in cardiovascular medicine to detect abnormalities and specific type of illnesses. In order to enable more effective detection of particular heart conditions machine assisted applications can be of great benefit. One of the most important tasks in cardiovascular medical imaging is 3D segmentation that requires 3D ground truth of the heart model in order to optimize

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performance. 3D ground truth model is usually made by manual segmentation done by medical doctors. Specifically, the segmented 2D slices of the heart are manually segmented and the vertexes of the segmented borders are connected between neighboring slices. Using extracted geometry of the 3D point cloud corresponding to the segmented vertexes, in this paper, we aim to perform adequate rendering and mathematical modeling the 3D heart particle. For rendering and visualization we compute the normals depending on the vertex connectivity and geometric position, while mathematical modeling to be done is parametric providing thus possibility to flexibly deform the obtained model.

Key words: *hart modeling, 3D visualization, 4D CT*

1. VISUALIZATION IN MEDICINE

Visualization of medical data is area of science that is having enormous expansion over last decade. With appearance of modern personal computers that have large computation power, limitations that researchers used to reach are now moving further and further. Graphical cards that allow for large scale multicore computation allow every researcher, and later user, to have power of small supercomputer at their disposal.

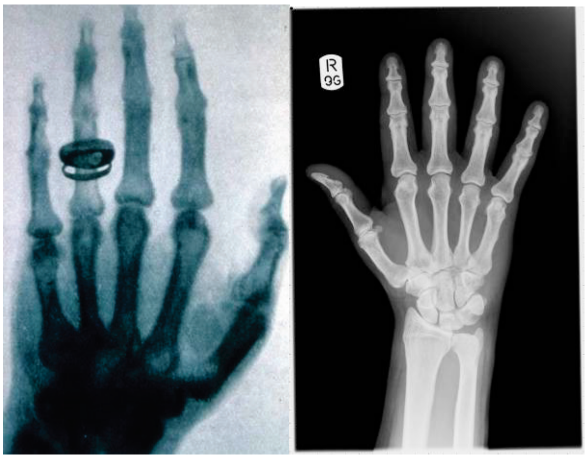

Figure 1. *First ever radiography scan (left) and modern version (right)*

Idea of using modern technology to graphically represent medical data is not new. In 1895 with appearance of first radiography (Figure 1) techniques, also started search for methods of medical imaging. Later developed were Magnetic Resonance Imaging (MRI), Ultrasound, Computed Tomography, Photo acoustic imaging and other techniques. This allowed medical experts to relay more on measured data and less on subjective feeling of patients, and to faster and more easily reach diagnosis. Improved was also preventive diagnostic, where by looking at patients medical images doctor is able to find potentially dangerous but currently dormant health problems, and allow preemptive measures.

All previously mentioned techniques are based on two dimensional images. Currently great efforts are dedicated to expand theses imaging techniques in 3D space. Medical experts today are able to see three dimensional models of particular organ. This allows them to see details that are less visible under other angle, to get better feeling of deformations that appear in some area or zoom some area for better visibility. While visualization is not available for all areas of human body, with every year more mysteries of human body can be analyzed.

Currently there is great number of researches conducted on topic reconstruction of 3D model from 2D images [1]. Some of this methods, such as photogrammetry, are not applicable to presented problem because they deal with images of exterior of surface that is reconstructed, and are very sensitive to noise that always appears with medical imaging. While there are some studies that try to rectify these problems (see [2], [3], [4]), focus of our research is not creation of universal procedure. Our goal is to create method that shall allow precise hart visualization with great precision. There are some results in this area (see [5]), but they do not allow visualization of internal structure, that allows great deal of parameters to be measured, which are very important to medical experts.

2. 3D GROUND TRUTH

Starting point with any visualization research would include ground truth model that allows for measurement of correctness of implemented algorithm. With research of this kind problem that arises is that only model that is available lies in patient, and is not available for further measurements than those of inputted data. This presents certain difficulties, and makes even making of ground truth model long term process that has to be carefully planned. In case of this research, CT scans of patient were used. Ultimate goal presents to develop method that will allow for 3D model and animation to be generated that shall behave over time in way that patients, who's CT scan was inputted, behaves.

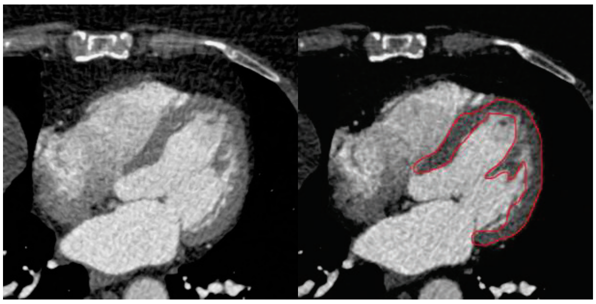

Figure 2. *CT scan of patient (left) and scan with contour drawn (right)*

2.1 Building point cloud

To generate ground truth model that shall be of greatest precision manual segmentation was chosen. While this approach asks for greatest time, it is also one of most flexible, as trained human shall more easily overcome any unforeseen situation that can happen than artificial intelligence. In case of this model this unforeseen situation was presented with bridges and closing in part of hart that has been selected for first analysis. Researchers first used software for image conversion from DICOM format to some more common image format. DICOM format allows medical experts to read additional data that was gathered during image gathering process, but it is incompatible with most image processing software.

After images were converted they had to be segmented. By using some image processing software of vector kind, splines are drawn over borders of area which is to be segmented. To achieve better model, between two successive images same number of vertices are placed, and their position changes for minimal value. In case of our example, we used 50 vertices for one layer. Because in some layers structure is open, and in some closed, variation in number of vertices can appear. This allows for easier and better connection between two layers. After placing vertices, using software tools that work with vector graphics, coordinates of vertices are extracted. These coordinates shall have very important role in further parts of visualization. To allow custom built application to easily access vertices data, they are stored in XML files, which are used as intermediate file format between different systems. X and Y coordinates are stored, and as we know distance between two layers from medical information stored in DICOM file format, Z coordinate is also known.

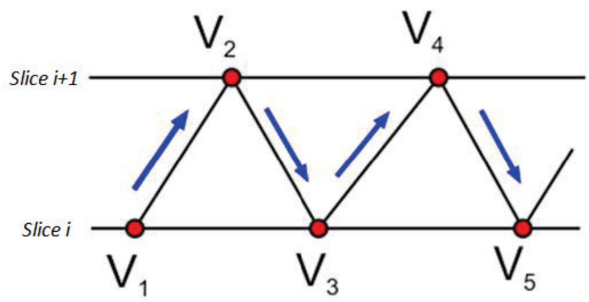

Figure 3. *Vertices connection method*

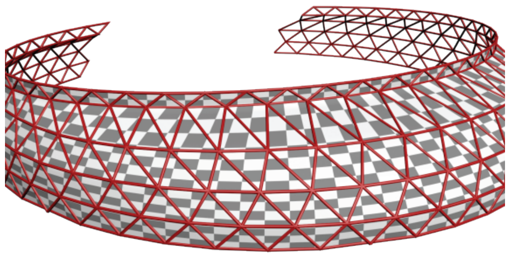

Figure 4. *Vertices connection method in practice*

Vertices are used in custom built application for visualization to form strips of triangles in principle shown in figure 3. Using these triangle strips, surface of presented part of hart is formed. To achieve better performance, library that allows for execution of parts of code on graphical processing unit was used. While data could be processed by processor, because of nature of calculations, GPU execution appeared as better choice. In many cases of visualization of medical data it is possible to achieve better performance, as most algorithms process independent data sets, with large number of simple calculations, which is very similar to original purpose of graphic card.

2.2 Normals of vertices

While this approach allowed for fast implementation of surface generation, it left problem of normal of vertices. As lighting is used to achieve greater realism of visualization, correct normal for each of vertices has to be computed. First problem that appears is that a line for which position of vertices is located is based on two dimensional space. This allows computing of normal only in two dimensional space. To solve this problem the surfaces that are formed are used. Each vertex is part of six triangles. Normal of plane formed from vertices A, B, and C is calculated by forming two vectors $\overrightarrow{AB} = (x_1, y_1, z_1)$ and $\overrightarrow{AC} = (x_2, y_2, z_2)$.

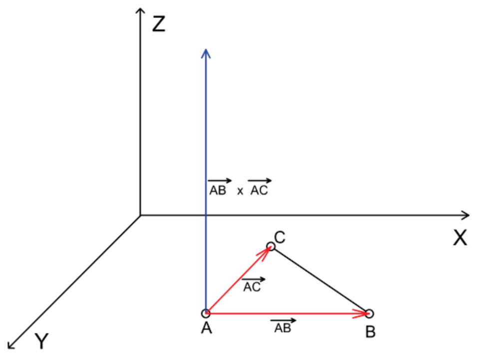

***Figure 5**. Diagram of calculation of normal*

When cross product of these two vectors is formed $\overrightarrow{AB} \times \overrightarrow{AC} = (y_1 \cdot z_2 - y_2 \cdot z_1, -x_1 \cdot z_2 + x_2 \cdot z_1, x_1 \cdot y_2 - x_2 \cdot y_1)$, third vector is gained that is normal to surface formed by these two vectors. As starting two vectors are edges of triangle, and define plane on which triangle of vertices A, B and C lies, new vector is normal of this surface. Here should also be mentioned that intensity of this vector is not of importance, as value is later normalized to reduce intensity to 1, which allows for faster calculation of lighting.

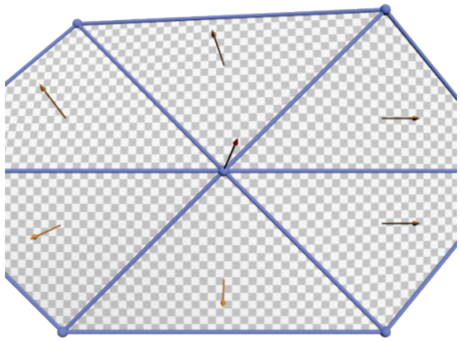

Figure 6. *Calculating normal as average of surrounding surfaces*

As normal for triangle is easy to compute, we can use average of these values, and use this for normal. This allows for more complex tasks later to be executed, that require normal of vertex. In later phases of research, normal of vertices can be computed from first derivate of algebraic curves that would be approximating surface of hart. In current conditions, gained values have high enough precision.

2.3 Advantages and disadvantages

Let us emphasize that this method has its limitations. As it is time consuming generation of ground truth model in this way is usable only in situations like heart segmentation that is mentioned here, as it is very hard to obtain data of other kind for comparison. Another problem that appears is human error. Even with most precise users who work very carefully on their task, there is no easily definable border between tissues in some cases. This gives some rather edged surfaces (Figure 4.), as there is no smoothing applied and input data has some noise. While visualization would be more attractive with smoothing algorithm applied, data needed to be preserved in its original form, to be later caparisoned with models that shall be developed in further research.

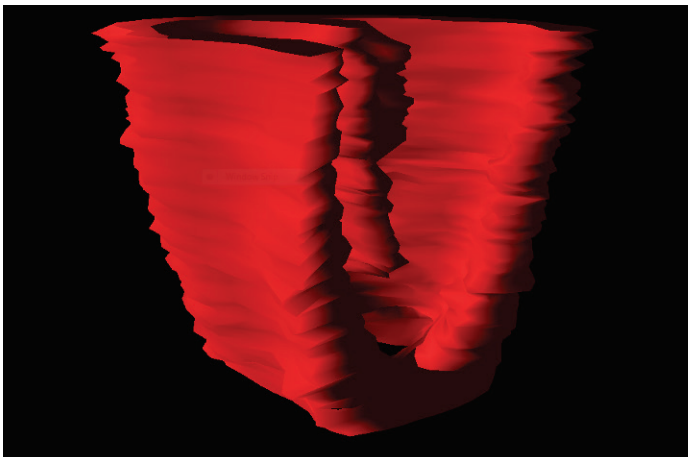

Figure 7. *Visualization of obtained ground truth model*

3. CONCLUSION

Method of manual segmentation that is described in this paper allows for efficient ground truth modeling. While it has its limitations, it presents good foundation on further research of model that shall allow full 4D visualization of medical data gained by CT scan. Further direction of this research shall include methods for automatic development of model, faster and more efficient methods of visualization and methods for numerical calculations of medical data.

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QUANTIFYING THE METRIC-QUALITY OF LINEAR OBJECT'S POINT-CLOUD AS A FUNCTION OF SHOOTING-DISTANCES AND NUMBER OF CAMERA POSITIONS/I.E. SHOOTING-DIRECTIONS

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Abstract

The purpose of this paper is to investigate the impact of both: various object-to-camera distances and number of station-points (i.e. number of used shooting directions) on the level of achieved Metric-quality of DSM/MVS Point-clouds as photogrammetric representations of linear object elements (with respect to defined quality-valorization criteria), as well as to draw practical conclusions based on conducted comparative analysis of obtained/cross-referenced results.

It is concluded that for a fixed focal length, shooting directions perpendicular to the axis of targeted linear object, station-points uniformly radially distributed around the object (at the circle of 360deg) and process-quality descriptors values which belong to the satisfying/recommended ranges, the smaller values of Object's-Photo-Coverage, the smaller distance-error will be. Namely, metric-quality of an object's DSM/MVS Point-cloud (i.e. accuracy and precision) can be considered as slightly dependent on level of Object`s Photo-

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Coverage: the smaller values of Object's-Photo-Coverage, the higher both accuracy and precision will be.

Key-words: *Close-range photogrammetry, Dense-Surface-Modeling (DSM), Computational image-based 3D-reconstruction, Point-cloud metric-quality*

1. INTRODUCTION: PREVIOUS WORK AND RESEARCH GOAL

Previous research in this field of interest has mostly been focused on investigation criteria for quantifying the accuracy of surface and terrain modeling by use of a broad spectrum of photogrammetric packages [1],[3],[5],[6].

Bearing in mind the mentioned fact, the aim of this paper is to scientifically quantify the metric-quality of linear object's Point-clouds - as a function of shooting distances and number of camera positions i.e. shooting-directions (with respect to defined quality-valorization criteria). Conclusions drawn (based on conducted comparative analysis of obtained/cross-referenced results) will prevent to make all possible mistakes in station-points' definition (thus, to avoid potential decrease of generated DSM/MVS model quality).

These activities concern not only precise definition of camera movement-path geometry (related to concrete axes directions of analyzed linear elements) but also a number of cameras strictly connected to the proper horizontal and vertical shooting-angle separations, that are, often, difficult to achieve in reality) [2],[7] .

2. TEST-FIELD SETUP

Test Field is an experimental scene defined in an empty indoor space. Because chosen space is reachless of natural targets (that is not the case in real scenes), "Ringed Automatically Detected" targets ("RAD") are also applied so that computer-guided photo-matching (and point-referencing) can be performed more precisely and accurately.

As regards the aim of this research, Test-Field is composed of the following elements:

(a) Experimental object ("Stick"), represented by a wooden cylinder (Length=25cm Diameter=10mm). There are two white spherical targets fixed at the ends of the stick so that its axis becomes easily identifiable (Fig.1). Since the length of the stick is drastically larger than the diameter itself, the stick can be taken for linear entity. The stick is positioned vertically and remains toughly fixed during complete shooting procedure.

(b) Artificial light source (professional photo-reflector), used to generate additional amount of light and thus to annul both existent light-sources impact on shadow appearance and possible imbalanced saturation distribution on the stick-surface. For the directional-light, generated by the reflector, to be considered as an ambient one, light-rays are oriented towards the ceiling [7].

(c) Camera, that rotates around the stick so that the stick-axis represents the axis of rotation (camera rotation plane is perpendicular to the stick). As regards the experiment's purpose, station-points are positioned at three different circle-paths (whose radiuses are 70cm, 110cm and 220cm). Chosen camera distances are not defined respecting the doubling progression (min. distance is 70 instead of 55cm), in order to avoid a possible impact of such ununiform distance-change rate on analyzed output data behavior. Number of uniformly distributed station-points vary from 24 (defined by 15deg camera radial-movement angle), 12 (defined by 30deg radial movement) to 8 (defined by 45deg radial movement). For all photos, the target is the mid-point of the stick's axis and shooting directions are always perpendicular to this axis. Radial-movement-rate of 15deg corresponds to min. acceptable shooting-angle separation (which should optimally be 90 deg) [2],[3]. Shooting distances grater than 220 are not analyzed due to very small stick's abundance on the photographs (i.e. "object's photo-coverage"). Camera radial-movement angle over 45deg is not analyzed because these cases would have too low number of station-points, affecting drastic decrease of accuracy and precision [1],[3]. Following the above mentioned, there are 9 experimental cases, designated as "70/15", "70/30", "70/45", "110/15", "110/30", "110/45", "220/15", "220/30" and "220/45".

(d) Vertical RAD-target panels (W=15cm, H=35cm), put on the horizontal floor and uniformly/radially positioned around the stick at the distance of 100cm (15 pcs/24deg). Each panel consists of 24 printed

RAD-targets (created by PMS software), each with unique graphic-code. During entire shooting procedure, panel positions remain unchanged. Total number of panels and their spatial distribution in the Test-Field is defined so that each target be visible from at least two successive station-points (photos) and there are panels perpendicular to every concrete shooting direction (or almost perpendicular i.e. 50-90deg) [2] (Fig.1)

(a) (b)

Figure1. *(a) Experimental object: cylindrical wooden stick (L=25cm, Diameter=10mm) and (b) printed RAD-target Panel (W=15cm, H=35cm)*

3. EQUIPMENT AND TECHNOLOGY USED

In this research the following were used:

- Computer: Acer Aspire Timeline X with IntelCore i5 - 45DM processor and 8GB DDR3 RAM,
- Professional photogrammetric software, produced by EosSystems Inc: PhotomodelerScanner (“PMS”), Version: 2014.0.2.1338 (64-bit) [2] ,
- Mesh-analysis and comparison software, produced by D. Girardeau-Montaut: CloudCompare (“C2C”), Version 2.5.3 (64bit) [4] , and
- Semi-professional 8MP camera: PowerShot S5 IS, produced by Canon Corp.

PowerShot S5 IS relevant technical characteristics are:

- Physical Sensor Size (‘Format Size”) (in mm): 5.7260/4.2926,
- 8 MP Sensor Size (“Image Size”) (in pxls): 3264/2448, and
- Sensor Pixel Size ("SPS") (in mm/pxl): 0.001754289/0.001753531

4. SHOOTING AND PROCESSING PARAMETERS DEFINITION

Bearing in mind the shooting directives related to the needs of Ground-based (Close-range) photogrammetry [2],[7], the following shooting options are used: (a) short (wide angle) lens “f” of 6.0mm[1] (due to object capturing from closer distances (max. 220cm), (b) Aperture-priority Mode (instead of-stop value of f/8 as an optimal for ground-based projects, f/15 is used because it determines optimal depth of visual field during close-distance shooting), (c) Shutter-Speed of 1/15sec (because of indoor shooting), and (d) ISO-speed of 400 (for the photos not to be very dark: instead of 100 which, in general, optimally corresponds to chosen Shooter-Speed).

Also, next camera settings are turned off (ensuring that all shots are manually controlled): (a) Auto-focus, (b) Digital-zoom, (c) Image-stabilization, (d) Auto-sharpening and (f) Image-rotation [2],[7].

Image-size of all photos is the same (max. possible for the chosen camera model) - set to 3264/2448 pxls while Image-quality is set to “Superfine”.

Point-cloud creation of chosen experimental object is performed using Eos' innovative DSM “Multi-view Stereo Technique” (“MVS”).

Table 1 shows chosen DSM/MVS parameters.

Table 1. Chosen PhotomodelerScanner`s DSM/MVS parameters

DSM/MVS parameters	Setup/ref. value	MVS parameters	Setup/ ref. value
Min. Visible Images	3 (max.10)	Max. Group Size	20 (>0)
Min. Angle of Point	10 (>0)	Window radius	3 (>0)
Texture Strength	0.1 (max 1)	Number of iter.	1 (max.10)
Down-sample Level	1 (>0)	Curvature Factor	0.5 (min. 0)
Point Spacing	2 (>0)		

All MVS parameters listed above are software-defaults, instead of: “Texture Strength” (default is 0.7), and “Number of iterations” (default is 2). This change is performed due to the need to decrease expense of processing speed (and thus the processing time: from an hour to approx. 15 min on computer used). Regardless of the facts

[1] Difference between the chosen focal length “f” of 6.0mm (also registered in Photos' Exif files) and processed/used value of 6.1637mm (identified by PhotomodelerScanner Self-calibration procedure) does not affect achieved Point-cloud quality (that is proven by affirmative Process Status Report with no problem notifications and possible suggestions).

that both mentioned changings affect decrease of DSM quality[1], the argument for doing so lies both with the nature of the experimental object (which is flatten and with no details) and with the fact that all defined experimental cases are processed under identical conditions.

5. METHODOLOGY

Due to geometric nature of the experimental object (primitive is Surface of Revolution), DSM-procedure is not based on usage of Stereo-photo-strips (obtained by translation of the camera) but radial ones (with minimal shooting-angle separation of 15 deg.).

Each group of photos, related to a concrete experimental case, is separately processed by PMS. Final results are 9 different Point-clouds. Intrinsic and extrinsic camera parameters (referring to each concrete case) are solved together with corresponding Point-cloud (DSM/MSV) creation - in two successive processing phases: (a) by running "Smart-matching" procedure (used for natural targets identification and 3D-reconstruction of the Test Field) and (b) by re-processing 3D-reconstruction (by running "RAD-targets matching" procedure), used for final refinement of obtained results (automatically, semi-automatically and manually).

Because DSM/MSV creation process is consequent to 3D-reconstruction, it is clear that obtained results of 3D-reconstruction directly affect quality of created Point-clouds [2],[3]. According to the previously mentioned, achieved Point-clouds quality will be discussed on two levels:

(a) by analyzing characteristics of 3D-reconstruction process-quality descriptors (related to precision of identified intrinsic and extrinsic camera parameters as well as to quality of consequent photo-matching and referencing procedure), and (b) by analyzing characteristics of Point-cloud metric-quality descriptors (related to the metric-quality of generated Point-clouds only).

[1] Lower value of "Texture Strength" causes an increase of the point-count (during the processing) and, consequently possible larger Point-Cloud Noise while only one processing-iteration causes poorer Point-cloud refinement, including loss of some details [3]

(a) Analyzed “Process-quality” descriptors as relevant [1],[2],[3]. are:

(a1) Final/Last Error

(a2)Point Marking Residuals/in pixels (Overall RMS, Min RMS and Max RMS),

(a3) Point Tightness/in cm (Min and Max),

(a4) Point Precision/in cm (Overall RMS Vector Length, Min and Max), and

(a5) Point (Surface) Angle (Max, Min and Average)

(b) Second group of criteria corresponds to “Metric-quality” of each generated Point-cloud - as a function of chosen object-to-camera distance and camera radial-movement angle (i.e. number of station-points). With regard to that, several “Metric-quality” descriptors are introduced:

(b1) Abundance-percentage of specific Cloud-points (according to Total number of created ones): accurately generated points, precisely+accurately generated points, precisely but inaccurately generated points and imprecisely+inaccurately generated points - as a function of chosen object-to-camera distance and camera radial-movement angle (i.e. number of station-points), and

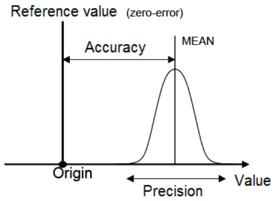
(b2) Difference between previously found abundance-percentage of specific points and their statistically acceptable number - as a function of object-to-camera distance and camera radial-movement angle (i.e. number of station-points).

Process-quality descriptors from the first group are actually 3D-reconstruction process-outputs, taken from PMS's “Process Status Reports” which are related to each concrete Point-cloud creation (each experimental case).

Metric-quality descriptors from the second group are results of concrete Point-cloud-To-Reference-mesh comparison (in metric/distance sense). Mentioned Reference/mesh (identical to experimental object) is actually a cylindrical mesh in AUTOCAD 2014 (created by the authors themselves). Such comparison (based on statistical calculations and estimations) is performed by C2C software according to Gaussian Normal Distribution characteristics (i.e. calculation of Mean and Sigma (Standard deviation) values - related to each concrete Point-cloud (each experimental case)).

As regards both: the nature of this experiment and statistical meaning of the Gaussian Normal distribution curve (i.e. statistical meaning of “accuracy” and “precision”)[1], two definitions ought to be initially introduced:

[1] In a statistical manner, according to Gaussian Normal Distribution curve, known meaning of accuracy and precision (used in this research) is graphically presented on the drawing below (created by the authors themselves).



Vertical Chart-line represents actual number (or percentage) of generated Cloud-points, while horizontal (“Value-line”) actually is a “gradient norm” scale of mutual Point-cloud-To-Reference-mesh Euclidean-distances and represents levels of “3D-reconstruction/distance errors”. According to the experimental nature and description meaning of the “Value-line”, its values cannot be less than zero and negative (they are distributed only to the right hand side - toward the positive direction of the Chart`s “Value-line”). Origin point marks position of the “reference value” that corresponds to “zero closeness” (“zero distance-error”).

Also, "distance-error" values, considered as “precise”, are those positioned symmetrically from the central (vertical) “tendency-line” (i.e. from the Mean) and belong to the “Chart-field” whose maximal width is 6xSimga ((+-) 3xSigma from the Mean toward both “Value-line” directions). On the other hand, values considered as “accurate” ones are parts of the “chart-field” spread from Mean to the Reference line.

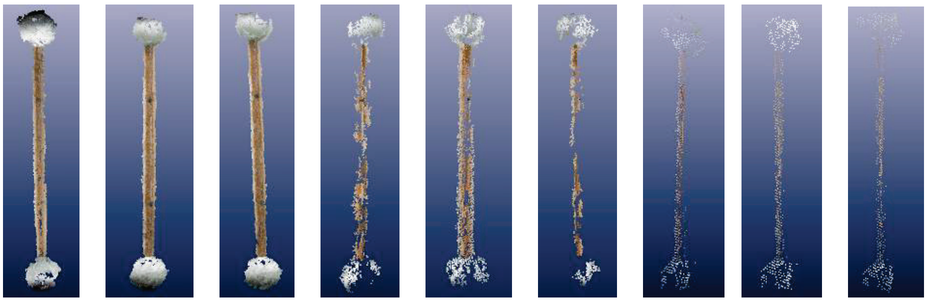
Actual data are distributed strictly with respect to the mentioned Gaussian Normal Distribution provided all of them are “covered” with Gaussian Curve and there are exactly 50% of “Precise+accurate” points and 50% of “Precise but inaccurate” points. Note that each deviation from Normal Distribution, by means of increasing either the number of “Precise+accurate” points (in favor of others) or “Precise but inaccurate” points (in favor of “Imprecise+inaccurate” ones) can be considered as a quality-asset.

• <u>"Metric-accuracy"</u> of the Point-cloud, which refers to the level of "closeness" between generated points and the surface of the Reference-mesh (describing actually how close a restituted value is to the actual/real one), and

• <u>"Metric-precision"</u> of the Point-cloud, which refers to the level of "closeness" between achieved Point-cloud-To-Reference-mesh "distance-spread" and corresponding (calculated/estimated) Gaussian Normal Distribution characteristics of that "spread" (describing actually how close the restituted values are to each other).

6. EXPERIMENTAL RESULTS

Generated point-clouds, related to all experimental cases are presented on Fig2.



70/15 70/30 70/45 110/15 110/30 110/45 220/15 220/30 220/45

***Figure2**. DSM/MVS results: Point-clouds relevant to each experimental case*

6.1. Process-quality outputs

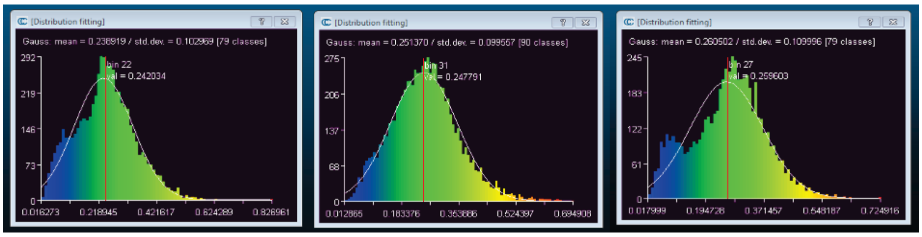
Concrete PMS output values of process-quality descriptors, mentioned in the previous chapter (as relevant to each experimental case), are part of PMS "Process Status Reports" (created for each case separately).

There are no Reports with any problem notifications and possible suggestions that declare all nine experimental cases as successful. According to that, all preconditions for quality DSM/MSV Point-clouds creation are satisfied. Only unusual output-data characteristics, assumed as quality-dependent, will be discussed later on - by analyzing behaviour of relevant process-quality descriptors.

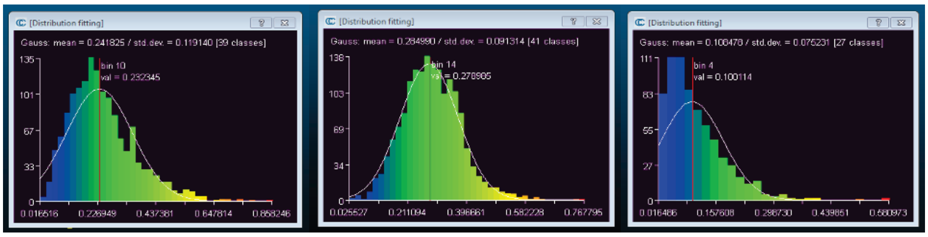
6.2. DSM/MVS outputs

Related to Metric-quality, mutual "fitting" (distance-error) between each generated Point-cloud and the Reference-mesh is automatically analyzed and calculated by C2C software. In order to increase calculation precision (by decreasing distance-threshold used in calculation), "Octree-level" is set to 8 (instead to 5 as default). Bearing in mind that higher Octree-level requires more RAM (causing unwanted expense of processor speed and time), further increase is not needed, especially because all experimental cases are to be processed under the same conditions (including chosen Octree-level of 8). Regardless of the fact that both compared entities (Point-clouds and its Reference-mesh) are ordinary in geometric sense, in order to achieve better alignment between them (as an additional precaution), they are mutually registered: not only by the usage of "Match-bounding-box centers" procedure but also "Fine ("ICP") registration" (i.e. "Iterative Closest Point Procedure") [8].

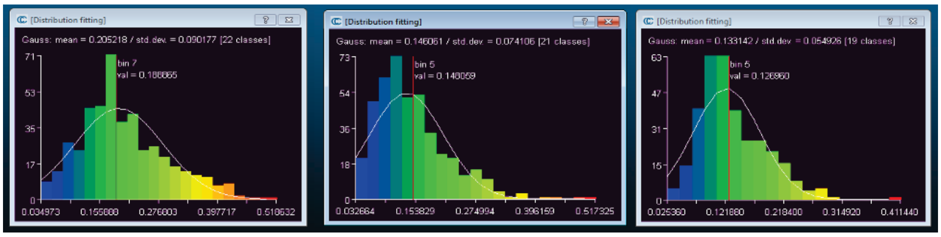
C2C output data are in the form of Metric-quality Histograms (Fig.3). The meaning of histogram's axes-data is described in the Footnote6. Histograms are gradually colored (from red/on the right to blue/on the left) representing gradient of Point-cloud-To-Reference-mesh distance-variation (red highlights the strongest, while dark blue (close to Origin) shows the smallest level of that variation). Thin white curve (as a part of each histogram) represents calculated statistical law of mentioned "closeness-distribution". This law is based on Gaussian Normal Distribution characteristics (i.e. values of calculated Mean's and Gaussian Standard Deviations (Sigma), visible at the upper part of each histogram (vertical reddish bar marks the approx. position of each concrete Mean (average Cloud-To-Mesh distance-distribution value).



70/15 70/30 70/45



110/15 110/30 110/45

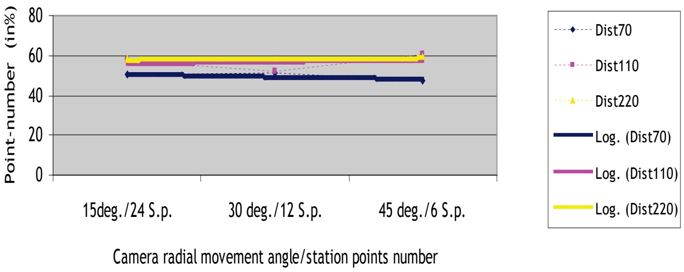


220/15 220/30 220/45

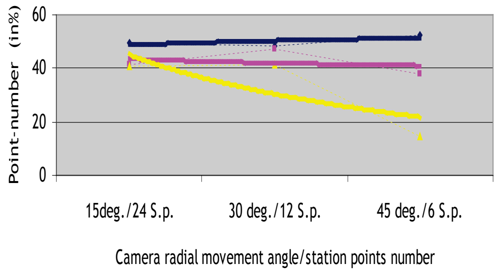
Figure 3. *Point-cloud-To-Reference-mesh closeness/distance-error distribution Histograms (named as “Gradient norms (C2M signed distances”) and corresponding Gaussian Normal Distribution curves, related to each experimental case*

Based on data - extracted from presented histograms (including values of calculated Mean and Sigma), it is possible to obtain values of studied metric-quality descriptors (related to precisely+accurately, precisely but inaccurately and imprecisely+inaccurately created points), expressed as percentages of the whole created points that a concrete Cloud consists of. Mentioned descriptors` values are graphically presented in the form of metric-quality charts (shown below), created by Excel software. In order to generalize achieved results, each chart represents not only actual abundance-percentage of output data (dotted lines) but also its logarithmic Trend-curves (wider/continuous lines).

Charts1. *Abundance-percentage of relevant Cloud-points (with regard to all created points) as a function of camera radial-movement angle/station-points number. Values refer to: (a) accurately+precisely generated points and (b) precisely but inaccurately generated points*

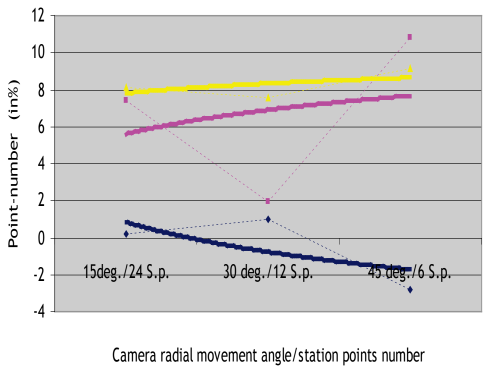


(a)

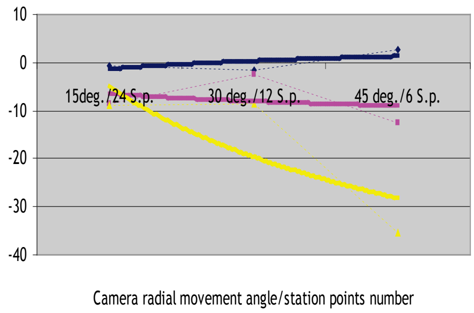


(b)

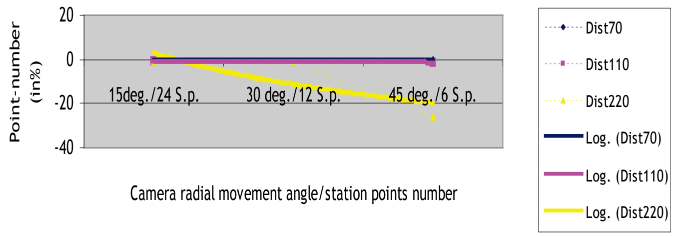
***Charts 2**. Difference between abundance-percentage of relevant Cloud-points and its corresponding statistically acceptable percentage as a function of camera radial-movement angle/station-points number (estimation is based on calculated Gaussian Normal Distribution characteristics). Values refer to: (a) accurately+precisely generated points (ref. = min. 50%), (b) precisely but inaccurately generated points (ref. =min. 50%) and (c) imprecisely+inaccurately generated points (ref. =0%).*



(a)



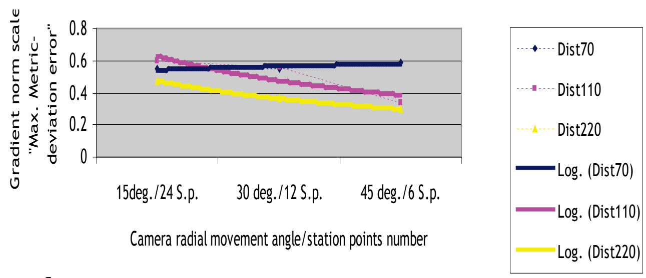
(b)



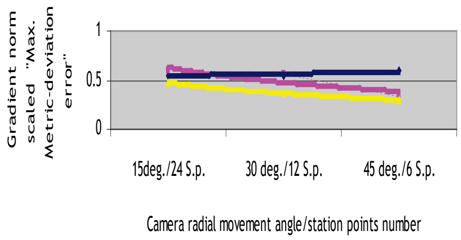
(c)

***Charts 3**. Closeness (distance-error) between created Cloud-points and corresponding Reference-mesh points as a function of camera radial-*

movement angle/station-points number (estimation is based on calculated Gaussian Normal distribution characteristics). Values refer to: (a) accurately+precisely generated points and (b) precisely but inaccurately generated points and correspond to concrete Gradient norm scales, taken from adequate histograms above.



(a)



(b)

7. DISCUSSION

Globally comparing Metric-quality Histograms of all experimental cases, it is obvious that created Point-clouds-To-Reference-mesh closeness distribution generally fits corresponding Gaussian Normal Distributions, with no excessive variations that can be considered as metric-quality warnings. It means that the majority of points (ones "covered" with the Gaussian curve) are precisely created in a statistically acceptable number. According to the mentioned, rare clusters of yellowish and reddish points, (positioned right from the corresponding MEAN values) cannot be lower DSM/MSV metric-quality indicators, because they are very small ones (in number). Contrary, large number of points (related to the same cases) that outcome "Gaussian level of acceptance" (due to their under-curve positions) are strong indicators of PMS software high accuracy, because their locations are from the Mean's left sides. Additionally, their calculated "distance errors" are very small (near to corresponding Charts'

Reference-lines i.e. close to the origin) or even have zero-value that characterizes (affirmatively) all experimental cases.

As regards Footnote6, all presented histograms (i.e. corresponding Gaussian-law characteristics), clearly show that there are no accurately but imprecisely created points. The mentioned is a consequence of the fact that "left half-width" of each corresponding Gaussian curve (which value is Mean+3*Sigma) is larger than its concrete Mean-To-Origin distance (all Gaussian curves intersect chart's "Reference-lines" - above the Origin!). Hence, output data analysis will primarily include precisely+accurately generated points and precisely but inaccurately generated ones. It is important to stress out that lack of accurately but imprecisely generated points is not a negative fact, because of the majority of precisely generated points in all (both precise+accurate and precise+inaccurate ones).

There is no need those histograms be additionally analyzed (from the same point of view), because data taken from are cross-referenced and as such presented on previously shown charts in a more informative way.

In accordance with abundance-percentage of relevant Cloud-points, (calculated with regard to all created ones in the function of camera radial movement-angle/station-points number), the following conclusions ought to be pointed out (see Charts1).

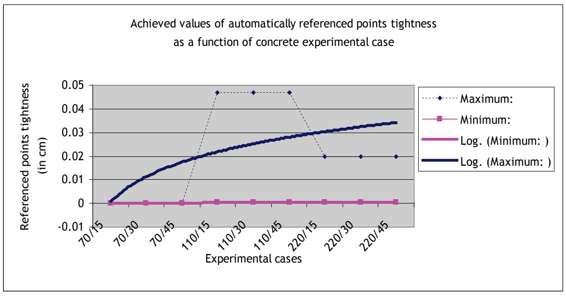
- For all experimental distances there are no drastic differences between abundance-percentages of precisely+accurately created points (of approx. 60% - in the cases of larger distances (110cm and 220cm) and of approx. 50% - that refers dist70) (Chart1(a)). Lower abundance-percentage of precisely+accurately created points from the dist70 can be explained by the fact that total number of visible/photographed and processed natural- and RAD-targets from that min. distance is the smallest one (comparing with two other experimental cases) [1],[2],[3]. Because a slight decrease of abundance-percentage - related to dist70 is totally insignificant, for all applied shooting-distances it can be considered that abundance-percentages of precisely+accurately generated points are not prone to camera radial-movement angle (i.e. station-points number).

- As regards precisely but inaccurately generated points (Chart1(b)), their abundance-percentage is "balanced" and not prone to camera radial-movement angle (i.e. number of station-points) in the cases of shooting from 70cm and 110cm. On the other side, abundance-percentage of the same point-type which refers to dist220, permanently decreases (from approx. 40% to approx. 20%) as camera movement-angle increases. Such tendency (that naturally affects photogrammetric-measurement process i.e. accuracy), can be explained by analyzing characteristic process-quality descriptor mentioned as “Point-Tightness” and its behaviour related to shooting distance-changing [2]. Namely, in accordance with “increasing behaviour” of Logarithmic Tightness Trend-curve [1] it is clear that tightness values evidently increase as shooting distance incerases. This behaviour is not affirmative because the larger value of point-tightness, the worse the quality of mutual intersections of corresponding optical-rays is (as well as final achieved accuracy).

- On the other side, due to the fact that high abundance-percentage of precisely+accurately generated points (around 60%) is almost balanced/distance-independent - contrary to precisely but inaccurately generated ones (which abundance is smaller and decreasingly-oriented in the favor of slight growing-tendency of “remaining imprecise+inaccurate minors”), it is evident that “precision” (showing how near successive 3D-reconstructions are to “true” values) and “accuracy” (showing how much successive 3D-reconstructions mutually differs) are not significantly affected by shooting-distance change. In the same way, this conclusions highlight Charts2 also.

In accordance with the nature of Charts2 content, negative values shown refer to the fact that actual abundance-percentage of concrete analyzed point-type is lower than its statistically acceptable percentage. Such (negative) difference is to be considered as “Deficit” of points of this type. Contrary, positive values of mentioned

1



differences correspond to analyzed points “Suficites”. One should bear in mind that as regards the concrete nature (type) of these points, deficit/suficite can point out to either a positive or a negative trend.

Bearing in mind the mentioned facts, Charts 2(a), 2(b) and 2(c) bring the following conclusions:

- There are similar trends related to precisely+accurately generated points referring to the shots from dist110 and dist220 (Chart2 (a)). Namely, corresponding Logarithmic Trend-curves rise-up - pointing-out suficite-increase (positive) tendency (according to its statistically acceptable abundance-percentage of min. 50% of all generated points): slightly intensive suficite-increase refers to the case of dist110 (from approx. 5.5% to approx. 8%) and higher, but more stable suficite-increase is related to dist220 (from approx. 8% - 8.5% only). Contrary, dist70 characterizes obvious (negative) deficit-increase as camera radial-movement angle increases. These tendencies can be explained by the previously mentioned fact that the total number of visible/photographed and processed natural- and RAD-targets from that min. distance is the smallest one (comparing with two other experimental cases).

- There are similar characteristics of logarithmic Trend-curves of precisely but inaccurately created points – related to dist70 and dist110 (Chart2(b)). Both of them show stable (slightly changing) tendency – almost independent on camera radial-movement angle (i.e. station-points number). On the other hand, while dist70 characterizes presence of statistically optimal abundance-percentage of analyzed points (zero-deficit/suficite), shots from dist220 produce drastic deficit-increase as camera radial-movement angle increases (from approx. 10% to approx. 30% - according to calculated statistically acceptable suficite-level of min. 50% of all generated points). This tendency cannot be declared as one totally negative (present due to mentioned “tightness-reason”), because this growth in difference between abundance-percentage of created precise but inaccurate points and its corresponding statistically acceptable percentage is done in favor of adequate increase of precisely+accurately created points shot from the same distance (220cm) (Chart1(a)).

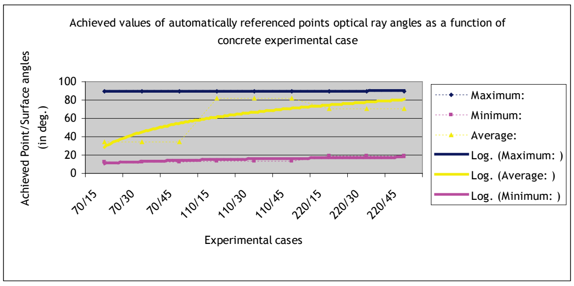
- Chart2(c) shows that dist70 and dist110 have mutually overlapped logarithmic Trend-curves which show constant zero-deficit/suficite of imprecise+inaccurate points. It means that abundance-percentage of analyzed points is equal to its statistically acceptable abundance-percentage (of 0% only). On the other hand, case related to dist220, characterizes obvious suficite-increase (as a negative trend for this type of points, due to drastic increase of its abundance-percentage overcome (from statistically acceptable level of 0%!). Reason for such behavior lies with the explained Point-tightness distribution (as a function of shooting-distance) i.e. dominant "tightness-influence" on accuracy/inaccuracy.

Charts 3(a) and 3(b) show next:

- Experimental cases related to dist110 and dist220 characterize the fact that distance-error decreases as camera radial-movement angle increases (Chart3(a)). As already mentioned, such decreasing tendency (from approx. 0.5 to approx 0.3 in the case of dist220 and from approx. 0.6 to approx.0.4 in the case of dist110) is the consequence of the behavior of logarithmic Trend-curve related to another process-quality descriptor – mentioned as "Point/Surface Angle" [3] [1]. Namely, evident increase of these Point/Surface angle values (esspecially "Average" ones) - as Object-To-Camera distance increases, makes 3D-reconstruction quality significantly better and thus, imprecision i.e. distance-error evidently smaller [2],[3]. Contrary, dist70 shows slight increasing tendency which can be considered as insignificant and thus, almost camera-independent. This slight increase of distance-error in the case of dist70 (from approx. 0.5 to approx. 0.55) can be explained by a smaller number of natural- and RAD-targets visible and used in processing (comparing to other experimental distances).

8. CONCLUSIONS AND OUTLOOK

1



For the given conclusions to be more useful in everyday professional practice, explicit (actual) relations between analyzed parameters i.e. [object distance] and [camera radial-movement angle/station-points number] are described relatively - as a function of calculated percentage values of achieved “Object's photo coverages” (“OPC”). Due to the fact that the experimental stick was positioned vertically in all experimental cases, “Photo-Width-Coverage” calculation (as characteristic because of small (10mm) stick-diameter) is performed only. Necessary calculations are based on the use of intrinsic camera parameters, identified by PMS Calibrator (Table2).

***Table 2**. Values of “Real Object (Surface) Resolution” and “Object's photo Coverage” as a function of experimental object-to-camera distances (for object's diameter of 10mm)*

Calculated parameters/Distances	dist70cm	dist110cm	Dist220cm
Real Object Resolution (in mm/pxl) (0.5<ref.<1)	0.1992313545/ 0.1991452699	0.3130778428/ 0.312942567	0.66261556856/ 0.625885134
Object's Photo Coverage (OPC) (in percentage of Sensor (Image) Width)	approx. 2.1	approx. 1.3	approx. 0.7

Bearing in mind all facts underlined in previous chapter, it is possible to formulate the following conclusions:

- The highest abundance-percentage of precisely+accurately generated Cloud-points (of approx. 60% of all generated ones) refers to the experimental case related to OPC of 0.7%. This percentage is not dependent on camera radial-movement angle i.e. station-points number (if they belong to recommended range which provides accurate and precise process-quality outcome [1],[2],[3]). Slightly lower (and also “camera-independent”) abundance-percentage is characteristic of the case related to OPC of 1.2%. There are no significant differences between cases OPC-07% and OPC-1.2%. Small but also insignificant difference appears in the case OPC-2.1% which becomes slightly angle-dependent (percentage of generated Cloud-points slightly decreases as camera radial-movement angle increases).

- The largest difference between abundance-percentage of relevant Cloud-points and their corresponding statistically acceptable abundance-percentage of min. 50% (as an affirmative trend) refers to precisely+accurately generated Cloud-points (of approx. 8-9%) in the case of OPC-0.7%. This percentage is slightly dependent on camera radial-movement angle (this suficite insignificantly increases as camera radial-movement angle increases). Slightly lower suficite-increase (but, a little more “camera-dependent” - with the same trend) is characteristic of the case related to OPC-1.2%. “Inverted” camera-dependence refers to the case related to OPC-2.1% with slight suficite that transforms to more increasing deficit (according to its statistically acceptable abundance-percentage of min. 50% suficites of all generated points).

- The largest closeness (the smallest distance-error) between Cloud-points and corresponding Reference-mesh refers to precisely+accurately generated Cloud-points in the case related to OPC-0.7%. Level of distance-error is slightly dependent on camera radial-movement angle (it decreases as camera radial-movement angle increases) (from approx. 0.5 to approx. 0.3). The same trend characterizes case of OPC-1.2% but with insignificantly higher errors (from approx. 0.6 to approx. 0.4). Slightly “Inverted” camera-dependence refers to the case related to OPC-2.1%. Namely, as camera radial movement-angle increases, distance error increases (from approx. 0.5 to approx. 0.55).

Generally, for a fixed focal length, shooting directions perpendicular to the axis of targeted linear object, station-points uniformly radially distributed around the object (at the circle of 360deg) and process-quality descriptors values which belong to the satisfying/recommended ranges, the smaller values of Object's-Photo-Coverage, the smaller distance-error will be. Namely, achieved metric-quality of an object's DSM/MVS Point-cloud (i.e. accuracy and precision) can be considered as slightly dependent on level of Object`s Photo-Coverage: the smaller values of Object's-Photo-Coverage, the higher both accuracy and precision will be.

Looking at the renderings, presented on Fig.2., the discussed results may appear illogical, because of a significant sparsity of previously pointed-out Point-clouds (related to experimental cases: 220/15, 220/30 and 220/45 which correspond to the case OPC-0.7%). But, one must bear in mind that these conclusions are based on research of metric-quality descriptors only and its influence on point-cloud metric-quality. Other DSM/MVS quality-descriptors like density-, roughness- and curvature-quality descriptors will serve as a starting point for further investigations in this field.

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INFLUENCE OF FLOOR PLAN GEOMETRY AND ORGANIZATION IN AIM TO IMPROVE DESIGNED BUILDINGS

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Abstract

Housing stock in European countries on average spend about 40% of the produced energy. Emissions of CO_2 in the atmosphere causes a greenhouse effect, so it is necessary to raise the environmental awareness of the people. Architects with their skills and ability should have the task to design sustainable structures and thereby provide thermal, acoustic and air comfort to the space. Sometimes we ignore large energy consumptions in order to achieve better comfort. It is because, if we want to achieve optimal approach to design and balance between energy consumption and comfort, special attention to the geometry of the base and its organization should be paid. In this way, the heat losses could be minimized, proper sizing and orientation space could reduce energy consumptions, and users of space would have more comfort in the house. Using the methods of comparison, description, analysis and synthesis different architectural solutions were considered in order to find the most optimal geometry basis and their organizations. The paper also lists the most common errors that occur when the functional organization, structures and

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guidelines that architects should adopt to ensure that their projects were more functional and facilities more efficient and comfortable.

Key words: *geometry, floor plans, energy efficiency, room function, comfort*

1. INTRODUCTION

In the beginning man was building a house to hide from the cold, excessive heat, rain and other natural disasters. The house eventually became its artistic and spiritual inspiration. The Serbs, in accordance with their simple way of life, throughout the 19th century and the first decades of the 20th century, built a simple but functional living quarters. Today in Serbia a small number of old houses remained, but on the basis of these residues we can still understand what was the most important thing when these buildings were built.[3]

For the past half century, new building construction has greatly increased. Building energy consumption also has grown significantly as building energy loads became larger due to the introduction of new systems of heating, air-conditioning, ventilation, and artificial lighting.[5]

Energy consumption of buildings in developed countries comprises 20-40% of total energy use and is above industry and transport figures in EU and USA. The growing trend in building energy consumption will continue during the coming years due to the expansion of built area and associated energy needs as long as resource and environmental exhaustion or economic recession allows it.[7]

A large number of researches was carried out in order to reach results which would show relevant information related to the operation of the building. Carmody et al.[6] did energy simulations by using a model of a typical room in a commercial office building in order to find how fenestration parameters, solar heat gain coefficient, glazing type, visual transmittance, window to wall ratio, heat transfer coefficient, window position, shape and orientation, affect building heating, cooling, lighting, and total energy consumption.[5]

Each of these studies supports the fact that architects must design conscientiously and pay close attention to a number of relevant parameters which will during operation directly affect the functioning of the facility as well as energy consumption. Variability of people's needs over the lifetime is considered as one of the factors which has been given special attention in this paper.

2. HOUSING STOCK IN SERBIA

Urban and spatial planning is an important segment of the design process. They dictate the position, orientation, and often the dimensions of the building. Positioning and orientation of the site and the parcel should be adapted to the principles of designing energy efficient buildings, for a given climate (microclimate) requirements, to the extent that urban conditions permit. The most convenient location is a rectangular shape, with the broad side of the east-west and the narrow side of the north-south direction. Such form shall be geared to the location of most of the streets that are set in an ideal east-west direction. Cities in the past developed stochastic without a prescribed order. Today, it is striving to invest in the organization and development of cities in order to use the space more optimally. Unfortunately, in many cases it is very difficult to do so, and sometimes impossible.

Adapting to climate conditions and terrain increase the quality of solutions (Figure 1.). If all relevant parameters were observed, to comply with volume factor, floors and building organization, it is certain that the object itself will give favorable results in later exploitation [1].

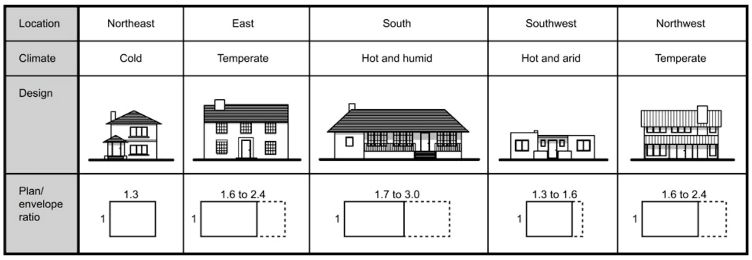

Figure 1. *Examples of suitable housing for different climatic conditions*

The relationship between the interior space and the environment depends on the location and its impact on the energy consumption and costs for heating and cooling. In addition to the orientation and layout of the rooms a great advantage have those objects which have simple geometry of floor plans. Flexibility and variability are perhaps the biggest advantages of modern living. They allow us to reorganize the old buildings or a room, to change their purpose, which would be the higher level of utilization of the old buildings.

Proper positioning of the rooms (Figure 2.) within the building can significantly save energy required for heating and cooling. Rooms which are used rarely and only at night should be orientated towards the north side.

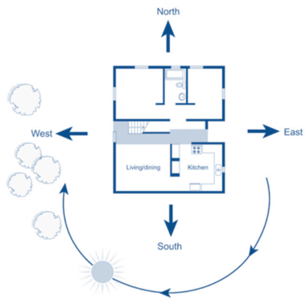

Figure 2. *Proper positioning of the rooms [1]*

In the early 19th century, after the First Serbian Uprising, the Serbian villages were established in a form that we meet today. Then begins the development of rural architecture, but during that time villages and houses in them, were built spontaneously. Except in Vojvodina, where there were a strictly rules on the appearance of the house and plan of the village, there were no official regulations in Central Serbia . Even after what had started with the Allotment of larger settlements, which resulted in the construction of a particular type of home, the appearance of villages still depended on the terrain. So for mountain landscapes the broken type of the village was characteristic, while the flatter areas occured in compact villages.[3]

In addition to urban settings, it is important to statistically examine the functioning of the individual objects. Every-designed facility need to be carefully studied in order to reach the relevant information about it. Before 2010. in Serbia did not exist adequate regulations and information, and it was consequently impossible to do analysis of energy efficiency for the building sector. Strategic data based on the specific facts have enabled decision making and future planning. The Table 1. represents number of constructed residential buildings in Serbia during different time periods. It is clear that the total building stock of family housing compared to the multi-family housing accounts for more than 95% of the total housing stock.

	породично становање family housing		вишепородично становање multifamily housing			
	SFH	TH	MF	AB	Σ ком. Σ items	%
< 1919	117 985	17 394	592	40	136 011	6.05%
1919-1945	194 546	10 937	3 129	170	208 782	9.29%
1946-1960	286 259	12 034	3 357	1 209	302 859	13.48%
1961-1970	376 057	23 328	7 285	2 355	409 025	18.21%
1971-1980	454 893	20 636	9 980	4 752	490 261	21.83%
1981-1990	386 958	19 768	9 861	4 339	420 926	18.74%
1991-2011	252 884	12 567	10 034	2 971	278 456	12.40%
Σ ком. Σ items	2 069 582	116 664	44 238	15 836	2 246 320	100.00%
%	92.13%	5.19%	1.97%	0.70%	100.00%	

***Table 1**. The number of constructed residential buildings in Serbia during different time periods [8]*

The most common type of houses in Serbia built from the early 19th century were one-piece, modest houses. However, as soon as they have gained favorable historical circumstances, the vitality of the Serbian people soon came to the fore, so that two-piece construction begun to be built, which later led to houses with several rooms.[3]

The geometry of the house is definitely harmonious and precise. The traditional way of designing provided a certain level of security, and there was no need for large experiments related to the shape of a house. However, the regulations [4] have changed in the meantime, and therefore demands increased. Objects that until very recently satisfied the basic criteria today are far from it. Control of heating and cooling as well insulating barrier can significantly affect the energy consumption in households.

In a study conducted in order to raise awareness about energy conservation turns out that a large number of people familiar with the way of excessive energy consumption. The largest number of responses (Figure 3.) was related to rehabilitation of facilities, as well as adding insulation to the walls and/or roof or replacing of the windows.

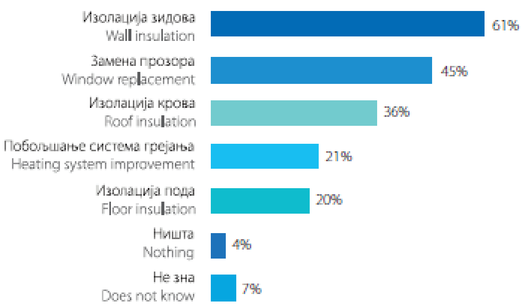

***Figure 3**. Public awareness about measures of energy saving in Serbia [8]*

The lifespan of a modern family is not based only on the needs of only one generation. The young remain attached to the house longer, and the development and expansion of their family is directly related to their parents. In Figure 4. the scenario of modern family life cycle is presented. In accordance with the above mantioned it can be concluded that the expectations that we have of the apartments or houses is much higher than that these facilities can afford.

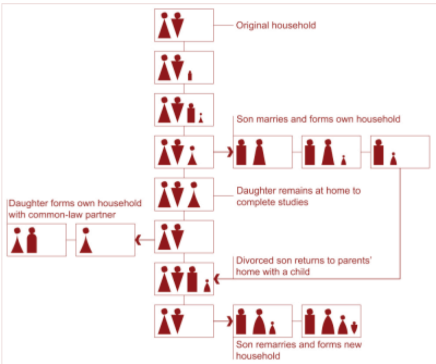

Figure 4. *Scenario of lifecycle of modern family [1]*

3. ARCHITECTS ARE RESPONSIBLE FOR THE FUNCTIONING OF THE HOUSES

The need for number of bedrooms, size of the rooms, arrangement of furniture as well as time spent in the apartment change over time. When designing architects take into account the dimensions of a standard room. Geometry is largely standardized and tends as much as possible to implement modular measures. What is expected of architects is that designed building should be comfortable for people.

In Serbia, most of the houses were built with flat ground floor and the upper floor with the identical organization and initial ideas. In most cases architects want to simplify the project. This is the best option for construction of the object and implementation of installations of the facility. Sometimes this is the most rational solution, but it often happens that there is no need for the same premises or for the same functional organization, and identical geometry basics does not give the same resultsand does not provide tenants identical comfort.

Various organizations of the rooms on different floors, the understanding of the real needs of the users of space and a rational approach to the design of the basic guidelines that every architect should follow. That means that every square meter of an apartment or house is used in the best possible way, and therefore unnecessary electrical consumption is reduced to a minimum. Identical ground floor bases of a residential building cane be organized in several different ways according to the needs of tenants and their requirements for the functional use of space (Figure 5.).

Figure 5. *Identical ground floor bases of a residential building can be organized in several different ways [1]*

Efficient use of a small space can be achieved by reducing the communication and proper positioning and sizing of the hall. It is important to provide cross ventilation, but also as it is beneficial to contribute better air flow through the facility, it is important to reduce lines and movement of tenants. The clean lines of movement, proper sizing of the rooms, smaller corridors and proper positioning are also very important and lead to the quality of solutions(Figure 6.).

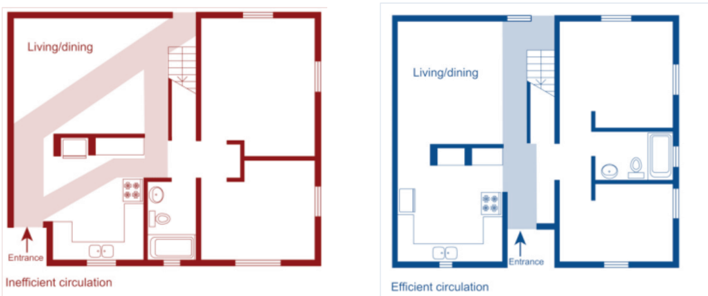

Figure 6. *Efficient use of a small space can be achieved by reducing the communication and with proper positioning and sizing of the hall [1]*

In cases where the architects do not have enough space to accommodate all the necessary room, a good way to solve this problem is to introduce mobile elements in the interior to allow room to get a dual function. This is a very rational approach to design because in the different parts of the day we use different rooms, and therefore the savings and utilization of every square meter is very important (Figure 7.).

Figure 7. *The introduction of mobile elements in the interior enables room to get the dual function [1]*

Interior design and furniture layout and dimensions, as well as the use of colors and materials greatly affect the final quality of an object. Figure 8. depicts furniture, equipment and components that make up the interior. Proper selection and arrangement of these elements defines the geometry of the flat of designed objects.

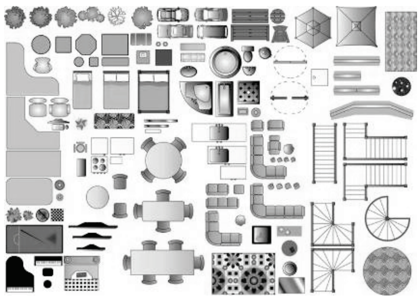

Figure 8. *Human needs over the lifetime change, and therefore the need for the dimensions of the rooms in the household are changing*

The future of architecture are prefabricated - dismantling structures. They allow us the highest degree of flexibility and adaptation. By adding and subtracting we control room volume and surface area of the apartment, and therefore the comfort in these objects is significantly better. Geometry adapts to a changeability of man and his family and the demands can be monitored by changing the object of living (Figure 9.).

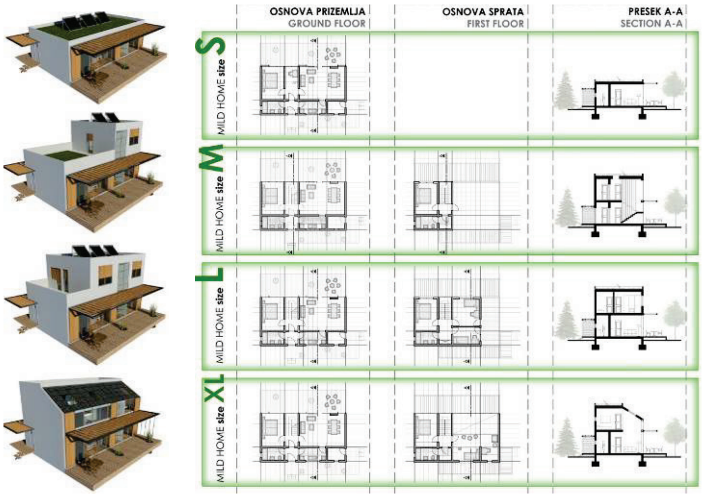

Figure 9*. The future of architecture are prefabricated - dismantling structures*

One of the biggest debates in contemporary architecture is based on prefabricated buildings. It turned out that the prefabricated elements contribute to faster construction of industrial halls, warehouses, garages or cabins. Everything indicates changes in development of living and commercial spaces in the near future.

4. CONCLUSION

Taking into account the fact that it is financially impossible for the citizens to implement all the required regulations and that the proper design and positioning of the buildings is the most important, it is easily to come to conclusion that the architects are responsible for the functioning of the residences and that they can contribute to reducing energy consumption in buildings. The economic situation in the country leads to conclusion how it is much more realistic ro investment in existing facilities rather than building new ones. In addition to interventions such as adding insulation to the façade and solve some structural problems in buildings, reorganization of internal functional elements can significantly improve the quality of the architectural design of the building.

Of course, it is inevitable that in accordance with population growth, the emergence of new technologies, tightening regulations and increasingly stringent demands of the owners of apartments,special attention must paid to the new solutions. That's exactly what is the future of design. Adaptability is the most important aspect of the existence of every living man, and house as an inevitable part of every human being must also be adaptable to the needs of man. Prefabricated buildings with its variable geometry will be the most appropriate solution for all requirements imposed by modern life in the 21st century.

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WINDOWS GEOMETRY AS CHARACTERISTIC OF ARCHITECTURE OF DESIGNED BUILDINGS

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Abstract

Windows are an essential element of each object. Their main function, in addition to allowing natural light and ventilation, is visual connection to the exterior. There are numerous types of glazing solutions and buildings around the world. Over time, in addition to the basic functions Windows got more important role because they can be in a wide variety of forms, and sometimes so dominant on the facade to become a real feature of the constructed facility. In addition to the variety of color, position and material, along with innovative technological discoveries they allow architects complete freedom in the design, without having to disturb the basic comfort requirements of designed objects. The aim of this study is to present the most interesting solutions of windows in modern architecture using the methods of description, comparison and analysis of facilities around the world. Their geometry varies in size, shape, and in some buildings is "decorating façades" went so far that openings on the objects are merely cosmetic. In accordance with modern needs, a desire to formally refine and make unique, this trend is inevitable and

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these details on the facade and roof are of great importance for the ultimate look of the designed objects.

Key words: *windows geometry, the position of openings, aesthetic value,comfort*

1. INTRODUCTION - BASIC FUNCTION OF GLASS ON THE FACADE

Window is opening in the wall of a building for the admission of light and air; windows are often arranged also for the purposes of architectural decoration. Since early times, the openings have been filled with stone, wooden, or iron grilles or lights (panes) of glass or other translucent material such as mica or, in the Far East, paper. Modern windows are almost always filled with glass, though a few use transparent plastic.[4]

The use of glass became more generally available by the fifteenth century, allowing large expanses of weather-sealed glazing. Windows were essentially asymmetrical, being located to satisfy the needs of the interior, and there are many examples of such houses where the interiors are beautifully modeled by daylight, gaining immeasurably from the changing variety of light available.[9]

The penetration of daylight can be provided only by using transparent structures. Glass leads in structural and functional characteristics compared to any other material. Glass surfaces abolish the boundary between interior and exterior, and yet we still have the necessary protection from outside influences. Its importance is unsurpassed, and the modern architecture is inconceivable without glass surfaces.

2. GLASS SURFACES CONTRIBUTE TO COMFORTABLE LIVING

Factors that provide comfortable living are air temperature, amount of sunlight, humidity and adequate air circulation. All of these factors simultaneously ensuring that the building is healthy and avoid sick building syndrome. Glass coverings on the facade despite all favorable impacts can pose a major problem for users. Overheating and great reflections are just some of the adverse consequences of transparent façade systems, and it is necessary to provide adequate protection and prevent these adverse effects.

The glass facades of the building envelope must meet a number of requirements: Thermal insulation, Protection against moisture, Sound insulation, Fire protection.

Air quality is a basic need to ensure healthy indoor air, in both residential and commercial premises. Good air quality is important as much as a good thermal, acoustic and visual comfort. This is also the reason why new window ventilation systems were developed. With this system building can perform controlled ventilation without opening the windows. In this way, a controlled amount of air, per unit time, is simply introduced. This is essential element of a healthy housing. The elementary principle of air flow is the difference in density as the driving force due to temperature differences of outside and inside air.

It is very important to use this simple device - "the regulator of ventilation" in winter mode because of the low temperatures. It is not recommended to "handle" the windows during cold days, because it can lead to deformation of fittings and seals, and to perform ventilation in an uncontrolled manner. Ventilation is necessary for air quality in the room. These technological advances affect the geometry of the window because it allows greater freedom in the design and formation of large glass surfaces which do not need to be mobile.

3. INFLUENCE OF WINDOW FRAMES ON THE WINDOW SHAPE

Window frames may be made of different materials. Window frames made of wood or metal, as well as combinations thereof, are stable and have long-lasting mechanical strength. Of great importance is the quality design of structural details due to thermal bridges. Different insulation value profiles of which are windows manufactured directly affects the performance of windows.

Application of new technologies in processing of wood ensures achievement of all necessary profiling and dimensions, for both modern, as well as historical objects and shapes. This will ensure the best possible fit in picture of the existing facade. The choice of aluminum profiles which are combined with wood also has a wide variety of shapes and colors to properly fit in the given conditions. Aluminum window systems are unrivaled when it comes to the large dimensions of the hole. The advantage of PVC profiles is the cost of a large series and standard size opening. This includes the serial production of profiles without the possibility of variation and adaptation.

4. THE DIVISION OF THE WINDOWS, THE DIVERSITY IN POSITION AND MATERIAL

A window in a vertically sliding frame is called a sash window: a single-hung sash has only one half that moves; in a double-hung sash, both parts slide. A casement window opens sideward on a hinge.[4] Windows can slide, lift, drop, swing or stay still (Figure 1.).

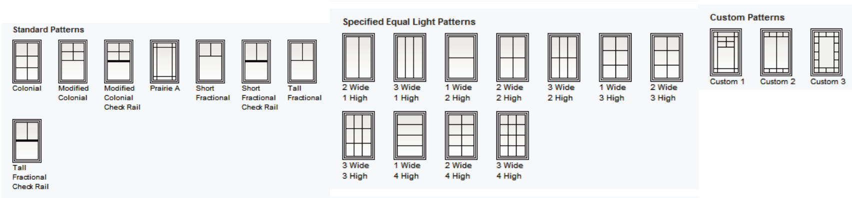

Figure 1*. - Different types of window patterns [6]*

Type of window defines the material because not all the materials have the same characteristics. Aesthetics, functionality, size and other characteristics can be a big limitation for architects. Selection may depend on the climatic conditions, the purpose of the building, the ultimate architect's ideas. It is not difficult to attract the attention of passers-by, it is difficult to meet all the necessary requirements that are imposed and to compromise some basic aesthetic standards. In the past, windows had more modest role in the architecture. Even when they formed a large glass surface, they were divided into smaller units. The reason why the previously formed glass was with smaller dimension was primarily based on economic factors.

Traditionally, glass was extremely expensive, and accordingly the production of large pieces was limited to extremely significant objects. I the last decade, in line with technological development, that barrier was surpassed, and we can see the large glass surfaces more often. Contemporary glass is formed without any structural division. It gives the impression of elegance, clean lines and inevitably provoke admiration of every passer-by. Sometimes the glass surface form a wall. Of course, large glass surfaces are usually fixed, they only serve to visually link with the exterior, or if we want to show something from the interior to the outside world.

Nearly all contemporary window units are constructed with dual glazing — two sheets of glass set about half an inch apart — to help insulate the home.[8]

The pane is the section of glass in the window. Windows may be formed from multiple layers, and they sometimes used to be literally divided (usually in older buildings). When the panes are actually separate, as in traditional styles, they call it “true divided light.”

Sliding windows are widely used because of their favorable geometry, small areas that require when opening. The elegance that we provide them stand out from the conventional window and thus have an increasingly important role in the architecture.

Sometimes angular parts of the building due to constructive solutions limit the viewpoint, so the angular translucent surfaces would overcome that barrier. Mitred window allows complete freedom of view and relationship with the surrounding landscape. This solution can be very expensive and difficult to perform due to structural problems.

Casement window represent a classic way of opening windows (opening in the same way as the door), and these windows are opened from the inside which makes the external appearance of the building very classy.

Awning windows have no time barrier, they are equally popular among traditional and modern facilities.

Glass block represent a trend in bathrooms or in any room where it is desirable natural lighting, and without the need to provide a degree of privacy. These elements can form a glass wall, and often can be found on the modern facilities.

Aluminium is leading in the selection of materials of modern window frames. Wooden frames are more commonly found in older buildings and modest shape and size. These two materials are also the most dominant and there is a possibility of their combination.

Materials From Lowest to Highest Cost (in general)[8]: Vinyl, Aluminium, Fiberglass, Wood, Composite, Glass Block.

Type of Window From Lowest to Highest Cost (in general)[8]: Fixed, Sliding, Single hung or double hung, Casement, Awning, Glass Block.

5. CONSTRUCTION OF GLASS SURFACES

When selecting and building glass facade architects must pay attention to the assignment of the structure, geographic location, orientation and wind speed, static effects that this object has to receive as well as the dilatation of the structure

There are few different types of glass facade structure:

- Classical glass curtain wall is formed of vertical and horizontal bracket profiles that are fully visible on the facade.
- Structural facades (invisible support structure) and semi-structural glazing (support structure partially visible) are commonly used in high-rise buildings as well as in buildings which entire facade reflect the environment.
- Curtain wall (Figure 2.) is another possible option of applying structural glass as a finish of the facade. It consists of light elements that are hung on the support structure and hanging in front of it. They differ the framework (with vertical or horizontal supporting bars) and plate (of the finished panels) curtain wall facade. Curtain walling may have one or more layers, usually hiding supporting substructure and are very popular in architecture.

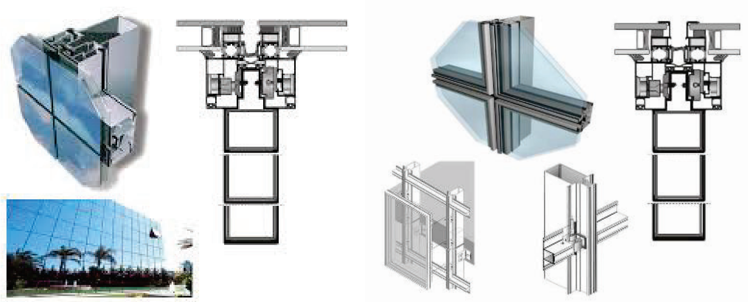

Figure 2. - Structural and semi structural curtain walls

6. WINDOWS AS THE MOST IMPORTANT ELEMENT ON THE FACADE

In traditional architecture, there are many examples of application of geometry in the design of religious buildings. The relationship of transparent and nontransparent surfaces is pre calculated, so the architecture of these buildings is harmonious and timeless.

For example the magnificent East Rose Window at Grace Cathedral has interesting geometric schemes underlying them. It's geometric scheme is exactly the same as that of Chartres Cathedral's Rose Window. And the best part is seeing how they make use of the same plan in different ways.[5]

On the Figure 3. a square is placed around the original circle of the geometric construction and overlaid it upon a beautiful photo of the Cathedral's east facade. It can be seen that the lines of the eternal, invisible geometry from which the solid, visible, translucent Rose Window materialized in its native place. In welcoming intangible but visible light to the Cathedral filtered through its geometric star, the Rose Window becomes the bridge between the eternal and the transitory. Next to this photo the geometry was enlarged so that its innermost circle grows to become the size of the whole window. The magnified geometry of the window suggests the scheme for much of the whole facade. Microcosm and macrocosm resemble one another: as the Rose Window welcomes light, the whole Cathedral welcomes the community.[5]

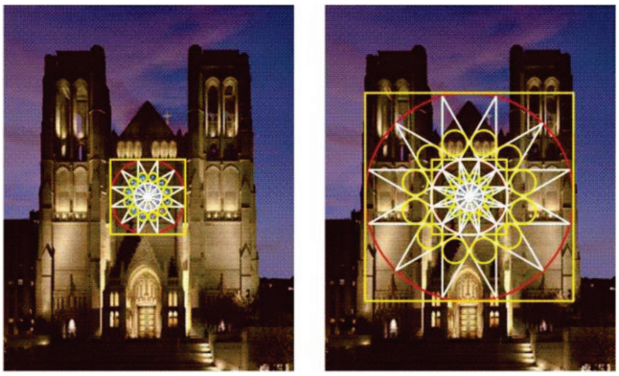

Figure 3. - A square is placed around the original circle of the geometric construction and overlaid it upon a beautiful photo of the Cathedral's east facade

Modern architecture is characterized by large transparent surfaces. Reflection of the glass, its neutrality and versatile design have included it in one of the most popular materials today. In addition to natural light and ventilation, windows provide a visual connection to the exterior. With transparent glass surfaces there is a mutual visual contact, while in some reflective glass surfaces, there is only a one-sided relationship. There are a number of interesting examples.

The most famous contemporary architects such as Norman Foster, the most important place in the materialization and shaping give to the glass. The dome of the German Reichsteig (Figure 4.) is entirely made of glass because of the symbolism of the parliament. The cupola is now an established Berlin landmark. Symbolic of rebirth, it also drives the building's natural lighting and ventilation strategies. At its core is a 'light sculptor' that reflects horizon light down into the chamber, while a sun-shield tracks the path of the sun to block solar gain and glare. As night falls, this process is reversed - the cupola becomes a beacon on the skyline, signalling the vigour of the German democratic process.[7]

Figure 4. - The dome of the German Reichsteig is entirely made of glass because of the symbolism of the parliament

Some of the buildings are really strange and usually produce amazement and admiration towards the designer. The most notable for its weirdness and its true beauty is hard to appreciate unless you have a really strange art sense. This building is shocking the viewer through its lack of windows and flat concrete slab facade. It kind of looks like a medieval tower, like those linking together portions of a defense wall of an ancient castle. (Figure 5.). The architect, William H. Whyte claimed that it features the tallest blank wall in the world. It is also one of the finest examples of the Brutalist architectural style, spawned from the modernist architectural and inspired largely by the work of the Swiss architect Le Corbusier. It may not be appreciated by most non-specialist and it does require a certain amount if twisted thinking to find it beautiful, but it's this unique and intriguing aspect that makes it one of the most interesting buildings in the world, a refreshing alternative to the steel and glass skyscrapers in today's landscape.[1]

Figure 5. - This building is shocking the viewer through its lack of windows and flat concrete slab facade

Intervention on the façade (Figure 6. Left), inadequate integration and subsequent changes can significantly impair the quality of architectural design. So bad its good: the perversity of windows cut into window frames suggests a different order of architectural composition, as well as a weird tension between the old and new.[3] The ISSHO architectural design office in Japan has created an apartment building called Fudomae with differently-shaped windows for a change[2]. Innovative technological breakthroughs allow architects complete freedom in designing (Figure 6. Right).

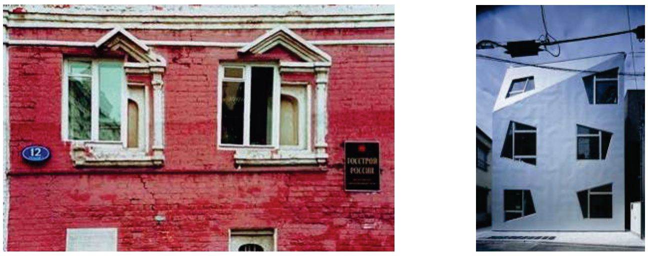

Figure 6. - Left - Inadequate integration and subsequent changes can significantly impair the quality of architectural design.

Right - Innovative technological breakthroughs allow architects complete freedom in designing

7. CONCLUSION

The influence of windows on the architecture of the building can sometimes be underestimated. Although their main role is to provide a sufficient intrusion of natural light, to provide natural ventilation and to protect the building from outside influences, they could be very important detail on the facade, and sometimes characterize the architecture of the entire building. Modern windows must meet a number of requirements related to energy efficiency. They have to belong to a particular style, made of predefined materials and sometimes cover very large areas of the building.

The answer for the question: What will be some features of "the house of the future"? is probably that some of the houses in the future would be like really big and weird looking and it might have floating sinks, beds, and floating toilets and weird stuff like that and big weird windows and the computers would be shaped ugly and might float.

Architects have to define what role the window will have on designed buildings. Sometimes technological limitations can significantly affect the final choice of the window. Selection of classic windows will not significantly attract curious glances, while specially designed windows are sometimes too expensive. The role of architects is to find a balance between their desires and opportunity as much as possible.

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DUAL CORE HOUSE - A CASE STUDY ON THE APPLICATION OF DIAGRAMMATIC PLANS AND 3D EXPRESSIONS FOR A HOUSE DESIGN -

Naomi Ando [1]

Abstract

This study examines the architectural design of a steel structured house for a nuclear family that is slowly splitting. The design is based on the diagrammatic analysis of "distributed-type" contemporary Japanese house that includes a common room and private rooms distributed individually, combined with "directly-connected-to-outside type", which allows for direct entrance and exit from the outside to the individual rooms. Moreover, a three-dimensional computer graphic (3DCG) program is utilized to design complicated steel frames to realize both types of plans in small premises.

Keywords: *Architectural design, diagrammatic Plan, 3DCG*

1. INTRODUCTION

"Dual Core House / House in Futako-Shinchi", hereinafter referred to as DCH, which has been designed by the author, was completed in 2013 (Figure 1). This house is steel-structured and partially structured with reinforced concrete, and includes three stories for four family members, such as a husband, wife, and two teenage daughters, in addition to one dog and one cat.

DCH is located in Kawasaki city, which is adjacent to Tokyo. The size of the site is 48.81m^2, with approximately 5m in width and

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approximately 10m in depth. In Japan's modern architectural climate, city areas are particularly crowded with houses; therefore, housing sites are often small sized.

The challenges of designing DCH considered family life in small premises and the realization of connections from outside of the house.

(Photo by Atarashi R.)

Figure 1. *Dual Core House / House in Futako-Shinchi.*

2. DIAGRAMMATIC PLAN

In the 1950s, a large family, in which eldest son lives with his parents before and after marriage, was common in Japan. After the 1950s, the mainstream Japanese family composition changed from large families to nuclear families. Architects, who designed houses for nuclear families after that time, have been challenged to relate common and private rooms and to relate internal spaces with outside areas.

The author has surveyed Japanese houses by using diagrammatic plans to verify their plane compositions and has pointed out several feasible types. Most Japanese house plans are nLDK type, which includes a common room, such as a Living room, Dining room or Kitchen, and private rooms, such as a child's room, bedroom, and study. Others are feasible plans include "one-space type", which has no private rooms, and "distributed type", in which a common room and private rooms are distributed individually.

To illustrate the plans of Japanese houses from the viewpoint of approaching from an entrance to a private room, most rooms are categorized into either of the following types: (1) “hallway type”, which allows entrance to private rooms from a hallway, or (2) “common-room type”, which allows entrance to private rooms from a common room. In addition, “terrace-type”, allowing entrance to private rooms from outside spaces, such as a terrace or a courtyard, and “directly-connected-to-outside type”, allowing entrance or exit directly from the outside to individual rooms, are also feasible.

Figure 2 shows the diagrammatic plan of DCH. As shown in this figure, DCH combines “distributed type” and “directly-connected-to-outside type”.

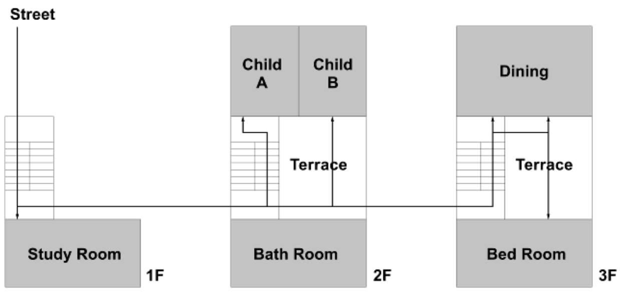

***Figure 2**. Diagrammatic plan of DCH.*

DCH does not depend on formal conventions, such as “a family should be united as one” and “private rooms should be connected to a common room inside a house.” Rather, it allows for family members to share a space while respecting one another and for the family to slowly split up, because even within a nuclear family, there are individuals, such as parents, children, siblings, and spouses, in addition to pets. In DCH, each member of a family that is slowly splitting lives in an individual space that connects to the outside. A child can access his or her own room directly from the outside without having to see his or her parents. However, all the spaces including the child’s rooms are loosely connected to other spaces through a terrace and stairs.

Plan, Elevations, sections, and photographs of the DCH are shown in Figures 3–5.

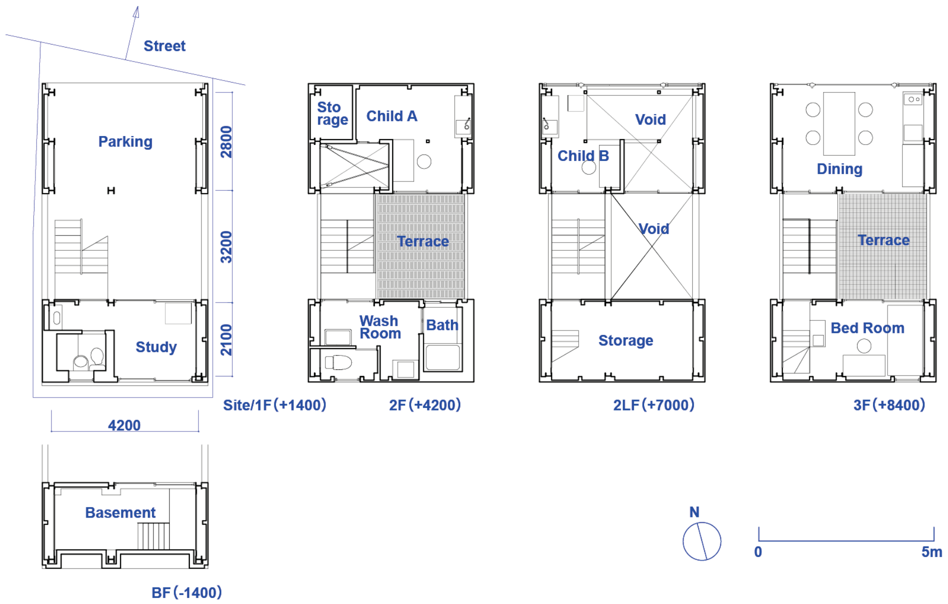

Figure 3. Plans.

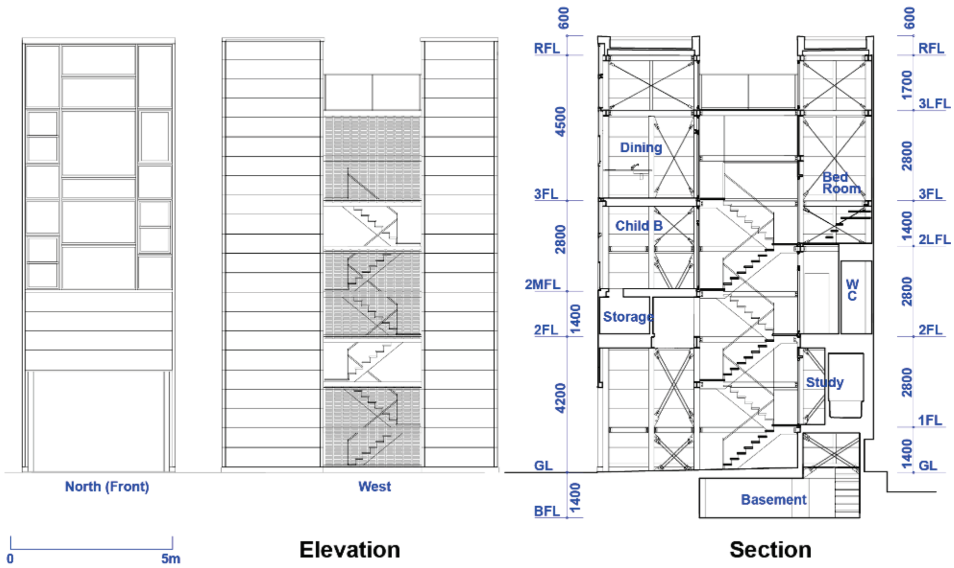

Figure 4. Elevations and Section.

(Photo by Atarashi R.)

***Figure 5**. Access to Rooms.*
(Left) 3F dining/2LF child; (middle) 2F child; (right) 3F bed/dining

DCH was awarded Good Design Award in 2013. The following evaluation of the plan was expressed by the juries: “It is unique that all the rooms can be accessed from a terrace as an outside space. Family members are one as a family, but they respect one another’s individuality and seem to see the other family members as roommates. It is also interesting that, when moving from one room to another, the family members need to go through the outside and are able to experience nature.”

3. SPATIAL COMPOSITION

The site of DCH is rather small, and only the north side is connected to a street approximately 5m in width; the other sides are adjacent to adjoining sites. However, across the street from the north side, Tama River offers a view of a peaceful landscape.

Within the site, two towers including a north tower with a 2.8m × 4.2m plan and a south tower with a 2.1m × 4.2m plan were designed with external terraces and a stairway in between. Because the site faces a river, height limitation of diagonal regulation from a frontal road did not apply; thus, the building’s height could be utilized. However, the number of floors was limited to three, in addition to one for the basement, to maintain the structure as a semi-fireproof construction, which is not subject to fire-proof construction codes, regardless of whether the site is located within a semi-fire preventive district.

The surroundings of the site and the site prior to construction are shown in Figure 6.

(Photo by Atarashi R.)

Figure 6*. Site of DCH. At right is the site prior to construction.*

The DCH aimed to create “a sense of distance” by inserting the outside space and utilizing the height as well as “a sense of transparency” by making use of materials, such as glasses and gratings, which are composed of permeable meshed steel plates.

H-shaped steel columns and beams served as frames for the first and second floors with heights of 4.2m each and the third floor with a height of 4.5m. These frames were wrapped with external walls composed of either glasses or fire-proof panels. The H-shaped steel frames were left exposed. Braces and equipment also remained exposed from the walls and ceilings.

The inside of each room is flexibly divided. The frames by the H-shaped steel aimed for minimum steel quantity while allowing for flexible separation of the internal space and structure redundancy or tolerance to changes. This frame structure will not collapse even if one of the columns exhibits strength decrease in case of fire, and the code such that columns must be covered with fire-resistant covering were waived (Building Standard Act Enforcement Order Article 70).

The following evaluation on the space structure was expressed by the juries of Good Design Award: “Although the premises are small, by making the ceiling height high and using the space three-dimensionally, a spacious house is realized.”

4. UTILIZATION OF 3DCG

Generally, steel frames are manufactured in a factory before being assembled at a site. The steel frames include structural columns and beams as well as sub-structures that support walls and floors, a roof, and window sashes. Joint plates and bolts are attached to the steel frame as protuberances. During the production of the steel frames, careful attentions must be paid so that steel frames, fittings, finishing materials, and other equipment can be accurately stored without interfering with one another. If a fatal mistake in design and production phase is overlooked until assembly at the construction site, the construction will be suspended.

To appropriately design/produce complicated steel frames for DCH, 3DCG program was utilized during the design phase. All of the details including the bolts and the plates were modeled on a computer to simulate assembly.

Figures 7 and 8 show 3DCG examples of the steel frame model and 3D sections.

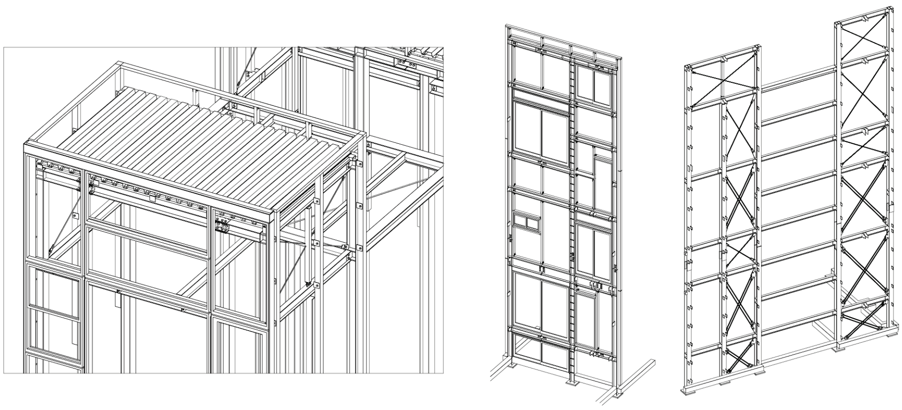

***Figure 7**. Steel Frame Models*

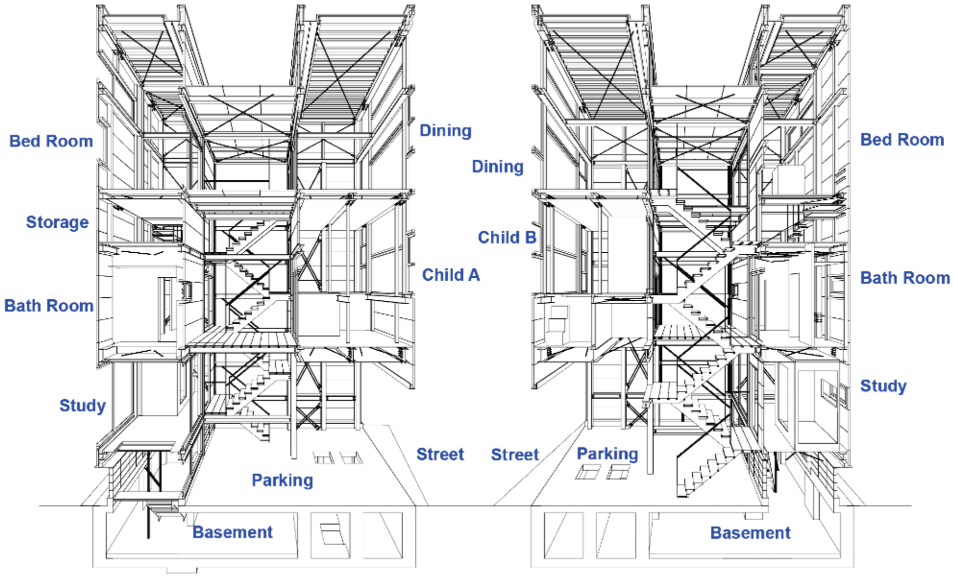

Figure 8. *3D Sections.*

5. CONCLUTION

An architectural work of a steel structured house with combined distributed and directly-connected-to-outside plans was presented in this study, and the utilization of a 3DCG program to realize the complicated steel frame structure was discussed.

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PERSPECTIVE STEREOSCOPE IMAGES

Dušica Filipović[1]

Abstract

Stereoscopy is a technique to achieve the impression of three-dimensional image, creating perspective image for each eye separately. Perspective image of an object is constructed for conventional distance of the monitors` eyes, one beside the other. It is ordinary that perspective images are coloured in different colours, and then to observe with the special glasses, in which glass in the left eye has a color perspective image of the right eye and vice versa. Such perspective images are called anaglyph. In this way, a convincing three-dimensional impression of the object is achieved. This way of displaying the object has been applied to film art and architecture, where we clearly perceive the reality of objects.

Keywords: *stereoscopic images, anaglyph, Film Arts*

1. Introduction

To obtain promising stereoscopic images, you need to select the position of the eye points (eye apple, the lens on the camera ..), and their distance from the object. [9] The most realistic display of the compared to the spacing of the eyes, which is 65-70mm, and the object should be located 20-50 times more in relation to the spacing of

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the eyes, 1400-3500mm. [6] Image with 3D effect is easiest obtained with the help of the camera, where for the first image the lens is placed in relation to the eye apple of the left, and for the other image in relation to the right eye apple. [4]

2. Methods to achieve three-dimensional EFFECT

There are several methods by which the three-dimensional effect is attained:

- Stereo Pairs (stereogram)
- anaglyph
- polarized glasses
- Active glasses

2.1 Stereo Pairs (stereogram)

A stereogram is a two-dimensional image that contains hidden information about the depth aimed to simulate the three-dimensional of the desired motifs, which detection is possible by activation the stereoscopic vision, [7] or method of crossing the eyes. By placing the two files, one next to each other and watching them with crossed eyes, there is a third image representing the three-dimensional image. [8] However, this technique is uncomfortable and can lead to visual damage out of excessive eye strain. [1]

2.2 Anaglyph stereoscopy

Anaglyph stereoscopy is the most famous method. [1] With it, by the help of computers and photoshop, we remove certain colours to achieve the proper effect. [2] Colour such as red, which is the warm colours [6] and objects which contain it, work closely [7] in relation to the objects that contain blue-green colour, which belongs to the cold. [6] The left eye is the past experience of the dimension of the observed object and that is why it joined the cool colours, respectively, we get an away image. While the right eye represents the current experience of the dimension of the observed object and therefore joining it the warm colours, that is, we get the close image. In order to achieve a 3D effect it is necessary to remove for the right eye blue-green component, and a red for the left eye. [7] Images are overlap, with the proviso that it is envisaged for the red colour, it is there over the image, which was designed for the blue-green colour, depending on which is the present and future experience of the observed object.

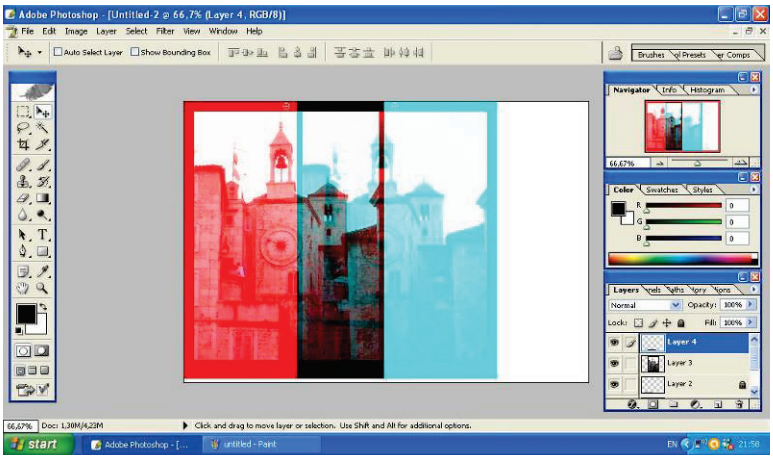

Figure 1: *The process of obtaining three-dimensional images in a photo shop*

The resulting image will be viewed with the help of 3D glasses, in which on the left lens is red optical filter, and on the right is blue-green optical filter. [5] For anaglyph presented so that the colours are recognized, it is necessary to keep just the right amount of red for one eye and blue-green for the second, how many already exist. [1] By observing the images with the appropriate filtration of colours we get the illusion of depth. [8]

2.2.1. Application anaglyph for Motion Picture Arts

This method is used for the film industry. Each of the pairs of films is set as to be different from each other by the number of pixels, exactly as many pixels as the depth wants to achieve. The optimal distance is 10 pixels [1] (increasing the height of the original image for 5%, from 100% to 105%) [2] for a picture with the blue-green anaglyph (left eye) on the right side of the object position, and for the image with red anaglyph (right eye), the optimal spacing is of 10 pixels from the left side, if you want to achieve the illusion that the object is farther from the eye and vice versa if you want to achieve the opposite effect. The first and last layers are so widely spaced, and each successive pair between, is removed for two pixels less. [1] This refers to the real position of the object, which is in the first picture and the desired distance of the object, which is located at the final image. The among images are present not to get the abrupt transition from the original position to the desired position. The conclusion is that the closest object has the smallest 3D effect and is the first to be noticed [2] (because it has a small number of pairs of anaglyph images and do not act blur) if the object is farther away, has more 3D effect, or more pairs of anaglyph image (as 10 pixels are more divided, more couples we get), and too remote objects from the focus are fuzzy and blurry, just because they have a lot anaglyph pairs.

Figure 2: *The nearest flower has the smallest number of anaglyph pairs and therefore a three-dimensional effect can be seen best.*

2.3. Polarized glasses

One eye receives vertically polarized light, while the other eye, horizontally polarized light. [6] By polarization of each image differently in relation to which eye is intended, the observer then can with the help of appropriate polarized glasses watch the images on the screen. Each eye will receive only the image that went through the proper polarization lens for that eye. [1] For the application of these techniques we need canvas on which the picture is, it must be made of special material. This method is mostly used in the film. [3]

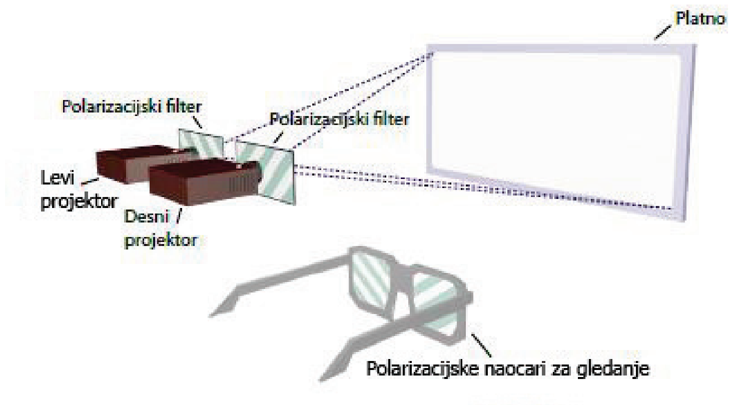

***Figure 3**: The process of observation of the film with the help of glasses.*

2.4. Active glasses

This method is often used for displaying images on a computer, and often it is on very high frequencies. The observer then put a pair of glasses with two screens with liquefied crystal, where each channel blocks one eye, we look at the picture, using the computer. These glasses require power and synchronization. Therefore, they are associated with the source image (projector). [1]

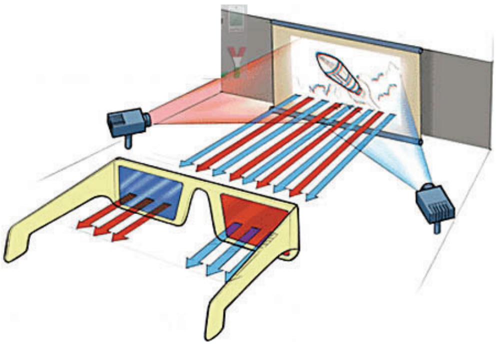

Figure 4: *Auxiliary projectors for the better effect.*

3. APPLICATION OF ANAGLYPH IN ARCHITECTURE

This method of presentation may help if we want to show the environment in a residential block and to replace it easily. We can show the changes to the very object. Different types of windows, different facade materials, building onto object and appearance of the same before and after the upgrade can be checked using the anaglyph. The position of the new object at the current location can be verified using anaglyph perspective images. This way of checking the fitting of the object in the current environment seems more real to the viewer's eyes, than setting up model, done in one of the computer programme on the photo of the location.

Figure 5: *Construction of a residential building. Close your left eye - see the trees, close the right eye - see the object without interference alley.*

***Figure 6**: The position of the new object.*

4. CONCLUSION

Anaglyph is used to create three-dimensional images using two different colors for photos of each eye separately, the usual adjustment range. These perspective image contribute to a realistic showing an object. Increasingly being used to create a virtual reality in various animations, movies, games ... It is necessary to keep in mind that anaglyph couples do not deviate one from another, or lens must be set for both eyes at the same distance from the subject, a common space for pupils observers. `The opposite there may be an artificial effect and appearance of ordinary two-dimensional images, or get lost in the realistic portrayal of the object. It is essential that for anaglyph perspective images viewed using the 3D glasses, in which the glass in the left eye has the same color as the photograph of the right eye and vice versa. This fact allows the audience to observe the film facilities and objects that appear in it seem more realistic, three-dimensional, although the design of the two-dimensional canvas. This way of representing objects may find application in the architecture. Integration of the facility into the existing site, using anaglifnih perspective pictures (photos), it's easier, because it can easily change the environment and elements of the building. Realistic display of objects is very important, because in modern film and presentation of architectural designs are increasingly emphasizes realism, especially in the era of the development of computer technology.

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ON THE REPRESENTATION OF ROOFS BUILT WITH THIN SHELLS

Carmen Mârza[1]
Delia Dragan[2]

Abstract

In order to erect roofs for buildings with special architecture, one could make use of thin shells. The design and the structure of these elements requires both creativity and in-depth engineering-based knowledge on behalf of the designer. In this paper, the authors aim at investigating upon the geometrical representation of this kind of roofs and of their advantages and disadvantages. The surfaces under investigation can be grouped as:

- *surfaces generated by algebraic curves with known parameters;*
- *warped surfaces;*
- *blending surfaces, generated by geometrical modelling processes on computer.*

Key words: *thin shells, sphere, the witch of Agnesi (or versiera), cylindroid, conoid, hyperbolic paraboloid, blending surfaces.*

1. INTRODUCTION

One of the major issues in the design and erection of buildings is represented by finding the optimal ways in which to cover buildings. Such concerns have been present since early times, with the first constructive forms dedicated to the habitat where mainly functionality

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was aimed at, and only then the external appearance was to join and present similar weigh.

- A past and present frequently met manner of covering spaces is given by the roof framing system that is able to cover a wide range of contours. In such a case the roof framing design is based on achieving equal or unequal slopes, found with the help of the intersections of planes. However, this solution has its limitations.

The discovery of modern materials and technologies, the upgrading of structural calculus methods, the wish to erect buildings with spectacular architecture and last but not least the need to be able to cover large span areas have all led to the search of new solutions that could meet the listed demands.

Thin shells in modern buildings are solutions that respond to the constructive and aesthetic requirements of today's society as well.

The most widely used are:

- surfaces generated by algebraic curves of known parameters, which exhibit advantages related to the calculus and surface drawing, and respectively
- unwrapped warped surfaces, which have an important benefit as the cross sections are identical and hence, pattern making is much simplified.

At the end of the 20th century, with computer assisted software the generation of the so-called free-form surfaces was made possible.

2. THE GEOMETRY OF SOME COVERING SURFACES WITH THIN SHELLS

In the following part, several solutions already used or that could be used in civil engineering for covering large span buildings and with special and unique architecture will be presented.

2.1 Surfaces generated by algebraic curves

The analytical calculus of this type of coverings with surfaces generated by algebraic curves of known parameters can be performed quite rigorously considering that in any point of the surface one can write the equation of the cutting curve, of the tangent and normal lines to the mentioned curve. An undisputable advantage for the erection stage is given by the possibility of making graphically the surfaces cross section.

As generatrices of such surfaces one can list the **conical** surfaces: circle, ellipse, parabola, hyperbola, cisoid, versiera or the witch of Agnesi, Neil's parabola, etc.

The most common among these surfaces is the sphere, defined as a surface generated by a circle rotating around one of its diameters. The sphere was studied by mathematicians as early as Antiquity. Due to the simplicity of the generation, the sphere as a whole or portions of it were used since the first century for cupolas, domes and other shapes and for covering circular contours of large span having only external support. In this sense, it is worth remembering the dome of the Pantheon in Rome (126 AD), built with the famous Roman concrete. This was a lightweight concrete incorporating volcanic tuffs as aggregates known as ”puzzolana”. The formula of this material is given by Vitruvius in the work called Ten Books on Architecture (25 BC). Another amazing cupola is to be found in Byzantine architecture in the St. Sophia Cathedral of Constantinople (415 AD). The development of the cupola as a structural member will continue in the Middle Ages and modern times.

In contemporary architecture, spheres are frequently used though in a more modern manner.

A talented design based on the intersection of simple geometrical forms (mainly the sphere surface) led to the building of one of the most staggering world architecture creation, the Sydney Opera House - Figure 1.

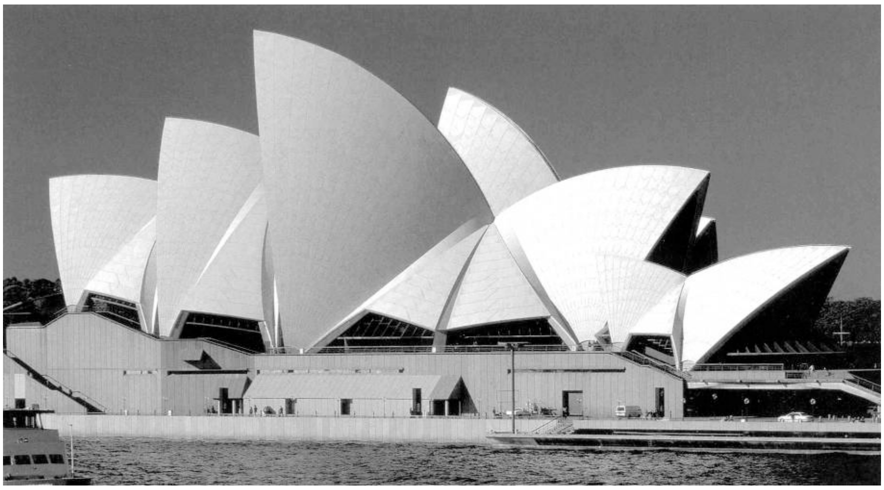

Figure 1. *Sidney Opera House, Sidney, Australia*

The Sidney Opera House, severely criticised for the lack of concordance between form and function, was designed by the Danish architect Jorn Utzon in 1956, but it was erected and finished only in 1973. This long time interval is due to the difficulties arising during the execution and to the novelty of the solution, to which the lack of proper materials, technology and funds was added.

In the same group of surfaces generated by algebraic curves are included the surfaces generated by the translation of the versiera.

A much less known curve, the versiera needs some details on the construction and mathematical definition. Versiera is a third degree algebraic curve whose construction can be seen in Figure 2.

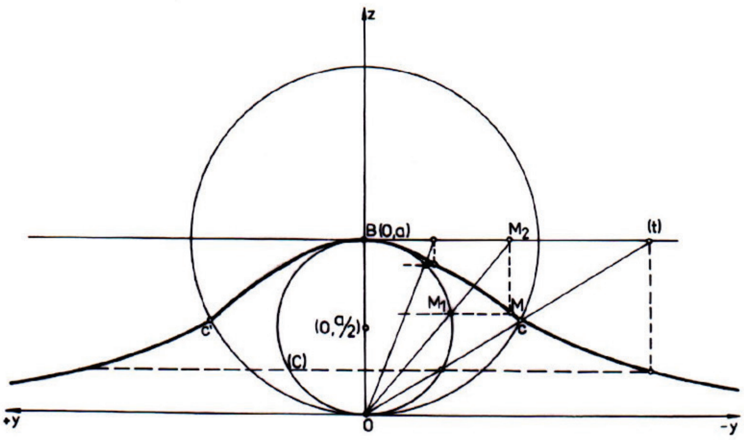

Figure 2. *Graphical construction of a versiera*

In relation with the Cartesian system in Figure 2, the equation of the versiera will be:

$$x^2 y + a^2 y - a^3 + 0 \tag{1}$$

or

$$y = \frac{a^3}{x^2 + a^2} \tag{2}$$

where a = is the diameter of he auxiliary circle (C).

Versiera is a rational cubic form, symmetrical to axis y and admitting two actual inflection points at a finite distance, calculated with the relationships:

$$I_1\left(-\frac{a\sqrt{3}}{3},\frac{3a}{4}\right),$$

$$I_2\left(\frac{a\sqrt{3}}{3},\frac{3a}{4}\right). \tag{3}$$

A surface generated by de versiera is determined if the shape in plane of the construction is known, as well as the purlin directrix and the centre lie of the auxiliary circles of the versiera. The equation of the surface will be:

$$\begin{cases} z = kx + \dfrac{a^3}{y^2 + a^2} \\ a = f(x) \end{cases} \tag{4}$$

where,

a= the variable diameter of the circle of the generatrix, found with the help of the centre lines which is actually a frontal straight line;

k = the tangent of the purlin directrix angle with the horizontal projection plane.

Function of the shape in plane of the construction and of the type of ridge directrix respectively, one can find spectacular covering shapes. Such a case is the trapezoid geometrical shape of a construction meeting a ridge directrix in the form of an arc of a circle. The surface of the covering is represented axonometrically in Figure 3.

The positions of the generatrix of the versieras are situated in profile planes, and the geometrical locus of the points of inflection will be a plane curve of parabolic kind whose coordinates can be calculated. The value of the parameter k can also be found for any point of the surface in relationship (4).

One of the positive features of this type of surfaces lies in the fact that the cross section in any point is known, and consequently in practice formworks can be built quite easily for the concrete casting.

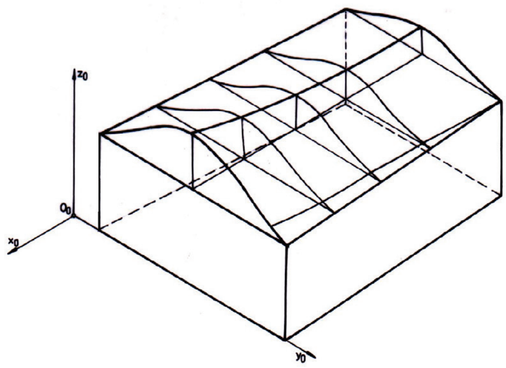

***Figure 3**. Surface generated by a versiera*

One of the positive features of this type of surfaces lies in the fact that the cross section in any point is known, and consequently in practice formworks can be built quite easily for the concrete casting.

➢ In this building covering surfaces are included the elliptical hyperboloid and the hyperbolic paraboloid.

➢ The **elliptical paraboloid** can be defined as a translation surface generated by the displacement of a parabola moving parallel to itself and sliding along another parabola. If the two parabolas have the curvature in the same sense, the paraboloid is elliptical. Its curvature will be fully positive, similar to a spherical dome, with translation surfaces with two circular directrices. The authors will present more details on the hyperbolic paraboloid in paragraph 2.2 as it can also be defined as a double warped surface.

2.2 Warped surfaces

Generally speaking, warped surfaces are the surfaces generated by a straight line moving in space according to a defined rule. The following surfaces are frequently used to make coverings from thin curves shells: cylindroids, conoids, and hyperbolic paraboloids.

In order to identify them more easily, here are some definitions of the respective surfaces:

- **The cylindroid** represents a warped surface with a directrix plane whose generatrix is supported on two directrix curves that are not situated in the same plane and which remains parallel to a given plane;

- **The conoid** is a warped surface made with a directrix plane whose generatrix is supported on two generatrices - a straight line and a curved line – and which remains parallel to the given plane;
- **The hyperbolic paraboloid** is defined as the warped surface produced by moving a straight line in two straight non-coplanar directions; in this displacement, the generatrix remains parallel to the directrix plane; this kind of surface is actually an oblique double warped surface.

One of the great experts with international recognition in the theory of thin membranes and platesin Civil engineering, professor Mircea Mihailescu from the Technical University of Cluj-Napoca studied and designed some works of reference in this field.

Figure 4 shows the Sports Hall in Onesti – Romania, a direct application of cylindroid type surfaces, while Figure 5 shows several halls in Brasov, erected with conoid type coverings.

***Figure 4**. Cilindroid-type surfaces*　　***Figure 5**. Conoid surfaces*

The hyperbolic paraboloid will be paid a special attention. Two forms are used mainly in civil engineering and they differ in the generation and calculation manner, as follows:

- The saddle hyperbolic paraboloid, whose surfaces is bounded by families of parabolas, that is it has curved margins;
- The hyperbolic paraboloid related to rectilinear generatrices enabling a new generation manner, namely as a warped surface (already defined).

In the following, the second type of hyperboloid will be discussed.

In the reduced form, the equation of the hyperbolic paraboloid is given by relationship:

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 2cz \tag{5}$$

where,

a and b represent constants defining the curvature and respectively

c orients the paraboloid, namely when c>0, the paraboloid will be oriented along Oy axis.

Figure 6 presents a hyperbolic paraboloid (HP) inscribed in a paralelipiped, and which has two straight lines $\mathbf{\Delta_1}$ and $\mathbf{\Delta_2}$, respectively $\mathbf{\Delta_3}$ and $\mathbf{\Delta_4}$ as generatrices, while the directrix planes are **ABba**, respectively **ADda.** In the particular case where the projection on the horizontal line is represented by a square the hyperbolic paraboloid is called equilateral.

The characteristics of rectilinear generatrices are:

- two generatrices from the same family will not be concurrent, as they are situated in parallel planes;
- two generatrices belonging to differing families will be concurrent in a point at the surface of the paraboloid and determine a tangent plane in te point in question.

The generatrices of the hyperbolic paraboloid parallel to the directrix plane determine equal ratios on the directrix lines. If the generatrices are extended up to the horizontal plane, one obtains the hyperbola passing through point **b** (Figure 6).

Figure 7 presents the railway station from Predeal – another achievement built in the 1970's by the Romanian prof. Dr. eng. Mircea Mihailescu. The railway station of Predeal was seen at the time as a work with avangarde architectural features.

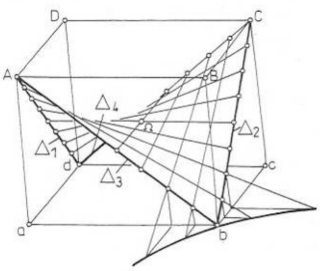

Figure 6. *HP inscribed in parallelepiped*

Figure 7. *Predeal Railway Station*

The covering of large surfaces with hyperbolic paraboloids has an advantage in the fact that more paraboloids can be grouped in one of the manners bellow:

- several paraboloids can be grouped together, as in Figure 8, to provide for the continuity of the surfaces through rectilinear generatrices;
- paraboloids can be intersected together and spectacular results are founds, as in Figure 9.

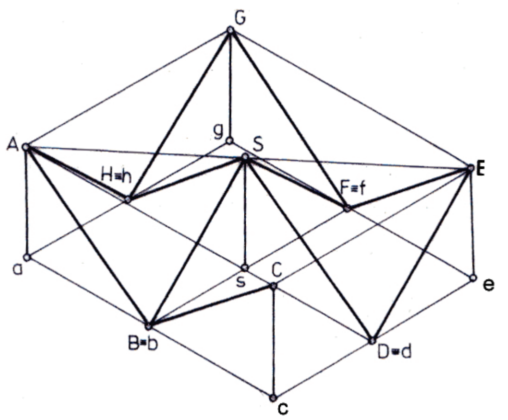

***Figure 8**. Four adjacent HP*

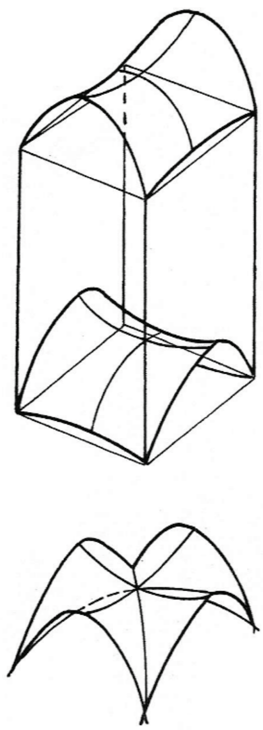

***Figure 9**. Intersection of two HP*

Another advantage for the effective construction of hyperbolic paraboloids lies in that double warped surfaces enable a much simplified formwork erection with the layout of straight strips along the rectilinear generatrices.

2.3 Blended surfaces

The release of the architectural shape from geometric constraints has led to the birth of free shapes. They are, in general, original, genuine and unique. Special computer-based software, prototypes and small-scale models are required for their study. The shape generation allows the use of intersections of simple geometrical volumes, and even complex volumes including surfaces generated with the help of graphical software.

A spectacular demonstration of the application of computer-generated surfaces in architecture is represented by the Guggenheim Museum in Bilbao city (Spain) – Fig.10.

The unique sculptural shape of this building designed by architect Frank Gehry and erected between 1991-1997 constitutes one of the strongest and most staggering contrasts to rational shapes that have dominated architecture for a long period of time in its history.

Computer-based generation of surfaces using mathematical relationships provides the advantage of a relatively easy exploration of a wide range of shapes. Previous statements can be supported by works [5] and [6], where with blending type interpolation methods (Coons) or of type Hermite and Birkhoff, families of free surfaces that could be used in constructions were generated. Figure 11 presents several particular cases of such surfaces.

Figure 10*. Gugenheim Museum (Bilbao, Spain)*

Such surfaces can be used in constructions and architecture, aeronautical industry, automobile design,. The algorithms developed in this type of interpolation can be of interest for CAD/ CAM software systems, as their use can improve the modelling capacity of these programs.

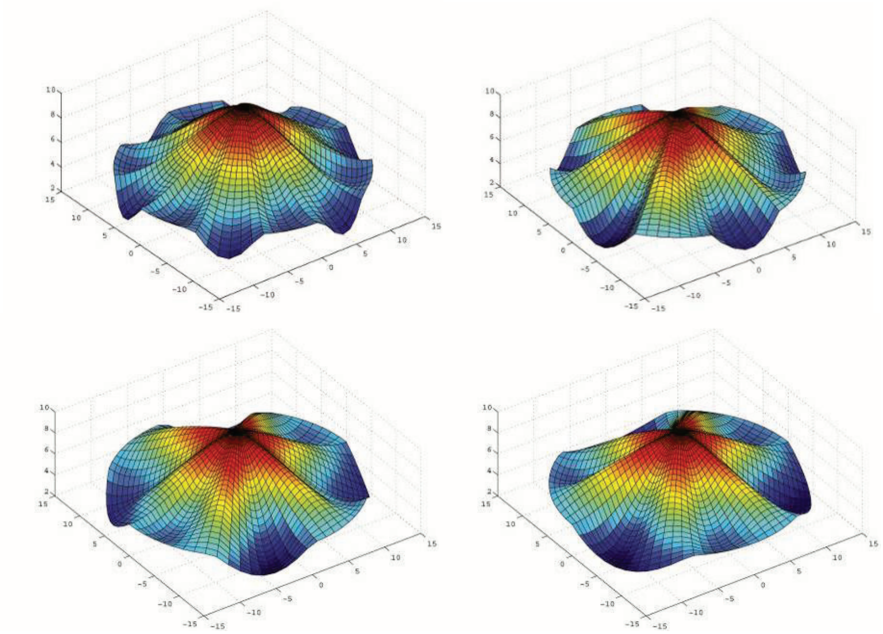

Figure 11. *Surfaces produced by interpolation*

3. CONCLUSIONS

Given today's rhythm of building development, various shapes of roof coverings have been designed and built for different projections in planes of the buildings in question. The present paper shows types of surfaces grouped according to the geometry and generation manner.

This kind of coverings can be used to cover large span surfaces, such as sports halls, nautical pools, commercial areas, warehouses. An additional benefit could be given by the opportunity to cover even wider areas, without providing intermediate columns.

In the selection of the optimal covering system, several criteria will be used, among which:

- the shape of the contour to be covered;
- the curvature itself;
- the potential mathematical formulation and calculation;
- to be easy to built;
- to have good and expressive appearance.

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ON DYNAMIC SPIRAL PATTERNS - POLYGONAL FRAMES INSCRIBED IN CIRCULAR SECTIONS OF QUADRIC SURFACES

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Abstract

Spiral forms, nowadays actual, especially in the area of architecture and design, were the inspiration point for an creative geometrical research. Acquainted with different approaches, present in practical and theoretical sense, from empiric creations to parametric modeling, we chose to explore the dynamic patterns which appear in spiral shapes generating process.

Since the term "spiral" is directly connected to circles we aimed our investigation to quadric surfaces with circular sections, where inscribed polygons obtain the spiral form by "twisting". We observed the series of inscribed polygons as dynamical spiral patterns of scaled frames, according to the geometry of the basic quadric surface. This investigation includes surfaces: cone, sphere, ellipsoid and elliptic hyperboloid. Three types of regular polygons are here included: triangle, square and pentagon.

3D model presentation of dynamic spiral patterns is performed in engineering software Auto-CAD. While considering the possibilities in application of such creations (models), some optimal intersecting surfaces are discussed.

Key words: *spiral patterns, helix, quadric surfaces, polygonal frames*

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1. INTRODUCTION

The expression that "everything is constantly changing and moving very fast…" would be an attempt to describe contemporary life style. The architecture, i.e. design have their responses to this concept in dynamic movements of the building's facade elements (surfaces), changeable in time dimension. Such architecture offers David Fisher. His "buildings are endowed with movement and are able to change their shape over the time" [9]. Here, the static observer has dynamic experience of the four-dimensional architecture. Vis-a-vis to the static observer the one in a motion, inside or outside the spiral structure, has a similar experience of the architecture [6]. Both offer an amazing dynamic effects which become the inspiration "origins" of our research. We focused the attention on the specific geometric topic: dynamic spiral patterns generated by spiral movement of the unit – a regular polygon.

***Figure 1**. The Twist Bridge over the Vlaardingse Vaart, Netherlands, by West 8 Architects, 2001.* http://www.west8.nl/projects/bridge_vlaardingse_vaart/

The dynamic spiral movement of the constructive "frames" on the pedestrian bridge in Netherlands derived an interesting example of dynamic spiral pattern (Fig.1). The origin geometric shape is a prism like with square base. The most common spiral patterns originated from prismatic geometric shapes with various types of the polygonal base. The other unusual kind of shapes, presented here, have their origin geometry referred to the 2nd order surfaces - quadrics: cone, sphere, ellipsoid and elliptic hyperboloid.

2. THE DYNAMIC SPIRAL PATTERNS CONCEPT

The most common spiral structures are generated by spiral movement of the "structural frame", i.e. unit, along the axis of

rotation. The important elements for the spiral surfaces classification are:
1. the frame shape: polygonal or curved (regular or non regular),
2. if the frame shape is constant, or variable in size,
3. the axis of rotation: straight line or a curve (planar or spatial) and
4. the relation of a plain containing a polygonal frame and the axis of rotation: perpendicular or non-perpendicular.

Our research concerns generation process of some specific spiral structures which geometric origins are quadric surfaces. The process begins with the system of inscribed polygons inside circular sections of the origin surface. In order to obtain spiral structure, i.e. an dynamic pattern, each polygon-frame rotates for a predefined angle.

Several prototypes of dynamic spiral patterns, presented in Table1 use some adopted criteria necessary for their construction:

- type of the regular polygon inscribed in the circular section of the origin surface
- fill rotation angle (sum of partial rotations) - φ/°
- partial rotation "step" – s/°
- number of partial rotations – n
- number of circular sections – n+1

Table 1. *Overview of the origin surfaces and necessary criteria for obtaining the dynamic pattern*

	Surface type	Polygon type	φ	S	n	n+1	Contour line
1.	CONE	Triangle	120°	5°	24	25	straight line
2.	SPHERE	Square	90°	5°	18	19	Circle
3.	ELLIPSOID	Pentagon	72°	4°	18	19	Ellipse
4.	ELHY	Pentagon	72°	6°	12	13	Hyperbola

The category of the spiral surfaces, containing polygonal cross-sections, elaborated by Ivanov, is called polyhedral "box type" surfaces [3]. Here, the author presented the analytical approach to the topic, while some magnificent applications in the contemporary architecture were reported by Shambina [5]. An multidisciplinary approach to similar topic offered Converso in the project of "Nagashima" lamp's prototype [1], which provided continuity of all the projects phases: from geometric design to technology processing, by "digital bridges"[1].

[1] "Digital bridges" are the procedures that establish a dialogue between two or more software programs [1].

The basic construction principles of the dynamic pattern are presented in Fig. 1 a, where the origin surface is a cone and polygon unit is a regular triangle. The "wireframe" 3D model is generated.

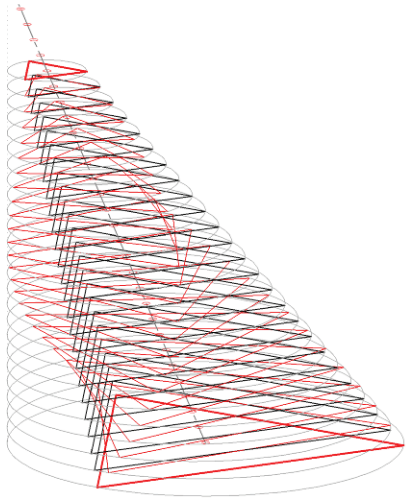


***Figure 1**. Wireframe 3D model of the system of rotated polygons; Origin surface – CONE; polygon unit – regular triangle*

The idea of remaining the identical position of the starting – "entrance" and the ending – "exit" polygon conducted the rotation fill angle $\varphi = n \times s$, where φ is the central angle over the edge of the basic polygon (fig.2) This principle resulted with dynamic patterns of *type A*.

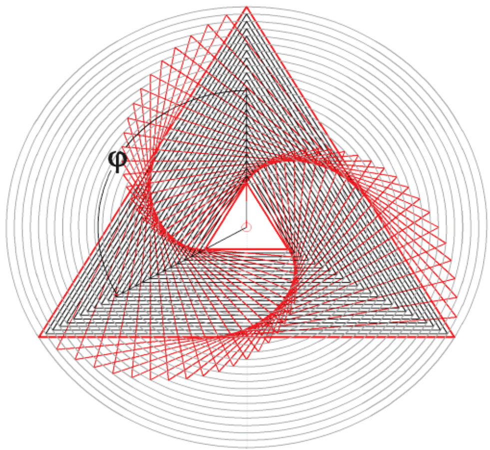


***Figure 2**. Spiral pattern view – line of polygon centers appear as a point;* ($\varphi = 120^{\circ}$, n=24, s=5°) *Origin surface – CONE; polygon unit – regular triangle*

The final model of the dynamic pattern requested dimensions (thickness) of the frame unit. Hence, the square cross section of the frame is added (Fig.3). 3D model structure included both: solid model of the spiral-twisted object and frames (Fig.3a). All the models of type A, shown in Table 2, were created by using advanced software's modeling tools in Auto CAD software.

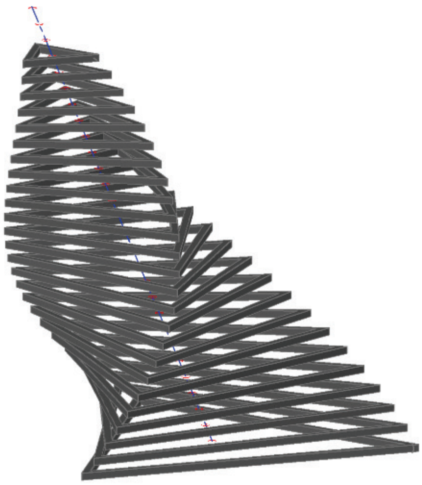


Fig.3 3D frame structure model A

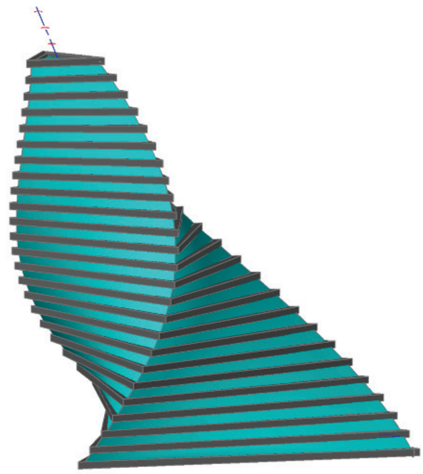


Fig.3a 3D solid structure model A

The previous author's investigation of the similar topic included practical aspect of employment of dynamical patterns, where the optimal intersection shape played the role of communication [2]. The

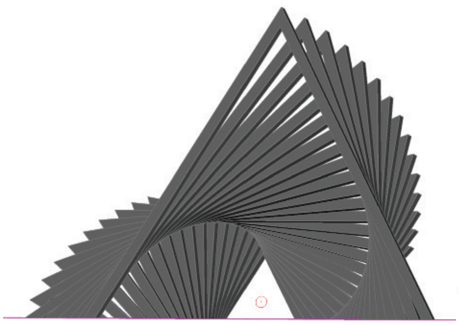


Fig.4 An intersection with a plane

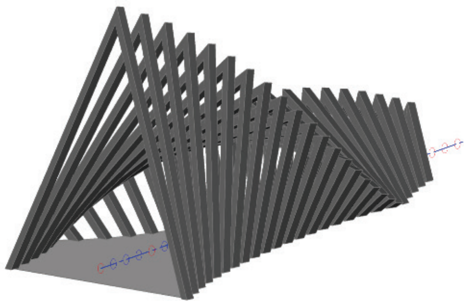
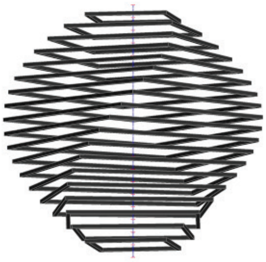
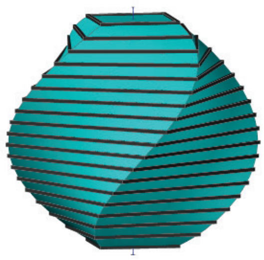
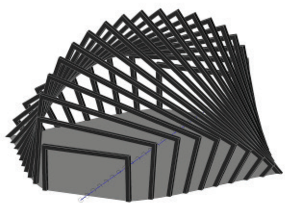
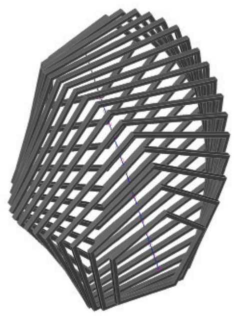
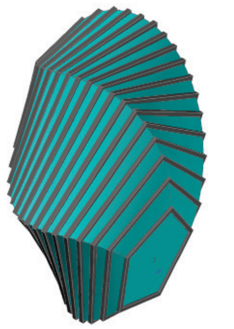
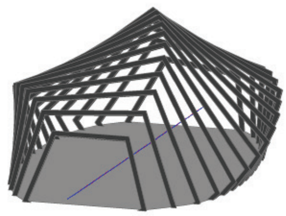
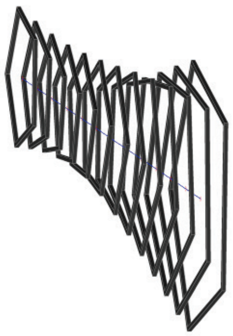
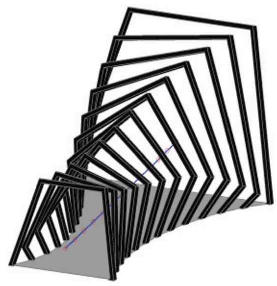


Fig.4a Axonometric view

3D frame structure model is intersected with the plane parallel to the line of centers, containing one edge of the smallest triangular frame. As the result, an attractive dynamics appear inside of spiral pattern over the irregular curved geometry of the "floor" surface (Figs.4 and

4a). Each pattern (Tab.2) has been analyzed, and cut in a manner that its dynamics retain (regarding the line of centers).

Table 2*. The dynamic patterns of type A inscribed in the origin surfaces*

	The frame model A	The solid model A	Intersection model A
2. SPHERE			
3.ELLIPSOID			
4. ELHY			

The variation of the previous concept with spiral movement of a basic frame (polygon) along the axis passing through the centers of polygons came with idea that line of centers could be some other line. The basic construction principles of the new dynamic pattern of Type B are presented by detailed explanations and figures, in the case of origin surface – cone and a polygon unit – regular triangle (Fig.4).

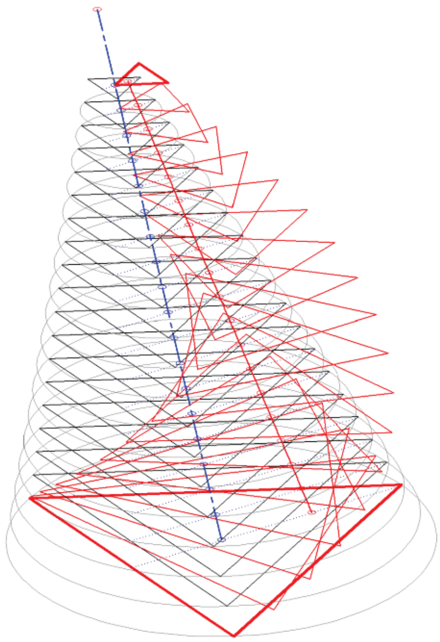


Figure 5. *Wireframe 3D model of the system of rotated polygons; Type B; Origin surface – CONE; polygon unit – regular triangle*

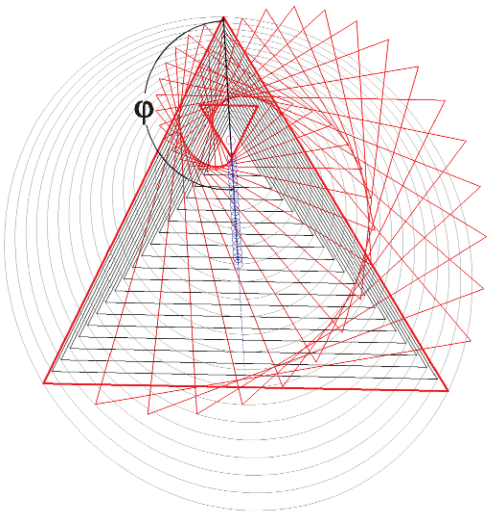


Figure 5a. *Spiral pattern view – a new line of polygon centers appear as a point;*(φ=180°, n=24, s=5°) *Origin surface-CONE; polygon unit –regular triangle*

The new adopted criteria, regarding the line of base points – centers of polygon's rotation, rely on the principle that the base point is a midpoint of radius connecting center of the polygon end the polygons vertex (Fig.5a-c). Hence, in the case of origin surface - cone, line of the base points is a straight line, while in the cases of origin surfaces: sphere and ellipsoid, this line is a planar curve. The adopted polygon's fill rotation angle is $\varphi=180^{o}$.

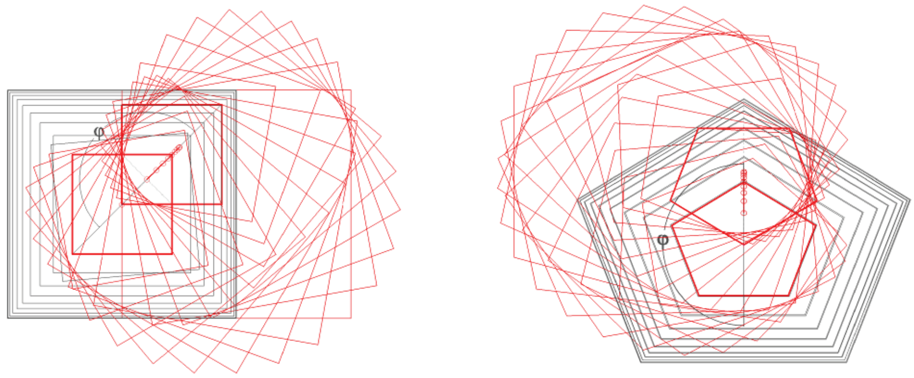


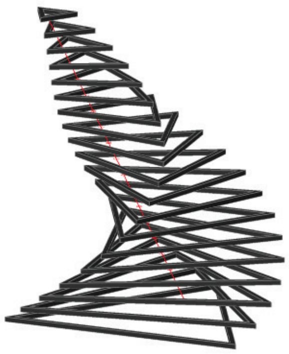
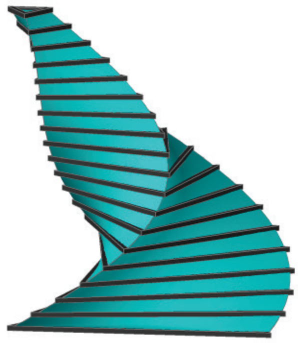
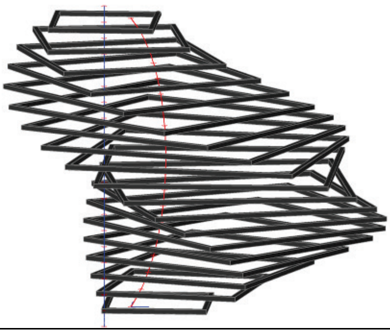
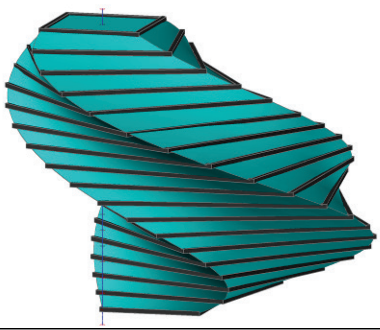
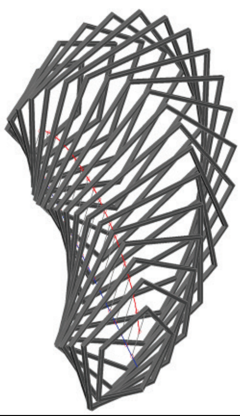
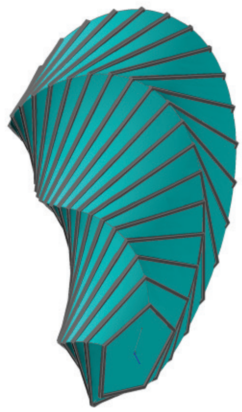
Fig.5b-c Spiral pattern view; Polygonal units: b)square, c)pentagon

The final form of all three frame dynamic patterns and 3D solid models of the spiral structures are presented in Table 3.

4. CONCLUSION AND FURTHER INVESTIGATIONS

Parametric modeling and advanced computer modeling software solutions have produced several significant innovations in "spiral design" of various "products": architectural design of buildings [4] and bridges [8], eco-installations, pneumatic architecture installations [7], furniture peaces [1], etc. The dynamic spiral patters and their shapes are for sure non-limited topic for further investigations. We believe that the types of dynamic polygonal patterns - A and B, presented in this paper, as well as 3D models of spiral surfaces that the patterns are incorporated in, have a significant place in a wide creative base for the innovative future design. Beside its creative role, in general, here presented topic has its educative aspect in the advanced Descriptive Geometry level concerning: elaboration of circular sections of quadric surfaces, 3D spiral structures modeling, prototyping and computer programming. In such manner, in further investigations we will include all of this roles into our consideration.

Table 3. The dynamic patterns of type B inscribed in the origin surfaces

	The frame model B	The solid model B
1. CONE		
2. SPHERE		
3. ELLIPSOID		

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THE DESIGN OF THE NEW SUN-REFLECTION-DIAL IN HEILIGENKREUZ/AUSTRIA

Hellmuth Stachel [1]

Abstract

A few years ago, the author was involved in the design of a sundial in connection with a big mosaic-work on a cylindrical wall. The original plan of the artist was based on the shadow of a slim vertical tower; but this was not realizable for geometrical reasons. The only solution was to use suitable stripes on the East- and Westface of this tower as a mirror such that reflected sunlight became suitable for a sundial.

In the lecture the geometric background for this sun-reflection-dial, which is unique in Austria, will be analyzed. This is also a good opportunity to explain why sundials cannot show the exact time all over the year.

Key words: Sundial, reflection, Equation of Time

1. INTRODUCTION

In the years 2011-12 the author came in contact with the *„Verein Moderner Sakralbau"*, an Austrian organization which promotes modern art for Christian churches. This organization planned a monument in the area of the Heiligenkreuz monastry[2]. This monument (see Fig. 4, left) should consist of a big mosaic-work (8 x 3.5 m) on a

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[2] a Cistercian monastery, approx. 25 km south-west of Vienna, the eldest continuously occupied Cistercian monastery in the world. It is also famous because of its Gregorian Chant. <http://www.stift-heiligenkreuz.org/english>

cylindrical wall and – at the center of the cylinder – of an 8 m high slim tower, called *'Gnomon'*, in form of a three-sided pyramid made from reflecting steel. According to the design of the French artist Philippe Lejeune (*1924), the shadow of this tower falling onto the cylindrical wall Ψ should be utilized for a time telling device.

The exact position of this monument (Fig. 1) is as follows: Eastern longitude 16.132° and Northern latitude 48.049°.

It is well-known that the shadow casted from a vertical tower on a vertical wall has not the necessary property that its position depends only on the local time but is independent from variations of the season (see, e.g., [1, p. 393]). On the other hand, meeting the necessities for a sundial, i.e., inclining the 'Gnomon' until it is parallel to the earth's axis, would totally destroy the appearance of the artist's design. The only compromise was to use suitable reflecting stripes on the East- and Westface of the central tower such that the reflected sunlight works like a sundial.

In the following, the geometric background for this sun-reflection-dial, which is unique in Austria [4], will be presented. This offers also the opportunity to explain with the help of Descriptive Geometry [3, p.50] why (surprisingly) sundials cannot show the exact time all over the year – because of the 'Equation of Time' (for further details see [1, 392-402] or [2]).

***Figure 1**. Heiligenkreuz Abbey with the marked monument „Epiphanie"*

2. WHY NO SUNDIAL WITH SHADOWS ?

We expect from a usual sundial that – independent from the season – at any given day-time t (e.g., 10 a.m.) the shadow of the style falls onto the same line. These so-called *hour-lines* are usually marked on the sundial. Of course, our requirement has consequences for the position of the *gnomon*, i.e., the style which causes the shadow. Let us first have a look on the shadow of one single point.

For the purpose of understanding sundials, it is convenient to adopt the geocentric view. This means we consider the earth to be fixed while the sun is moving relative to the earth. This motion is exactly inverse to the motion displayed in Fig. 6, the composition of the rotation of the earth about its axis and the translational movement along an elliptic path around the sun.

During the run of a year the line connecting the center M of the earth with the center S of the sun changes its inclination with respect to ('w.r.t.' in short) the equator plane. When the true local day-time[1] t is kept fixed over the year, the connecting lines SM vary within a plane through the earth's axis. Now we replace the center M by an arbitrary point P on the earth. In this respect, we may assume an infinite distance to the sun. Therefore we apply the translation $M \mapsto P$ and conclude: All sun rays which pass every day at the same true local time t through point P belong to a plane ε_t parallel to the original meridian plane. We call this translated plane a *hour-plane* ε_t. Which instant t we ever choose, the corresponding hour-plane ε_t contains the line a which is parallel to the earth's axis and passes through P. All hour-planes belong to a pencil with axis a, and when the date t increases by one hour the corresponding hour-plane rotates through an angle of $360/24 = 15°$.

The sun casts a shadow from point P onto a given surface Ψ. The shadow originating from this single point at the same true local day-

[1] For any position X on the earth, the *true local time* is defined in the following way: Noon is fixed by the fact that the sun reaches its daily culmination relative to X, i.e., the sun passes exactly the meridian plane of X (= plane connecting X with the axis of the earth). *One hour* (in true local time) equals the 24th part of the period between consecutive noons. For details like the deviation from the mean time see Section 4.
Historically, the need for an international *mean time* started only when a railway-network has been established.

time t varies from day to day along a hour-line which is the intersection of the surface Ψ with the hour-plane ε_t.

The gnomon must be chosen in such a way that the shadows of all its points fall onto the same hour-line. Therefore all its points must be located in the same hour-plane ε_t, and this must hold for all t. We can summarize (see also [1, p. 393 ff]):

Lemma 1: *The shadow casted from a style (=gnomon) at given local time t is for each t placed on the same hour-line independently from the season if and only if the gnomon is parallel to the earth's axis.*

Concerning the initial plan for Heiligenkreuz (Fig. 4, left), what are the conclusions ? A vertical tower used as a gnomon contradicts Lemma 1. Only at noon we would obtain a correct result as the shadow points North. In order to obtain a classical sundial, the gnomon must be slanted with an inclination of about 48° against the North direction. However, this would totally destroy the optical appearance of the artist's design. This was the reason why we started to pay attention to the reflecting properties of the faces at the original 'Gnomon'.

3. SUNDIAL BASED ON THE REFLECTION OF SUNLIGHT

Suppose, the sunbeam which is reflected at any point Q of the reflecting face μ meets a given surface Ψ at the point *Q'*. Then due to Fig. 2 (left), the luminous point *Q'* coincides with the shadow of point Q w.r.t. a *virtual sun* $\overline{S}$ which is the mirror of the original sun S w.r.t. μ. The daily movement of this virtual sun $\overline{S}$ around the earth is a rotation about an axis which is the mirror of the earth's axis w.r.t. μ. Therefore, for any given true local day-time *t*, the luminous point *Q'* in Ψ varies over a year along a hour-line which is the trace of the reflected hour-plane $\overline{\varepsilon_t}$, and $\overline{\varepsilon_t}$ includes the mirror $\overline{a}$ of line a. Now, Lemma 1 implies the following:

Lemma 2: *Suppose, the reflection of sunbeams along a line segment* ℓ *in the reflecting plane* μ *generates at given local time t on a surface* Ψ *a luminous curve segment* ℓ_t*. This spot* ℓ_t *is for each t a subset of a corresponding 'hour-line' all over the year if and only if the reflecting segment* ℓ *is parallel to the mirror of the earth's axis* *w.r.t. μ. Because of $\ell \subset \mu$ the reflecting plane μ must be parallel to the earth's axis.*

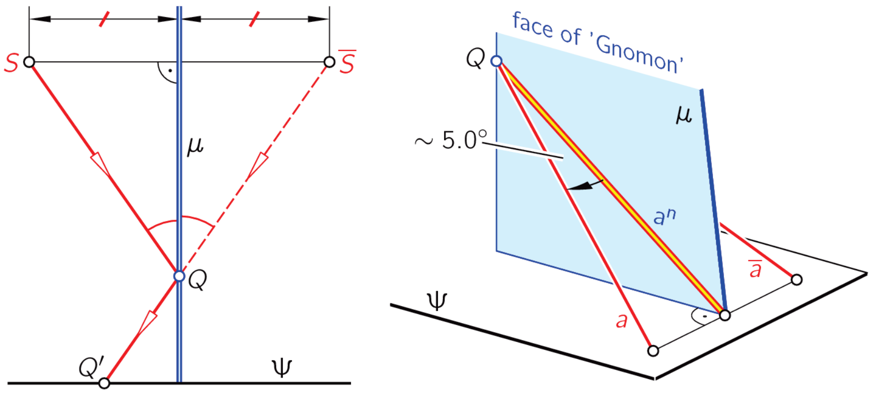

***Figure 2**. The luminous point Q' caused by reflection of a sunbeam in the plane μ at point Q equals the 'shadow' of Q w.r.t. the reflected sun.*

Now we face a problem: According to the design of the 'Gnomon' in Heiligenkreuz (Fig. 4, left), no face is parallel to the earth's axis; neither any line ***a*** (Lemma 1) nor its mirror $\overline{a}$ (Lemma 2) is located in one of the reflecting faces μ of the 'Gnomon'. [1]

Consequently, we have to confine ourselves to an approximation: We replace $\overline{a}$ by its orthogonal projection a^n in μ, which at the same time is the orthogonal projection of line ***a*** (Fig.2, right). The angle between ***a*** and the reflecting face μ is smaller than 5°. Therefore this approximation seems to be admissable. Fig. 3 reveals that in fact the reflection of a stripe ℓ along a^n gives luminous stripes ℓ_t in Ψ which for each ***t*** follow almost a 'hour-line' over the seasons.

Remark: We note in Fig. 3 that for ***t*** = 7 a.m. the monthly luminous stripes ℓ_t fit better to a hour-line than for ***t*** = 11 a.m. This results from the fact that the exact hour-plane ε_6 for 6 a.m. is orthogonal to the meridian plane and therefore very close to the plane which connects the lines ***a*** and a^n. So, the error of our approximation by

[1] After reflection in μ the sunlight would cast from a style parallel to $\overline{a}$ a shadow which satisfies the requirements of a classical sundial.

choosing a^n instead of $\overline{a}$ is smallest at 6 o'clock in the morning and in the afternoon.

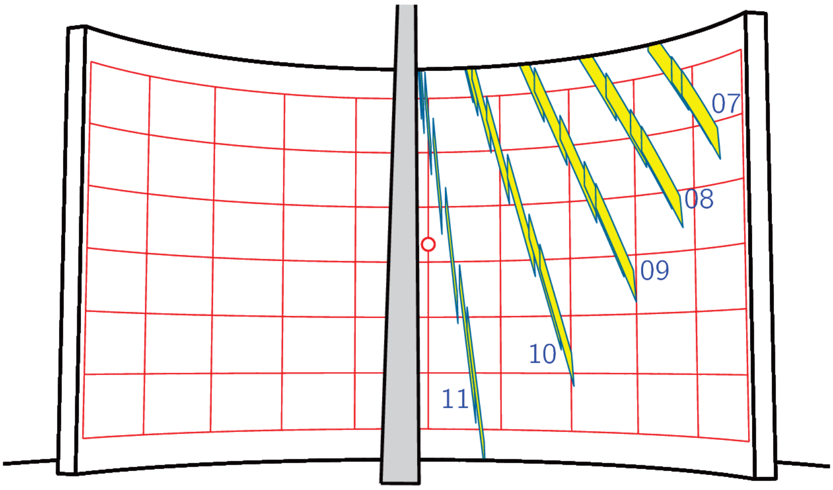

Figure 3. The luminous stripes ℓ_t on the wall Ψ vary from month to month, but can be combined to hour-lines

The result of our approximation was the plan displayed in Fig. 4 (right). The East-face of the 'Gnomon' serves as a mirror in the morning, the West-face in the afternoon. Only around noon the reflection fails; at this time only side-sunlight meets the two faces. This is the reason why the *noon line*, i.e., the hour-line for true local noon is missing at the final status (Fig. 10). Fortunately, just at noon the shadow of the 'Gnomon' shows the correct time.

The altitude of the reflecting stripes on the 'Gnomon' (Fig. 4, right) and the position of the 'Gnomon' w.r.t. the curved wall Ψ resulted from the fact that even at winter and summer solstices a luminous stripe should be visible on Ψ. While at classical sundials on the Northern hemisphere the shadow moves during each day from left to right, i.e., from West to East, at a sun-reflection-dial the luminous spots move in the opposite direction. The hour-lines on the monument in Heiligenkreuz are portions of (almost) ellipses since they are the intersections of the cylindrical wall Ψ with the (almost planar) reflected 'hour-planes' $\overline{\varepsilon_t}$.

Figure 5 shows the original plan for the workmen. The hour-lines were drawn only outside the mosaic-work. Since on the left and right hand side of the mosaic the portions of the hour-lines are rather short, they were extended over the vertical edge of the wall. These extensions were defined in such a way that for a visitor who stands exactly on the middle-axis a few meters in front of the 'Gnomon', the extensions look like straight elongations of the hour-lines (note the photo in Fig. 10 and compare the right and left hand side extensions).

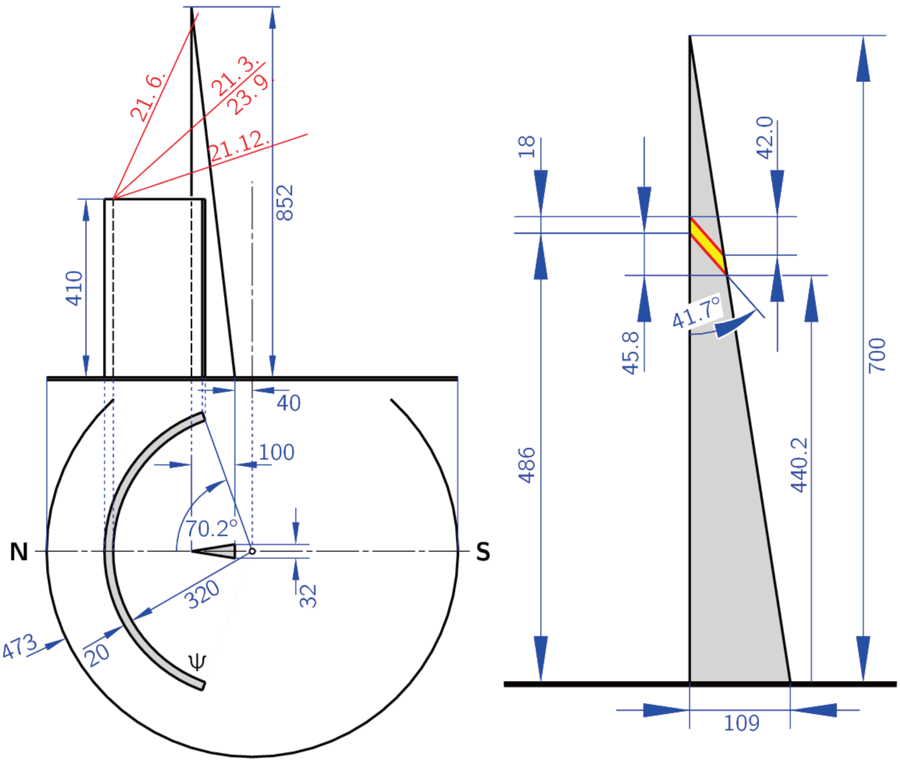

***Figure 4**. Left: The initial plan of the monument; Right: the final position of the reflecting stripes on the East- and Westface of the 'Gnomon'.*

Figure 5 shows also that the hour-lines for morning and afternoon are not totally symmetric. This is caused by the fact that the sun-reflection-dial shows not the local time for Heiligenkreuz but CET, i.e., Middle European Time (wintertime). Because of the longitude ~16° of Heiligenkreuz, the sun reaches its daily culmination here at approx. 11:56 p.m. – apart from the general deviation according to the Equation of Time (see Section 4).

4. ON THE PRECISION OF SUNDIALS

Now we skip the geocentric view and turn over to the heliocentric view. From now on, our fixed frame includes the sun and the directions to the fixed stars.

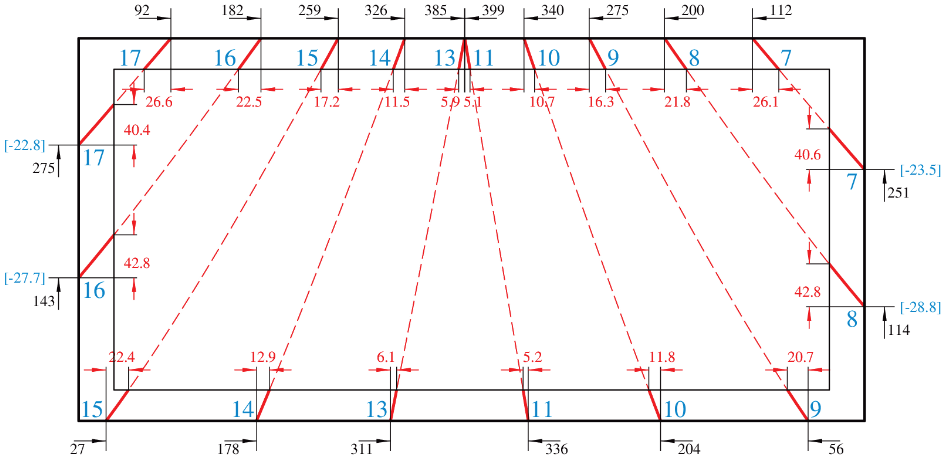

***Figure 5**. The original plan for workmen in order to paint the hour-lines*

During the movement of the earth along the *ecliptic* around the sun (see Fig. 6) the direction of the earth's axis remains fixed (in first order approximation). The angle ε between the planes of the equator and the ecliptic is called *obliquity of the ecliptic*.

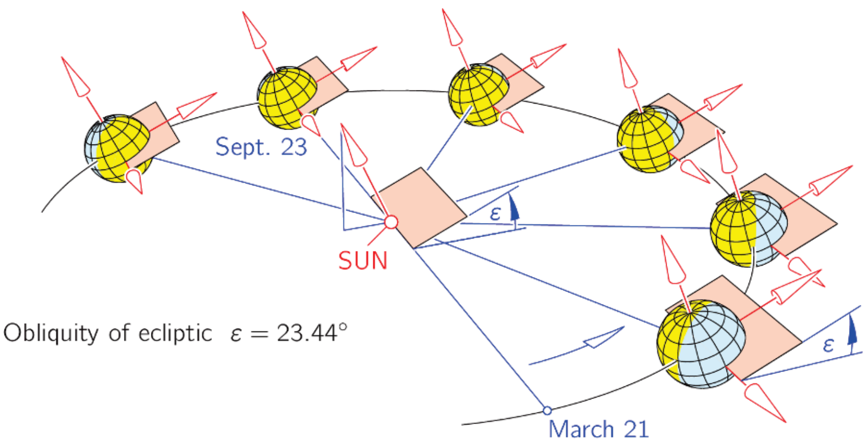

***Figure 6**. The earth travels around the sun along the ecliptic*

In order to inspect the rotation of the earth about its axis in true size, we use an auxiliary view in direction of the earth's axis (Fig. 7). This view reveals: During consecutive sun culminations, i.e., from noon until noon of the next day (true local time), the earth must rotate about its axis through an angle of $360^\circ + \varphi$ where φ is the center angle swept during this time interval (~360°/365). However, even when the earth would move along a circular path with constant velocity, the center angle φ varies because of the affine distortion of this circle in our auxiliary view. Consequently, the duration of a day (w.r.t. true local time) measured in mean time is not constant.

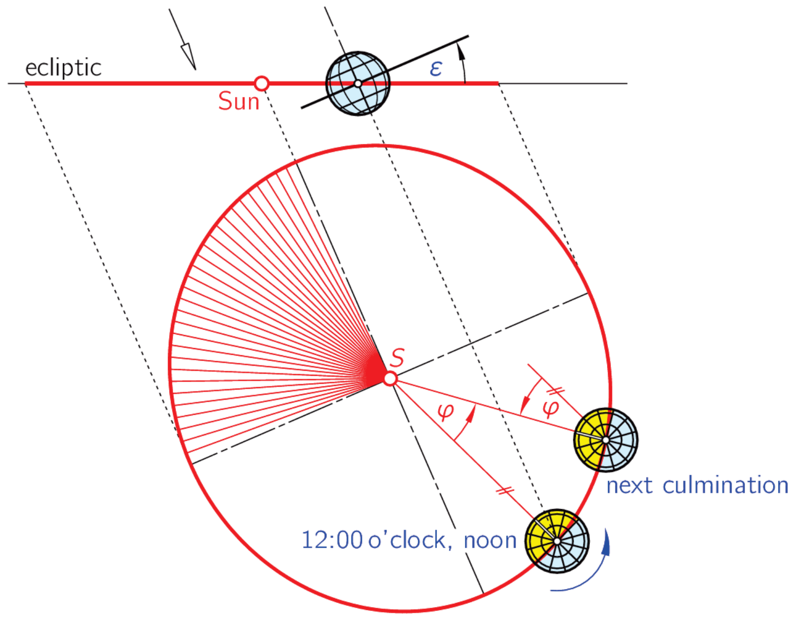

***Figure 7**. Auxiliary view in direction of the earth's axis*

However, the obliquity of ecliptic is not the only reason for the variable duration of the period between consecutive sun culminations. Due to Kepler's First and Second Law, the ecliptic is an ellipse with focal point *S*, and the earth travels along this ellipse (with very small numeric eccentricity e/a = 0.0167) with constant areal velocity. This means, in periods of equal duration the segment *SM* connecting the centers of the sun and the earth sweeps sectors of equal area (Fig. 8).

Note that affine transformations preserve the ratio of areas; therefore also in our auxiliary view the earth moves with constant areal velocity.

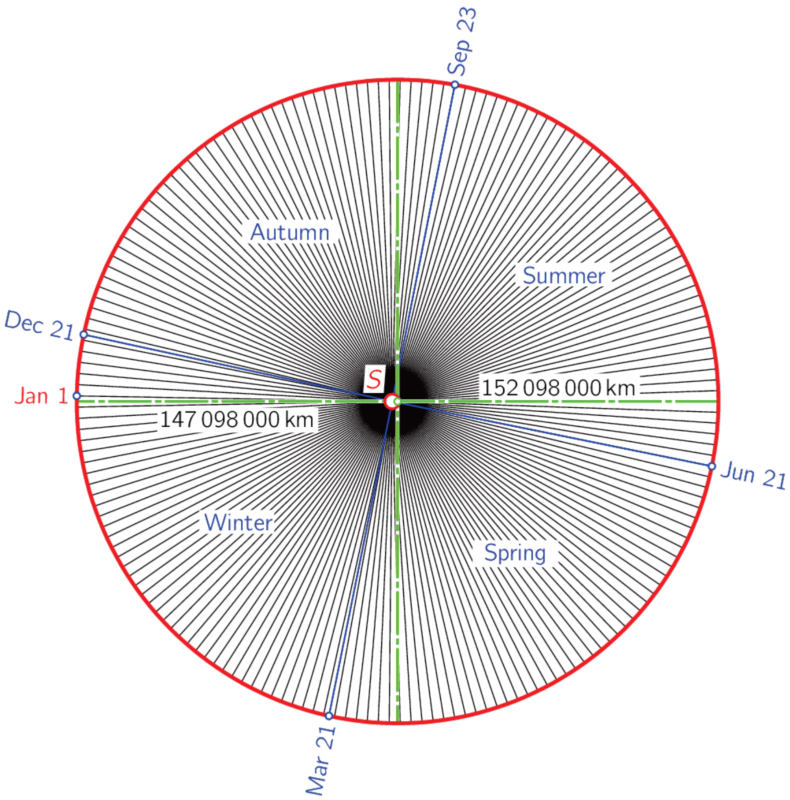

Figure 8. *According to Kepler's First and Second Law the earth moves around the sun with constant areal velocity along an ellipse with focal point S*

Both effects, the affine distortion in our auxiliary view and the elliptic shape of the ecliptic, influence the *'Equation of Time'* (Fig. 9), which shows the difference *z* between true local time (reduced to CET) and *mean time* on our clocks. This deviation lies between approx. +15 and -15 minutes. The dotted line in Fig. 9 shows the pure influence of the obliquity of ecliptic, i.e., the deviation for a circular path. The dashed line in Fig. 9 indicates the influence of Kepler's Laws in the case of a vanishing obliquity.

The biggest deviations happen at the beginning of November – the sun is about 16 minutes before the median time (it is „getting dark earlier") – and at February 10 when the sun is approx. 14 minutes delayed (days „last already longer"). On the other hand, there is a high conformity between true time and mean time at midth of April and June, at the beginning of September and at (catholic) Christmas time. Of course, we cannot expect that a sundial pays attention to the change from CET to CET summertime every year.

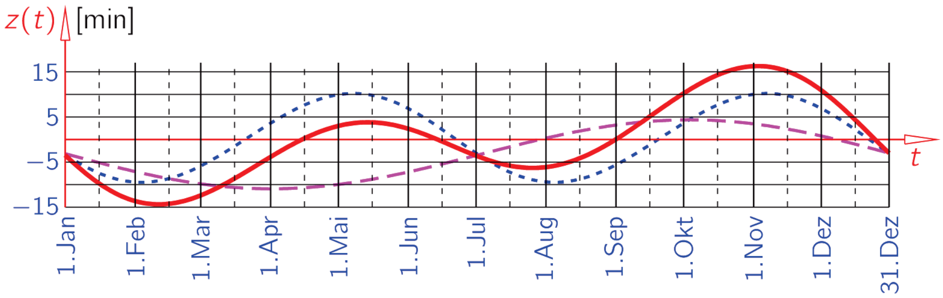

***Figure 9**. Equation of Time: z = true time – mean time*

5. HOW TO READ THE TIME ?

***Figure 10**. The final appearance of 'Epiphanie', a declared monument „for Freedom of Conscience and Religion as a Foundation for Peace"*

Figure 10 shows how the monument 'Epiphanie' with the hour-lines in the final status looks like. The photo was taken on August 14 and shows in the upper right corner the (additionally marked) luminous stripe. It indicates approx. 8:05 a.m. However, we must pay attention to the summertime. And, in addition, for midth of August the Equation of Time shows 5 minutes delay of the sun against CET. Hence, the result is approx. 9:10 a.m. which comes very close to the date stored in the camera.

The photo in Fig. 10 shows near the bottom some irregular light concentrations which can be confusing for visitors as they have nothing to do with the sundial. These strange looking spots are caused by the fact that the lower parts of the East- and West-face are slightly bent (due to production errors) but still reflecting. One can actually note that the reflection in the total East-face, which apart from the reflecting stripe and the lowest portion is unpolished, produces a vertical shine on the wall; this shine includes the marked luminous stripe above as well as the light concentrations at the bottom.

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CHANGES IN GEOMETRY OF THE HYPAR MEMBRANE STRUCTURES UNDER POINT LOADS

Vuk Milosevic [1]
Biserka Markovic [2]
Dragan Kostic [3]

Abstract

Membrane structures are spatial surface structures that have a double curved shape with negative Gaussian curvature. Their self-weight is the lowest compared to all other structural systems, and their thickness is about 1 mm only. Because of this, unlike traditional structural systems, they cannot counteract external loading with their mass, but rather with changes in their geometry and internal forces. These changes in geometry last only as long as the external loading. The aim of this paper is to show the effects of point loads to the geometry of the membrane structure with hyperbolic-paraboloid shape.

Key words: *membrane structures, double curvature, point load*

1. MEMBRANE STRUCTURES

Engineering advancement can essentially be divided into two aspects: perfecting the properties of the materials and maximizing the

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potential of existing materials. While the first one is mainly the job of materials science, structural engineers search for the best ways to use the materials. It is well known that concrete has high compression strength, thus its best application would imply the absence of tension and shear forces. The simplest structure that can be completely compressed is a column. The next linear structure that can be fully compressed in the exploitation phase is the arch. The relation between the longitudinal section of the arch and the thrust line of the arch defines if the arch will be fully compressed [4]. Shell structures are more complex than the arches in the sense that they are space rather than linear structures. They have been developed at the beginning of the 20th century as a solution for the problem of creating a compressed space structure more complex than the cupola. In such a way, the maximum potentials of concrete regarding its current properties are practically exhausted. Since the material that uses the compression forces has been developed, the focus of the researches turned to the utilization of tensile forces. Linear structural elements that are completely tensioned are catenaries and cables, but a completely tensed space structure was still missing at that time. In the middle of the 20th century, the cable net structural system was developed. It uses cables positioned in more than one direction to create a discretized tensioned surface. Shortly after, membrane structures were designed as an improvement of the cable nets.

Figure 1. *Membrane structure*

Membranes structures are space surface structures that have to be tensioned at all points at all times. In order to achieve this they have to have a double curved geometry with negative Gaussian curvature. Without external loading, membranes would also work as planar structures, but in that case the deflections of flat membranes under external loading are too high. Generally, more curvature results in less deflection [3]. In order for such tensile structure to function properly, a special material had to be developed. Two most commonly used membrane materials today are the so called PVC and PTFE membrane materials [2]. They have certain specific characteristics but basically function in the same way. These materials can resist high tension forces, but fail under compression. The thickness of membrane materials is about 1 mm only. Membrane structures tend to take the minimal surface form, which results in the minimal area of the material used for covering a certain space. This minimal surface area of the material combined with its thickness results in the least amount of the material used for covering the structure. Thus membranes are regarded as extremely economical, both in financial and energy efficiency senses. The advantage of the tensile structures is in the absence of buckling that is present in the compressed structures. The mentioned properties of membrane structures compared to other structural systems make it obvious that membranes are the state of the art in structural engineering. The only rival to membranes is the pneumatic structural system that has similar self-weight and function principles, but it is highly dependent on electricity, and thus fails short of the leading position among the structural systems.

2. LOADS AND GEOMETRY OF MEMBRANES

Internal loads are the most important loads for membrane structures. Internal tension forces introduced in the prestress stage ensure that the membrane be tensioned at all times. They are calculated so that even the worst load case will not cause compression in the membrane. External loads can be categorized as area loads or point loads, and can be divided into static and dynamic loads. Area loads have been researched a lot more in the past, since they are more common. The most frequent area loads are wind loads as dynamic loads, and snow loads as the static ones. Point loads are induced usually by workers erecting, maintaining, or repairing the membrane. They will be analyzed in the next chapter.

The geometry of the membrane is the most important factor in resisting external loads. Both internal and external loads define the geometry of the membrane, thus making it an “active form” structure. Other factors that the form depends on are the properties of the material [1] and the properties of the edge supports. The geometry defined by the internal forces and the arrangement of supports is considered to be the final geometry of the structure. It is a result of the formfinding process that is carried out by the specialized software. The external loads also affect the geometry of the membrane, but do so only temporarily, for as long as they are applied [5]. Thus these deformations are regarded only as temporary changes in the geometry of the membrane.

Traditional structural materials counteract the external loading both with their mass, and the rearrangement of internal forces. They have higher thickness and more possibilities for resisting different stress types. Their deformations under external loading are generally low, and their geometry is not important for reducing deformations. If we would compare a simple 6x6 meter membrane structure 1 mm thick, with the concrete slab of the same size, but with the thickness of 20 cm, both loaded with the same load, the difference in geometry change would be obvious. For the membrane, the changes in geometry under a certain load are in the range of 1000 times higher than for the concrete slab. The exact number is here not presented, since it is dependent on many factors, such as prestress forces in the membrane, type of edge supports, reinforcement of the slab, type of concrete, etc. In order to show the importance of geometry, one more model was created, a concrete structure 20 cm thick, but with the same geometry as the model of the membrane. The changes in geometry under the same load are about 10 times lower compared to the flat concrete slab. It should be mentioned that concrete shells never have such high thickness, and are usually up to 10 cm thick even for much larger spans.

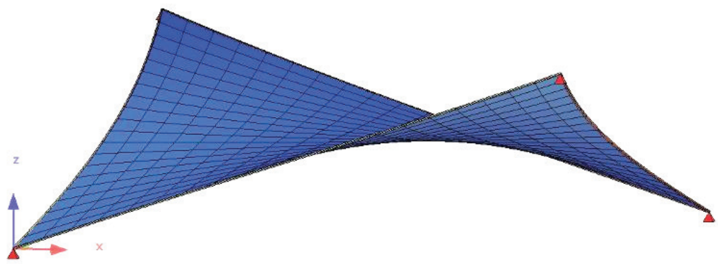

Figure 2. *Model of the membrane structure*

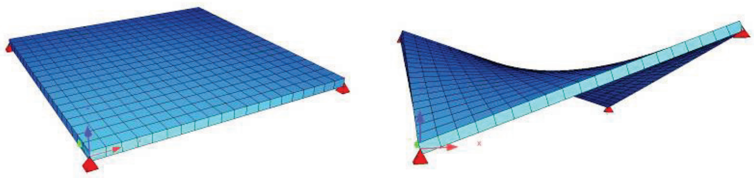

Figure 3. *Models of two concrete structures*

Since the deformations, or the changes in geometry, of membrane structures are so high, they can not be neglected. In certain cases these deformations are as high as 1/10 of the span of the structure.

3. GEOMETRY CHANGES UNDER POINT LOADS

Point loads have been researched a lot less in the past due to the fact that they occur less compared to the area loads. While these loads do not lead to high increase of internal forces, they can lead to critically high changes in geometry. Most commonly, the structures are dimensioned according to area loads such as wind or snow, and then the deflections are checked for point loads.

Point loads are usually applied with intensities up to 1 kN. However there are no standards that regulate this issue and structural engineers mostly have to rely on their own experiences. So the problem is dealt with in a case-by-case manner. The structures are usually analyzed for the expected intensities of the point loads for each specific structure. The same goes for the position of the point loads. Structures are usually checked for point loads at several distinctive points, rather than at all points on the grid. For hyperbolic paraboloid membranes, the point in the middle of the structure usually gives a good impression about the maximum deflections of the structure.

The model of the simple membrane from Figure 1 is analyzed for different point and area loads. This mathematical model was created by the software specialized for finite element analysis. The membrane is prestressed with 1 kN/m in both principal directions. The edge cables are prestressed with 20 kN, and their diameter is 20 mm. The warp and weft directions are parallel to the edges. The high points are at 2 meters above the low points. Elastic modulus of the membrane in warp direction is 500 N/mm^2, and 375 N/mm^2 in weft direction. The Poissons ratio is 0.2, and the shear modulus is 5 N/mm^2. The results showed that the point load with intensity of 1 kN in the middle of the structure has almost the same maximal change in geometry as the area load of 0.3 kN/m^2 over the whole structure. In both cases the maximum change is at the middle point of the structure, and it is about 300 mm.

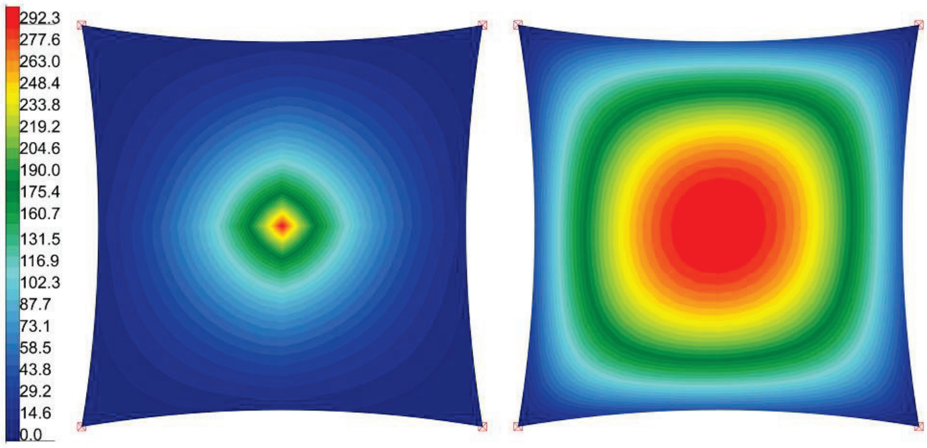

Figure 4. *Deflections under point load of 1 kN and area load of 0.3 kN/m^2, on the same color scale (in mm)*

The area load of 0.3 kN/m^2 can also be regarded as a load of about 10 kN spread over the whole structure. This basically means that the loads of 1 and 10 kN have very similar maximal deflections. The only difference is that in one case the load is concentrated in one point, and in the other it is spread over the whole structure. Of course, the deflections of other points of the structure are not the same, and will be much higher under the area load. The changes of position of nodes under point and area load are shown in Figure 4.

Applied external loading changes the position of all points of the membrane thus changing the whole geometry. It is important to mention that the relation between the intensity of the load and the intensity of deflections is non linear [6]. The model of the membrane from Figure 1 is used to show this relation. At the middle point of the structure, the point loads with intensities ranging from 0.1 to 1 kN, with step of 0.1 kN were applied. The maximal deflections were recorded. The result data is shown in Figure 5. The consequence of such non linear relation is that the resulting deflections under loads could not be superimposed. A similar relation applies to all other points of the structure. Even the points that are not loaded show the same behavior, but with much smaller changes in position.

Simultaneous loading of several point loads results in much more complex changes of the geometry of the structure.

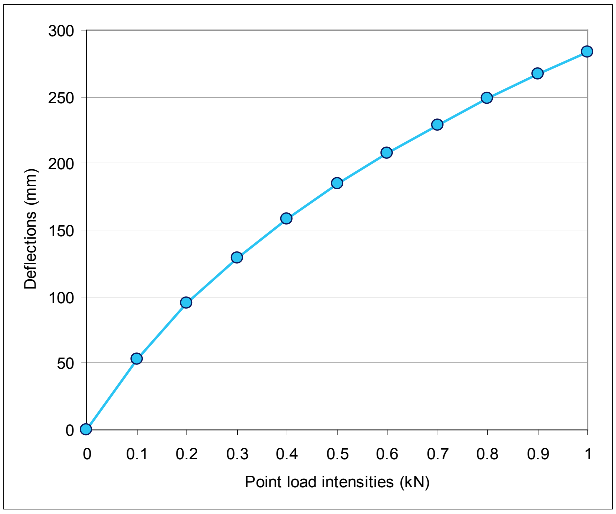

***Figure 5**. Deflections of the middle point under different point loads*

There is one more, and probably the most important difference between the effects of area loads and point loads. As previously mentioned, area loads result in deflections that are evenly spread out across the structure, while the deflections of point loads are highly concentrated around the position of the load. Both change the geometry of the structure, but the area loads do not change the character of the form. On the other hand, point loads create geometry that is no longer the regular double curved with negative Gaussian curvature. The area around the position of the point load becomes a cone-like form. Viewed independently, this form is also double curved with negative Gaussian curvature, but the principal curvatures have the opposite signs compared to the original structure. This area can create a problem for the entire structure, since it might cause ponding that can be fatal for membrane structures. Further research on the issue of this form deviation from the original form is needed. The size of the area around the point load, which shows irregularities in form, is directly dependent on the intensity of the point load and the properties of the material. This relation needs to be precisely defined. The changes in geometry under the point load applied at the middle point are shown in Figure 6. Vectors are showing the displacements of points from the original to the deformed structure.

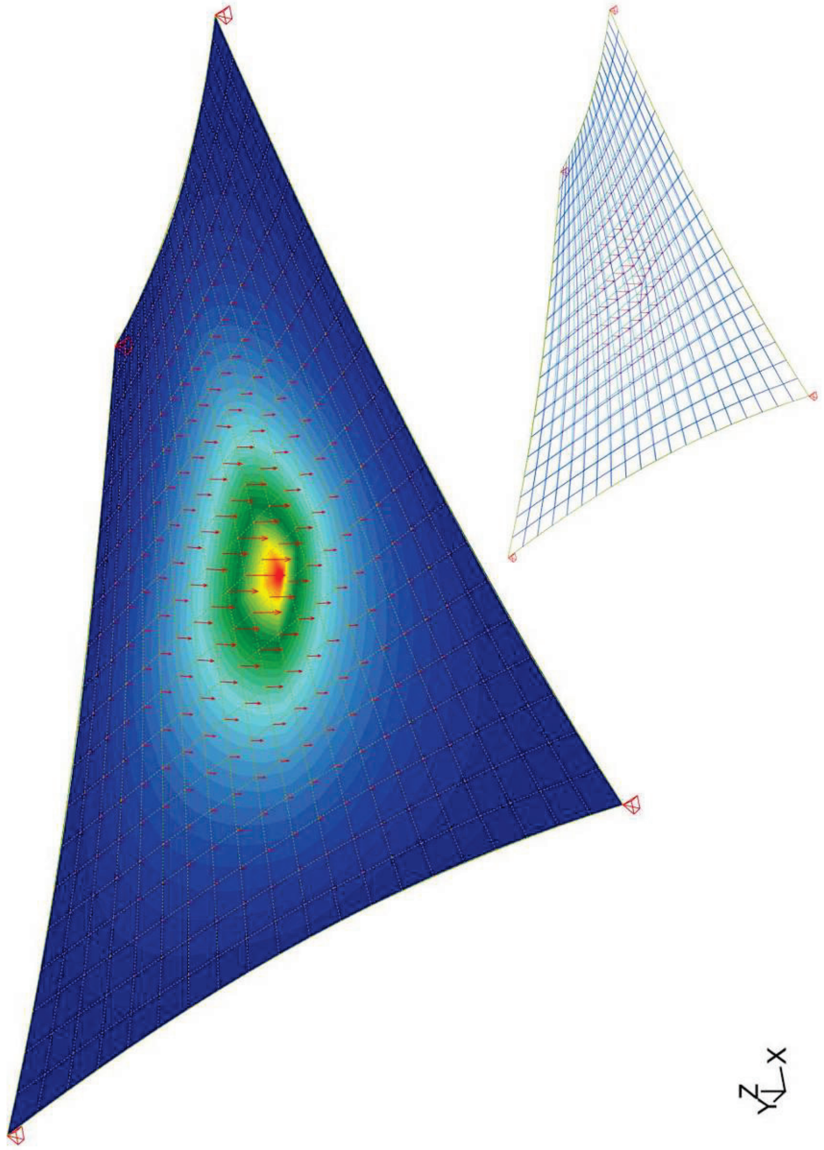

Figure 6. *Change in geometry of membrane under point load: colored and wireframe*

4. CONCLUSION

Point loads have so far been often neglected in research of membrane structures. Although they do not occur as frequently as area loads, they are important for membranes. Their most significant impact on the membranes is in the change of geometry of the structure.

This paper deals with different aspects of point loads and their application to membrane structures. In the first part, the comparison between the area and the point loads is made. The results of the changes in position of all points of the structure and thus the geometry of the structure are shown. While the area loads have a global effect on the geometry, the point loads induce changes locally. The relation between the intensity of the point load and the maximal changes in geometry is shown on one example. For this purpose, a mathematical model of the membrane structure was created, and experimentally tested in finite element software Sofistik. The analyzed relation is non linear. Finally, the most important effect of point load application is presented. Point loads produce a deformation on the form of the membrane that is not in line with the geometry of the structure. This deviation has a different curvature compared to the initial geometry, and may have very negative effects on the overall structural stability. The problem of geometry changes under point loads is pointed out in this paper, but it needs to be further researched. The issues that need to be precisely defined are the area of this deviation and its dependence on the load intensity, its geometry and the eventual threats to the structure.

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ABOUT DESIGNING THE GEOMETRICAL SHAPES OF MULTI BODIES SOLIDS

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Dragos Popa [3]

Abstract

The products, regardless of their type, shows a high variety of forms. Initially, the product designing and manufacturing requires a rigorous analysis of the geometric shapes. No matter how complex is the shape of an object, it can be decomposed into basic geometric shapes.These forms can then be joined together resulting in a complex object shape or a multi body. This paper presents aspects of getting in shape parameterized multi bodies using info graphics techniques. Are used a series of operations such as Boss and Cut Extrude, Boss and Cut Revolved, Boss and Cut Sweep, Cut Loft, Thinken Cut, Cavity. They presented different modeling techniques and examples used in the present technique of SolidWorks: Bridging, Local Operations, Boolean Operations, Tool Body, Patterning, Weldments.

Key words: *info graphics, 3D shapes, multi body solid, virtual prototype.*

1. INTRODUCTION

Modern society is characterized by a highly competitive environment in the development of new products. Customer needs, with an emphasis on techniques such as quality and price, is deployed

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to assist in finding customer needs and help them achieve a company still at the design stage.

Organizations depend on their customers and should understand current and future customer needs, meeting customer needs, have concerns for exceeding customer expectations. With the development of human society and the evolution of knowledge to science and engineering, has been outlined and then grew the need for a synthetic descriptions, clear and unambiguous to the shape and size of objects in the real world, and that the human mind has devised and which man has decided to produce them for the convenience of his life.

The study of new disciplines have to permit the elaboration of models and theories more and more close to reality, reaching today at Virtual Prototyping and Instrumentation. A bigger calculation power permits new simulation, processing, control, tele-connection, etc capabilities in different domains, materialized by new product, more and more intricate, personalized, and multifunctional. A second more quickly in market means tremendous today. A product, regardless of their type, shows a high variety of forms. Initially, the product designing and manufacturing requires a rigorous analysis and geometric shapes.

No matter how complex is the shape of an object, it can be decomposed into basic geometric shapes.

2. CONTENTS

The multi body solids are the pieces that contain more than one solid. For the design of the pieces which requires some separation distances between solids are used multi bodies techniques. The advantage consists in the fact that these bodies can be accessed and modified separately and then be subsequently joined into a single body.

For the creation of the multi body solids can be used a series of options which can create a several solid bodies with one operation. The commands which have the option of creating multi bodies are Boss and Cut Extrude, Boss and Cut Revolved, Boss and Cut Sweep, Cut Loft, Thinken Cut and Cavity.

Are presented a few efficient techniques for the realization of multi bodies models.

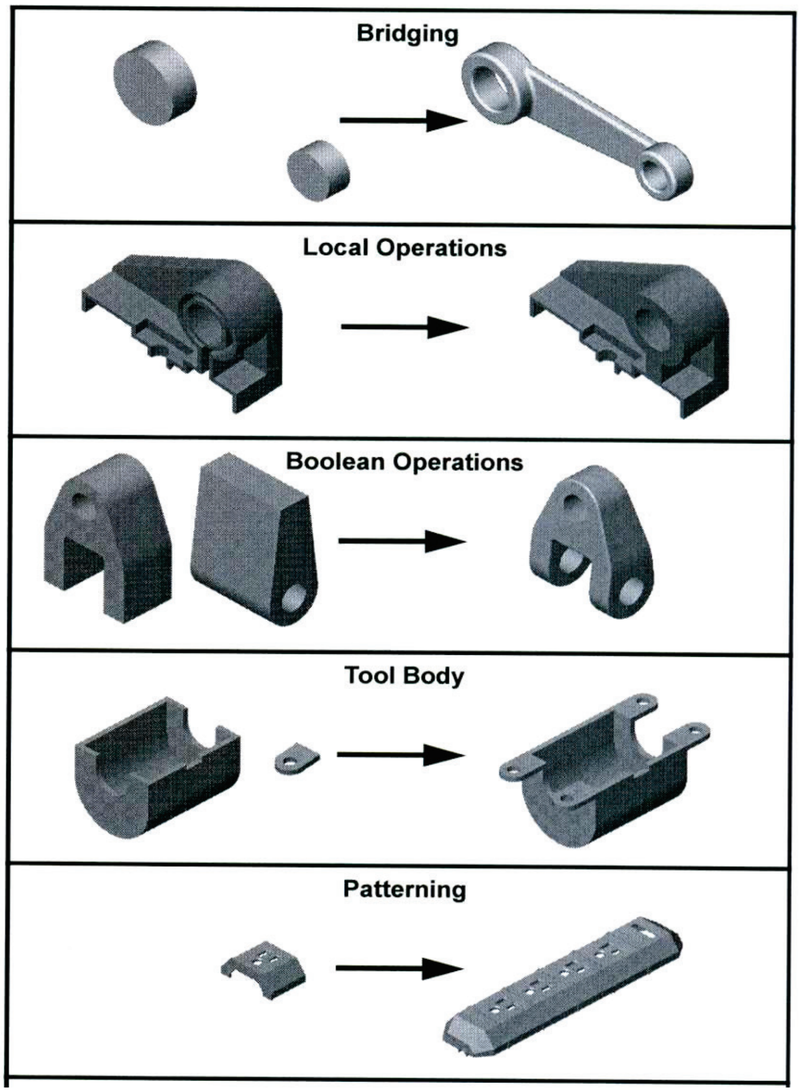
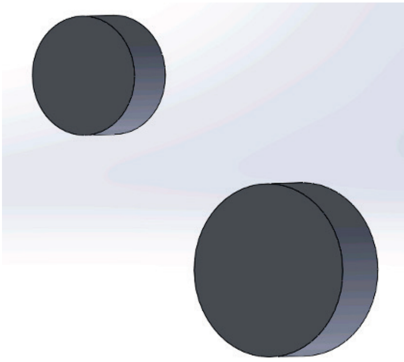


Figure 1. *Multi bodies technicques*

The **Brinding** technique is used for the construction of connecting geometry between many bodies. A multi body is created when a few bodies are connected and joined by a new operation Boss. Successively were created two pieces of cylindrical form. The two Boss operations were created without intersecting and were saved as multiple bodies. The Merge box remains selected by default and the bodies will unite if the body will intersect due to the subsequent changes.



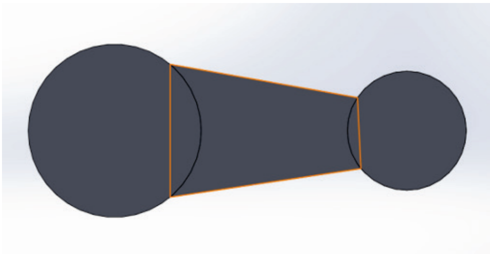


***Figure 2**. Too cilinder* ***Figure 3**. Cylinder with connation*

The file created contains all the body of the piece and each body can be hidden in this file. The two separate cylinders were connected through a Boss operation.

Finally were made the final forms of the piece with Fillet of 3 mm, Cut Extrude the hexagons s1 = 14, s2 = 24 and chamfer of 1.5 mm.

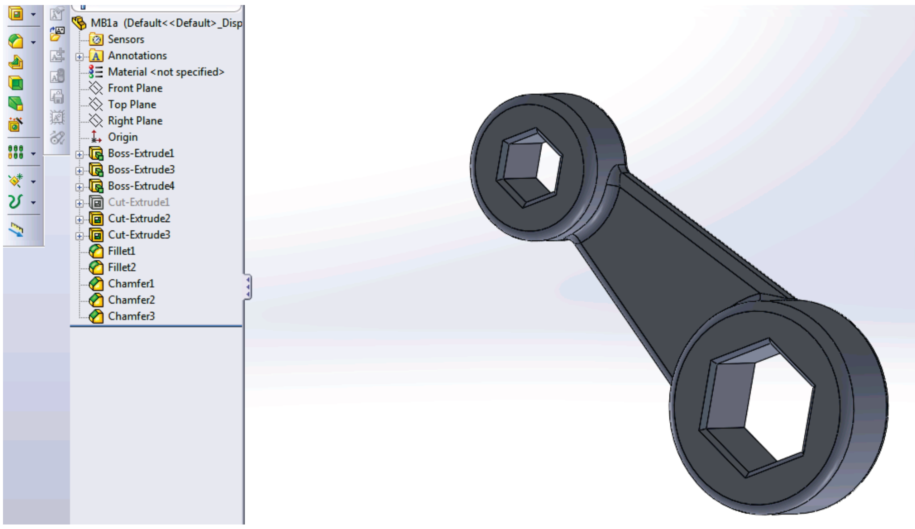


***Figure 4**. Multibody final*

Modifications can be made separately on any component, for example on the edge where exaggerated the dimensions were modified at one end (Fig.5)

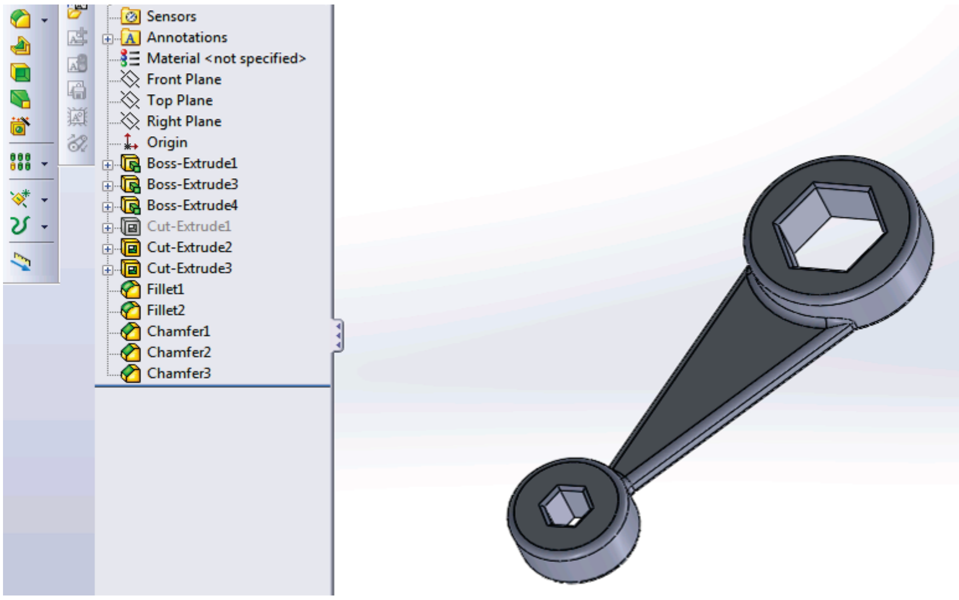


Figure 5. *Modify Multi body*

The **LOCAL OPERATIONS** techniques is used to modify a solid body without changing the other body.

The most representatives cases are the variations of the Shell operations.

The Shell operations affects in implicit mode all the operations of the solid bodies. Using Merge result and Combine can be changed only a part of the piece.

The **Combined Bodies** operations is used to create a single solid through the adding, extraction and intersecting the volumes of the solid bodies.

The Tool Body technique is used to add or cut volumes using special instruments (Insert Part, Move/Copy Bodies, Mate References, Bodies to Pattern, Mirror).

Patterning is used to help the creation of pieces using pattern operations. With this Technique the solid bodies and not the operations are patterned and combined.

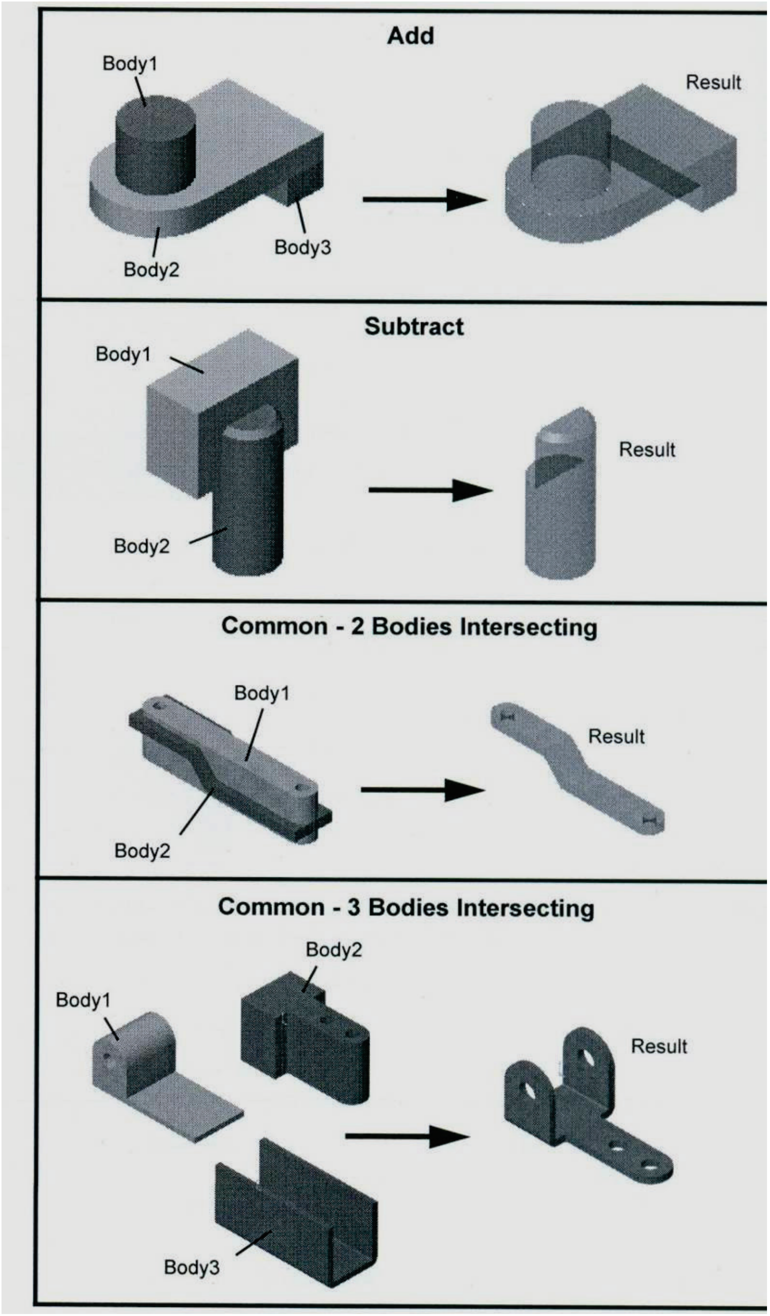


Figure 6. *Combined Bodies Operation*

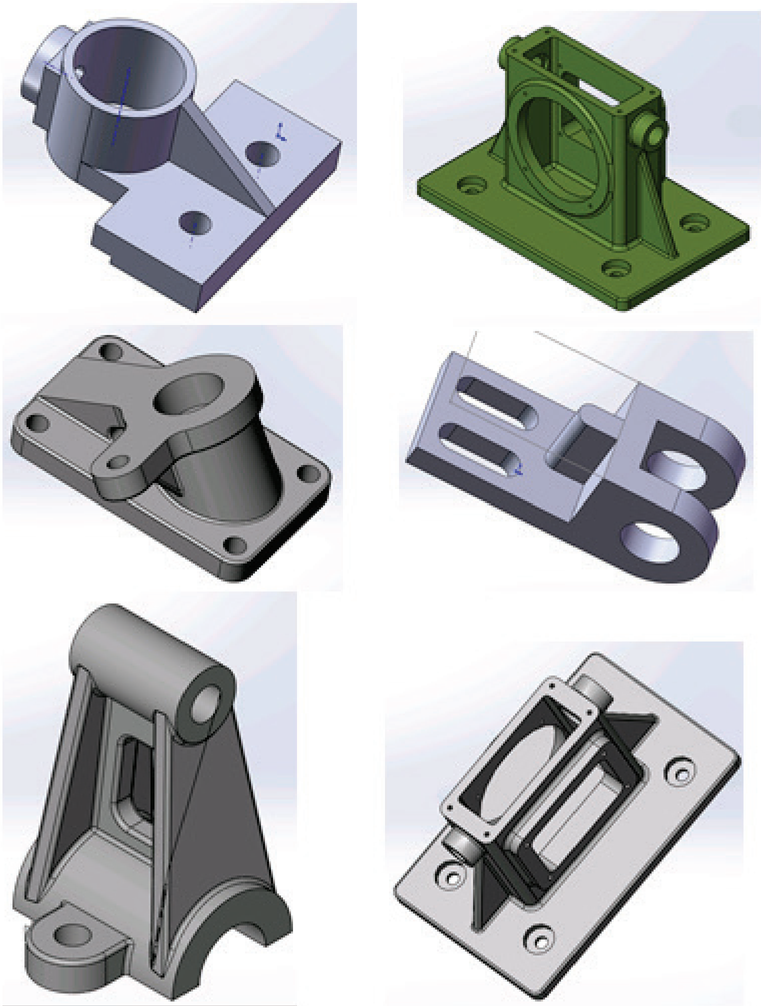


***Figure 7**. Examples of multi bodies*

3. CONCLUSIONS

The success on market is conditioned by the product capacity to satisfy a necessity, conditioned in its turn of the understanding level of the buyer. In present, CAD – Computer Aided Design is more and more used in the different domains and according the specialists opinion this technology reached its maturity.

The recent transformers of the main CAD systems prove that the CAD domain is being in a full evolution. This regards not only the general architecture and the addition of new modeling instruments and functions in the existent design systems, but also their possibility to create not only simple 2D sketches with hachure and dimensions, but also and geometric models and surfaces, based on parameters indicated by designer engineer. Many of the used programs permit the conception of the pieces and assemblies directly in three dimensions; without to draw, first of all, drawings in bi-dimensional representation offering a large variety of integrated solutions to satisfy all aspects about design and manufacturing. To shorten the perfection time of the product, the project evaluation have to made more quickly, the results have to be directly incorporated in the design process. In this sense, it has to see the importance of the design intention in the conception and design of objects using technologies of multi body. One or more solid bodies in a multi body part can be saved as separate pieces. They can be used to generate specific commands to other assemblies.

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SOFTWARE TOOL FOR 2D AND 3D VISUALIZATION OF REQUIREMENT INDICATORS IN COMPRESSION EVALUATION FOR PACS

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Veljko B. Petrovic[2]
Dragan Ivetic[3]

Abstract

This paper presents the continuation of our work on developing a web based software tool for visualizing the multidimensional quality evaluation space. The software tool is based on the LiveGraphics3D Java applet, JavaScript, and HTML. It is used to visualize requirement indicators and to support decision making process during PACS installation. Requirement indicators point out whether a compression technique fulfils PACS requirement or not. We expand the software tool to support two-dimensional and three-dimensional graphics and dynamic content presentation. Thanks to dynamic content presentation it is possible to accommodate different two-dimensional and three-dimensional evaluation spaces adjusted to different PACS requirements. In the paper we describe the use of the proposed software tool and how it can be expanded and improved even further.

Key words: *data visualization, data visualization software tools, 2D graphics, 3D graphics*

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1. INTRODUCTION

An important issue in evaluation of still image compression in PACS (Picture Archiving and Communication System) is visualization of the results [5]. Conclusions on still image compression acceptance for a given PACS are drawn based on the visualization of the results.

Often there is a need to choose an appropriate medical image compression for a given PACS [1, 2]. We have developed a modular multidimensional quality evaluation system to assess if a still image compression is acceptable for a given PACS. We named it the SICEP system (Still Image Compression Evaluation for PACS). Multiple individual metrics are grouped into requirement indicators, forming a multidimensional evaluation space in which measured values are analyzed numerically and graphically. Two-dimensional (2D) and three-dimensional (3D) parallel coordinates are most often used to visualize multidimensional data [8]. SICEP system supports result visualization using both types of parallel coordinates [3].

We searched for a graphical environment that would allow us to build a software tool for 2D and 3D visualization of requirement indicators in compression evaluation for PACS. The environment should support mouse manipulation, zooming, rotation (low/high overview of graphical representations), 2D and 3D representation, dynamic content presentation, and should be simple to implement. We found this environment in the LiveGraphics3D Java applet [3].

A simple prototype of the software tool implemented using the LiveGraphics3D applet has been described in [3]. It supported only static 3D content presentation meaning that graphical representations have been coded inside HTML. In this paper we report an extension of this prototype, the SICEP software tool. It supports 2D and 3D graphic representation and dynamic content presentation based on descriptions contained in XML files. All of the LiveGraphics3D features [6] are also included such as user adjustable viewpoint and magnification, mouse interaction, automatic update of mathematical expressions, hidden surface and line rendering, etc.

The organization of the paper is as follows. A short background on result visualization in still image compression evaluation for PACS is summarized in Section 2. Overview of the SICEP system is given in Section 3. The SICEP software tool is described in Section 4. Section 5 concludes the paper.

2. BACKGROUND

We identified more than 250 individual metrics used to evaluate still image compression quality [1, 2]. Only a small subset of these metrics is used combined for evaluation. The results are presented using tables with numerical data and visualized using correlation, line, and/or bar diagrams. For example, in [7] correlation diagram is used to visualize the correlation between the compression ratio (CR) and the time needed to losslessly compress several medical images, Figure 1.

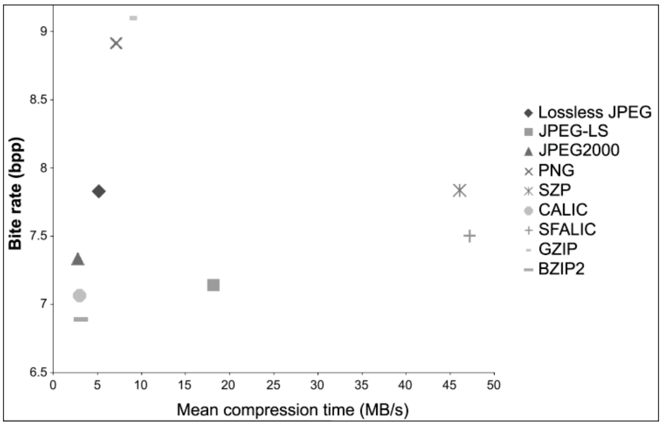

***Figure 1**. Correlation diagram used in [7]*

However, even when more individual metrics are used, the results are usually visualized in pairs. Most often a separate diagram is used for correlating CR to every other metrics. Sometimes these diagrams are showed as scatter plot matrix [9]. The SICEP system integrates more than 10 individual metrics in several requirement indicators. Thus more than ten diagrams should be analysed. Also it is possible, and often necessary to visualize the correlation between other pairs of individual metrics rather than to show only the correlation to CR. This increases the number of 2D diagrams needed. For example, it is possible to use 4 metrics to evaluate lossy image compression quality: PSNR, SSIM, ROC, and CR. For such an evaluation system, six 2D diagrams are needed to visualize all the correlations.

The diagrams mentioned in previous paragraphs are not suitable for the SICEP system. They contain too many seemingly independent diagrams that contain too much information to process. Connections between the measured values are easier to observe if they have been shown on the same diagram [5].

3. THE SICEP SYSTEM

An overview of the SICEP system and the mathematical model that it is based on are described in [4]. In short, a set containing all of individual metrics (more than 250) is projected onto a smaller sets needed to evaluated if a still image compression fulfils an individual PACS requirement. The smaller sets of individual metrics are called requirement indicators. There are several PACS compression requirements that are compiled before the evaluation process. These requirements are different for different PACS implementations. Number of requirement indicators equals the number of requirements.

Each requirement indicator forms a subspace inside the multidimensional evaluation space. Each individual metric forms a dimension of the subspace. Depending on the level of details of SICEP system the requirement indicators are visualized conjunctively or separated. There are three levels of details in SICEP system:

1. *Overview level*, enables visual composition of requirement indicators without many details.
2. *Indicator level*, enables visualization of single requirement indicators or their comparison.
3. *Detail level*, tables containing numerical values are presented with all the measured values for all the individual metrics.

Before they are visualized, measured values are normalized to interval *[0,1]*. This achieves equivalence between the dimensions and brings them all into proportion with one another. A measured value is considered acceptable if it is bigger than some predefined threshold. Each individual metrics has to reach a different threshold which depends on a given PACS.

The requirement indicator could be visualized using 2D parallel coordinates [9], Figure 2b, and/or extended CMRP coordinates (Clustered Multi-Relational Parallel coordinates [5]), Figure 2a. In both figures, $\boldsymbol{P_{roi}^{6}}$ requirement indicator is visualized. This requirement indicator is used to assessed if a still image compression supports region of interest (ROI) coding in acceptable manner. Six individual metrics are used to assess acceptance: PSNRb and SSIMb for assessing presentational-objective quality of decompressed image background, PSNRroi and SSIMroi for assessing presentational-objective quality of decompressed ROI, ROC for assessing presentational-subjective quality of the entire decompressed image with ROI, and CR. Different levels of gray are used to visualize if measured values are acceptable or not. A still image compression is acceptable only if all of the measured values are acceptable.

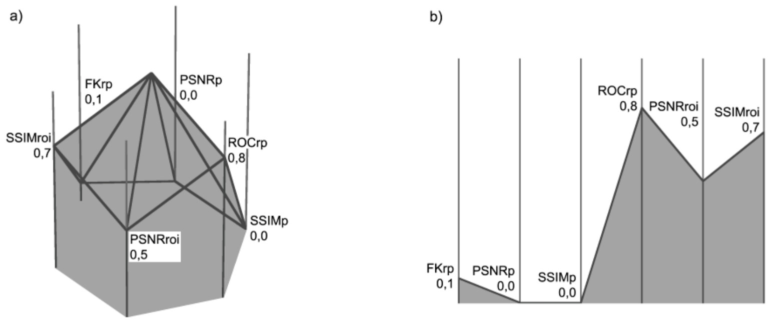

Figure 2. *An example of a requirement indicator visualization*

In the SICEP system the parallel coordinates or extended CMRP coordinates are used to visualize the requirement indicator — *indicator view* — while the parallel coordinates are used to visualize results of several image compressions simultaneously, *comparison view*. These two views are included in the SICEP software tool. The extended CMRP coordinates are used for visualization at the *overview level*.

LiveGraphics3D is a non-commercial Java 1.1 applet [6]. It supports display and rotation of three-dimensional graphics described by Mathematica code. LiveGraphics3D supports animations, stereo graphics calculation, basic mathematical notations rendering, bitmap backgrounds, and parameterized graphics. It is possible to use simple Mathematica expressions instead of coordinates which is described in more details in [3]. The description can be predefine or it can be generated dynamically using JavaScript [3].

4. THE SICEP SOFTWARE TOOL

The SICEP software tool is based on Web technologies. Results are spread over several HTML pages. Beside the LiveGraphics3D, HTML and JavaScript are used for content generation and presentation. After the introductory page, the *overview level* of the SICEP system is presented for all the still image compressions evaluated, Figure 3. The first page of the SICEP system remained the same as described in [3]. The SICEP software tool is implemented in the Serbian language and thus all the text in Figure 3 is in Serbian.

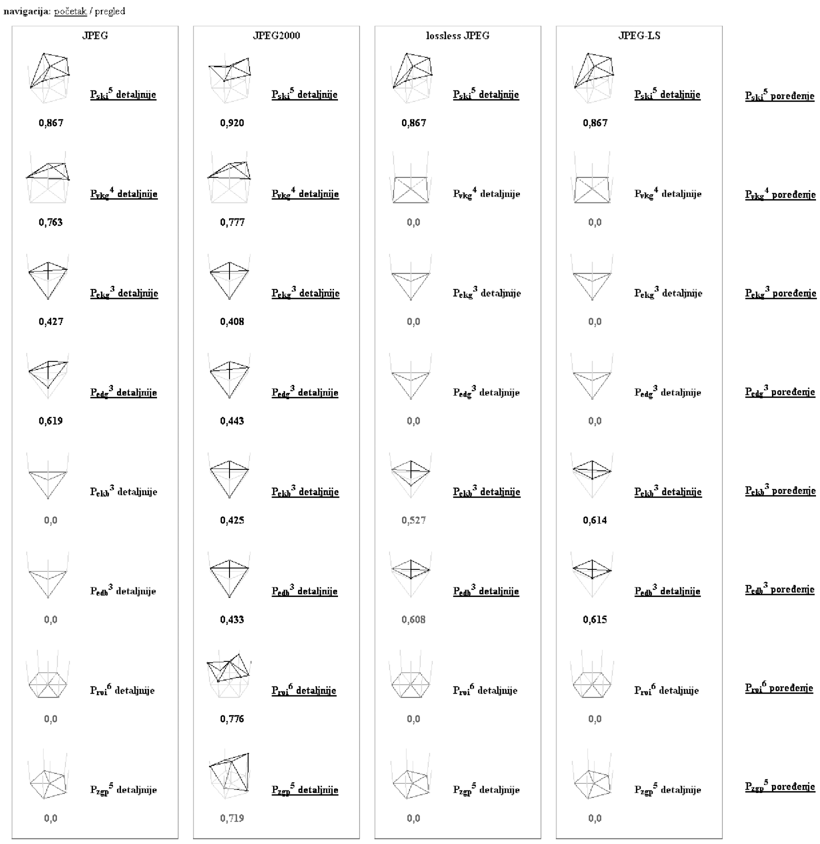

Figure 3*. The overview level in the SICEP software tool*

The results from Figure 3 show actual values obtained from literature for JPEG, JPEG2000, and JPEG-LS still image compressions applied on medical images. The mark which expresses the acceptability level of the compression evaluated is shown below each of the requirement indicators. Only, the most obvious things could be observed on this level, such as if a compression is acceptable or not and if a compression feature is supported. If a figure formed by measured values is flat, the compression feature is not supported. Values of the individual metrics are not included. There are eight requirement indicators. The number of requirement indicator could change depending on the PACS installation and requirements.

From the *overview level*, it is possible to choose one of the two views for the *indicator level*: *indicator view* (*detaljnije* links) or comparison view (*poređenje* links). The *Indicator view* of the SICEP software tool is shown in Figure 4. Which model of representation is used (parallel coordinates or extended CMRP) depends on the configuration loaded during dynamic content generation. We intend to extended this feature to be user defined.

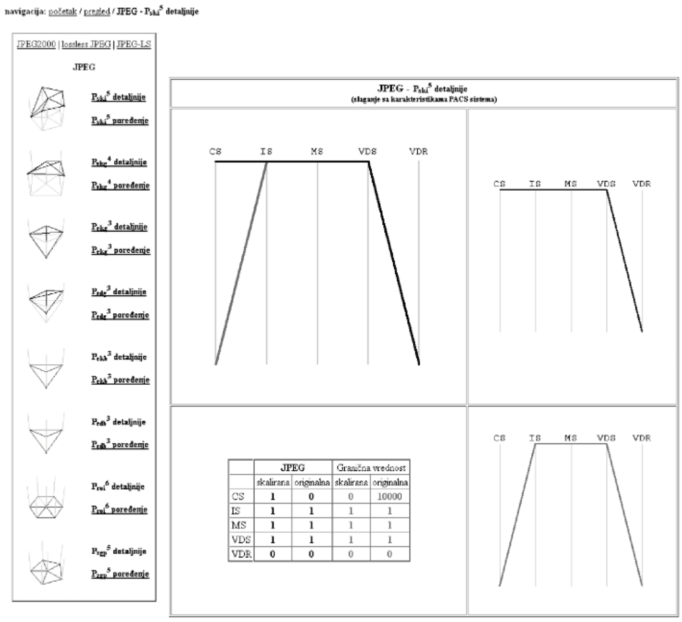

Figure 4. *Indicator view in SICEP software tool*

This page contains two parts. First part of the page contains navigation to the other *indicator views* (*detaljnije* links) and *comparison views* (*poređenje* links) of still image compressions evaluated. Second part of the page contains the visualization of the measured values. There are three views: measured values and threshold shown together and separately. Also all of the measured values and the thresholds are displayed in a table which is included to increase the informational value of the visualization.

In the example in Figure 4, 2D parallel coordinates are generated based on XML description. The same description is used to generate extended CMRP coordinates. Only the JavaScript functions and Mathemtica syntax are different. For example, the first 3D object in top left corner of Figure 3 is generated using the same XML description used to generate diagrams in Figure 4.

When using 2D graphics in 3D graphical environment there is a probability that users could unintentionally rotate 2D diagrams. Rotation of 2D diagrams could diminish the visualization value of diagrams because parts of the diagram could become invisible. Due to changes in the viewing angles, this diagram would deform and it would be hard to interpret the results. Fortunately, LiveGraphics3D has an option to disable rotation. It is only necessary to set MOUSE_DRAG_ACTION property to NONE [6].

The comparison view is used to show the comparison between values obtained from different compressions for the same requirement indicator. Two-dimensional parallel coordinates are used to visualize and compare the results, Figure5. This Web page is also divided in two parts. The left part contains navigation to the other Web pages of the presentation. The right part of the Web page contains the actual comparison of the measured values.

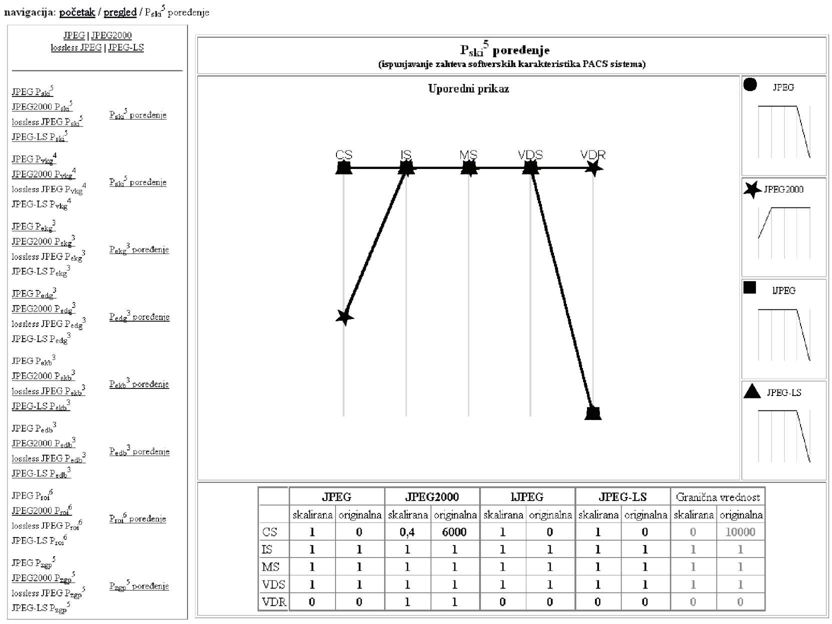

Figure 5. *The comparison view in the SICEP software tool*

JavaScript code is used to generate the LiveGraphics3D graphics based on a description contained in an XML file. Example of the XML file is shown in Figure 6. The XML file contains the description of the requirement indicators, labels that should be presented, the threshold values, and whether a *indicator view* should be visualized using 2D parallel coordinates or extended CMRP coordinates. Different JavaScript functions are used to generate 2D and 3D graphics for requirements indicators containing 3, 4, 5, and 6 individual metrics. Base coordinates remain the same, only measured values differ. Number of coordinates is equal to the number of *element* fields from the *request_indicator* field in XML file.

```
<sicep version="v1">
    <request_indicator name="ipSKI">
        <element name="CS">
            <acceptable original="10000" scaled="0"/> <acceptable>
        </element>
        <element name="IS">
            <acceptable original="1" scaled="1"> </acceptable>
        </element>
        <element name="MS">
            <acceptable original="1" scaled="1"> </acceptable>
        </element>
        <element name="VDS">
            <acceptable original="1" scaled="1"> </acceptable>
        </element>
        <element name="VDR">
            <acceptable original="0" scaled="0"> </acceptable>
        </element>
    </request_indicator>
    <request_indicator name="ipVKG">
        ...
</sicep>
```

Figure 6*. Simplified example of an XML file containing description of the requirement indicators that form the multidimensional evaluation space*

Additional adaptability is achieved with the measured values contained in an XML file similar to the one shown in Figure 6.

5. CONCLUSION

In this paper we described the SICEP software tool companion to the SICEP system used for still image compression evaluation for PACS. This tool is based on the LiveGraphics3D applet, HTML, and JavaScript. Visualization using 2D parallel coordinates and extended CMRP coordinates is supported. The *overview level* and the *indicator level* of the SICEP system are both implemented. Requirement indicators are generated dynamically using XML descriptions and currently support visualization of requirement indicators that contain 3, 4, 5, and 6 individual metrics. The system is easy to implement and maintain.

For future work we plan to upgrade this SICEP software tool to enable users to describe their evaluation. Users could define the number of still image compressions tested and they will insert the measured values during SICEP software tool start-up. Also we plan to implement the software tool using some other Web based visualization tool [3], such as X3D or HTML5, and to test which solution is better.

ACKNOWLEDGMENT

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GEOMETRY OF GOLDEN RATIO IN ARCHITECTURE

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Abstract

The architecture has always searched for the perfect dimensions and ideal proportions. The man is a subject who designs and at the same time an object for whom it is designed. Everything that is done in the architecture, it is done for him, ie. must meet his needs, and therefore must comply with its dimensions. Various studies of human body shows that its parts are in relation that corresponds to the ratio of edges in golden rectangle. Starting from ancient times to the present day, it is possible to find many examples of architectural structures in which can be recognized the elements of geometry of golden section. This kind of architecture has always been well accepted by people and always seemed harmonious. The question is whether the reason for this is that the geometry is in accordance to the geometry of the human body? This paper deals specifically with this issue, and finds and analyzes examples of buildings in which it is possible to spot golden ratio elements. Special emphasis is placed on examples of modern architecture. The methods applied in this paper are analysis, synthesis, description and comparison.

Key words: *golden ratio, proportion, architecture, geometry*

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1. INTRODUCTION

In ancient times it was believed that the golden ratio is God's gift. In this regard, it was also believed that buildings with some elements that have features of golden ratio, have a special impact on the people who are in them. Ancient architects thought that rectangular buildings with dimensions that specified golden section, have remarkable aesthetic appearance. It can be said that the contemporary architects share a similar opinion. Respectively, they also believe that the properties of the golden section contribute to a more beautiful and harmonious appearance when it comes to buildings.

The following paper will expose some important attributes of a golden section. Through the analysis of constructed facilities will be found a relationship between the geometry of the golden section and architecture. The examples used in this paper are presented chronologically from ancient times to the modern era. Architecture has always strived to get closer to the man, because it is primarily intended for him. One of the ways to achieve this, is geometry. Observing the forms of nature, man has understood that there are certain regular relations and harmony of parts of the form and that those parts are, how it has been considered, in perfect natural or God-given ideal ratio and proportion. Many mathematicians, philosophers, scientists and researchers, starting from the ancient Greeks (Euclid, Phidias, Pythagoras ...), to Vitruvius, Fibonacci, Leonardo da Vinci, Le Corbusier and others have dealt through the history with secrets of geometry and proportions of human body. They came to amazing conclusions, which are associated with the golden ratio. Those conclusions had a great impact on architecture.

2. DEFINITION OF GOLDEN SECTION

First of all, we should mention the definition of the golden section: If line segment AB is divided with point C in a way that a larger cut-out represents geometric mean of line segment AB and smaller cut-out, ie. AC: AB = BC: AC, then we say that was made a golden section of line segment AB.[1] In other words, the golden section is the ratio in which the larger segment relates to the smaller segment as well as the whole line segment to the larger segment. The division of line segment according to the golden section is graphically shown in Figure 1.

Mathematically, the golden ratio can be expressed in the following way:

$$a:b=(a+b):a, \text{ or, } a^2=b(a+b).$$

If a=1, then b=0.618 which means that the length of the whole line segment a+b is 1.618, which is the golden ratio or golden mean, which is designated by a golden number ϕ - phi[1]. Numerical value of ϕ is approximately 1.6180339887499…or rounded 1,618.

Figure 1. *Division of the line segment according to the golden section*

The term golden ratio can indicate a point that divides line segment into segments that have above mentioned relation, but it can also mean ratio or proportion.

2.1. The construction of golden section

The simplest construction of a golden section is given in Figure 2, and can be done in the following way:

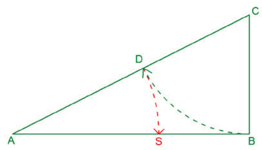

Figure 2. *The construction of golden section*

- First, the segment AB should be divided into two equal parts.
- From the point B should be withdrawn vertical segment BC which is equal to the half of the segment AB, and then points A and C should be connected.
- From the point C as a centar, should be drawn arc with radius equal to CB, from point B to the intersection with the AC at point D.
- From the point A as a centar, should be drawn arc with radius equal to AD, from point D to the intersection with the AB at point S.
- In this case, the point S divides the segment AB into two parts which are in the golden ratio.

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[1] in the honor of the Greek sculptor and architect **Ph**idias.

There are numerous ways to construct a golden section. Further in the paper are shown some of them. For example. golden ratio can be constructed using the bisectors of the angle, as shown in Fig. 3

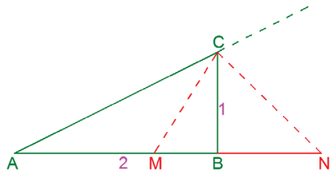

Figure 3. *Constriction of the golden section with angle bisectors*

First it is constructed a right-angled triangle ABC with cathetus 2 and 1. Based on a theorem on harmonic division of a line, which says that bisectors of the inner and outer corners of some vertex of a triangle, divide opposite side into parts that are proportional to the respective remaining sides of the triangle, follows:

$$MB:MA=BC:AC$$

or

$$MB:MA=1:\sqrt{5}$$

Since the MB+MA=2, it follows MB=2/(1+:$\sqrt{5}$)=0.618, respectively MB=ø.

Based on a theorem on the length of the height of a right-angled triangle, since the triangles ABC and CBN are similar, follows:

$$BC=\sqrt{MB*BN}$$

$$1=\sqrt{ø*BN}$$

$$BN=1/ø=\varphi$$

Golden Section through Heron's construction can be done in the following way (Figure 4): First construct the circle k with a diameter equal to the segment AB and which touches the line AB at point B. Then, withdraw the line that contains point A and the center of the circle C. Find a point G that belongs to the segment AB and the circle with center at point A, which touches the circle k.

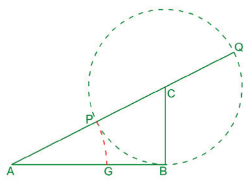

Figure 4. *Heron's construction of of the golden section*

If it is assumed that AG=1 and AB=a, it follows:

$$AC^2=AB^2+BC^2$$

or:

$$(1+a/2)^2 = a^2+(a/2)^2$$

The further rearranging leads to the following equation:

$a^2-a-1=0$, whose only positive solution is φ.

Golden Section is also possible to construct using a circle and a square (Fig. 5).

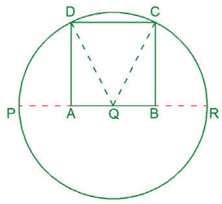

***Figure 5**. The construction of the golden section with a circle and a square*

If ABCD is a square with a side length of 1, then the diameter of a circle with its center at the point Q (the midpoint of AB) and which contains the vertices of the square C and D, is equal to $\sqrt{5}/2$. That means PQ $=\sqrt{5}/2$, which implies :

$$PB=PQ+QB=\sqrt{5}/2+1/2= \varphi$$

On the other side:

$$PA = PQ-AQ=\sqrt{5}/2-1/2= ø$$

Based on the above: $AB^2=1=PB*AP$, respectively, point A is the golden section of line segment PB. For the same reason, it follows that B is the golden section of line segment AR.

2.2. Construction of a golden rectangle

The ideal rectangular area is one in which the ratio of length to width is equal to ϕ = 1,618. This is the most harmonious rectangular shape that is most commonly used and it's called the Golden Rectangle or Auron.

So, the golden rectangle is one whose sides are in relation 1: φ. If the golden rectangle divides into square and new rectangle, sides of new rectangle will also be in ratio of 1: φ, because those rectangles are similar.

Euclid defined the golden ratio using the term division in the middle and final scale, where he talked about line division where:

$$GB*AB=AG^2$$

or:

$$AG:GB=AB:AG$$

If GB=1, AG= φ, then follows:

$$\varphi=(\varphi+1)/\varphi,$$

wherein is obtained the well known equation:

$$\varphi^2-\varphi-1=0$$

Golden rectangle is constructed from squares in the following way (Figure 6):

- construct a unit square,
- draw the line - a diagonal from the middle of one side in a opposite corner,
- use that line as the radius and draw an arc that defines the longer dimension of the rectangle,
- construct rectangle.

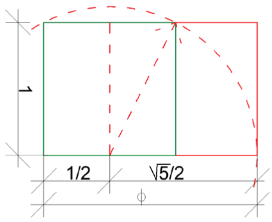

Figure 6. *Constriction of the golden rectangle*

2.3 The construction of the golden spiral

Golden spiral is based on the Fibonacci series of numbers and it's common form in nature (snail, arrangement of seeds in plants ...). Consecutive points that lie on the long edge of the rectangle and that participate in the division of the golden rectangle to a square and a new golden rectangle lie on a logarithmic spiral, which is called the golden spiral. The construction of the golden spiral is presented in Figure 7.

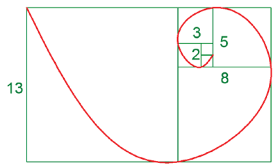

Figure 7. Construction of the golden spiral

3. HISTORICAL REVIEW

When exactly is discovered golden ratio is not known, but it goes through the history for a long time. Some people believe that the ancient Egyptians knew of his characteristics of golden ratio and that they applied it during the construction of the pyramids. It was observed that the ratio of the length of the side and the height of the Great Pyramid is approximately equal to the golden section. However there is no evidence that the ancient Egyptians knew the golden ratio, and this statement can be treated only as a coincidence.

The ancient Greeks certainly studied the golden ratio. Many of the buildings on the Acropolis of Athens contains elements of these proportions. The overall appearance of the Parthenon is based on the golden section.

The first definition of the golden section (although this term at that time did not exist) was given by Euclid around 300 BC, in his book The Elements. He defined the division of line segment that fits golden ratio as the division of the middle and final scale. Using this knowledge, later, in his fourth book Elements, he gives the construction of the golden triangle[1].[2]

It is considered that the term ``golden section`` was introduced in the 19th century by the famous Martin Ohm in the second edition of his textbook Pure elementary mathematics, where he emphasized that he did not invent the term, but he accepted generally used name.[3]

4. EXAMPLES OF GOLDEN SECTION IN ARCHITECTURE

The greatest number of examples can be found in ancient times. Golden Section is widely used in architecture of the ancient Greeks. It is usually used in the construction of Greek temples, especially the doric, as can be seen in the example of the Parthenon on the Acropolis. Some studies of the Acropolis shows that many elements of the Parthenon approximates the golden ratio.[4] In Figure 8 is shown the facade of Parthenon, where it can be clearly notice geometry of the golden section. The entire temple is inscribed within the golden rectangle, and also its parts on the facade can be placed in the rectangles corresponding to the golden section. Its decoration was

[1]Isosceles triangle which every angle on base edge is two times larger than the third angle.

entrusted to Phidias[1], who had studied the golden ratio to apply the knowledge on the object.

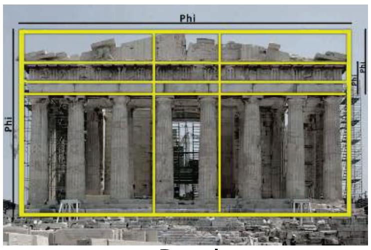

Figure 8. Parthenon

Some medieval buildings also respected the principles of the golden section. As an example is given the Cathedral of Notre Dame in Paris. Notre Dame is the most famous early Gothic cathedral dedicated to the Blessed Virgin Mary. The cathedral is 130 m long, 48 m wide and 36 m high. It is one of the most famous examples of Gothic architecture. In its form dominate two truncated towers that frame building, while supporting pillars and arches are arranged cascade in multiple rows. Building exudes harmony, balance and calmness of symmetrical architectural elements. When observing the geometry of its facade, it can be established that its parts are in relation to each other, that corresponds to the ratio of majors and minors in the golden ratio. In figure 9 are graphically specified relations of the individual dimensions. It can be assumed that the harmony of architecture originate from the harmonious geometry of the golden section.

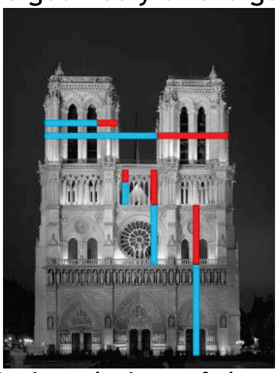

Figure 9*. Notre Dame in Paris, relations of the certain elements on the facade that correspond to the golden ratio*

http://upload.wikimedia.org/wikipedia/commons/a/a4/NotreDameDeParis.jpg

[1] Phidias (480-430 BC), a Greek sculptor and mathematician.

The best-known example of modern architecture in which geometry dominates the golden ratio is the United Nations building in New York (Fig. 10). The building is the headquarters of the United Nations, and its construction was completed in 1961. The building is result of work of the most famous architects of the period. Before deciding on the construction, committee considered 50 different designs. The solution is affected with limit dictated by the highway nearby. In this regard, it was necessary to build a tall building that will accommodate the building of the Secretariat. The basis of the final design is based on the Le Corbusier drawings, which are known as "pattern 23A". Le Corbusier incorporated the elements of the golden rectangle in the design of the building. The width of the building and height up to every tenth floor correspond to the ratio of the golden rectangle.

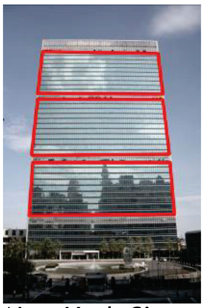

Figure 10. *UN building in New York City, photo of the facade with a sketch of the relationship of some of dimensions*
http://upload.wikimedia.org/wikipedia/commons/1/14/UNO_New_York.JPG

The Nautilus house is located near Mexico City, and is the work of Mexican architect Javier Senosiain. It is an example of modern organic architecture.[5] Its form grew out directly from the inspiration found in shell. The form is pretty strange and unusual. If we analyze its geometry, we could find connections with the golden spiral, which is shown through sketch in Figure 11.

Figure 11. *a) Sketches of the The Nautilus House, b) sketch of the golden spiral*
http://www.atlasobscura.com/places/nautilus-house-seashell-architecture

5. CONCLUSION

Architecture has always been known as the link between mathematics and art. Golden Section, as a geometric phenomenon has been investigated through the long history of mankind. Its discovery found applications in many areas. Intentionally or unintentionally, the geometry of the golden section has been applied in different situations. The golden ratio is something that is recognizable in nature, and as such it becomes an unavoidable element of many architects. When it comes to architecture, it can be seen in many different styles and in various eras. Buildings where the geometry of golden ratio prevails, regardless of the diversity of forms, temporal and spatial context, usually have something in common. This ``in common`` is reflected in harmony, balance, calmness. Regardless of their monumentality, they still remain proportionate to man. Perhaps because of the reason that man can find in them something similar to himself, the geometry of which he is built, the geometry of the golden section. The aim of this study is to find, through geometry of golden section, links between architecture and geometry, ie. and unbreakable bond of man and his works. Man has always looked for perfection. Golden ratio can be regarded as a universal mathematical formula for perfection and beauty.

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INFLUENCE OF COLOUR AS A DESIGN FEATURE ON THE PERCEPTION OF THE ARCHITECTURAL OBJECT

Aleksandra Milinković [1]
Jovan Đerić [2]
Dijana Apostolović [3]
Ksenija Hiel [4]

Abstract

Perception of the environment is an important process in the formation of identity and shaping of the collective consciousness of the community. This paperwork researches the influence of selection and application of colour on the facades of buildings in Novi Sad, depending on the typology, shaping, morphology and materialization of the building, as well as character of the location in which the building is incorporated. Through comparative analysis of the examples will be the validated numerical values and lacks of building with a pronounced colour finish. In relation to the immediate surrounding, that colour has primacy and is such a distinctive element or negative connotation. Another distinctive group consists of buildings whose form is expressed through mass, and the colour is simply a neutral element of design; form, composition and materials are more pronounced and dominant in the final part.

Key words: *colour, perception, architectural concept, Novi Sad*

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1. INTRODUCTION

Modern society is founded in ideologies that consider city a structure completely subject to change aimed at meeting the needs, visions of prosperity and lifestyle quality and comfort of all its inhabitants. Hence the confirmation of the standpoint that "..the right to the city cannot be conceived as the simple right to visit or return to traditional cities" [1], according to Henri Lefebvre, because the right to the city today is a legitimate worth of anyone who considers it his/her place of belonging, as a whole of delicate and unique identity rooted in all aspects of life of its inhabitants.

"Visual chaos of the modern city"[2] has become a representative image of each ambience that gradually acquires a different character due to heterogeneity leading to morphological and physical changes of the urban structure on a global level. City areas thus become separate entities, completely freed of the need to correspond to the surrounding space, and the city a whole that "acquires a unique and strong character" leading to the fact that the whole itself "must not appear as the sum of its individual parts" [3].

Experience of the surrounding space is important for generating a general image of a place, where *locus*, as referred to by Aldo Rossi, does not exist in inhabitant's consciousness as a whole, but is rather shaped as a series of interconnected fragments. Visual asynchrony of built and open spaces, may significantly affect perception and abstract from the inhabitant's mental maps only spaces with strong identities, urbanity and significance or those otherwise distinguished as separate entities in collective memory.

[1] Lefebvre H., *Pravo na grad,* u Operacija: Grad - priručnik za život u neoliberalnoj stvarnosti, Reprint, Zagreb, 2008, pg 28
[2] Lynch K., *Slika jednog grada*, Građevinska knjiga, Beograd, 1974. , pg 6
[3] Haberer G., *Die architektonische Gestalt*, Buchhandlung Walther Konig, Koln, 1986, pg 40

2. VISUAL EXPERIENCE OF AN AMBIENCE – PROMINENT IDENTITIY OF NUMEROUS NOVI SAD URBAN AREAS

The attitude and overall impression that "old cities always seem carefully structured since spatial relations were not disturbed by centuries long introduction of new styles, which always complimented each other." [1] is rather intriguing. It creates an impression of a unique, homogenous whole created as a result of a clear strategy, with spaces with strong genius loci, sensational ambiental value and great building achievements. Mental images formed by senses, visualizing the perceived space, take precedence in the memory of the visited, seen and experienced, and there is a vast number of factors affecting senses and attracting attention.

Historical, functional, economic and social genesis is visible in central Novi Sad urban areas, where spaces are of strong and conspicuous character that is a positive and global representative of the particular areas; peripheral urban areas develop spaces of disturbed or altered identity. The attractive power of the city centre takes shape in its content, architecture, social and cultural promotion, which is why it is visually the first association to a city. Particular buildings are also prominent as urban landmarks, urban identity, orientation spaces, formal representatives of a certain typology, political or social hierarchy or monuments to social-cultural development of Novi Sad. "Expressive nature of architecture is its ability to convey messages, which is a permanent quality, since houses have "communicated" be it through their form, spatial concept, or materials and details, form the early beginnings of building practice." [2]

Now leaving the city centre, its numerous squares, buildings, fortress, quay etc., one enters predominantly residential urban areas with different urban morphology and block arrangement, buildings that form a physical and visual boundary, lifestyle, number of visitors and those who identify themselves with certain urban quarters. Urban residential building typology today increasingly allows investors to disregard visual postulates and allow style, expressive and formal discord with the surroundings, even non-acceptance of all in the immediate surroundings. Such a blatant rejection of visual

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[1] Brolin B., *Arhitektura u kontekstu*, Građevinska knjiga, Beograd, 1988, pg 31
[2] Reba D., *Ulica-element strukture i identiteta*, Orion art, Beograd, 2010, pg 72

characteristics of the existing urban context results in grave loss of ambientality, creative infertility and perceptive chaos. If we examine the stand of *Nicolas* Le Camus *de* Mézières that "true harmony in architecture depends on accord of the masses and different parts" [1], is contemporary construction practice in the transformed urban areas of Novi Sad not a discordant design of the space we live in?

2.1 Colouring as element of interaction between the observer and space

Urban colouring scheme and its design are a layered and complex architectural-urban design task, which may solve the issue of colouring priorities and harmony. Colour as an element of emphasis is in architecture as "an ancient world language" because "we announce ourselves thorough them and comprehend environment signals".[2]

Forms in space communicate in a manner in which the cultural dimension establishes an interaction between their programmes, form, building period, social importance. In such relations of forms, interaction of man and form and the way a space is experienced bear great significance. Social-psychological relationship between the space that is key, context and concept and the person is thus defined in a specific manner. Relationship between man and his surroundings is layered, conditioned precisely by such spatial relations, morphological determinants, overall physical structure, as well as final expression, which creates reaction in the people’s minds.

Building design concepts may have several starting points, which may meet functional requirements as well as numerous artistic-design postulates that would emphasize each spatial form as a well designed, harmonious spatial structure.

This paper shall hereafter classify and present Novi Sad buildings as following:

- Buildings with form expressed through geometrical masses, and colour as a secondary design feature, and

[1] Le Camus N., *Genie de L Architecture*, P.M.E, Bruxeles, 1999, pg 150
[2] Folmar K., *Velika knjiga o bojama*, Laguna, Beograd, 2011, pg 9

- Buildings with colouring as a primary design feature, in relation to geometrical compositions and spatial distribution of masses.

3. BUILDINGS WITH FORM AS A PRIMARY DESIGN FEATURE

In respect to a building's location in the urban structure, position in the structural configuration, height, typology and numerous other factors, geometric shape of a building is emphasized as the language of architectural articulation and urban discourse with its surroundings. "Role of buildings as street elements may be defined as static" [1]; however, the power of a built structure to attract observers' attention is of great importance. Architectural form embodies volumes and architectural masses, harmonic and stylistic relations, symbolic and spiritual expressions, compositional advantages of materials, light, texture, and often colouring ambience.

Regular forms often impose a balanced harmony, order and tune, but monotony as well; monotony does not cause significant intrigue. A chaotic structure with vertical and horizontal dynamism represents lively movement and geometrical diversity. There also seems to be a connection between building's design and colouring in the sense of monochromatic and polychromatic design approach. Bulkiness and spatiality significantly affect the choice of design approach, so if a building is non-residential and spatially and morphologically dominant in its immediate surroundings, in Novi Sad it is most probably designed using mass, often monochrome or in a calm colour scheme and subtle gradient.

"Shape is a much better means of identification than colour, not only since it offers more types of qualitative differences, but also because characteristics of shape are much more resistant to environmental changes." [2] Arnhem's position is not a postulate, since architectural-urban design practice has exceptions to the rule that negate such claims; speaking on a global scale, this statement is mostly true when it is the question of non-residential typology and urban landmarks. If a building is expressive in its form, colours are

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[1] Reba D., *Ulica-element strukture i identiteta*, Orion art, Beograd, 2010, pg 66

[2] Arnhajm R., *Umetnost i vizuelno opažanje,* Univerzitet umetnosti u Beogradu, Beograd, 1987, pg 282

mostly secondary design features used to further emphasize it, and expressive colouring schemes for purposes of accentuation are often completely excluded. Effect of colours on perception is thus rather weak; symbolically, its absence is compensated through use of lights, which better compliment and emphasize monochromatic surfaces.

Geometry and spatial organization of buildings, composition of masses within structure, verticality and horizontality, symbolic accentuation of certain parts, harmony, dynamism and rhythm of compositional elements etc., influence orientation in space and, to a great extent, establish a building as an urban landmark. In order to render itself landmark, a building must distinguish itself from its immediate surroundings, but do so in a positive or negative system of relations. Jurgen Joedicke states that "wholeness without multiplicity leads to monotony in architecture, while multiplicity without unity implies chaos." [1] Both approaches, monotony and chaos, are systems to be avoided should the final design result be correct and meaningful.

Images 1,2,3. *The Ban's Palace, NIS building, Serbian National Theatre*

Most buildings in Novi Sad that belong to this group are situated in the city centre, as they are either architectural landmarks or monuments of representative public typologies. Architecture of Dragiša Brašovan, the Ban's Palace and the Main Post Office, settled along the Mihajlo Pupin Boulevard, are examples that verticality and horizontality in a meaningful composition may dominate geometrically rather than through colouring; they are, in fact, symbolic, functional, and urban landmarks.

Bulkiness and spatiality realized through masses is evident on the example of Novi Sad City Hall, Bazar Mall, City Assembly building, "Svetozar Miletić" Workers' House, Serbian National Theatre, Metals Bank HQ building and others. Each of these structures is unique and dominant in its immediate surroundings, whereas semantic and

[1] Joedicke J., *Oblik i prostor u arhitekturi*, Orion art, Beograd, 2009, pg 81

aesthetic expressiveness was achieved primarily thorough symmetric or asymmetric position of masses and the right choice of materials. Colouring as a secondary design feature may contribute to the overall impression if the design concept is generated as a result of the functional answer, or in respect to the surrounding space, rendering it calm, uniform and not causing observers' reaction. Although this concept is in Novi Sad mostly applied on residential typologies, there are examples of such typologies that do not conform to this norm, such as Adamović and Vatican Palaces in the city centre, which represent secular architecture with a calm colouring scheme, giving precedence to structure and composition of facades.

4. BUILDINGS WITH COLOURING AS A PRIMARY DESIGN FEATURE

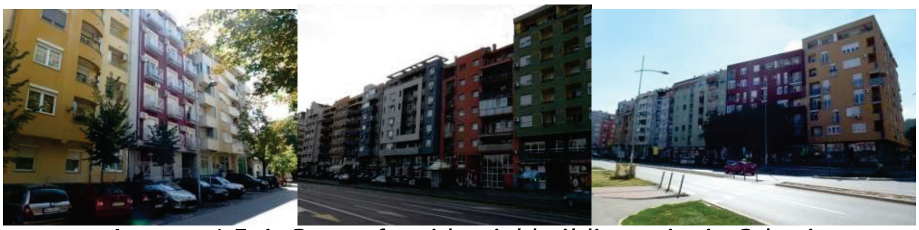
Colours have a notable role in perception, as they affect the observer ''on all levels: physical, spiritual and mental."[1] When colour becomes a dominant shaping/design element, it renders form and correlation of parts within the structure secondary, affecting change of character of overall visual experience of the built environment. Careful choice of colour ranges in space may have a stimulating effect on eyesight of the observer; however, inadequate selection of colours can also disturb the harmony between morphological elements of a city. What additionally diminishes such a structure in relation to structures with accentuated form, is the fact that expressive form is emphasized by the play of light and shadow, whereas a simple form offers much less superposition possibilities, regardless of the choice of colour.

Intensive construction of residential building typologies in the last decade, has to a large extent affected the image of certain urban residential areas in Novi Sad. Accelerated construction due to expansion of urban perimeters, desire for profit, strict and unimaginative urban plans and insufficient deliberation of architectural requirements, have resulted in quarters lacking morphological characteristics and distinctive form. Design similarities of multi-family residential units resulted in strikingly similar urban areas, significantly negatively affecting urban identity, orientation and identification. Architecture of such urban quarters is distinguished by reduced morphological elements and withheld spatial relations between them,

[1] Folmar K., *Velika knjiga o bojama,* Laguna, Beograd, 2011, pg 11

raising the question of architectural value and complicating their prominence in the space they occupy.

Formed by such a design approach, long rows of street facades along boulevards surrounding urban residential areas, and vast network of almost identical streets, have complicated orientation and movement. Movement along such an urban space becomes monotonous, with attention focused on the destination. Such a design trend disregarded use of correlation of spatial elements, mass, harmony, proportion and accentuation. Disregard of architectural form and dismissal of a design approach that emphasizes spatial relations, materialization of facade primarily through colour and texture becomes a dominant exterior design concept.



Images 4,5,6. *Rows of residential building units in Grbavica*

If colours are regarded as „visual IDs“[1], space should, therefore, gain prominent features and identity elements through such a design approach. Lack of spatial attributes, elements and prominent masses has conditioned choice of colour in accordance with the aspirations to distinguish built structures from its surrounding. “Attracting attention is affected by intense and sudden events that arise in the field of attention and a range of internal factors, such as needs, interests, attitude.“[2] Translating this to architectural terms, it implies that each spatial event, be it positive or negative, will attract attention; this may be the reason our surrounding often houses built structures with expressive colouring scheme.

[1] Folmar, K., *Velika knjiga o bojama*, Laguna, Beograd, 2011, pg 9

[2] Milošević, S., *Percepcija, pažnja i motorna aktivnost*, Zavod za udžbenike i nastavna sredstva, Beograd, 2002, pg 127

5. CONCLUSION

Language of architecture is multifold and partially defined by each element contributing to the overall expression. If architecture is indeed a "hierarchical structure of well arranged parts and elements"[1] , legibility and visibility of the basic concept in the course of shaping is key to recognizing harmony and accord in the final expression.

Novi Sad residential architecture practice hones disharmony and polychrome forming of buildings. There are very few examples of contemporary residential architecture shaped by mass, pronounced form and hierarchical positioning of elements. Functionalism completely alters the image of the city and gives new character and identity to a growing number of streets, rendering Grbavica, Novo Naselje, Detelinara, Banatić undistinguishable. Uniformity is to be evaded in the design practice, whereas inauthenticity and eccentricity attract criticism. Such an approach leads to colouristic disharmony, poor orientation and loss of recognition and genius loci.

On the other hand, it has been concluded that structures shaped in a meandering and dynamic forms, with colour posing secondary and function to form, render more noticeable, symbolic and significant to inhabitants. Community's collective memory certainly houses structures with an expressive colour finish, such as Tanurdžić Mansion, Zepter Mansion, Bishop's Palace, with this perceptive policy carefully designed by architects. Appropriate choice and concept is not exclusively one of the aforementioned principles, but a meaningful combination thereof, portraying the structure as urban monument and perceived as part of a well coordinated, dynamic unity, ever-amusing for all spectators.

6. ACKNOWLEDGEMENT

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[1] Filarete, A., *Trattato di Archittettura*, I.P.M, Roma, 1996, pg 167

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TRIFOCAL CURVES IN MATLAB AND JAVA

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Abstract

In this paper we present implementation of graphical representation of trifocal curves as an application in programming language Java and as library for software package MATLAB. Also presented are advantages and disadvantages of each approach, and possible applications of developed implementations.

Key words:*Trifocal curve, Java, MATLAB*

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1. TRIFOCAL CURVES AND THEIR APPLICATION

In the year 1679 Pierre de Fermat formulated famous problem as *“datis tribus punctis, quartum reperire, a quo si ducantur tres rectae ad data puncta, summa trium harum rectarum sit minima quantitas”* or in the English translation “for three given points, the fourth is to be found, from which if three straight lines are drawn to the given points, the sum of the three lengths is minimum”. This problem, suggested to Evangelista Torricelli in private correspondence, will later result in finding of Fermat-Torricelli point, fifth significant point of triangle, and first one to be discovered after ancient Greeks. While Torricelli was first to find method for finding point of minimal sum of distance, his construction of this point is rather complicated (see Figure 1.). Later this construction was simplified by English mathematician Thomas Simpson in his paper „Doctrine and Application of Fluxions“.

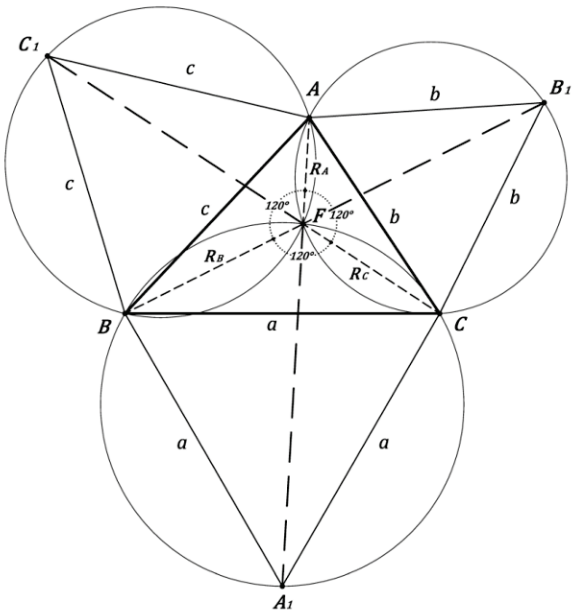

Figure 1. *Torricelli construction of point of minimal sum of distances*

Fermat-Torricelli point is starting point for solving many optimization problems of today. Austrian economist Alfred Weber considered use of Fermat-Torricelli point in economical and urbanistic sense: find the location for factory such that transport costs to the factory from three resource suppliers are minimized. Distances are multiplied by weight factors of objects that signify their importance to production process. Other applications can be also found. By use of negative weight factor, we can calculate point where negative influence from tree points is minimal. Optimal position for repeater of signal can be calculated in this way. Position of store based on metro station exits can be optimized. Position of chip on printed circuit board can be calculated using input port positions. Many more applications in architecture, urbanism and electro-technics can be found.

One of limitations for using Fermat-Torricelli point is that it can be positioned in some inaccessible location. To circumvent this limitation, trifocal curves can be used. Instead of one point, we define area with some tolerance parameter S, so that $R_A + R_B + R_C = S$ where R_A, R_B and R_C are Euclidean distances to points A,B and C. If we introduce weight factors into this equation, we get $w_A \cdot R_A + w_B \cdot R_B + w_C \cdot R_C = S$. With change of parameter S we can define how large trifocal curve we want to use. With growth of parameter S, larger area is defined by our curve. Let us notice that value of S cannot become smaller than that of S_0, where S_0 is value of sum of distances from foci A,B and C to Fermat-Torricelli point. By use of trifocal curve in place of Fermat-Torricelli point, we can see whole area of points that are not optimal, but are close enough to meet our criteria.

2. JAVA APPLICATION

Java application that shall be described in this paper was developed for visualization of trifocal curve, and for demonstration of its use in optimization problems of spatial type. Application is available at [17] . While programming language Java allows for online and platform independent distribution of software, it also limited types of parallelization that are available, which introduced some other limitations in software.

User interface that was introduced in application is very user friendly. Central part of application window is occupied by visualization area. In visualization area users can by simply clicking and dragging points change position of foci used for forming trifocal curve. On right side of screen are located controls that are wired to values of weight factors appointed to each distance from foci. Value of parameter S is also set in this section. Top section of window is reserved for menu bar, in which users can select type of visualization method, level of opacity or background image for visualization.

Application allows for two types of visual representation of trifocal curve. One type was created to allow for better visualization of trifocal curve. It also maps area inside of trifocal curve by use of color, where areas with dark color have value of function $f(x,y) = R_A + R_B + R_C - S$ very close to 0, while red areas have values similar to value S_0. This mode is very useful for determining area for optimal placement of object in relation to three foci with use of appropriate opacity.

Another type of visualization gives users better understanding of how parameter S influences formed curve. In area defined by two corners of selected area each point is assigned color formed from value of function f. Using HSV color system, cyclical repetition of color values appears, and concentrically form trifocal ellipses of same color with origin in Fermat-Torricelli point. With each of these types of visualization basic information about formed curve and parameters that led to it are shown in bottom left part of visualization part.

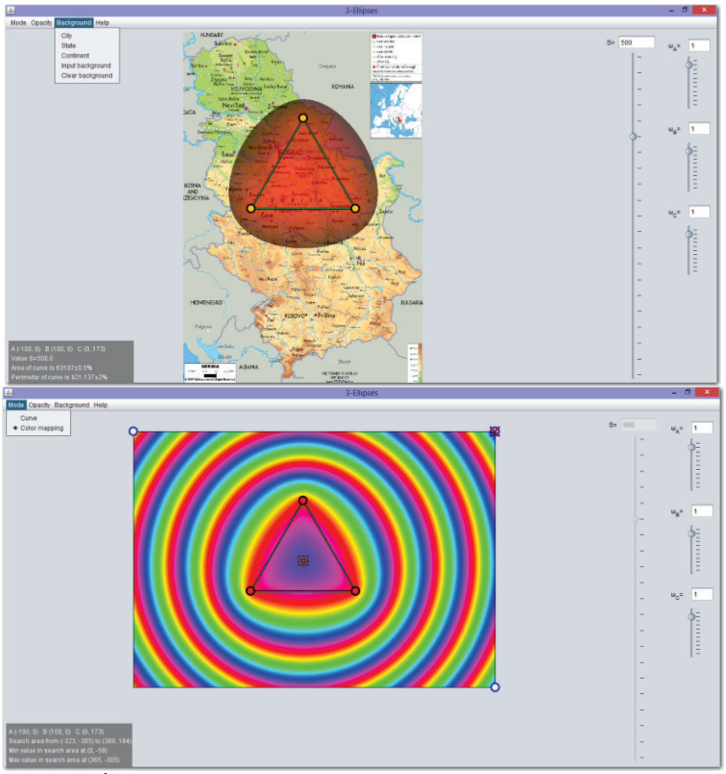

***Figure 2**. Types of visualization in application*

Greatest problem that appears with these types of visualization comes from large number of calculations that have to be done. For each pixel value has to be calculated. Most calculations have to be done in floating point arithmetic. While job can be parallelized by use of GPU, choice of distribution as internet browser application has limited to usage of only processor multithread environment. If color coding of value was to be avoided, it would be possible to use algorithms which are more efficient, and severely speed up process of drawing. While theses algorithms would allow better performance, on most standard computers application will still work in real time, with only some possible lags when user is moving some of foci, and much of information would be lost without use of color coding.

3. CALCULATING FERMAT POINT USING MATLAB

MATLAB(Matrix Laboratory) is well known and often used software system. It is an interactive environment for numerical computation, visualization and programming for analyzing data, developing algorithms and creating models and apps.

MATLAB has ability to create *GUI (Graphical User Interface)*, which gives users great option to use features of MATLAB without knowledge of programmingsyntax.GUI can be created with very simple interface and typically contains controls such as menus, toolbars, sliders and buttons. Using the *GUIDE (GUI development environment) Layout Editor*, programmer can visually design user interface. Then, GUIDE will automatically generate MATLAB code for construction of desired interface, which can be modified to program behavior of GUI app.

Because of the good features of MATLAB it is possible to create a GUI for calculating Fermat – Torricelli point. Based on the set of three points and property of trifocal ellipse, GUI calculates FT point and positions it with respect to the given set.

3.1 Fermat-Torricelli Point - GUI

Running code created by use of GUIDE Editor we get GUI window ready to use. On figure below it is possible to see how GUI looks like on opening.

GUI contains Menu with Items - ***File and Background***. File gives us option to ***Print*** our GUI or ***Close*** it. ***Background*** gives us options to select image to use for calculating optimal distance or FT point. With

Background option we can select predefined image of ***City***, ***Country***, ***Continent***, ***Choose*** any image we want from our PC or by selecting option ***No Background*** we can calculate FT point in Cartesian coordinate plane.

On selected image is given set of three points. At the start points are in some predefined position but it is possible to change position of any point in any time with dragging and moving it on desired position. Set of three points creates triangle. That triangle is important in geometry to calculate FT point because that point is one where sum of distances from the three vertices of the triangle to the point is the minimum possible. Moving any of this three points GUI automatically draws new matching triangle. MATLAB code written for this GUI calculates FT point from well-known formula of trifocal ellipse. FT point is marked with blue star and also automatically changes with moving any of given three points.

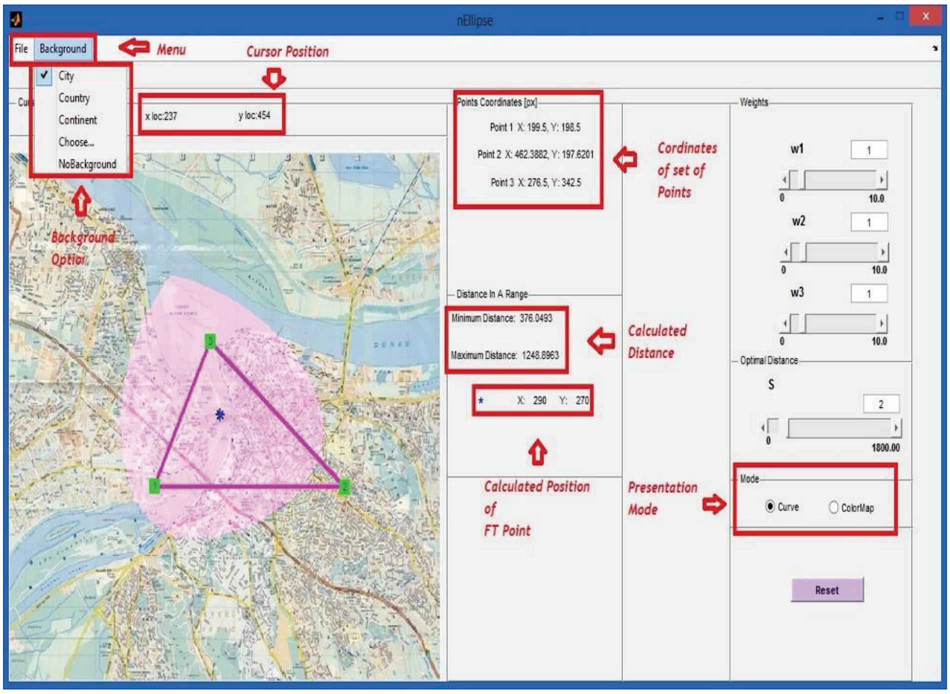

Figure 3. *GUI for calculating FT Point*

On first running of GUI, ***Curve Mode*** is selected as default. In that mode, GUI, based on given data (position of points, calculated FT point), draws matching curve – trifocal ellipse for some ***Optimal***

Distance. Curve is pink shaded (Figure3) and it is possible to change value of optimal distance by slider ***S***. Choosing the ***ColorMap Mode***, GUI presents all ellipses created from minimum to maximum distance in some range, colored with RGB map.

Some parts of GUI give users information and options for better usage of GUI app. It is possible to see position of cursor on GUI plane, coordinates of set of points, minimum (FT point) and maximum distance in given range, coordinates of FT point and weights to choose importance of some point.

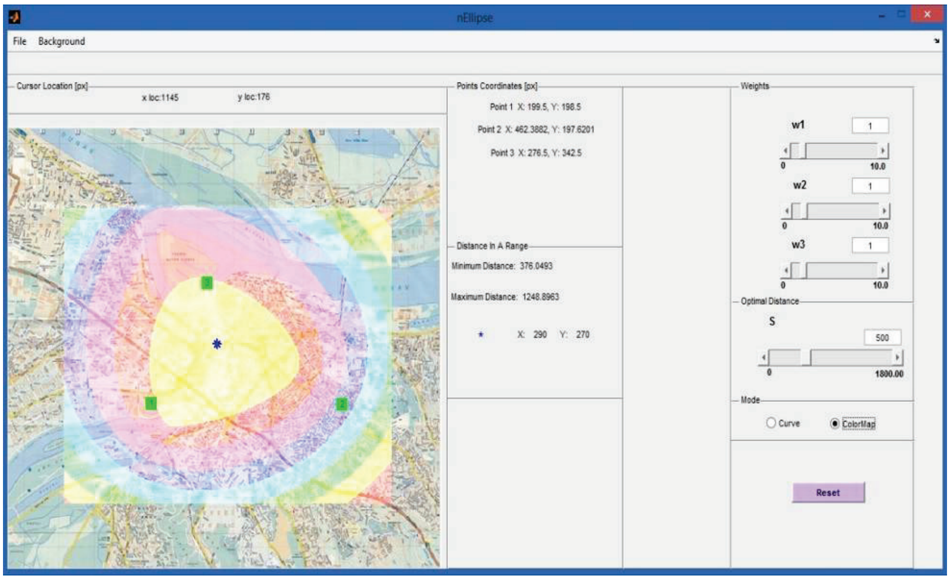

Figure 4*. ColorMap option for given set of points*

All images, position of points and calculated values are given in pixels. At the end, there is Reset button. Clicking on it, everything comes back to the initial value.

4. CONCLUSION

Two presented methods both have their advantages and disadvantages. Application developed in programming language Java has more flexible user interface, and runs a little faster, but is not possible to integrate in some other system, which reduces its usability without additional programming. It is better for some projects where it is more important to get visual impression of trifocal curve behavior, and in educative purposes. Application developed in program package MATLAB is better integrated, and offers wide range of tools that can be used to further analyze data gained by it. Choice of implementation depends solely on needs of users. Users that shall have need of some analysis that is used for one problem, could prefer MATLAB because it offers complete solution that can be run directly on data from other results. For tasks that are run more than once, upgrade of Java application for desired task is more adequate.

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BASIC PRINCIPLES AND TECHNIQUES IN POST PRODUCTION OF THE RASTER IMAGES IN ARCHITECTURAL PRESENTATION

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Ljiljana Radović [4]

Abstract

Developing computer 3D model of architectonic structure presents setting basic visual properties. After that, by an adequate computer program the complex visual properties are being set, that is the texture and the color; and also the adjustment of lights and the setting of the perspective views on the object, i.e. the whole scene.

Finished raster images, produced in certain computer programes, can be further visually improved, which includes the post production. Principles and techniques of image post production in architectural presentation are specific and can be classified in several basic groups. In this paper the elementary principles in architectural presentation are presented by using computer programes.

Key words: *architectural presentation, post production, architectural visualisation, raster graphics.*

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1. INTRODUCTION

Computer 3D visualisation of architectonic structures, i.e. making of the presentation of architectonic structures, contains three phases, **Figure 1**:

1. making of computer 3D model of the object (setting the basic visual properties – shape and size),

2. materialization of finished 3D model (setting complex visual properties (texture and colour), i. e. the setting lights and perspective views adjustment) and

3. making raster images or animations, as well as their postp roduction, compilation and design of the final architectural presentation.

Figure 1*. Three phases of the architectural visualisation, 2014. (V. Nikolić, O. Nikolić)*

After the second phase, the result is the vector image, raster image, or animation of architectonic structure. According to format of exit file, processing is continued by some specialized computer program. If it is about raster graphics, Photoshop and GIMP are usually used. The raster images are further modified by setting the colour parameters, as well as additional interventions on the visual properties of objects (size, shape, texture etc). It is also common to add secondary elements of architectural presentation, in order to save time of processing in the second phase or to gives more possibilities of manipulation with image elements. This stage of architectural visualization involves adding human figures, urban equipment, vehicles, greenness, text, background, adding location photography etc., **Figure 2**. The third phase of processing also involves making the final digital or printed presentations.

Figure 2*. Visualisation of the bussines building on the corner of Stefan Provenčani street and Mačvanska street in Niš, 2014. (V. Nikolić, O. Nikolić)*

2. PRINCIPLES AND TECHNIQUES IN POSTPRODUCTION OF THE RASTERS IMAGES

Basic purpose of architectural presentation is to visualy describe „atmosphere“ that will dominate around or in building after completion. Architectural presentation not always be the photo realistic to successfully describe the desired „atmosphere“. It is possible to successfully describe and conjure up spirit of a place (genius loci) applying certain principles during raster image post production. Those principles can be realized through techniques of raster image post production in architectural presentation and can be classified into several elementary groups of modification methods:

1. modification of colours and raster images tonalities,
2. modification of shapes and proportions of some elements,
3. removing and adding element of images.

After phase two, applying complex visual properties 3D model, processing is usually continues with adjustment tonality and colour of raster images.That involves setting colour balance, colour range, hue, saturation etc. Intensity and way of performing these modification above all depends from desired visual effects. That intervention can refer on different additional images and elements that can be used in presentation design. It can also be the location photographs, that is to say context in which structure will be placed, with the view of their adaptation for achieve desired effect, **Figure 3**.

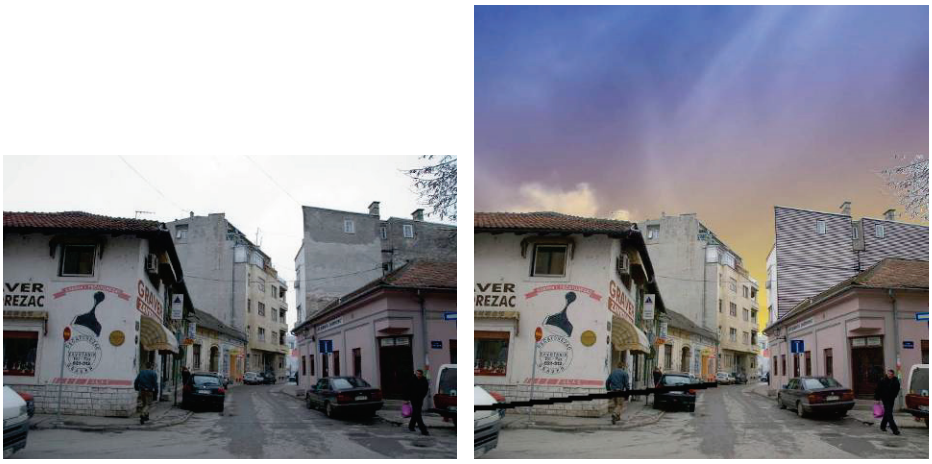

Figure 3. *Tonality and colour modifications with removing and adding certain elements in environment of future building*

On electronic devices, raster images are shown in RGB colour mode, and are printed in CMYK colour mode. In RGB and CMYK colour modes it can be shown limited part of visible spectrum, that reduced visual experience of future environment. One way to overcome those limitations is to overemphasis certain visual properties of raster images by adjustment appropriate tonality and colour. Those adjustments can result with successfully visualisation of object and its context, according previously defined principles, **Figure 4**.

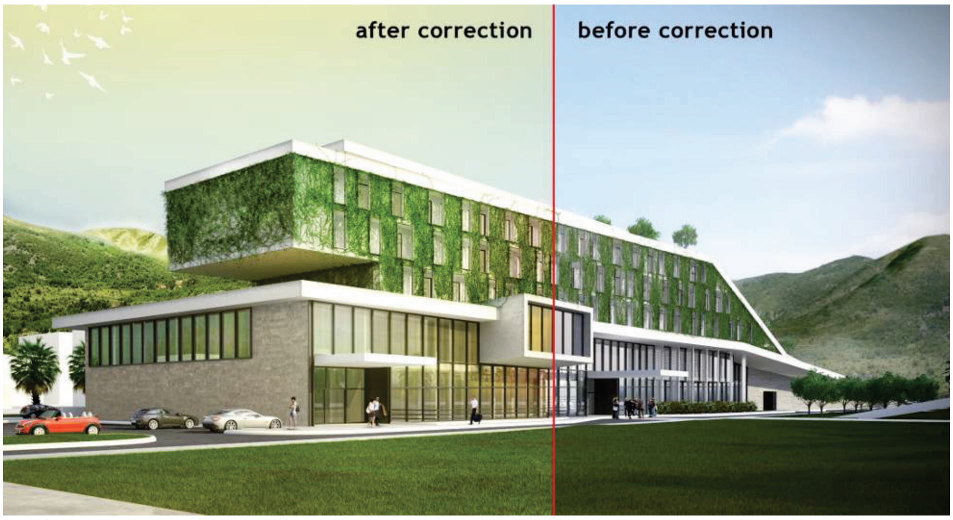

***Figure 4**. Modification of colours and tonalities – Hotel in Bar, Montenegro, 2012 (V.Nikolić, O. Nikolić, B. Stojanović, M. Stevanović)*

Shape and proportion correction of the whole structure or some of its parts is possible on many ways. Usually, it is corrections in perspective view of presented building, as well as additional setting of its certain parts, without returns to previous phase of visualisation, **Figure 5**.

***Figure 5**. Perspective view correction with adding secondary elements of architectural presentation – Competition proposal (B.Stojanović, V. Nikolić, O. Nikolić)*

During post production of raster images, it can be added or removed, above all, some secundary elements of architectural presentation that improve experience of „atmosphere“ that will be achieved. Human figures, greenness, elements of urban equipment are usually added. There are lots of ways of visual improvement by using secondary element of presentation, but the aim is only one - describe „spirit of a place“. On **Figure 6**, it is presented three previously mentioned groups of post production techniques applied in visualisation of the Shopping mall interior.

Figure 6*. Post production of raster image of the Shopping mall presentation, Paris, 2014 (Celereau & Partners, V. Nikolić, O. Nikolić, B. Stojanović)*

Adding elements in raster images of architectonic structures may implied setting complete scene, i.e. photograph of surroundings. That is one of the most effective and the simplest way to conjure up „spirit of a place“. That example is presented on **Figure 5** and **Figure 7**, where previously modified photograph of surrounding are inserted in 3D model of architectonic structure and vice versa. This procedure always requires adjustment both elements of the image. This procedure always requires adjustment both elements of the image.

***Figure 7**. Architecture structure adaption in image location, 2012 (V. Nikolić, O. Nikolić, B. Stojanović)*

Sometimes, interventions are performed directly on existing photograph. In that cases, compilation of 3D models and their further processing will take a lot of time with much less quality effect. With adequate intervention on the existing raster image, could be achieved desired result on very effective way. Example on **Figure 8** shows roof parts modification directly made on photograph using Photoshop.

***Figure 8**. Real image and roof parts modification image, 2013 (V. Nikolić)*

The same technique was used to improve photograph of model, shown on **Figure 9**. Surrounding of model was changed with abstract environment. Created image can be used for different purpose, with its own, completely new „atmosphere“ in surrounding.

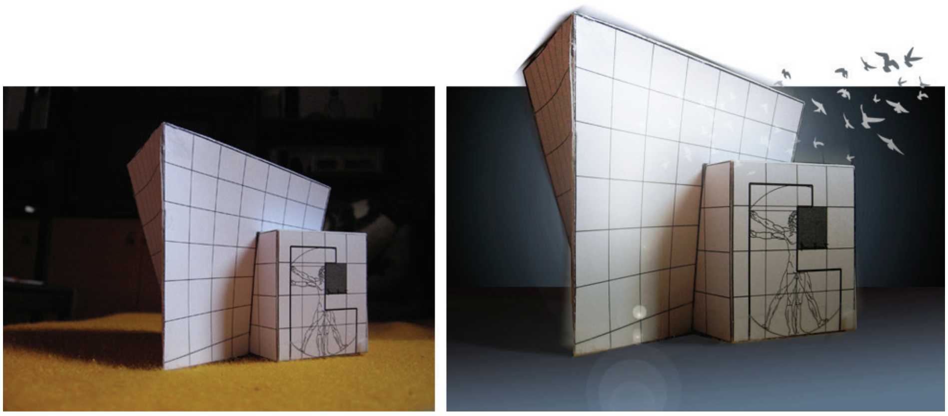

***Figure 9**. Real image and modification of background, 2006. (V. Nikolić)*

3. CONCLUSION

Post production of raster images belong to third phase of the architectural 3D visualisation. Although postproduction presents finishing and improvment previous two phases, it has very important part of design a quality and successful architectural presentation. Post production gives the biggest possibility of parameter manipulation and modifying elements of raster images. Its essence, in context of architectural presentation, is to visually describe „atmosphere“ around or in future architectonic structure. Adhering to the basic principle and using three basic group of techniques for raster images modification can be produced required architectural presentation for architects and investitors, i.e. presentation with strong personal signature design.

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ARCHITECTURAL FORMS OF CONTEMPORARY AIRPORTS

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Hristina Krstic[3]
Petar Pejic [4]

Abstract

Airport complexes are considered one of the most complex functional organizational units in the field of architectural design. From the begining of air transport, airports were improved in terms of function and form, but today, with the increase and complexity of air traffic, they are getting more and more important as the impressive, modern and monumental forms, within which the flow of goods, passengers and information is performed. Each building has an individual expression, represented through the form, function and organization. Airports, whose construction was thriving recent decades, are particularly interesting subject in terms of architectural form.

The aim of this paper is, by presenting the historical development and analyse new, representative examples, to show contemporary tendencies in the design of this type of buildings, then to classify influential factors and demonstrate their implementation in architectural form of terminal.

Key words: *geometric form, airport terminal, architecture*

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1. INTRODUCTION

In this paper, the authors present airport terminals in terms of architecture and geometric forms. Based on actual literature and analysis of the present-day objects, it will be presented the ongoing direction of development in the design of this type of public building.

Airports were once called *fields*, and were formed on a wide grassy areas that have had convenient winds, with possible side facilities for accommodation of passengers. With the popularization of air traffic, in the late 1920s, special facilities emerged, with regulated customs, waiting rooms and space for baggage. The architecture of a new type of object is created based on a model of existing types of transportation buildings - railway stations. However, the railway terminal of the nineteenth century, with the steel construction of a small span, could not be modified to the needs of air traffic. Designers, until the present day, are trying to optimize the airport's function and form, which as a results has different types of airport complexes.

2. DEVELOPMENT OF DESIGN METHODS AND SIGNIFICANT ARCHITECTS

Pioneers in the area of architectural design, architects William Adams Delano (1874-1960) and Chester Holmes Aldrich (1871-1940), designed the terminal in Miami (Pan American Airways) (project year: 1931, construction year: 1934). It was a prismatic terminal, with a two-storey central block, cut off with single-storey symmetrical "wings". Applied art-deco style is a reflection of contemporaneity of the building. Specific details used are motifs on the frieze of the facade (globe, rising sun, waves, eagles) as well as motifs of the zodiac, eagle and globe into the central hall of the building.

Architect Eero Saarinen (1910-1961) designed the airport John F. Kennedy in Idlewild, New York (project year: 1943, construction year: 1948). The idea of the new "flying" terminal was implementing form that resembles a bird in flight. Two symmetrical shells of rotating ellipsoid were cut off with two vertical planes, with symmetrical conoidal surface in the central part that connects them.

During the construction of the airport in Washington, DC (Dulles International Airport) (project year: 1958, construction year: 1962) Saarinen approached the project from the aspect of functionality then the form of the airport. For the first time, there was the idea of establishing a link between the shape (cut off of cylinder as the primary geometric surface, with catenaries as constructive elements) and functionality of the airport, and since then it is constantly improving.

Figure 1. *JFK (left); Dulles International Airport (right)*

Norman Foster (b.1935.), Richard Rogers (b.1933.) and Renzo Piano (b.1937.) are contemporary architects whose airport projects are considered highly successful and representative. They introduce a different approach to the design of the terminal: no metaphors of flight, no symbolism and the revival of past. They represent a building which demonstrates the functional and structural unity. The result of their access gave the entire new generation of airports with "elegant shell": in Hong Kong (1992-1998), Beijing (2003-2008) - Foster, Madrid (Barajas Airport, Spain, 2000-2005) and London (T5 Heathrow Airport, UK, 1989-2008) - Richard Rodgers and Japan (Kansai Airport, Osaka, 1988-1994) - Piano. Applied geometric forms, "elegant shells" are mostly single or double curved surfaces,or their cut offs, with large diameters of curves in relation to the size of the basics.

2.1. Modern architecture of airport

Easily spotted during the analysis of the work of leading architects mentioned above (Foster, Piano and Rogers), is their combined contribution to this area of design, but also the individual search for the adequate solution. Roger's horizontal parabolic cylinder at Terminal 5 of Heathrow airport provides a large open space, natural lighting and views towards the runway. Foster's Chek Lap Kok (Hong Kong, China, 1992-1998) is an example of a logical organization of indoor and outdoor space under the cylinders on a branched basis. Former classical division on the public part of the airport and duty free zone is present at Foster's Stansted (Stansted Mountfitchet, UK, 1981-1991), where "simple and direct" are words that describe object with rectangular base, with a four-sided pyramidal modular elements on the roof structure.

Figure 2. *Heathrow T5 (top left); Stansted (down left); Chek Lap Kok (right)*

Approach to airport design was changed since last couple of decades. After a period of uniform and monolithic airports, present trend are the terminals as a landmark and the dominant part of the complex.

3. FACTORS AFFECTING ARCHITECTURE OF MODERN AIRPORT

The one of the main influential factor in the development of the airport terminal was technology development, which has left its mark to a greater extent on this type of public buildings then the others. The reason for this is in correlation between the aspects of form of the object and functional organization. Using a new technology, the need for manpower is reduced as well as serviced area, and the degree of efficiency and mechanization is increased.

The way new airports were designed affects the society development, which indirectly, through new technologies, economic power and way of thinking, influences the appearance of the new facility.

Basic characteristics of the airport incurred during the period between 2006 and 2014th, from aspects of architecture and form are:

• spatial, monolithic and often symmetrical forms,

• using the inside of the roof structure as a landmark and design element,

• larger use of natural light through transparent façade,

• representation of the state's cultural identity through architectural form.

Monolithic structure, symmetry and compact dimensions are the main characteristics of the architecture of modern airport. The floor plan is usually rectangular or elliptical shape, while the roof constructions are single or double curved surfaces, with spatial grid or line beams. Monolithic and simple structures are directly related to the development of architectural thought in functional terms: tending to reduce the walking length of passengers, better connection of different parts and plain and uncomplicated spatial-functional organization (examples: Terminal 5 Heathrow Airport (UK), Madrid Barajas Airport (Spain), Pulkovo Airport, (Russia), Carrasco International Airport (Uruguay), Shenzhen Bao'an International Airport (China)).

Inside of the roof structure as a landmark is the dominant interior detail that occurs in a lot of new airport terminals. This form is a very significant from the aspect of geometry. The ceiling represents a compound of construction, installation (lighting, ventilation, etc.) and signposts which connects into a harmonious unity, pleasant to the human eye. Reason for potentiating and utilization of ceiling lies in the organization of the interior of the terminal building: This is the only part of the interior which is visible from the perspective of the human eye (examples: Barajas Airport (Spain), Pulkovo Airport (Russia), Chhatrapatishivaji International Airport (India)).

The use of of transparent facade, usually curtain walling, has a dual role: utilization of natural light and highlight the geometric form of the roof structure. Also as a design element can be seen (depending on region) overhangs of the roof in the form of canopies. That is a case in areas with higher insolation, and in these areas the terminals have a dominant roof structure, while the façade is unnoticeable. (Beijing Airport (China), Carasco Airport (Uruguay), Queen Alia Airport (Jordan)). In continental areas dimensions of the floor plan and the boundaries of the roof planes are in the same line, and roof often remains hidden by the attic or other constructive - facade element (Airport Kutaisi (Georgia), Lleida Airport (Spain)).

Presentation of cultural identity - Airports are considered as miniature cities that reflect the values and aspirations of the population and the environment in which they are located. The design of the airports represents a nation more than any other public building along with terminal buildings as main part in public perception of the airports.

4. EXAMPLES OF BUILT TERMINALS

4.1.Terminal 5 - Heathrow Airport (London, England; Richard Rogers Partnership; 1989-2008)

Terminal 5 at Heathrow airport in London is typical example of the new approach to airport design. When it's construction is finished 2006, a new generation of airport facilities arise. While the first terminals were largely monotonous, poorly lit and with large walking distance, new terminals use natural light, spacious and undulating forms.

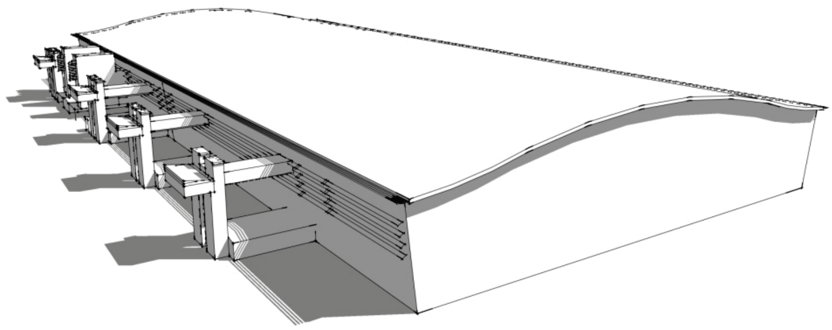

***Figure 3**. Illustration of the model of Heathrow T5 airport*

Newly-built Terminal 5 has more economical structure and simplicity of the volume. The roof is a single horizontal cylinder, with elements of roof lights that guide passenger's movements. A simple rectangular floor plan and transparent facades allow roof structure to be the most dominant element of the object.

4.2. Terminal 4 - Barajas International Airport (Madrid, Spain; Richard Rogers Partnership; 1997-2005)

Based on the basic concept of given project task, Terminal 4 is composed of three linear prismatic entities, which vary by function. The building looks more like articulated, telescopic extruded form with clear modular divisions, rather than a monolithic cube. Within applied modular system, the roof is the most dominant architectural element.

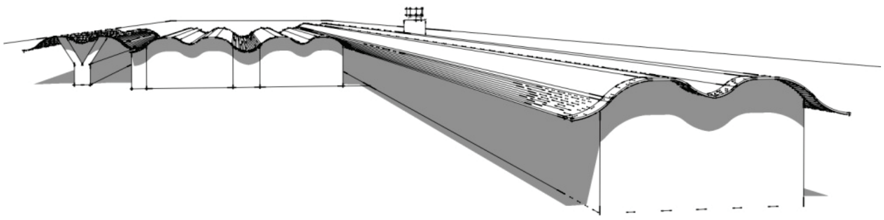

***Figure 4**. Illustration of the model of Terminal 4 on Barajas International Airport*

Applied geometric form is presented by connected parabolic cylinders. The roof with its small over-hangings "floats" above the building, which puts facade in the background. Part of the basic idea of the project was terminal's roof structure presentation as interior landmark, using longitudinal direction of expanding. The ceiling is significant in terms of design also because of colors applied on the structural elements.

4.3. Terminal 3 Beijing Airport (Peking, Kina; Foster+Partners; 2003-2008)

A large number of required gates and optimization of passengers walking distance were some of the main factors that influenced the formation of the basic footprint of the airport. The shape of the circle (which has the smallest volume relative to the surface) as a conceptual solution could not meet the needs of the airport, due to the necessary area for aircraft parking and gate formation. The solution was to make a limited space with three circular large-radius arcs and straight lines. In order to put an object along longitudinal axis, it was necessary to use double-curved roof, which was the reason for implementing graphical surface on irregular base. As a result, roof surface is made of number of different arcs, all of which are defined by three reference points.

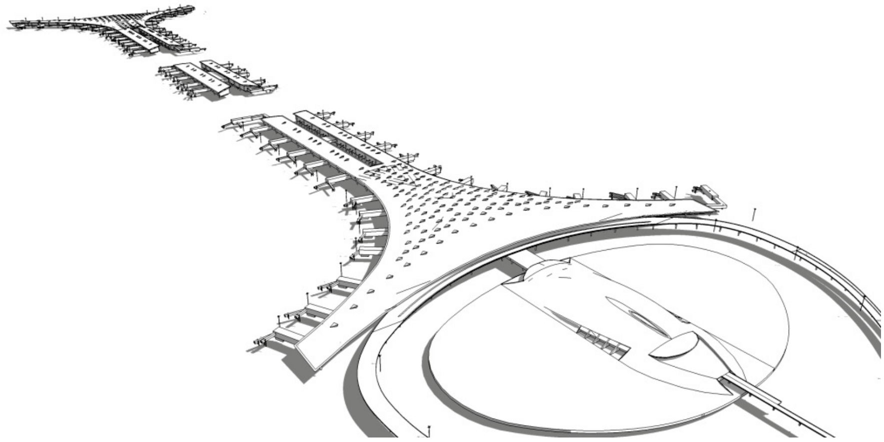

***Figure 5**. Illustration of the model of Terminal 3 on Beijing Airport*

This facility combines the terminal building and satellite in the geometric composition of the shallow arc, making it integral part with Beijing's urban structure.

4.4. Carrasco International Airport (Montevideo, Uruguay; Rafael Viñoly; 2007-2009)

Carrasco airport was presented in 2009 as a milestone in terms of investment, architecture and technology. Architectural design of Carrasco airport is modern in terms of space, function and structure, while the roof was created considering surrounding of the building and fits into the local topography. Slightly curved, low and monolithic roof surface, with a length of 365 meters, was inspired by the undulating dunes present along the coast, and extends over the basic footprint of the building. The roof has a different cross-section and height, which varies from 50m to 127m, and provides strategic use of natural light, creating a shadow in the inner space.

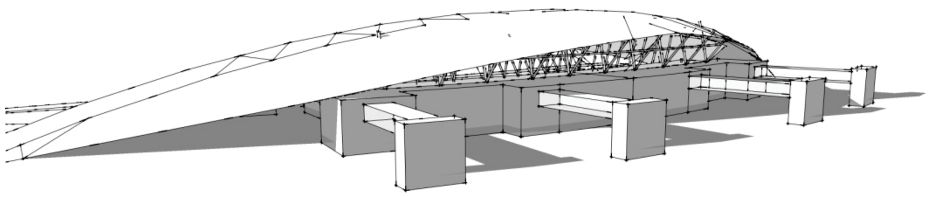

Figure 6. *Illustration of the model of Carrasco International Airport*

Curtain-wall system, 15 meters high, surround terminal building, creating a transparent facade almost unnoticeable because of the dominant roof structure.

4.5. Pulkovo International Airport (Saint Petersburg, Russia; Grimshaw Architects, Ramboll, Pascall+Watson; 2007-2014)

Large impacts on the final appearance of the building were the climate and cultural heritage of the city.

The dominant spatial structure is the roof over a square base, organized as a system of pyramid folds, whose one of the role was to deal with the loads of frequent snow.There are also pyramidal folds In the inner part of the roof structure, which should distribute the weights on different parts of the structure. Lighting pattern follows metal panel’s triangular folds, while the gaps in-between serve as a skylight that allows natural daylight in.

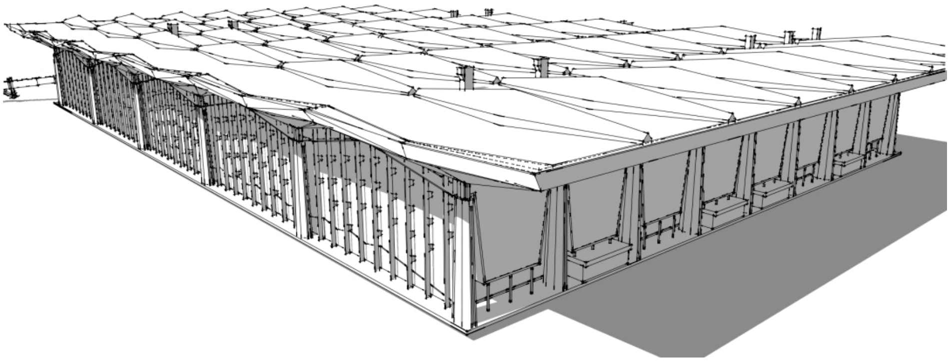

Figure 7. *Illustration of the model of Pulkovo International Airport*

5. CONCLUSION

The airport designing methods has changed with time, and it all started from famous Sullivan’s concept "form follows function". The airport buildings are the type of the buildings which function has to be taken into consideration, but the fact is that contemporary trend tends to simplicity so the building occupy as little as possible, and all it's functions allow easier navigation. Today, the priority in terminal design has geometric form. Single and double curved shells are used very often on a simple and symmetrical base. Quite often, the central attention is on the inner part of the roof structure, which ceilings are becoming the dominant parts of the interior, as well as on the better usage of natural light through the transparent façade. All things mentioned show designers tendencies for creating a terminal which will be integral part of airport complex and also represent the state in which it is located.

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PRESSES FOR DESIGNING FLEXIBLE PIPES CORRECTION, FINITE ELEMENTS ANALYSIS AND PREPEARING "G" CODE FOR CONSTRUCTION ELEMENTS OF PLASMA CUTTER

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Branislav Popkonstantinovic[3]
Zorana Jeli[4]

Abstract

With the development of computer technology the cost of designing and prototyping mechanical structures is greatly reduced. Software packages that have appeared on the market offer incredible opportunities to constructor, and computers that are developing exponentially, allowing obtaining results in a small period of time.
Constructor's primary task was in a short period of time to correct the press constructed of flexible pipes for the heating system, which was supposed to meet the definition of requirements:

1. To have as less as it's possible parts, so as not to lose when working in the field,
2. To cover the three pipe diameters using,
3. To be as less as it's possible mass.

Design of mechanical parts and assembly is done in SolidWorks, and after that the finite element analysis performed in the same program. After alteration of the model (assembly) and several

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analyzes we obtained a final model that satisfied all the conditions given. Technical documentation is done, and then transferred to the final parts of CATIA software package which has been done generation "G" code that was optimized for the control unit Siemens SINUMERIK 840D. It was made after testing the prototype and the press went into production.

This paper gives all information about work done during resolving of that tasks.

Key words: *G-code, design,SolidWorks, CATIA*

1. INTRODUCTION

During the operation of various machine comes to unexpected problems that are not predicted without that period. In many cases such problems can be repaired almost done remodeling or modernization of existing same. In some cases, however it is impossible or unprofitable to do repairs. Sometimes clients, dissatisfied with the preceding solution, requires the creation of new machines. This paper describes the process of recording the original machine, the process of designing and testing new and the process of installing and commissioning a new machine.

2. THE PROBLEM

Press offered by the manufacturer with its product (flexible tube) created the problem in the operation in terms of not giving consistent results. Extremely useful, in this case the client wanted to improve production, the result had problems bending pipe, there have been losing the belt around the jobsite and cracking due to wear them on the ground.

In a joint analysis it was concluded that the existing press is not possible "repair". The idea was to press with as less as it’s possible removable parts that will always give the same result in exploitation. It had to be made in a short period of time using less money and it is not possible to make a large number of prototypes.

Fig. 1 *The original press*

3. THE SOLUTION

First it was sketching in conceptual design modeling concepts as the basic elements of the assembly in SolidWorks software package. After that the same is done making the software elements into a functional whole.

The first elements of colic Search results analysis showed that the design can fully perform the work for which it is intended, but it was too difficult to transport.

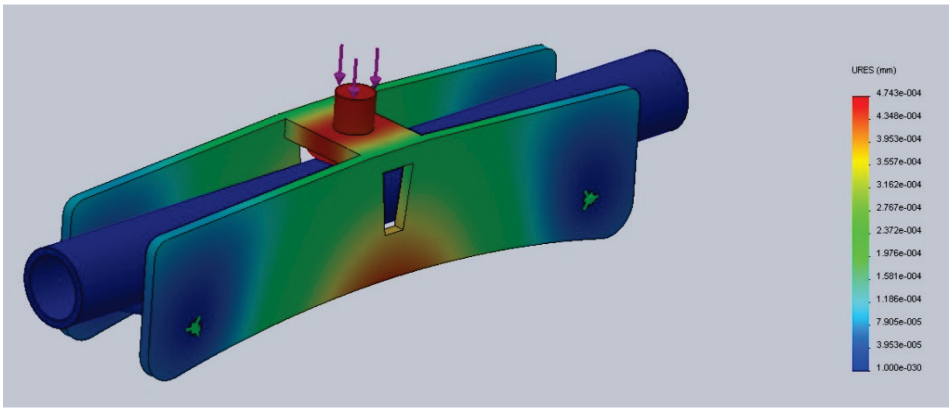


Fig. 2*. Assemby-solution*

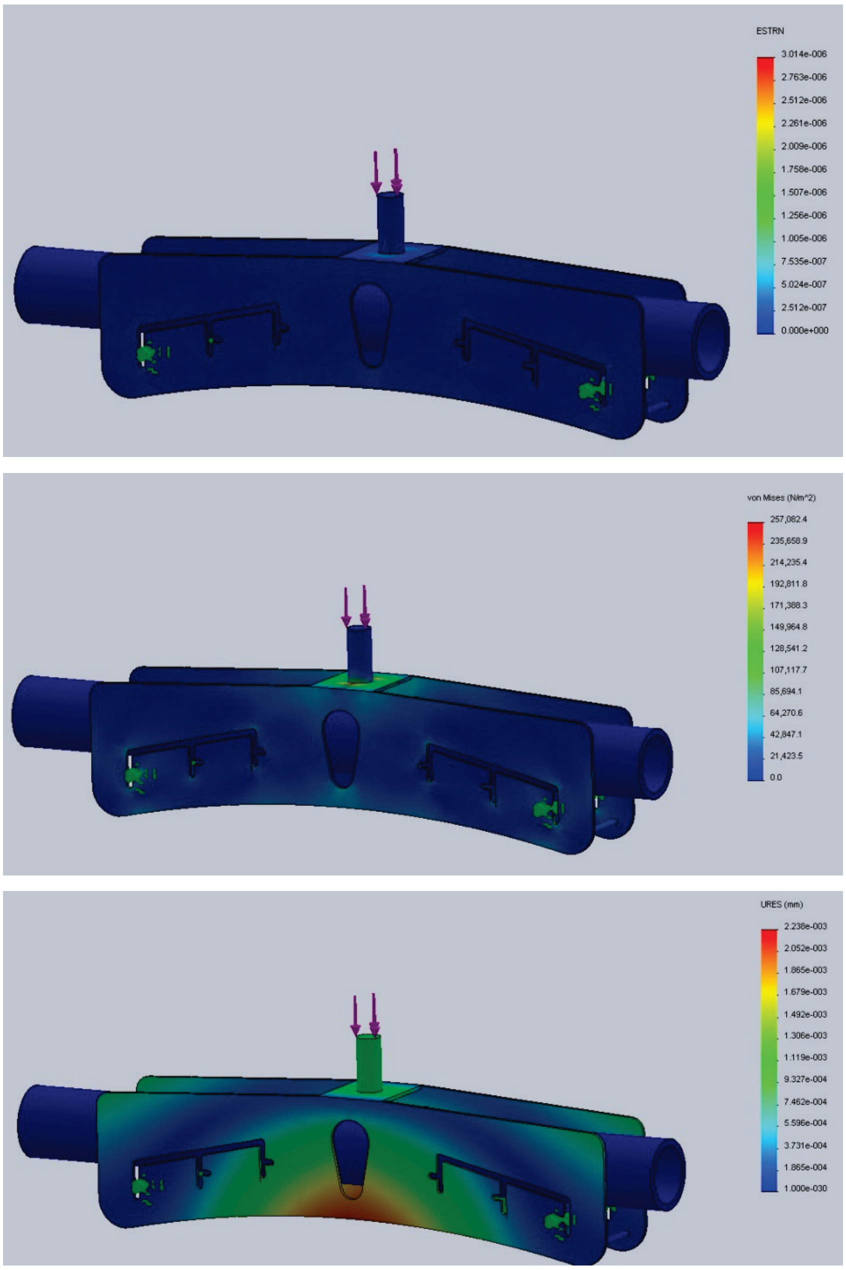


Fig. 3 *Stress analysis*

This model can be seen that the stress concentration occurs in the scope of the pneumatic piston, also recognizes that the opening which is used to control does not affect significantly the stress concentration.

After these analyzes created a new model in which the reduced thickness of the side panels to reduce weight. Also check the hole is enlarged and its corners are rounded. On the new model were performed a complete analysis of the SolidWorks software package, after which it was concluded that the model meets all the requirements that were set before the constructor and that construction can go into production.

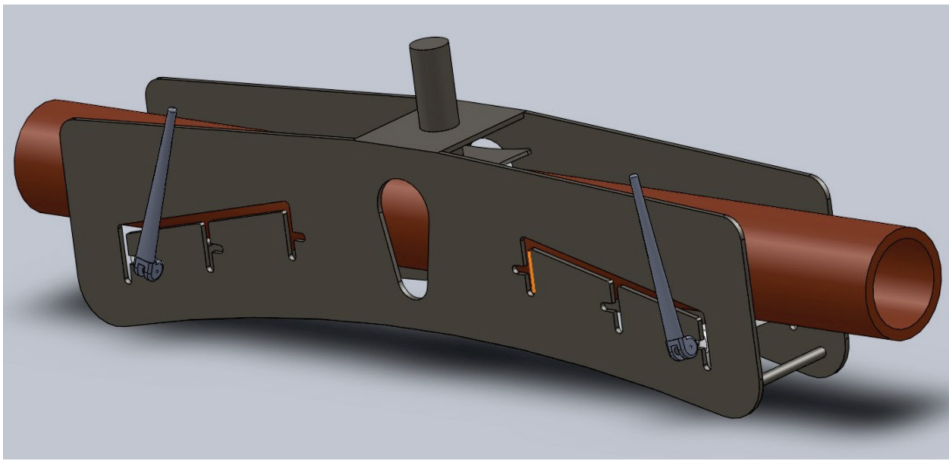


Fig. 4 *Final press*

Afther that we aproch on the preparation of technical documentation for the program of the assembly.

The development of new machines, automating the production process and implementation of computer technology in creation of machine tools, able to engineer a short period of time gets produced the desired sections.

Modeled side panels are stored in a format for exchanging 3D models between software (. Iges) and opened the computer package CATIA.

CATIA using PRICES postprocessor generates "G" code that is directly executable on Simens control unit. Specifically in our case, the control unit type used Sinumerik840D Siemens, which serve the plasma cutter

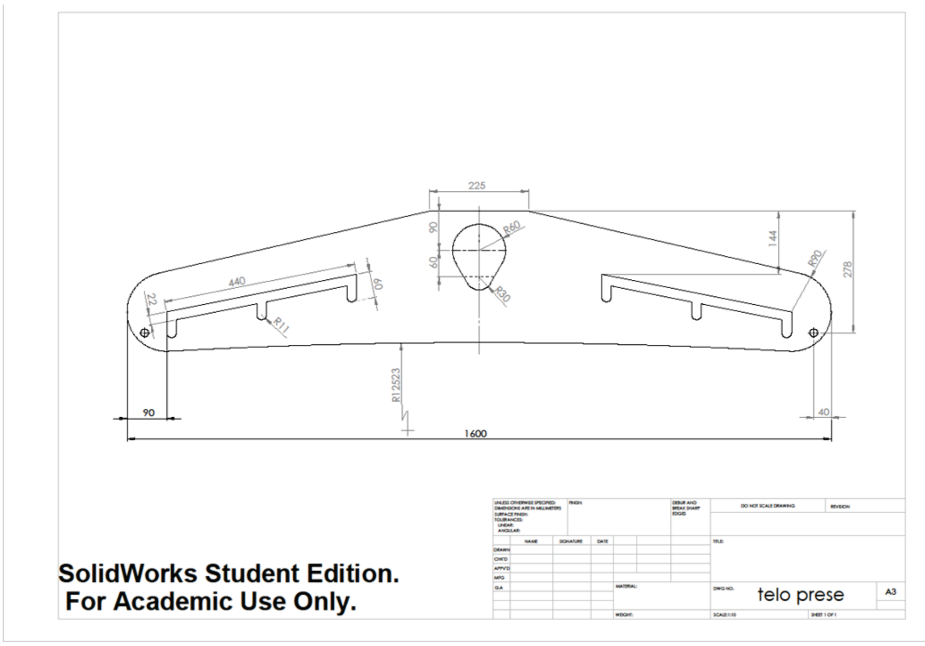
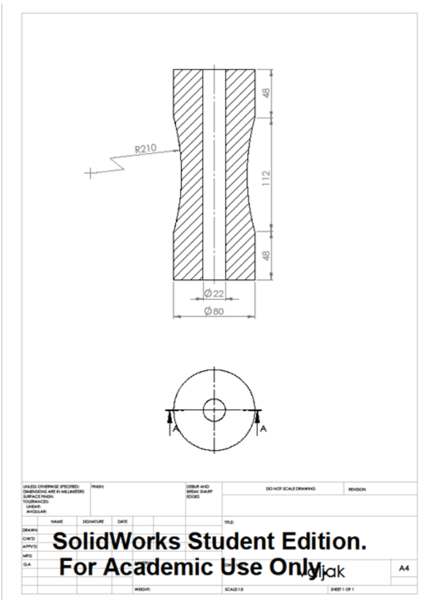
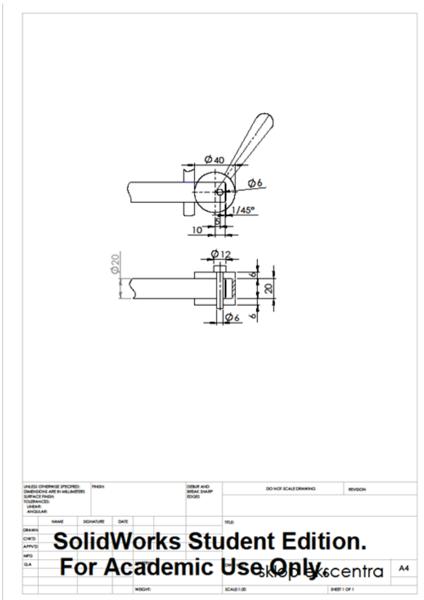


Fig. 5 Technical drawings for new press





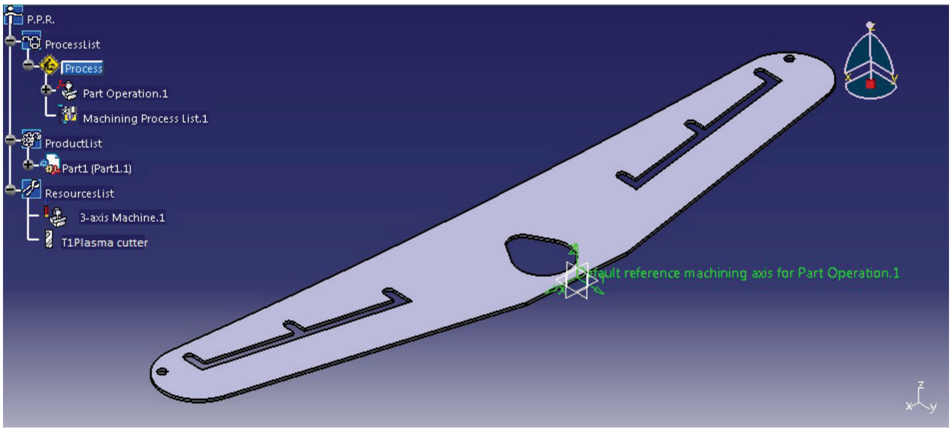


Fig. 6 *Preparation for "G" code*

When all is done we receive next "G" code:

N10 G54
N20 TRANS X800 Y400 Z10
N21 T1 M06
N22 M1
N24 G01 X731.642 Y-137.497 Z0 F1000
N25 G02 X704.652 Y-324.849 I-21.642 J-92.502
N26 G01 X613.808 Y-320.058
N27 X522.931 Y-315.927
N28 X432.026 Y-312.457
N29 X352.466 Y-309.963
N30 X272.891 Y-307.975
N31 X181.936 Y-306.322
N32 X90.97 Y-305.331
N33 X0 Y-305
N34 X-90.97 Y-305.331
N35 X-181.936 Y-306.322
N36 X-272.891 Y-307.975
N37 X-352.466 Y-309.963
N38 X-432.026 Y-312.457
N39 X-522.931 Y-315.927
N40 X-613.808 Y-320.058
N41 X-704.652 Y-324.849
N42 G02 X-731.642 Y-137.497 I-5.348 J94.85
N43 G01 X-123.139 Y4.869
N44 X-122 Y5

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N45 X0
N46 X122
N47 X123.139 Y4.869
N48 X731.642 Y-137.497
N49 X755 Y-278
N50 G03 X755 Y-278 I5 J0
N51 G01 X697.659 Y-280.903
N52 Y-237.213
N53 X276.784 Y-150.14
N54 Y-196.313
N55 G03 X288.784 Y-196.313 I6 J0
N56 G01 Y-171.017
N57 G02 X294.797 Y-166.121 I5 J0
N58 G01 X476.672 Y-203.748
N59 G02 X480.659 Y-208.645 I-1.013 J-4.897
N60 G01 Y-238.492
N61 G03 X492.659 Y-238.492 I6 J0
N62 G01 Y-213.196
N63 G02 X498.672 Y-208.3 I5 J0
N64 G01 X681.672 Y-246.16
N65 G02 X685.659 Y-251.056 I-1.013 J-4.896
N66 G01 Y-280.903
N67 G03 X697.659 Y-280.903 I6 J0
N68 G01 X0 Y-35
N69 G03 X-47.631 Y-117.5 I0 J-55
N70 G01 X-21.651 Y-162.5
N71 G03 X21.651 Y-162.5 I21.651 J12.5
N72 G01 X47.631 Y-117.5
N73 G03 X0 Y-35 I-47.631 J27.5
N74 G01 X-276.784 Y-196.313
N75 Y-150.14
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N77 Y-280.903
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N79 G01 Y-251.056
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N81 G01 X-498.672 Y-208.3
N82 G02 X-492.659 Y-213.196 I1.013 J-4.896
N83 G01 Y-238.492
N84 G03 X-480.659 Y-238.492 I6 J0
N85 G01 Y-208.645
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N86 G02 X-476.672 Y-203.748 I5 J0
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N88 G02 X-288.784 Y-171.017 I1.013 J-4.896
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N91 M30

Following the development of switching parts was done assembling and testing prototypes (Fig. 7-8)

Fig. 7 *Making of prototype part 1.*

***Fig. 8** Making of prototype part 2.*

4. CONCLUSION

New computer programs provide the opportunity to be with the least number of prototypes (even without making prototypes) make a final product that meets the needs of final users. Also, these programs provide the possibility of esy and rapid design, testing and commissioning of various technical systems.

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