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## **THE USE OF 3D PRINTING TECHNOLOGY FOR RECONSTRUCTION AND REPRODUCTION OF HISTORIC SITES**

**Summary:** The paper considers the concept of 3D printing, its features and modern spheres of applications. The most popular technologies and appropriate types of 3D printers are described in detail. Examples of the use of three-dimensional printing for the restoration of historic sites are given and described.

**Keywords:** 3D printing, 3D printer, 3D model, Cinema 4D.

## **ZASTOSOWANIE TECHNOLOGII DRUKOWANIE 3D DO REKONSTRUKCJI I REPRODUKCJI ZABYTKÓW**

**Streszczenie:** W artykule przeprowadzono koncepcję drukowanie 3D, jego cech i zaawansowanych aplikacji. Szczegółowo opisane najbardziej popularne technologie i odpowiednie rodzaje 3D-drukarek. Zaprezentowano przykłady użycia druku trójwymiarowego do rekonstrukcji i reprodukcji zabytków.

**Słowa kluczowe:** drukowanie 3D, 3D-drukarki, model 3D, Cinema 4D.

### **1.General information about 3D printing**

Modern digital technologies have reached a level of development our ancestors could tell about only in science fiction novels. This makes new impressive capabilities in science, medicine, technology, education, architecture etc. available. For example, since the beginning of the new millennium the concept of «3D» is closely included in our daily lives. Now there is no single person who would never

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heard of 3D printing technology, but not all imagine its possibilities and scope. A few years ago, 3D printer was a technological innovation, and now it is a widely used tool to improve human life.

Although 3D printing became popular relatively recently, its idea was put forward 80 years ago, in the twentieth century. In 1987, Scott Crump created fused deposition modeling technology that is the most simple and popular now. In 1988, Charles Hull created stereolithographic technology and founded 3D Systems Company, which currently is one of the main manufacturers of 3D printers. However, despite the further development of these technologies, only in 2005 Z Corp. created 3D printer, capable of printing in color and with sufficient quality. Two years later, a printer could print half of its parts.

Now 3D printing device is capable to create three-dimensional objects of any shape and of a wide range of materials with different properties. It can be applied in almost all spheres of human activity. Specifically, 3D printers can work with photocurable resins, various kinds of plastic filaments, ceramic powder and metal clay. The use of these materials allows making a printed prototype sufficiently close to the original. Materials in different colors, different flexibility, rigidity or transparency can be used. They can imitate gold, silver, porcelain, wood, rubber and many other metals, minerals or substances.

### **1.1. 3D printing technology**

Today the foundation of printing of three-dimensional objects lies in the principle of gradual layering of the necessary material created according to a special computer program model. The approach, which is used in industrial production now, has many shortcomings, the main among them are time expenditure and a high proportion of waste that is simply going to landfill. For an item is made by cutting off excess in various ways, for example, using machine lathe. Therefore, the first field of application of three-dimensional printing is the industry. With 3D printers, this operation appeared to be several times cheaper, quicker and clearer. We can say that 3D printer is a kind of non-waste machine, which can make quite diverse products.

To understand how the 3D device works, we need to consider today's most widespread methods of three-dimensional printing, because they differ by speed, by principle of action, by the materials used, and consequently, by the result of the work. For example, only 3D printers, which use inkjet principle, can create full-color products, while others only print monochrome. The most common modern technologies are SLS (selective laser sintering), FDM (fused deposition modeling) and SLA (stereolithography).

Stereolithography technology works like this: the laser ray is directed to the liquid resin, which makes it to harden in an appropriate way. A liquid resin is a translucent material that easily deforms under the influence of atmospheric moisture. After hardening, it can be fused, mechanically processed and painted.

Selective laser sintering technology uses sintering of powdered agents under the laser ray. To the purpose, it is the only 3D printing technology, which is used to manufacture molds for metal and for plastic casting. Plastic have excellent mechanical properties, providing them significant functionality. SLS technology can

also uses ceramics, powdered plastic or already mentioned above metal. According to the established computer models the products of particular molds are formed.

HPM technology (often called FDM) allows one to mold not only models, but also the final details from the standard, construction and high efficiency thermoplastic. This technology of printing is advantageous concerning cleanliness, ease of use and suitability for everyday needs use. Thermoplastic products are resistant to high temperatures, mechanical loads, chemicals or degree of humidity.

HPM technology allows one to create complex multilevel molds, cavities and holes that are difficult to get using other methods.

3D printers based on this technology create objects layer by layer, warming the material to semisolid state and squeezing it using a needle-like nozzle according to the computer generated routes. The plastic filament is fed from 3D printer section to the printing head that moves depending on the change of coordinates X and Y, defined by 3D model. When printing is completed, the product is easily separated from the printing surface and can be ready for use.

In addition, new three-dimensional printing technologies are appearing, such as printers based on DLP technology using digital light processing. They use photocurable resins and DLP projector. Electron-beam melting is commonly used to create a three-dimensional metal objects. For this, such an interesting material as metal clay is used. It is made from a mixture of organic glue, cuttings and a certain amount of water. To form ink into a solid object, it must be heated to a temperature at which glue and water burn out and cuttings melt into a monolith. There are also EBM-machines that generate electronic impulses instead of a laser ray for melting metal clay. It should be noted that this method provides high print quality and excellent manufacturing of fine details.

Of course, as well as technologies differ, 3D printers are quite different that is each device is created only fitting a particular printing technology. Also based on complexity, quality, speed and size of objects made 3D printers are divided into domestic (available to public users) and industrial by means of which quite complicated things can be created. This enables the use of 3D devices in extremely different spheres of production.

## **1.2. Applications of three-dimensional printing**

It has been said that in the near future people would not need any factories, and everything could be printed at home. Meanwhile, 3D printing has given great opportunities for experiments in such areas as architecture, construction, medicine, education, fashion design, small-scale production, jewelry, and even food industry.

In architecture, for example, 3D printing allows one to create three-dimensional models of buildings or even entire neighborhoods with the entire infrastructure. In construction, there is every reason to believe that in the near future, the process of construction of buildings will much simplify and accelerate. Scientists will create 3D printing systems for the construction of large-scale facilities that will operate on the principle of the cranes, which build walls from the concrete layers.

Now three-dimensional, small-scale production printing is widely used for the manufacture of exclusive products such as pieces of art, figures of different kinds of characters, clothes and shoes, gifts, toys, jewelry, prototypes of certain products or

any design details. A few restaurants in the world already give the opportunity to taste food printed on 3D printer.

In medicine, due to three-dimensional printing technology doctors reproduce copies of the human skeleton or certain tissues of the human body. 3D printers are now used in prosthetics and dentistry. Currently, scientists are working on a printing of human organs. As you can see, the possibilities offered by the 3D printing are truly endless in almost all spheres of human activity.

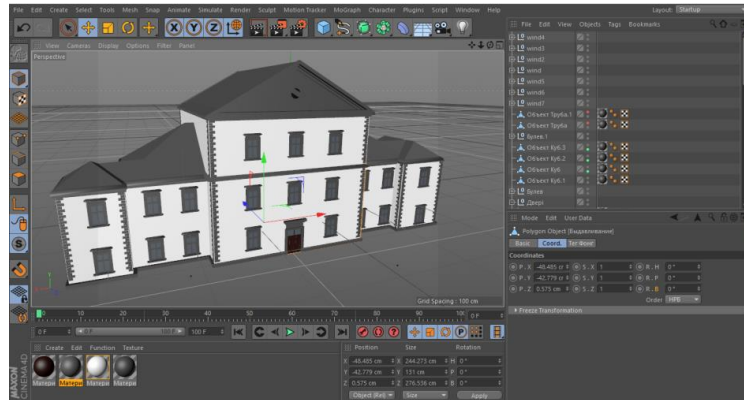
Before printing a three-dimensional object, one must create its computer 3D model. There are a lot of programs allowing to do it, but the most common today can be considered the following: Autodesk 3Ds Max, Cinema 4D, Blender, Wings 3D, ZBrush, Art Of Illusion, Zmodeler, Luxology Mogo. Of course, each has its own characteristics, but all 3D editors work on the basis of mathematical representation. The created 3D model is represented by a set of points in 3D space, combined by different geometric objects such as triangles or lines. In addition, three-dimensional models for printing can be acquired by using 3D scanners, which greatly facilitates their development.

## **2. 3D printing as a means of modeling and reconstruction of historic sites**

We believe that 3D printing can be a great solution to the question of reconstruction and reproduction of historic sites. Now in the region, as well as throughout Ukraine, there are a lot of completely or partially destroyed churches, castles, and buildings that are important to the history and culture of our country. It is important to keep the memory of them, visually convey to future generations all their beauty, elegance and grandeur.

Students of the Department of Computer science and Teaching Techniques of Volodymyr Hnatiuk Ternopil National Pedagogical University decided to give impetus to this process and created a series of 3D models of castles of Ternopil. In particular, a three-dimensional model of Ternopil Castle has been already developed and published. The Department conducted work on finding the necessary archival materials that would demonstrate the perspective, design and scale of certain parts of the building. A range of 3D editors that would allow putting the plan into practice was considered, a selection of the correct dimensions of the castle was made.

Direct development model was conducted using Cinema 4D programming package (Figure 1). The model was established based on found information on the planning of the castle and its front view. In addition, its optimization was held to avoid problems during printing, as well as a division into smaller pieces for faster printing time and minimal use of resources. With a special Slicer program, 3D model was converted into a drive code, understandable by 3D printers.



*Figure 1. Model of Ternopil Castle in the software environment*

Printing of the model was implemented using the technology of fused deposition modeling (HPM/FDM) which benefiting in high accuracy and printing quality. Generally, about two kilograms of white and gray thermoplastic were spent. Since the size of the print surface was smaller than the established model, its individual elements were published and then pieced by the students. The castle took about two weeks to make it after 3D printing is quite a long process. Depending on the complexity, quality and size of the model it can take from several minutes to several days. A diminished finished copy (Figure 2) of Ternopil Castle was presented in April 15, 2016.



*Figure 2. Finished model of Ternopil Castle, printed on 3D printer*

We have examined the main features of 3D printing, its technology and application, and a software needed to create three-dimensional models. As you can see, although 3D printing is a relatively new field, but it is widely used today in many areas of human activity. The interest deepens in Ukraine, too. Today, 3D printers do not

seem to be the devices from fiction films or novels. They are a reality and bring a great benefit to humanity.

We believe that 3D printing is a future of engineering and science. The reconstruction and reproduction of historic sites of our region can be considered as another promising area of application of 3D printing. This process is relatively fast, high quality, inexpensive and visual, and the models created will conform to the originals at the most.

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