УДК 7.01:7.02-021.131

Цитування:
Sovhyra T. Three-dimension evolution: from illusion of three-dimensional image (in graphics and paintings) to three-dimensional objects in real space (3D printing) [Еволюція 3D-виміру: від ілюзії тривимірного зображення (в графіці та живописі) до тривимірних об'єктів в реальному просторі]. *Вісник Національної академії керівних кадрів культури і мистецтв : наук. журнал.* № 2. Київ : ІДЕЯ ПРИНТ, 2020. С. 104-109.

Sovhyra T. (2020). Three-dimension evolution: from illusion of three-dimensional image (in graphics and paintings) to three-dimensional objects in real space (3D printing). National Academy of Culture and Arts Management Herald: Science journal, 2, 104-109 [in Ukrainian].

Sovhyra Tetiana,
Ph.D. in Art, Senior Lecturer of Variety Art and Mass Event Direction Department,
Kyiv National University of Culture and Arts,
ORCID: https://orcid.org/ 0000-0002-7023-5361
STIsovgyra@gmail.com

THREE-DIMENSION EVOLUTION: FROM ILLUSION OF THREE-DIMENSIONAL IMAGE (IN GRAPHICS AND PAINTINGS) TO THREE-DIMENSIONAL OBJECTS IN REAL SPACE (3D PRINTING)

Purpose of Article. The article is devoted to clarifying the features of stereographic images, the main aspects of using 3D printing as modern creative technology in various fields of human activity. **Methodology.** General scientific and concrete-scientific methods are applied in the work: theoretical – to clarify the conceptual-categorial apparatus of research; analytical – to analyze philosophical, art, history, cultural literature on the topic of research; historical – to clarify the development of stereography and the stages of formation of 3D-technologies; comparative-typological – to compare the specifics of using three-dimensional printing in various fields of human activity. **Scientific Novelty.** The genesis of 3D measurement features from the illusion of volumetric flat images to the creation (printing) of unique 3D objects is considered for the first time. The article analyzes the specificity of stereoscopic images and the principles of creating three-dimensional products using 3D printers. **Conclusions.** It has been proven that 3D printing is developing globally thanks to many advantages and affordable prices. 3D printing is a technology that allows going through the entire chain of the design process in a closed and continuous cycle: from the generation of an idea to the final design result.

Key words*:* stereo image, painting, art, technology, stereolithography, artifact, printer, 3D printing.

Совгира Тетяна Ігорівна*, кандидат мистецтвознавства, старший викладач кафедри режисури естради та масових свят Київського національного університету культури і мистецтв*

Еволюція 3D-виміру: від ілюзії тривимірного зображення (в графіці та живописі) до тривимірних об'єктів в реальному просторі

Мета роботи. Стаття присвячена з'ясуванню особливостей стереографічного зображення, основних аспектів використання 3D-друку як сучасної креативної технології в різних сферах діяльності людини. **Методологія дослідження:** у роботі застосовано загальнонаукові та конкретнонаукові методи: теоретичний – для з'ясування понятійно-категоріального апарату дослідження; аналітичний – при аналізі філософської, мистецтвознавчої, культурологічної літератури з теми дослідження; історичний – для з'ясування розвитку стереографії та етапів становлення 3D-технологій; порівняльно-типологічний – для порівняння специфіки використання тривимірного друку в різних сферах діяльності людства. **Наукова новизна** роботи полягає в тому, що вперше розглядається ґенеза особливостей 3D-виміру від ілюзії об'ємності пласких зображень до створення (друку) унікальних 3D-об'єктів, аналізується специфіка стереоскопічного зображення та принципи створення об'ємних продуктів за допомогою 3D-принтерів. **Висновки.** Доведено, що 3D-друк розвивається в глобальному масштабі завдяки багатьом перевагам і доступним цінам. 3D-друк – це технологія, яка дозволяє проходити весь ланцюжок процесу проектування в замкнутому і безперервному циклі: від генерації ідеї до кінцевого результату продукту.

Ключові слова: стереозображення, живопис, мистецтво, технологія, стереолітографія, ламінування, артефакт, принтер, 3D-друк.

Совгира Татьяна Игоревна*, кандидат искусствоведения, старший преподаватель кафедры режиссуры эстрады и массовых праздников Киевского национального университета культуры и искусств*

Эволюция 3D-измерения от иллюзии трехмерного изображения (в графике и живописи) до трехмерных объектов в реальном пространстве

Цель работы. Статья посвящена выяснению особенностей стереографического изображения, основных аспектов использования 3D-печати как современной креативной технологии в различных сферах деятельности человека. **Методология исследования**: в работе применены общенаучные и конкретнонаукови методы: теоретический – для выяснения понятийно-категориального аппарата исследования; аналитический – при анализе философской, искусствоведческой, культурологической литературы по теме исследования; исторический – для выяснения развития стереографии и этапов становления 3D-технологий; сравнительно-типологический – для сравнения специфики использования трехмерной печати в различных сферах деятельности человечества. **Научная новизна** работы заключается в том, что впервые рассматривается генезис особенностей 3D-измерения от иллюзии объемности плоских изображений к созданию (печати) уникальных 3D-объектов, анализируется специфика стереоскопического изображения и принципы создания объемных продуктов с помощью 3D-принтеров. **Выводы.** Доказано, что 3D-печать развивается в глобальном масштабе благодаря многим преимуществам и доступным ценам. 3D-печать – это технология, которая позволяет проходить всю цепочку процесса проектирования в замкнутом и непрерывном цикле от генерации идеи до конечного результата продукта.

Ключевые слова: стереоизображение, живопись, искусство, технология, стереолитографии, ламинирование, артефакт, принтер, 3D-печать.

The relevance of the research topic. US President Barack Obama, in the context of his annual appeal to citizens, said: „There is now a modern laboratory in place of the closed staff, where new workers are mastering a 3D printer, which can potentially radically change the way of creating practically anything” [11, 29]. 3D technology is one of the most important discoveries of the late XX – early XXI century. Now, 3D printing is an innovative technology for creating physical objects, it is developing very rapidly and penetrates almost all spheres of human activity.

Formulation of the problem. Recall the popular expression „Let's draw – we will live” from the famous poem by Vitaly Petrow [16, 47]. We find these words in what is designated as phraseological unit and testifies to the ease of solving emerging issues, the simplicity of future work. No one could then think that this expression will become a reality when it becomes possible to get real artifacts from drawings, create houses, furniture, cars, and the like.

Analysis of recent research and publications. The literature on stereography and three-dimensional space has been written a lot. We find the first judgments about stereoscopic images in Western European and American scientific studies: „Contribution to the physiology of vision. Part the first. On some remarkable, and hitherto unobserved, phenomena of binocular vision” by Charles Wheatstone (England, 1838) [26], „Zwei neue stereoskopische Methoden” („Two new stereoscopic methods”) by Wilhelm Rollman (Germany, 1853) [22], „The Stereostore. Its History, Theory, and Construction” by David Brewster (England, 1856) [3].

Later, scientists, in particular Semen Gurevich, Nicholas Valius, devoted their research to the topic of stereoscopy as a science of visual perception of the three-dimensionality of the surrounding space. As Semen Gurevich points out, the stereoscope „enlivens the usual flat illustration, enriching the resulting visual perception with a real spatial construction of the third (deep) axis” [24, 5-6].

With the advent of stereoscopic images, it becomes necessary to study the phenomenon of „stereology”, which is a system of mathematical and statistical methods for describing the characteristics of 3D objects. This concept is considered in the article „Stereological method in neuromorphological research” by Michael Belen'kii and Zinaida Bryksina [1, 59-60]. However, these works must be analytical and descriptive. The phenomenon of three-dimensional printing is considered superficially, without a proper theoretical analysis of the fundamental foundations. This article does not claim to be a complete study of the manifestations of three-dimensionality, its purpose is to consider the evolution of three-dimensionality from flat images to three-dimensional objects.

The aim of the article is to clarify the features of stereographic images, the main aspects of the use of 3D printing in various fields of human activity.

The presentation of the main material. For centuries, painters of art have sought to give the image volume and a three-dimensional effect. The surviving fragments of drawings of the Church of the Tithes of the end of the 10th century, the Frescoes of the Chernihiv Savior with realistic black-and-white coloring indicate a search for artists of the illusion of the volumetric image. However, the founder of the new painting technique „chiaroscuro”, which provided the canvases with the illusion of a three-dimensional image by comparing light and shadows, became known worldwide scientist and engineer Leonardo da Vinci. The secret of depth, perspective, and volume of his paintings „Mona Lisa” (1503-06) and „The Last Supper” (1495-98) have not yet been discovered by scientists. It is fair to say that his paintings are inspired by the play of chiaroscuro and have a stereoscopic illusory effect.

Stereoscopic („stereo" – volume, physicality, „scopeo" – see, observe) image – an image that when viewed looks three-dimensional, capable of conveying the shape of the objects depicted, the nature of their surface (texture), the relative position of objects in space and others external signs. The volumetric image of a stereoscopic image is due to the binocular stereoscopic effect (stereo effect) that occurs when an object is examined with both eyes [13, 315]. To determine the images that correspond to the concept of „stereoscopic image", the term of the stereogram is the term, which means the relative position of the images, object, or scene, resulting in a stereo image [20, 8]. The concept of „three-dimensional space" now is not only „stereoscopic images" (images, creates the illusion of volume), but for now, it identifies secondary reality, a real art that can create real artifacts (three-dimensional objects) using 3D printing. „3D printing is the process of creating solid three-dimensional objects of any shape from a digital computer model" [11, 28].

The first experiments to create 3D models date back to 1970-1980. However, printers at that time were too large and had a high cost, so their production was limited. The emergence of technology FDM (Fused deposition modeling) or FFF (Fused filament fabrication) – modeling by the method of deposition of molten filament, consisting of molten plastic or photopolymer – has contributed to the development of mass production of 3D printers and owes its existence to the American inventor Scott Crump. The researcher, using a hot glue gun, tried to make a frog toy for his own daughter. Later, Crump decided to automate the mixing of plastic with wax – and already on October 30, 1989, he filed an application to patent his new invention: an apparatus for creating three-dimensional objects by the method of layer-by-layer melting. In the same year, he founded the company „Stratasys", which began the production and support of printers. In 2009, after the Stratasys patent expired, other companies began to create 3D printers based on this technology. But in view of the fact that the FDM acronym is owned by Statasys (used as a trademark), followers use different terminology FFF (Fused Filament Fabrication – „FFF") or „PJP" (Plastic Jet Printing, used by 3D Systems). A large number of names confuse people, but in fact, they were invented only in order to distinguish companies from each other.

Currently, there are several 3D printing technologies, including stereolithography, selective laser sintering, melting method (FDM), and lamination. Stereolithography (SLA) was invented even earlier than layer-by-layer surfacing by researcher Charles Chuck Hull in 1983. He founded the company „3D Systems" in 1986. SLA printers have a much more complex operating specificity: photopolymer resin is a consumable material (it has a high cost unlike plastic), which hardens and holds its shape when a beam of light, ultraviolet, or laser is directed at it. The technology of lamination (Laminated Object Manufacturing, LOM) was invented by M. Fagan in 1985. It allows layer-by-layer to form models from film, polyester, composites, paper, and plastic. K. Descartes developed Selective Laser Sintering (SLS) technology (1989), the difference of which is the use of powdered thermoplastic material. This technology is used in the aircraft and automotive industries and subject design.

The next CLIP technology (Continuous Liquid Interface Production) is currently a „curiosity" because it has not yet been put into practical use (there are no CLIP printers available on the market). Its main difference from conventional stereolithography is the use of special material for the bottom of the bath (lower platform of the printer), which allows oxygen to pass through and does not allow the photopolymer to freeze from below. The process of creating a three-dimensional product in a CLIP printer is impressive and spectacular: from the bottom surface (where the polymer is in a semi-liquid state), the 3D model „grows" upwards. However, apart from patents and demonstration video performances from foreign researchers, in particular Joseph DeSimon, there is no more evidence of this new technology.

Now, 3D printers can produce products for various fields of human activity: from education to healthcare, from archeology to engineering, 3D printers are already having a practical impact around the world. Given the specifics of the operation of the products, the material that will be used for printing three-dimensional models is determined. Professional 3D printers can make models from metal, ceramics, and many other materials, but this only applies to industrial and professional applications. In everyday life, such printers are not available due to the high cost and large sizes. Consider the use of 3D printing in various fields of human activity. In the field of education, scientists can print objects based on geometric formulas for better visualization of complex structures. With its ability to reproduce three-dimensional objects from archaeological artifacts, complex mathematical surfaces in medical prostheses, the technology has promising prospects for science. In architecture and construction, three-dimensional printing is used not only for the production of walls, objects for street use but also for the creation of houses, large sculptures, art objects. The largest, in my opinion, achievement in the field of 3d modeling was the project of the University of Nantes (France), in which a residential building was built using a 3D-printer. The model of the house was developed in the studio by a team of architects and scientists, then programmed on a 3D printer. Further, the printer equipment was delivered to the site of the house, where each wall, consisting of two layers of polyurethane and cement, was created in layers from the floor up, resulting in a dense, durable, insulated structure. The walls of the house, whose area is 95 m², were printed in 54 hours. The final cost of the construction (£ 176,000) was 20% lower than it could be using traditional technologies.

An indispensable advantage of this construction is that thanks to the 3d-modeling method, it has become possible to make it asymmetric, and the walls – curved, curved. Thus, the building was able to be placed among centuries-old trees, without disturbing the flora of the adjoining territory, and also due to curved walls – to improve air circulation, reducing potential humidity and improving thermal resistance.

However, this is not an isolated case of building a house using 3D technology. In the state of Minnesota (USA), the world's first fortress was constructed using a 3D printer. At the time of writing the article, France plans to build by 3d modeling 18 residential buildings in the north of Paris, as well as a large commercial building with an area of 700 meters. Researchers from the Chinese company Shanghai WinSun Decoration Design Engineering Co built 10 houses using a 3D printer in less than a day from recycled materials (construction and industrial waste). Professor and architect P. Ebner, together with companies „3M futureLAB” and „Voxeljet”, developed a 3D-printed mobile house made of a material (based on sand and glue) in the form of cowboys, in which there is a kitchenette, a bedroom with a multimedia system with a rear projection screen.

3D printing artifacts have been discovered in interior design, which is made not only of plastic, sand, or glue but even (no matter how impossible it seemed) of wood. „The 4 AXYZ„ company produces wooden furniture using 3D printers. In the city of Gemert (Holland), an eight-meter footbridge consisting of eight hundred layers of pressed concrete was printed on a 3D printer. Experts and scientists from the space industry are also interested in the new 3D printing technology into space launched the Electron launch vehicle, which is assembled from 3D-printed parts. 3D equipment is used to create building blocks for settlement on the moon in the project „3D printer of building blocks using the soil of the Moon”, funded by the European Space Agency (ESA). Thanks to the unique D-Shape technology (inventor Enrico Dini, Monolite UK), it was possible to create large porous blocks of sandy soil, its composition corresponds to regolith (soil of the Moon) and is stable in the absence of atmosphere and low gravity.

As indicated above, the 3D printing technology „D-Shape” makes it possible to print porous sand objects, which allows them to be used in the underwater world for the restoration of marine flora, structures for restoring the natural environment. Such equipment strengthens the roots of plants, restores the seabed, damaged by natural phenomena or human intervention. 3D printing is used in the medical industry for the manufacture of human tissue replacement and transplantation. A 3D printer is distributed everywhere: from the production of prostheses (for arms, legs, hands, etc.) to printing skin cells directly for wounds or printing frames for glasses. In Ukraine, A. Svyatov (Chernomorsk, Odesa region), independently, using a 3D printer, he printed for himself a prosthesis of the thumb of his right hand. In medicine, the concept of „stereology„ has established itself as a system of methods for calculating the characteristics of three-dimensional objects. Based on these calculations, it is possible using 3D printers to create (print) the necessary objects for implantation from a material that corresponds to the cellular structure of human skin. This technology is called „bioprinting”.

3D bioprinting is a technology for creating volumetric models on a cellular basis using 3D printing, which preserves the functions and viability of cells [1, 59]. The first patent relating to this technology was presented in the USA in 2003 and received in 2006. Bioprinting technology for the manufacture of biological structures, as a rule, consists of cells in a biocompatible basis, using a layered method for generating three-dimensional structures of biological tissues. Cellular material manufactured on a bioprinter is transferred to an incubator, where it is further grown. According to expert estimates, the American company Organovo (San Diego) was the first company to commercialize 3D bioprinting technology [25, 56-58]. The company uses NovoGen MMX Bioprinter technology. An Organovo 3D printer is used for the manufacture of skin, heart, blood vessels, and other tissues that can be adapted for surgery and transplantation. One of the spectacular demonstrations of 3D bio-arms technology took place in 2011. At the TED-2011 conference, where a special 3D printer was installed, which printed a 3D model of the human cavity during a speech by an American surgeon and bioengineer Anthony Atali.

A team of scientists at Swansea University in the UK is working on the development of 3D bioprinting technology along with biological methods to create living tissue. The aim of this project is to create living structures that can be used to replace damaged or diseased tissues. Dr. Daniel Thomas of the University’s College of Medicine, who is working on this study, explains: 3D bioprinting method has been developed to provide wider dissemination of technology that allows experimentation at both university and clinical levels. This approach should see wider adoption of this technology and further innovation in the short term, allowing research in the field to efficiently produce fabrics.

In the case of the manufacture of artwork or layout, the 3D printer makes it possible to obtain a finished object with an appropriate scale of all parts and produce the required number of identical elements, which significantly reduces the manufacturing time and improves the quality of the final product. Three-dimensional printing provided an opportunity to copy museum exhibits and place them anywhere. For example, Cosmo Wenman printed a 3D copy of the image of an ancient marble Athenian sculpture (438 BC), which represents the head of a horse. Another example: the public installation „Be your own souvenir" (Barcelona) from the company „blablablab": the Kinect sensor scans and produces a three-dimensional copy (three-dimensional object).

3D printing is now widely used in light industry. In the UK, they developed a printer, „knits" clothes; in the USA, 3D equipment prints a platform for sneakers made of polyurethane plastic. In the automotive industry, 3D-manufactured starter gear gears, bumper mounts, parts for the gear knob and power windows; handles, gears for washing machines, parts for the photo and video shooting (rails, clips), clothing accessories, small musical instruments, toys and parts for board games (figures and chips) are printed in the production of household things. Using 3D printing, it became possible to create a quadrocopter (suspension parts of a radio-controlled model). Production of three-dimensional objects as part of social projects. In the world, there are more and more projects based on a 3D printer aimed at solving the global problems of mankind. An example is the „WOOF project" (Washington Open Object Fabricators, USA), which allows manufacturers to produce sanitary products from used plastics. Thus, humanity gets rid of the problem of excess waste that does not decompose in the environment. Now the „Eternal Plastic Project" has been created, which represents the processing of plastic cups into thread, and is used for 3D printing of new parts necessary for operation. A mini-factory was established at the Laulenda 2012 festival in the Netherlands, where visitors could independently control the mechanism for converting the used plastic glasses to new 3D products.

Another project, Roy Ombetti (Kenya), is designed for 3D printing of special shoes for patients suffering from the disease of invasion of the fly top. Conclusions. Today, 3D printing technology is an exceptional tool that allows going through the entire chain of the design process in a closed and continuous cycle: from the generation of an idea to the final design result. Revolutionary 3D printing is evolving globally with many benefits and affordable prices. The technology is used in jewelry and footwear manufacturing, industrial design, architecture, engineering, and construction, in the automotive, aviation and space, dental and medical industries, education, geographic information systems, construction, and many other industries.; to create prototypes of robots, works of art, nano-structures, ships, houses, bicycles, weapons, cake decorations and the like. The study does not pretend to be an exhaustive analysis of the topic. Despite the rapid development of 3D technologies and their implementation in all spheres of human activity, a wide field remains open for further research.

Література

1.Беленький М., Брыксина З. Стереологический метод в нейроморфологических исследованиях // Развитие профессионализма. 2016. № 2 (2). С. 59-60.

2.Безклубенко С. Вступ до культурології. Київ: Альтерпрес, 2015. 508 с.

3. Brewster D. The Stereostore. Its History, Theory, and Construction, on Its Application to the fine and Usefel Arts and Education. London : John Murray, 1856. 235 p.

4.Buswell et al. Freeform Costruction: mega-scale rapid manufacturing for construction // Automat. Construct. 2007. № 16 (2). pp. 224-231.

5.Ceccanti F., Dini E., X. De Kestelier, Colla V., Pambaguian L. 3D printing technology for a moon outpost exploiting lunar soil // Proceeding of the 61th Internathional Astronautical Congress IAC, September 27-October 1 2010. Prague, 2010. pp. 1-9.

6.Cowan, M. (2019, 10 April). The world's first family to live in a 3D-printed home. URL: https://www.bbc.com/news/technology-44709534.

7.DeSimon, D. (2019, 8 January) What if 3D printing was 100 times faster. URL: https://www.youtube. com/watch?v=ihR9SX7dgRo.

8.DeSimone, J., Ermoshkin, A., Ermoshkin, N., Samulski; Ed. T., Hill, Ch. Пат. 2015/0072293 EIPI Systems US 14/456,270 Continuous liquid interphase printing. № 14/456,270; зав. Aug. 11, 2014; опубл. Mar. 12, 2015 https://patents.google.com/patent/US201500722 93A1

9. *Continuous liquid interphase printing*. URL: https://patents.google.com/patent/US20150072293A1.

10. Горьков Д. 3D-печать в малом бизнесе. Москва : 3D-Print, 2015. 104 с.

11. Гуревич С. С. Объемная печатная иллюстрация. Москва : Искусство, 1959. 328 с.

12. Fonda, C., Canessa, E., Zennaro, M. *Low-cost 3D printing*, Trieste: ICTP. 2013.

13. Hull Ch. W. (2019, 11 January). *Apparatus for production of three-dimensional objects by stereolithography*. URL: https://patents.google.com/patent/ US4575330, 9.01.2019.

14. Иофис Е. Фототехника : энциклопедия. Москва : изд-во «Советская энциклопедия», 1981. 477 с.

15. Кэмп М. Леонардо. Москва: АСТ: Астрель, 2006. 286 с.

16. Киплик Д. И. Техника живописи. Москва: СВАРОГ и К, 1998. 500 с.

17. Кузьмич В. Жгучий глагол: Словарь народной фразеологии. Москва : Зеленый век, 2000. С. 47.

18. Khoshnevis B., Hwang D. Contour Crafting, a mega scale fabrication technology // Manufact. Sys. Eng. Series. №. 6 (II). 2000. pp. 221-251.

19. Лунева Д. А., Кожевникова Е. О., Калошина С. В. Применение 3D-печати в строительстве и перспективы ее развития // Вестник Пермского национального исследовательского политехнического университета. Строительство и архитектура. 2017. Т. 8, № 1. С. 90-101.

20. Маркс К. Г. *Капитал.* Т 1. Москва: ООО «Издательство АСТ». 2001. 565 с.

21. Назаркевич Є. П. Стереозображення у графічному дизайні. Київ : КПІ ім.. Ігоря Сікорського, Вид-во «Політехніка», 2018. 206 с.

22. Плеханова В. А. 3D-технологии и их применение в дизайне // Территория новых возможностей. Вестник ВГУЭС. 2015. № 2 (29). С. 144-153.

23. Rollmann W. Zwei neue stereoskopische Methoden // Annalen der Physik. Berlin, 1853. Vol. 166. № 9. pp. 186–187.

24. Roman (2019, 9 January). 3D printing. Short and as clear as possible. URL: http://himfaq.ru/books/3d-pechat/3D-pechat_korotko-yasno-skachat-besplatno.pdf.

25. Валюс Н. А. Стерео: фотография, кино, телевидение. Москва : Искусство, 1986. 263 с.

26. Вергунова Н. С. Технологии 3D-печати в современной архитектуре // Науковий Огляд. 2017. № 8 (40). С. 56-65.

27. Wheatstone C. Contributions to the physiology of vision. Part the first. On some remarkable, and hitherto unobserved, phenomena of binocular vision // Phylosophical Transactions of the Royal Society of London. London, 1838. Vol. 128. pp. 371-394.

References

1.Belen'kii, M., Bryksina, Z. (2016). The stereological method in neuromorphological studies, *Razvitie professionalizma*, 2, 59-60. [in Russian]

2.Bezklubenko, S. (2015). *Introduction to Cultural Studies*, Kyiv: Alterpres. [in Ukrainian]

3.Brewster, D. (1856). *The Stereostore. Its History, Theory, and Construction*, London: John Murray.

4.Buswell, R. A., Soar, R., Gibb, A., Thorpe, A. (2007). Freeform in Construction: mega-scale rapid manufacturing for construction, *Automat. Construct*, 16 (2), 224-231. [in English]

5.Ceccanti, G., Dini, E., Kestelier, X., Colla, V., Pambaguian, L. (2010). 3D printing technology for a moon outpost exploiting lunar soil, *Proceeding of the 61st International Astronautical Congress IAC*, 1-9. [in English]

6.Cowan, M. (2019, 10 April). The world's first family to live in a 3D-printed home. Retrieved from https://www.bbc.com/news/technology-44709534. [in English]

7.DeSimon, D. (2019, 8 January) What if 3D printing was 100 times faster. Retrieved from https://www.youtube.com/watch?v=ihR9SX7dgRo. [in English]

8.DeSimone, J., Ermoshkin, A., Ermoshkin, N., Samulski; Ed. T., Hill, Ch. (2019, 11 January) *Continuous liquid interphase printing*. Retrieved from https://patents.google.com/patent/US20150072293A1. [in English]

9.Gor'kov, D. (2015). *3D printing in small business,* Moskow: 3D-Print. [in Russian]

10. Gurevich, S. (1959). *Volume printed illustration,* Moskow: Iskusstvo. [in Russian]

11. Fonda, C., Canessa, E., Zennaro, M. (2013). *Low-cost 3D printing*, Trieste: ICTP. [in English]

12. Hull Ch. W. (2019, 11 January) *Apparatus for production of three-dimensional objects by stereolithography.* Retrieved from https://patents.google.com/patent/US4575330, 9.01.2019. [in English]

13. Iofis, E. (1981). *Photographic equipment.* L. Artyushin (Ed.). Moskow: Soviet encyclopedia. [in Russian]

14. Kemp, M. (2006). *Leonardo*, Moskow: Astrel, 2006. [in Russian]

15. Kiplik, D. (1998). *Painting technique*, Moskow: SVAROG and K. [in Russian]

16. Kuz'mich, V. (2000). *Hot Verb: Dictionary of Popular Phraseology*, Moskow: Zelenyi vek. [in Russian]

17. Khoshnevis, B., Hwang, D. (2000). Contour Crafting, a mega-scale fabrication technology, *Manufact. Sys. Eng. Series*, 6 (2), 221-251. [in English]

18. Luneva, D., Kozhevnikova, E., Kaloshina, S. (2017). Application of 3D printing in construction activities and its perspectives, *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Stroitel'stvo i arkhitektura*, 8, 90-101. [in Russian]

19. Marx, K. (2001). *Capital,* vol. 1, Moscow, 2001. [in Russian]

20. Nazarkevich, E. (2018). *Stereo image for graphic design*, Kyiv: Politekhnika, 2018. [in Ukrainian]

21. Plekhanova, V. (2015). 3D technologies and their application in design, *Territoriya novykh vozmozhnostei*, 2 (29), 144-153. [in Russian]

22. Rollmann, W. (1853). Zwei neue stereoskopische Methoden, *Annalen der Physik*, 166 (9), 186–187. [in German]

23. Roman (2019, 9 January). 3D printing. Short and as clear as possible. Retrieved from http://himfaq.ru/books/3d-pechat/3D-pechat_korotko-yasno-skachat-besplatno.pdf. [in English]

24. Valyus, N. (1986). *Stereo: photography, cinema, television*, Moskow: Iskusstvo. [in Russian]

25. Vergunova, N. (2017), 3D printing technologies in modern architecture, *Naukovii Oglyad*, 8 (40), 56-65. [in Russian]

26. Wheatstone, Ch. (1838). Contributions to the physiology of vision. Part the first. On some remarkable, and hitherto unobserved, phenomena of binocular vision, *Philosophical Transactions of the Royal Society of London*, 128, 371–394. [in English]

27. Williams, J. (2019, 8 April). Research into 3D-Bioprinting may soon produce transplantable human tissues. Retrieved from http://www.3ders.org/articles/ 20140306-research-into-3d-bioprinting-may-soon-produce-transplantable-human-tissues.html. [in English]

Стаття надійшла до редакції 18.04.2020
Прийнято до друку 19.05.2020