

ANAGLYPH AND 3D MODEL USAGE IN EDUCATION OF MECHANICAL ENGINEERS

Abstract: *The development of computer technology and the use of 3D software has led to substantial changes in the education system and the way of thinking for future engineers. Until recently, both engineers and future engineers had to use plane projection for a spatial view of a certain part, making orthogonal design a necessity. However, due to advanced technology development, especially in the field of computers, this is no longer necessary. This paper provides an overview of the ideas that have been implemented in several courses held at the Faculty of Mechanical Engineering in Belgrade, where future engineers have the ability to learn about simpler, more modern and more efficient ways in which they can deal with the design of technical systems. The use of 3D modelling software packages in the design process significantly reduces the necessary time, and certain analyses of technical systems are made simpler and more accurate. For easier understanding of the problems of spatial layout and functionality of technical systems, students are learning about easy ways to display a physical technical system. This paper gives ideas on how to develop the education system for future mechanical engineers, but also how to prepare them to understand the traditional way of engineering and the design of technical systems.*

Keywords: 3D CAD model, modelling, visualization, perception, anaglyph, analysis.

1. INTRODUCTION

What is graphic communication? Firstly, it is a very effective means of communication between the technical idea and the final solution of the problem in engineering. Specifically, the process of engineering design begins with visualization, i.e., reviewing the problem and possible solutions. Sketching then leads to the preparation of the initial idea. This is followed by making geometric models, which are used for a variety of engineering analyses, and offer the designers more options for a better design. Finally, detailed drawings and/or 3D models are created, which are then used for the production process. Visualization, sketching, modelling and preparation of technical documentation are the ways in which engineers and technologists communicate in creating new products and structures in the modern technical world [1].

Graphic communication, which is carried by the engineering drawings and models, is a clear, practical language with defined rules that need to be complied with if one wants to be successful at engineering design (design). This language can be used to a large extent to overcome a number of problems encountered in engineering design.

92% of the engineering design process is based on the graphic display. The remaining 8% is divided between the mathematical calculations and written and oral communication. [2] About 50% of the design time is spent on purely visual and graphic activities (3D modelling and functional design).

Engineers like precision in communication. They use graphical tools, some of which are centuries old and are used day-to-day, while others are very new and conditioned by the rapid development of computer technology, such as CAD systems (Computer Aided Design).

This paper deals with research in the areas of graphic communications and the simplified field of virtual reality and their use in the development of technical systems and their components. The results of these studies have yielded new concepts in the development, design, production, testing and servicing of technical systems.

2. TECHNICAL SYSTEMS MODELLING

Modelling of a technical system is a process of presentation of an abstract idea, words and shapes, through proper usage of simplified text and pictures [1]. Engineers use models for thinking, visualization, communication, prediction, control and education. Models can be classified into two categories: descriptive and intuitive. A descriptive model presents abstract ideas, products and processes in a recognizable form. As a descriptive model it is possible to use, for example, an engineering drawing or a 3D CAD model. Before 3D CAD models, physical models were used as descriptive models. Drawings or 3D models are very good communication media, but it is not possible to use them for predicting behaviour or receiving performances of the technical system/part. The only way to achieve these performances is to use an intuitive model. Some mathematical models can be used for those purposes.

Geometrical modelling is a collection of complexly conceived ideas, technical systems/parts or processes, which use drawings or computer models instead of classical models in design. The final drawings produced by this method are 2D and 3D schemes, drawings and models. 2D schemes are useful for some types of engineering analyses, such as the kinematic analysis of an assembly, or electronic schemes and structural plans. 3D CAD models can be Wireframe or Surface. Wireframe models are used as input geometrical data for a simple analysis of the functioning of machine members, such as kinematical studies or finite elements

analysis. Surface models are used for visualization, automatic removal of hidden lines and animation. Wireframe models have a problem of uniqueness. If it is a simple form, it is possible to use it. In Fig. 1, we can see an example of a Wireframe model which represents more than one real model. Surface models are defined by surface characteristics and shapes of geometrical subject. Some of the most popular techniques of make them are: deflection, rotation, rolling and layering of border curves.

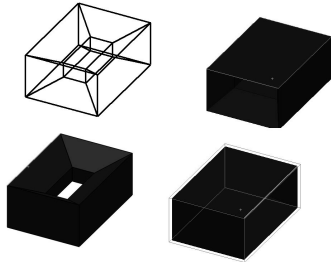


Fig. 1 Wireframe model and its real models [3].

2.1. Graphical computer methods for simulation, animation and analysis of virtual 3D models

Computer simulation is a set of very precisely modelled real situations that affect the technical systems in real time. A 3D CAD model can be used instead of the physical one for some types of analyses. Fig. 2 represents a simulation of a heat exchanger flow.

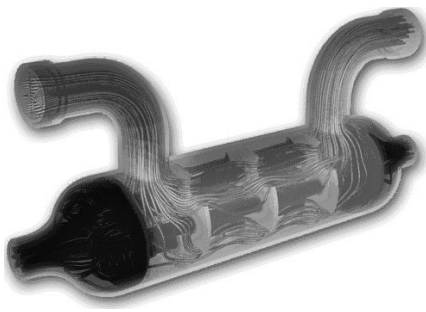


Fig. 2 Simulation of heat exchanger flow [4].

Regardless of the aesthetics of such presentation, it is possible to have a clear picture about the quality of design and its functionality. Through colour palette, the constructor can check his/her idea and repair it directly if it is necessary. This process does not take long and it is possible to repeat it as much as it is necessary to obtain a satisfactory result. Simulations are very important in scientific analysis of technical systems and play an important role in presentations. Computer animation is a presentation of the behaviour of a system in real time.

The main difference between animation and simulation is in the degree of accuracy of the achieve results. Thus, animation approximately describes the examined situation, while simulation describes it exactly.

Design analysis is a validation of the proposed design, based on the criteria defined in the primary phase of idea design. It is a big step in the design process and the

whole design team needs to be included. Typical analysis in design includes the following types [3]:

- Structural analysis, which evaluates the design based on physical features, such as strength, size, gravity centre, weight, centre of rotation, heating, fluid and mechanical features. The idea of structural analysis during the design of the press for pipe flexion is presented in Fig. 3. This example illustrates the analysis of strength and stress of the press during exploitation. Assembly analysis (Fig. 4) is used to define the position of some rigid bodies of the system and to check the process of assembly, using the geometrical characteristics and velocities of elements movement.

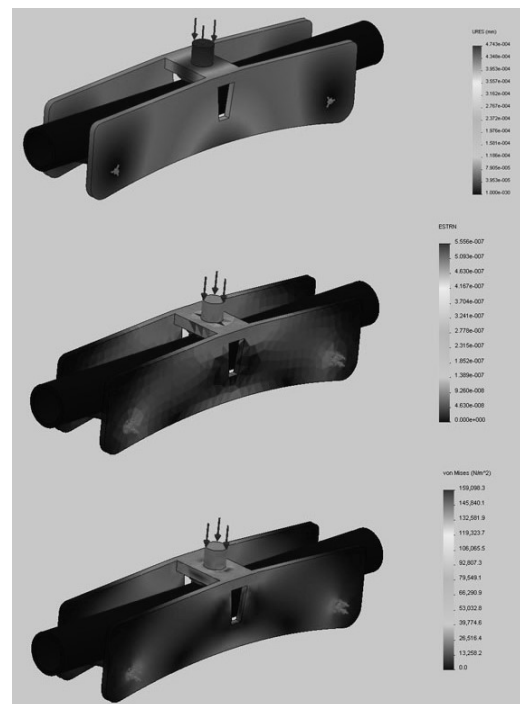


Fig. 3 Pres for pipe flotation analysis [5].

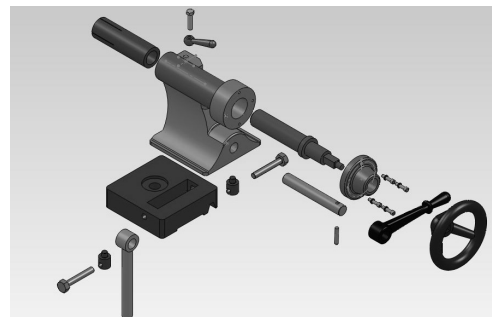


Fig. 4 Assembly analysis [5].

- Mechanical analysis of mechanisms deals with the motion of and loads on the mechanical systems of rigid bodies with connected joints. The most used types of mechanical analysis include kinematical and dynamical analysis. It is possible to use animation for the purposes of this kind of analysis
- Functional analysis determines whether the product

works the way it was designed.

- Human factor analysis (ergonomic) evaluates the design in the conditions of human usage, and determines whether the product is useful for the physical, emotional, qualitative, mental and security needs of the user. It is based on human body proportions. Fig. 5 presents a project of leakage device with a model of human body.
- Aesthetic analysis evaluates the design based on its aesthetic qualities.
- Market analysis determines whether the product meets the needs of the market, based on the results of interviewing the interested user groups.
- Financial analysis determines whether product price is in the range of the one predicted at the beginning of the design.

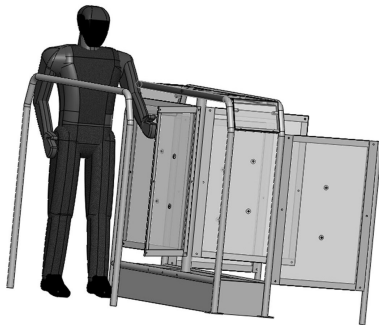


Fig. 5 Leaking device with a model of human body [5].

2.2. 3D models preparation, methodology of modelling

A solid model is an assembly of all pieces of volume and surface information for a 3D model. Most 3D models can be described by using basic geometrical forms (Fig. 6): prismatic, pyramid, spherical, torus, cylindrical and conical. By merging and subtracting these forms it is possible to obtain more complicated forms and parts.

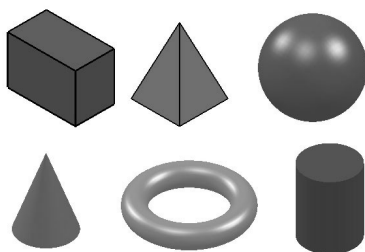


Fig. 6 Base geometrical forms [2].

The best way to obtain a 3D model is to create one from basic forms. For a long period of time, engineers used a 2D presentation of their ideas, and they were accustomed to using in-plane display. In that case, it was simpler to give a third dimension to a more complicated directrix. The development of 3D CAD techniques made it possible to create a model directly in 3D from basic 3D forms (Fig. 7).

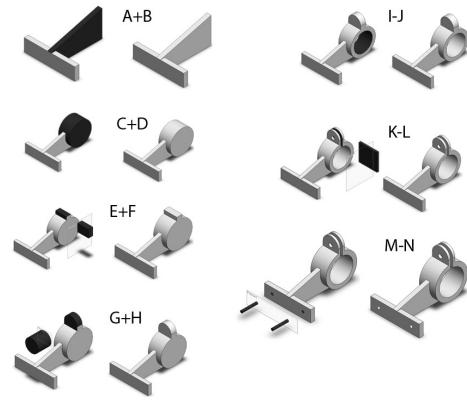


Fig. 7 Base geometrical forms.

3. ANAGLYPH

Anaglyph (αναγλυπος – carved in relief) is a form of 3D stereoscopic effect which is obtained by encoding each eye's image through the use of different filters (usually opposite colours by chromatics), such as red and cyan blue or red and green. An anaglyph 3D photo contains two differently filtered coloured images, one for each eye. When viewed through the “coloured” or “anaglyph” glasses, each of the two images reaches the selected eye (which has filters on it), revealing an integrated stereoscopic image. The visual context of the brain contributes to the perception and transforms it into a three-dimensional scene or composition. In the case of monochrome objects, (black-white) colour anaglyph display can be added, creating an anaglyph display. Fig. 8 shows an example of anaglyph images with a combination of red and cyan-blue filters.

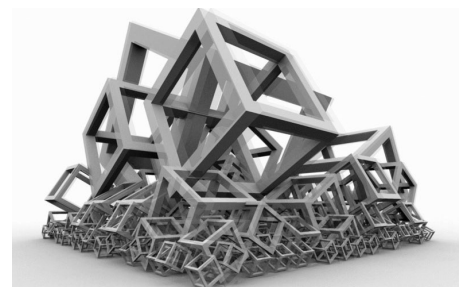


Fig. 8 Anaglyph red-cyan [5].

The term anaglyph stereogram may imply:

- Bichromatic stereogram, given in two complementary colours, so that one stereogram is shown in red and the other in the colour that is complementary to blue or green, or
- Polychromatic stereogram, which is shown in all colours of the spectrum, or so that one stereogram lacks the red colour and the second lacks a complementary colour, e.g. blue or green.

They are viewed using chromatic optical filters whose colours are identical to the colours of the bichromatic anaglyph. Anaglyph stereogram has all the geometric properties of any kind of stereogram, except for their

colours and techniques of realization. In order for a stereogram pair to cause the illusion of a three-dimensional perception of space, it is necessary that the geometrical characteristics of the respective images match the real binocular vision that enables fusion in Panum's retinal zone. In other words, this means that the distance between the ocular points of the mentioned central projections should be identical to the intraocular distance, which is 20 to 50 times larger. If the stereogram is bichromatic, to ensure that every eye in the binocular pair perceives the corresponding stereogram, it is essential that they are shown a pair of complementary colours (red-blue or red-green). If the stereogram is polychromatic, to ensure that each eye sees the appropriate stereogram, it is necessary that they are shown in those parts of the spectrum that lack complementary colours. If we are looking at the bichromatic pair anaglyph stereogram, where the red image is on the left and the right image is in a complementary (blue or green) colour, it is necessary that the left eye is red and the right eye optical filter is in a complementary (blue or green) colour. In addition, it is necessary for the distance at which the visor stereogram is positioned to be approximately equal to the distance of their central projections. In this case, the left eye sees only the green (blue) stereogram in green (blue) colour, while the right eye sees only the second stereogram in a complementary colour. If the surface is white, the left eye sees only the green (blue) and the right eye sees the stereogram in a complementary colour. During fusion, the central nervous system conveys to the observer the impression of observing a three-dimensional image.

4. ANAGLYPH PREPARATION

Anaglyph is a picture which gives the user an illusion of a 3D effect when he/she is watching through filters. There is a huge spectrum of software packages for the preparation of anaglyph presentation but all are based on the following idea [6] - Fig. 9:

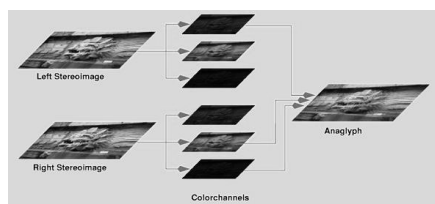


Fig. 9 Anaglyph preparation [6].

- The photo, picture, image or any other object that should be presented in anaglyph technology needs to be copied in 2 copies.
- The desired colour of copies for the eye is selected.
- The “filtering” of the object is performed, so that each eye is subtracted (or if the subject is not in colour, added) the desired colours. This type of presentation proved to be a very useful way to visualize the different types of tests in science and technology. It must be noted that anaglyph image does not require a large financial

investment, but is already one of the variants of virtual reality and largely evokes 3D space in a way that is easy for the user to be actively involved in this kind of environment. Anaglyph displays have also proved to be very attractive in terms of usability. Visualization system does not require very expensive and inaccessible equipment. It is possible to use slightly more advanced screens or projectors, which, together with the use of anaglyph glasses, to a greater or lesser extent give an impression of being “inside” the 3D space and of manipulating the technical systems that are given in 3D view inside the space.

For the purposes of testing of technical systems in study and education, an original software tool for creating anaglyph presentation was formed at the Faculty of

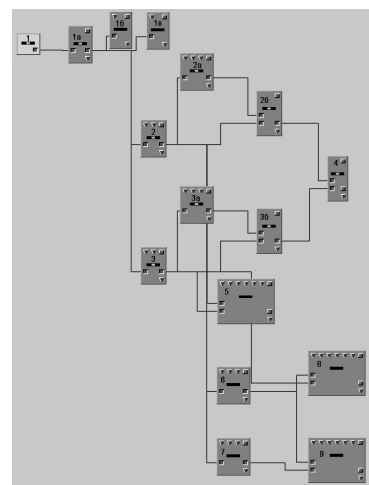


Fig. 10 Algorithm of anaglyph software.

Mechanical Engineering in Belgrade. Figure 10 provides an algorithm for making anaglyph software with the steps that are necessary in making the anaglyph display. For ease of understanding, the controls of computer-software tools have been replaced by the corresponding numerical codes. The steps of the algorithm are as follows: Position 1 – entering data, upload of any picture in *.bmp format.

Input – *im_in* *.bmp, output – file/picture.

Position 1a – preparation of the file from *.bmp format and its translation into a picture for the preparation of the desired view. The *.bmp file contains two types of picture-grey levelled 2D picture (*Img2duc*) and colour 2D picture (*Imc2duc*). Only the uncompressed *.bmp could be converted. It may be necessary to first convert the compressed *.bmp into uncompressed.

Input – *im_in* *.bmp, output – *im_out* converted picture, result can be *SUCCESS* or *FAILURE*.

Position 1b – refund proper value on the newly obtained object. The properties are specified on the basis of clear agreements according to the following parameters: 0 – number of columns; 1 – number of rows; 2 – number of planes; 3 – number of lanes; 4 – colour by scale and space (-1: no colour, or grey scale, 0:RGB, 1:XYZ, 2:LUV, 3:LAB, 4:HSL, 5:AST, 6:II2I3, 7:LHC,

8:WRY, 9:RNGNBN, 10:YCBGR, 11:YCH1CH, 12:YIQ, 13:YUV).

Input – *im_in* converted picture, results in values by selected characteristics.

Position 1c – a field that performs the same function as 1b. It is necessary to do the same procedure two times to obtain two 2D images that will later be passed through a filter of the desired colour (each image corresponds to each eye).

Positions 2 and 3 – the linear displacement image coordinate system (x, y), with the adoption of the origin in the top left corner. This step is necessary for binocular disparity. For each eye, or an appropriate pair of eyeglasses, one image was selected in 3D by “moving” after the x-axis coordinate system.

Input – *im_in* 2D colour image output – *im_out* object that is the same as the coordinate moving *im_in* that cannot be recognized at this level, the result is obtained in the form of SUCCESS or FAILURE.

Positions 2a and 3a – the formation of a new 2D image with constant values of RGB (red-green-blue). At this level, each pixel of the image receives a set of specified values of the colour (each pixel is filtered with a specific colour); a user can determine the colour according to the standard computer values. The following parameters are used:

R is the red component of the real value (0 to 255),

G is the green component of the real value (0 to 255),

B is the blue component of the real value (0 to 255).

This is essentially the level at which a particular filter is added.

Input – *im_in* 2D colour image output – *im_out* object that is the same as *im_in* with the addition of filters, the result is obtained in the form of SUCCESS or FAILURE.

Positions 2b and 3b – at this level, the result of “movement” in the image coordinate system and the filter, which has been assigned in the previous level, are combined, creating the image of a certain colour, with an adequate, desired “shift”.

Input – *im_in* 2D colour images, output – *im_out* object that is the same as *im_in* with the addition of filters and coordinate displacements, obtained as a result of SUCCESS or FAILURE.

Position 4 – the final output format of anaglyph display in the file in the format *.bmp, which can be seen as a spatial 3D display if glasses are used for anaglyph display. The images obtained at positions 2 and 3 have been combined according to the parameters that have been awarded at those levels.

Input – *im_in1* and *im_in2* RGB image output – *im_out* uniform RGB image obtained as a result of SUCCESS or FAILURE. These fields contain the most fundamental aspects of obtaining an anaglyph display and this is the most classical type of obtaining an anaglyph display an object. Taking into account the diversity of anaglyphs (next section) in the development of computer tools, when creating an anaglyph view it is necessary to include the following factors:

Position 5 – formation of anaglyph directly from the left and right 2D images. The images obtained in the

positions 2a and 3a are used as input data, and they contain directly loaded filters with the positions 2b and 3b. The following parameters are used here:

r1 and *r2* – the specification of the proportion of the red component in the left or the right picture.

g1 and *g2* – the specification of the proportion of the green component in the left or the right picture.

b1 and *b2* – the specification of the proportion of the blue component in the left or the right picture.

This type of formation of an anaglyph is seemingly simpler, but the formation of colours that are not a clean product of RGB primary colours proves to be a problem. Anaglyph display is very convenient when you need to display in 3d images and movies that are not in colour, but black/white. One of the main reasons for such a display method is to reduce the cost of printed materials.

To obtain such a display type the next steps are necessary.

Input – *im_in1* and *im_in2* RGB image, output – *im_out* unique RGB anaglyph file-image is obtained as a result of SUCCESS or FAILURE.

Positions 6 and 7 – the conversion of RGB colour images into a spatial image, using standard RGB colour parameters ($r = 0.299$, $y = 0.587$, $b = 0.114$).

Input – *im_in* RGB colour image, output – *im_out* anaglyph unique RGB colour spatial image obtained as a result of SUCCESS (successfully) or FAILURE (unsuccessfully).

Position 8 – obtaining anaglyph display so that the left side of the 2D gray, black/white display, a right 2D colour images. The same system is used as a parameter and the position 5.

Input – *im_in1* left grey, black/white and colour *im_in2* RGB image, output – *im_out* unique anaglyph RGB image obtained as a result of SUCCESS or FAILURE.

Position 9 – obtaining anaglyph in grey, black/white display. All the images obtained in the positions 2, 6, 7 and 8 are used as input data. The parameters are the same as in the positions 5 and 8.

Input – *im_in1* and *im_in2* gray, black/white photos, output – *im_out* unique RGB anaglyph black/white image, the result is obtained in the form of SUCCESS or FAILURE.

The next figures (Fig.11-Fig. 14) present Fig. 4 by using this software.

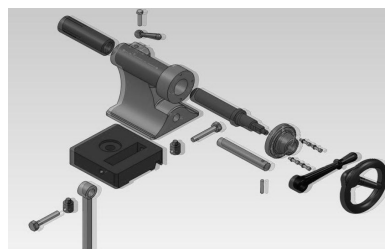


Fig. 11 Anaglyph presentation-position 4.

Fig. 11 is anaglyph presentation received on position 4 – the final output format of anaglyph display which can be seen as a spatial 3D display if glasses are used for

anaglyph display. This is the simplest form of anaglyph presentation.

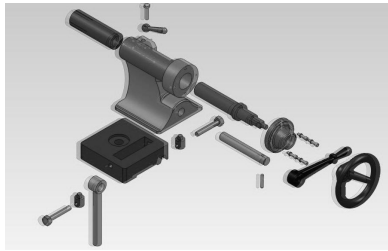


Fig. 12 Anaglyph presentation-position 5.

Fig. 12 presents anaglyph presentation received on position 5 – formation of anaglyph directly from the left and right 2D images, obtained in the as images with constant values of RGB (red-green-blue).

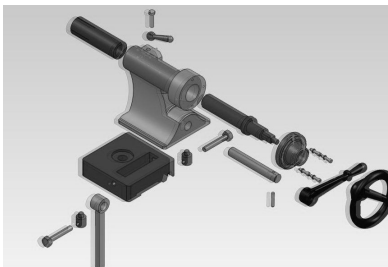


Fig. 13 Anaglyph presentation-position 8.

Anaglyph presentation received on position 8 – obtaining anaglyph display so that the left side of the 2D gray, black/white display, a right 2D colour images is presented on Fig.13.



Fig. 14 Anaglyph presentation-position 9.

Anaglyph in grey, black/white display-position 9 is shown on Fig.14.

5. CONCLUSION

The development of computer technology and the use of 3D software has led to substantial changes in the education system and the way future engineers think. The need to envision space as a plane and use orthogonal design, which has been the only form of display until recently, slowly disappears due to the rapid development of computer technology. Paradoxically, but we are getting back to the original idea of performing the design of technical systems by using 3D spatial models which

has been avoided over a long period of time due to the complexity of the process and/or high prices involved in making 3D models. Nowadays, it is quite feasible to produce a virtual 3D model with all the features of the real physical model without substantial investments.

In this paper authors tried to explain a new approach to 3D visualisation in educational process. We created a personal software for anaglyph preparation, easy to use in educational process. Now it is possible to use any kind of 3D design in education of future engineers and to make that process not so expensive.

REFERENCES

- [1] Beroline G.R, Wiebe E.N, (1995). *Technical Graphics Communication*, Irvin Graphics Series.
- [2] Beroline G.R, Wiebe E.N, (2007). *Fundamentals of Graphics Communication*, The McGraw-Hills Graphics Series.
- [3] Jeli Z. Popkonstantinovic B., Stojicevic M (2016). *Usage of 3D Computer Modelling in Learning Engineering Graphics*, Chapter 4, Intech, <http://www.intechopen.com/books/virtual-learning>
- [4] Barr R.E., Krueger T.J. Juricic D., Aantoo T.A. . (2004). *Engineering Design, Graphics Sketching Workbook, 5th edn*, Schroff Development Corporation, Mission, KS.
- [5] Jeli Z. (2012). *Graphic communication and virtual reality in technical system development (Graficke komunikacije i virtuelna realnost u razvoju tehnickih sistema)* Faculty of Mechanical Engineering, Ph.D. dissertation, Belgrade.
- [6] Matsamura F, Fujisava N. (2008). *Anaglyph Stereo Visualization by the Usage of a Single Image and Depth Information*, In: Journal of Visualization, The Visualization Society of Japan, Vol. 11 No1, pp 79-86, Springer.

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