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SYMMETRY IN SHAPE AND SYMMETRY IN MOTION OF DIGITAL 3D CHARACTERS

RATKO OBRADOVIĆ, IVANA VASILJEVIĆ, FILIP MIRČESKI and ISIDORA ĐURIĆ

Name: Ratko Obradović,
Profession: PhD, Full Professor
Fields of interest: Computer Graphics
Affiliation: Faculty of Technical Sciences, University of Novi Sad
E-mail: obrad_r@uns.ac.rs
Homepage: http://www.racunarska-grafika.com/index.php/katedra
Major publications and/or exhibitions:
Obradovic M., Vasiljevic I., Djuric I., Kicanovic J., Stojakovic V., Obradovic R.: Virtual Reality Models Based on Photogrammetric Surveys-A Case Study of the Iconostasis of the Serbian Orthodox Cathedral Church of Saint Nicholas in Sremski Karlovci (Serbia), Applied Sciences, 2020, Vol. 10, No. 8, Article Number 2743, DOI: 10.3390/app10082743, ISSN 2076-3417
http://www.new-silhouette-studio.com/
http://racunarska-grafika.com/karlovci/

Name: Ivana Vasiljević
Profession: PhD, Teaching Assistant
Fields of interest: Computer Graphics
Affiliation: Faculty of Technical Sciences, University of Novi Sad
Email: ivanav@uns.ac.rs
Homepage: http://www.racunarska-grafika.com/index.php/katedra
Major publications and/or exhibitions:
Vasiljevic I., Obradovic R., Djuric I., Popkonstantinovic B., Budak I., Kulic L., Milojevic Z.: Copyright Protection of 3D Digitized Artistic Sculptures by Adding Unique Local Inconspicuous Errors by Sculptors, Applied Sciences, 2021, Vol. 11, No. 16, Article Number 7481, DOI: 10.3390/app11167481, ISSN 2076-3417

Name: Filip Mirčeski
Profession: MSc, Teaching Assistant
Fields of interest: Computer Graphics
Affiliation: Faculty of Technical Sciences, University of Novi Sad
Email: filip.mirceski@uns.ac.rs
Homepage: http://www.racunarska-grafika.com/index.php/katedra
Major publications and/or exhibitions:
Vasiljević I., Mirčeski F., Milinković N., Obradović R. ORGANIC MESH AND RIGID BODY UV UNWRAPPING AND MAPPING TAUGHT IN THE SUBJECT TEXTURE AND LIGHT DESIGN. The 8th International Conference on Geometry and Graphics Mongeometrija 2021. September 2021. ISBN 978-86-6060-085-3

Name: Isidora Đurić
Profession: PhD, Teaching Assistant
Fields of interest: Computer Graphics
Affiliation: Faculty of Technical Sciences, University of Novi Sad
Email: isidoradjuric@uns.ac.rs
Homepage: http://www.racunarska-grafika.com/index.php/katedra
Major publications and/or exhibitions:
Djuric I., Obradovic R., Vasiljevic I., Ralevic N., Stojakovic V.: Two-Dimensional Shape Analysis of Complex Geometry Based on Photogrammetric Models of Iconostases, Applied Sciences, 2021, Vol. 11, No. 15, Article Number 7042, DOI: 10.3390/app11157042, ISSN 2076-3417

Abstract: *This paper presents some examples of symmetry and asymmetry in the geometry of 3D digital character, as well as in its movement. This is one of the topics studied in the Computer Graphics studies, which have existed for 11 years at the Faculty of Technical Sciences at the University in Novi Sad. The first goal of this paper is to show how to create a 3D digital character, which consists of a surface called Mesh that connects to a system that allows the movement of that character, and that the system consists of a bone system with associated controls and is called a rig. The character is most often created using symmetry, namely, a mesh of one half of the character is created and then the other half of the character is obtained by creating a symmetrical half, and the plane of symmetry is a vertical plane that halves the character. The second goal is to show that the 3D character created in this way can be geometrically symmetric or asymmetric. The next goal is to show how symmetric or asymmetric character creates body movement or facial expression. The main goal is to emphasize the need to use asymmetric characters in 3D animation, as well as the motive for this, which emphasizes the fact that ideal symmetry in humans does not actually exist. Also, asymmetry gives us far more opportunities to create interesting differences in 3D characters.*

Keywords: Asymmetric 3D Digital Character; Computer Animation; Character's Mesh and Motion; Bilateral Symmetry/Asymmetry

INTRODUCTION

One of the most common types of biological symmetry is bilateral symmetry. Bilateral symmetry indicates that both sides of the shape will develop as mirror images of one another after the reflection transformation (Benítez *et al*., 2020, p.1789). The human population belongs to a clade of species distinguished by an essentially symmetrical body plan (Corballis, 2021, p.914).

In nature, all living organisms are more or less symmetrical, while the extent to which the average individual departs from perfect symmetry is named fluctuating asymmetry (Babcock, 2005; Graham *et al*., 2010, pp. 466-540). Due to biological evolution, asymmetry is inseparable from the phenomenon of symmetry. According to Corballis and co-authors (2021, p.914) "bilateral symmetry and asymmetry coexist in a trade-off". Depending on the probability distribution of the differences between right and left sides, three types of asymmetries can be distinguished: fluctuating asymmetry, directional asymmetry, and antisymmetric (Benítez *et al*., 2020, p.1789). Fluctuating asymmetry represents small, random developmental morphological differences between the right and left sides of organisms, that have mostly a 1:1 left-right ratio, while directional asymmetry refers to unequal structure size or function, whereas the 1:1 left-right ratio is highly tilted (Benítez *et al*., 2020, p.1789; Zaidel & Hessamian, 2010, pp136-149). Since symmetry, hence, fluctuating asymmetry is ubiquitous in all life forms, the phenomenon of bilateral asymmetry is an important concept in creating faithful digital representations of living organisms, such as 3D characters.

In contrast to the real-world asymmetric characteristics of all living organisms, which are influenced by evolutionary processes, virtual 3D characters are mostly developed using the concept of bilateral symmetry. Consequently, such a concept results in 3D models of human characters based

on an ideally symmetrical body, which lacks essential characteristics of human nature. Even though symmetry often serves as a notion associated with a judgment of attractiveness and beauty, different studies of nature, art, and human faces showed that asymmetry does not necessarily mean the absence of beauty (Zaidel *et al*., 2007, pp. 423-431; Corballis, 2020, p.326). Except in nature, the concept of asymmetry is emphasized in art. In the Japanese aesthetic philosophy called Wabi-sabi, asymmetry represents the art of impermanence, which finds beauty in things imperfect and incomplete (Juniper, 2011). According to Zaidel and coauthors (2007, pp. 423-431), the attractiveness of computer-constructed perfectly bilaterally symmetrical faces was judged as significantly lower compared to natural faces. In that context, this paper focuses on the bilateral and directional asymmetry in developing the shape and motion of digital human 3D characters. Instead of using a usual workflow based on symmetry, we focus on design imperfections in 3D character design.

SYMMETRICAL 3D CHARACTERS

The first goal of this paper is to present a short pipeline for creating a 3D digital character (Figure 1, left), which consists of a surface called Mesh (Figure 1, right) that connects to a system that allows the movement of that character, and that the system consists of a bone system (Figure 2, left) with associated controls and is called a rig (Figure 2, centre and right).

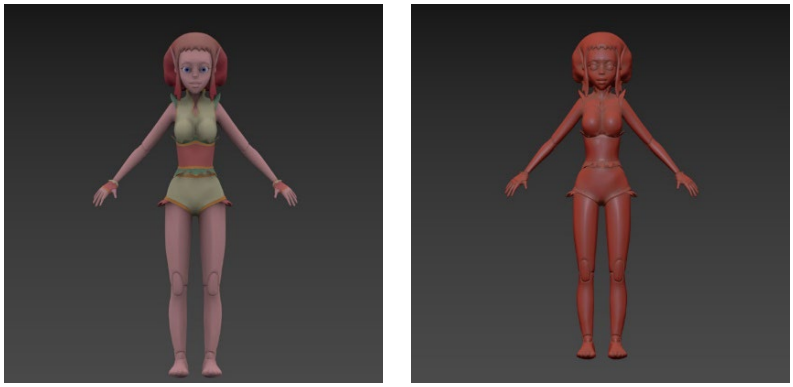


Figure 1 3D digital character and character Mesh

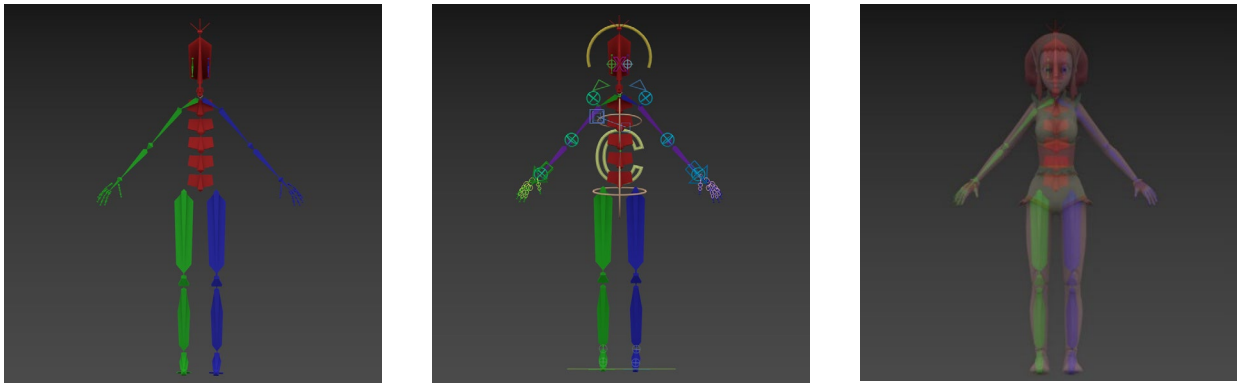


Figure 2 3D character bone system (left); bones controls (centre);
3D character and rig that make bones with controls (right)

The character is most often created using symmetry, namely, a mesh of one half of the character is created (Figure 3a) and then the other half of the character is obtained by creating a symmetrical half (Figure 3b), and the plane of symmetry is a vertical plane that halves the character.

The second goal is to show that the 3D character created in this way can be geometrically symmetric or asymmetric. If the character is such that it has a regular walking cycle, then the assumption is that the geometry of such a character is symmetrical. This means that his left half of the body is the same size as his right half. If the character is asymmetric, for example if one of his legs is shorter, then it is expected that his walking cycle is asymmetric, that is, that such a character is crooked.

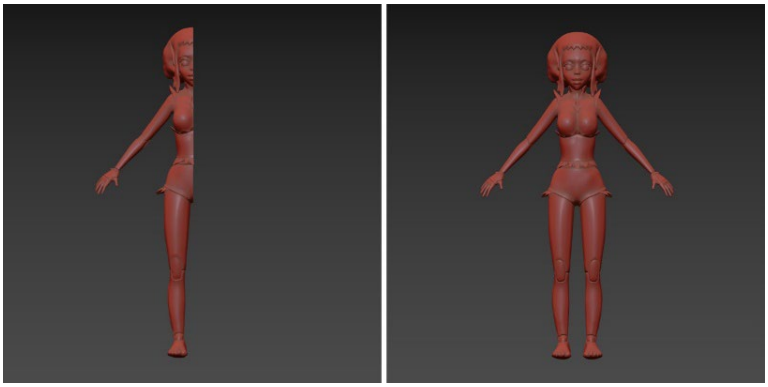


Figure 3 Mesh half character (left) and Mesh full character (right)

ASSYMETRY IN 3D CHARACTERS

The aim of this paper is to shift the focus in creating digital 3D characters toward such characters that are more in line with real life and nature in which nothing is perfectly symmetrical. Our intention is to emphasize several types of asymmetries in digital 3D characters that depict human nature and through this diversity show a much larger range of beauty and attractiveness than in ideally symmetrical characters. We will focus on two aspects of asymmetry, the first refers to the asymmetry of the shape of the face, that is, the body of a human-like 3D character, and the second to the asymmetry in facial expressions and character movement.

ASYMMETRY IN THE SHAPE OF THE FACE AND BODY

Different variations of deviations of human 3D characters will be presented to emphasize the importance of the concept of asymmetry in creating digital 3D characters. The idea behind creating such imperfect, asymmetrical 3D characters is to underline the attractiveness of impermanence and morphological complexity and diversity in form. The human body is symmetrical in that a vertical line can be drawn and on both sides of that line are the same things, what is not the same are the details that make a person beautiful. Even the internal organs have their symmetry and asymmetry, there are those that are on both sides of the body and those that are only on one. When you look at a

human face, you will notice that it is almost symmetrical, except for small details such as youth and eyebrows. One eyebrow is always a little higher than the other, one eye semi-closed (Figures 4-6), etc.

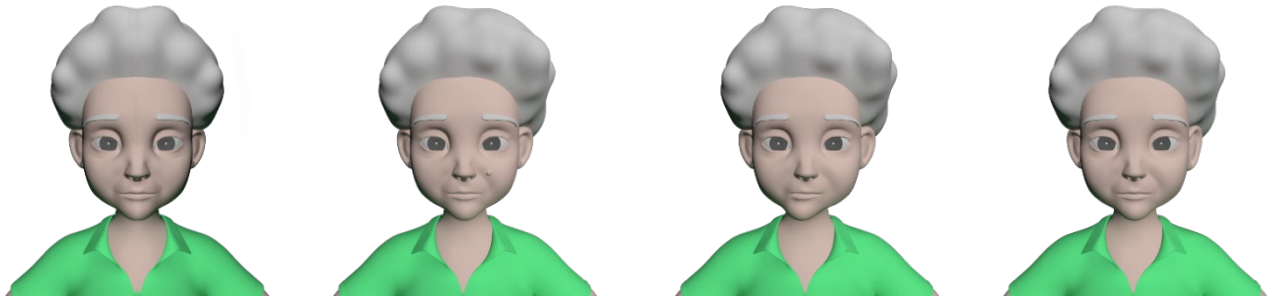
(a) (b) (c)

Figure 4. (a) Symmetrical; (b) asymmetrical in hair; (c) asymmetrical in hair, ear and piercing on the left eyebrow

The next goal is to show how character creates movement, that is, how the walking cycle is formed, or some movement, for example in sports. Here one can insist on symmetry in movement, but also on asymmetry. Namely, most people move symmetrically, so that the centre of gravity of the body alternately shifts from one leg to the other. However, this symmetrical step is actually visually boring, and does not give us any character traits. On the other hand, a character who "throws" his feet differently while walking, or a paw, is visually more striking and noticeable. This is due to the fact that people do not notice when a person walks physically correctly, while every deviation from it attracts our attention. It is a similar thing with the movement of the camera in the film, when that movement is continuous and "smooth", and when the movement of the camera is of high quality, we will not state that, because it goes without saying. However, we will easily visually recognize any anomaly in the movement of the camera.

(a) (b)

Figure 5 (a) Symmetrical; (b) wide left eye



(a) (b) (c) (d)

Figure 6 (a) Symmetrical; (b) youth on the left cheek; (c) jaw; (d) right ear

ASYMMETRY IN BODY MOVEMENT

There are a lot of papers dealing with different ways to create character movements (Obradović *et al*., 2018, pp. 1671-1681). Alberto Cannavo *et al*. (2019, pp. 125463-125480) created Virtual Reality (VR) based interface for 3D Character Animation. That means that VR is not only a medium for visualizing but also a tool for creating of animation. Mou *et al*. (2018, pp. 1-16) has debated whether it is more convenient to use a Keyframe or a motion capture system. The technique of using the Keyframe is the standard for learning Character motion and Motion Capture has become the industry standard for film production.

Asymmetries of different parts of the body and face as a consequence have and cause asymmetric movements of different parts of the body, but also asymmetric facial expressions. Asymmetrical movements can also be challenging with physical defects in character, such as the lack of one part of the body. In such cases, the person moves with the help of aids (crutches or wheelchairs, if we are talking about legs), or the deficiency is compensated by a prosthesis. Prosthesis is mostly made of some solid materials, special plastic, or metal, and therefore cannot fully imitate realistic movement (MAGNETFILM. 2017, March 20). Figure 7 shows the cycle of the grandmother's walking cycle in eight frames, in the first four frames the movement of the left leg is dominant, and in the remaining movements of the right leg, where there is a noticeable asymmetry in walking (*Inženjerska animacija*. 2022, April 11). Figure 8 shows the girl's facial expressions, moving her eyebrows, mouth, eyelids, and cheeks (red arrows show asymmetrical deformations that are emphasized).

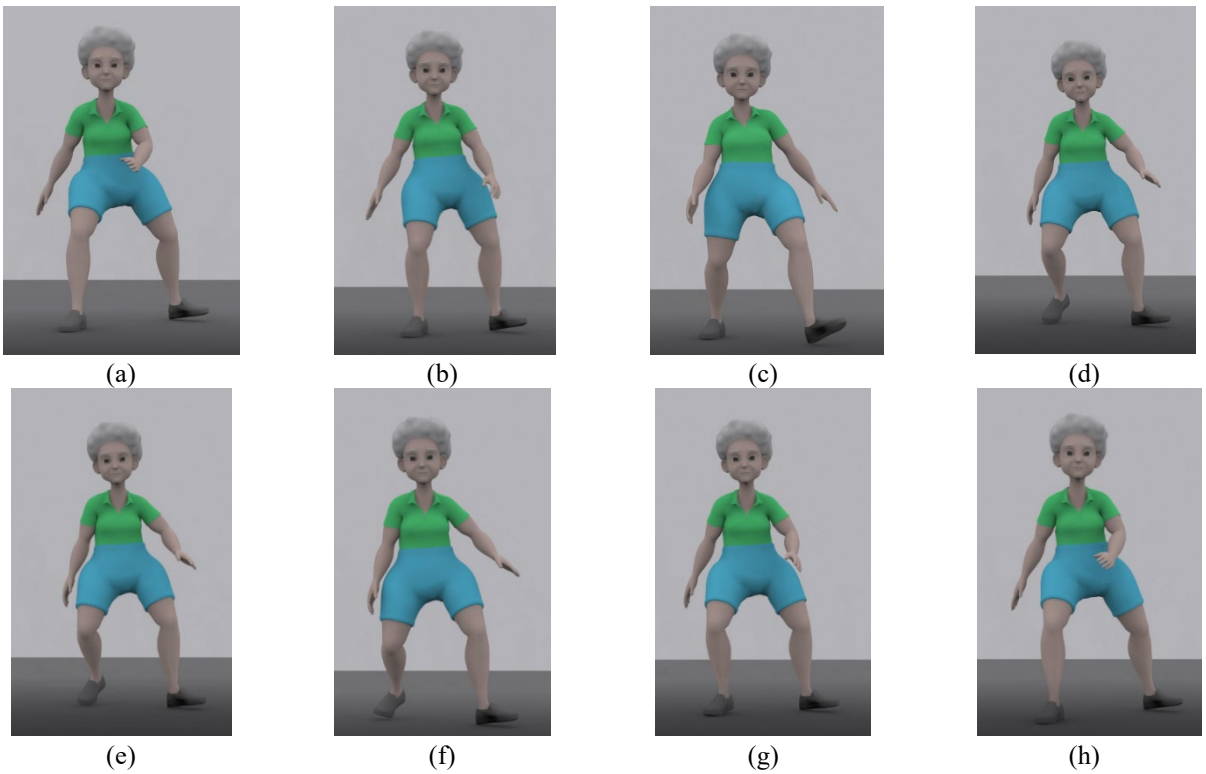


Figure 7 Grandmother's asymmetric walking cycle in eight frames: (a-d) left leg movement, (e-h) right leg movement

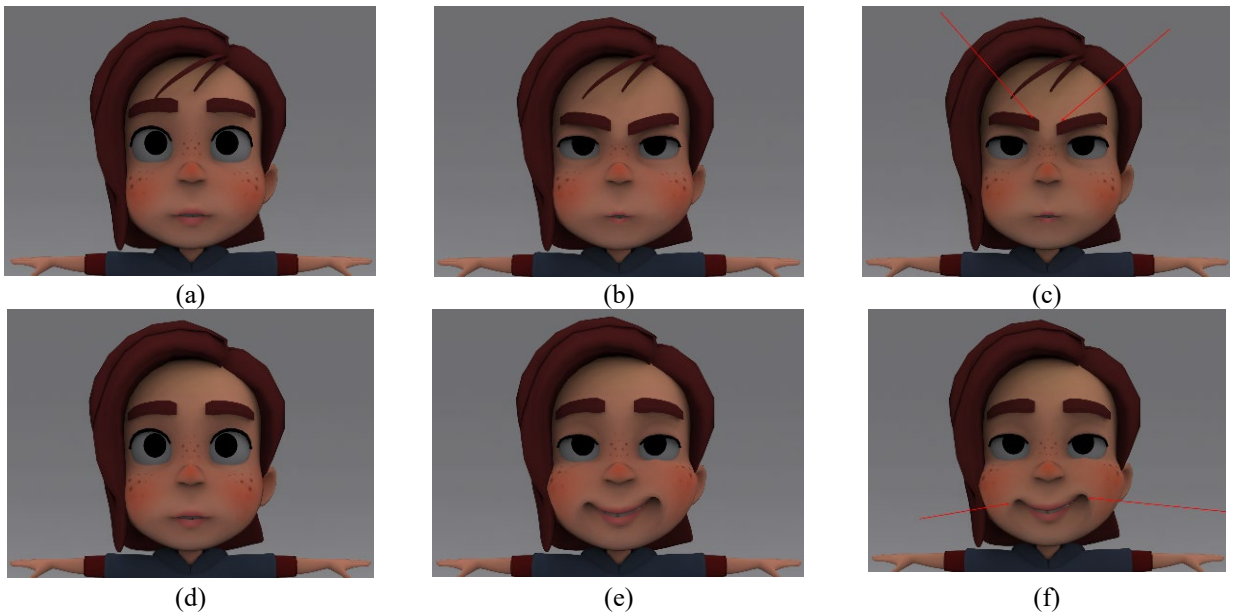


Figure 8 Girl's asymmetric facial expression: (a-c) angry, (d-f) smile

CONCLUSION

The paper reviews the use of symmetry/asymmetry in 3D digital characters. This symmetry/ asymmetry has been achieved on several levels. The first is a mesh of characters whose geometry may or may not be symmetrical. If the mesh of a character is symmetrical, then its geometry is usually obtained by creating one half of the geometry of the character and the other half is obtained by plane symmetry where this plane is vertical and divides the character into two equal parts. In the case of an asymmetric character, it can be reached in several ways: by "spoiling" the symmetrical character,

i.e., by deforming the body parts of the symmetrical character. Another variant is to create an asymmetric 3D model of the sculpture so that such sculptures are scanned using a laser scanner or photogrammetry. The second level of symmetry is in the movement of the character itself. And here we have multi-layered movement. For example, a character can be symmetrical but his movement can be asymmetrical, e.g., if the character "injured" the leg, his movement will not be symmetrical. Another approach is to create an asymmetric mesh of characters that leads to asymmetric movement. For example, if a character has a shorter leg, he will certainly limp on that shorter leg. The third new symmetry is hidden in the character's face. Facial geometry can be symmetrical or asymmetrical. An asymmetrical face will generally lead to asymmetrical movement. Symmetrical facial geometry also leads to asymmetrical facial expression. In this paper, an analysis of symmetry in 3D characters and its animation is made in accordance with the three mentioned criteria.

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Ratko OBRADOVIC

Ratko Obradovic is a full professor at the Faculty of Technical Sciences, University of Novi Sad, Serbia. His research interests include Computer Graphics, Computer Geometry, Computer Animation, CAD, Scientific Visualization, Virtual and Augmented Reality, Higher Education. He is the author or coauthor of four books and has published 40 journal papers and more than 50 articles in Conference proceedings. He is the founder of the CG studio "New Silhouette Studio" and he is also a coauthor of two CG animated films. He was a scholar of the Austrian Government (WUS Austria, 2006.), and German academic exchange services DAAD (project GEFFA - Geometry Education for future Architects, 2012.). He participated in the ERASMUS+ staff mobility for teaching and training project (Romania, 2016.). He is a member of the ICGG and from 2010 to 2012 he was the president of SUGIG. Hi is also a member of the ACM and SIGGRAPH.

Ivana VASILJEVIC

Ivana Vasiljević is a Ph.D. in Computer Graphics and a Teaching Assistant at Computer Graphics Chair at the Faculty of Technical Sciences, University of Novi Sad. She is a member of Serbian Society for Geometry and Graphics (SUGIG). Her research interests include computer graphics, computer animation, visualization, simulations, visual effects, virtual and augmented reality, photogrammetry, digitization, and cultural heritage. She is the author and co-author of four papers published in international journals from the SCIe list (journals with Impact Factor indexed by Web of Science), seven papers presented in International Conferences with printed Proceedings, two journal papers printed in national journals. She also has four art exhibitions organized by the Matica Srpska Gallery, National Museum in Belgrade and Museum of Vojvodina in Novi Sad, as well as an animated film (Head is not dead) shown in the competition program of the four International Festivals.

Filip MIRCESKI

Filip Mirčeski is a second-year doctoral student of Computer Graphics at the Faculty of Technical Sciences, University of Novi Sad, where he has been employed since 2019. Areas of scientific research are computer graphics and animation, augmented and virtual reality, photogrammetry, digitization of cultural heritage. He is a participant in projects in the field of digitization of cultural heritage, namely Digitization and virtual presentation of the art collection from the depot of the Gallery of Matica srpska, as well as digitization and virtual presentation of the art collection of the Terra Museum in Kikinda.

Isidora DJURIC

Isidora Đurić (born 27th Dec. 1990) is a teaching assistant at the Faculty of Technical Sciences, University of Novi Sad. She graduated from the same University: B.S. (2013) and M.S. (2014) degrees in *Architecture and Urban Planning,* and a Ph.D. degree (2021) in *Computer Graphics.* She

was awarded the Scholarship of the Ministry of Education, Science and Technological Development of the Republic of Serbia for Ph.D. students (2015-2018). She is a member of SUGIG (Serbian Society for Geometry and Graphics). Her research interests include computer graphics, photogrammetry, cultural heritage digitization, AR and VR. She participated in more than five national projects for the digitization of cultural heritage in the Republic of Serbia. She is the author or co-author of four journal articles and ten papers in international and national conference proceedings.