Section 6. Industrial art and design

https://doi.org/10.29013/EJA-21-1-183-196

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SUSTAINABILITY 3D PRINTER TECHNOLOGY

Abstract. This article is aimed at determining by the author of means, techniques, materials of ecological production and balanced nature management, proposing the classification of these means, determining the principles and methods of environmental use and production of objects created using 3D printing technology.

The author offers a new look at the prospects and directions of the application of 3D printing technology in environmental production and balanced environmental management: over time, 3D printing technology will replace the main types of industrial production as more environmentally friendly, advanced, and greatly simplify human life.

When analyzing publications relating to 3D printing technology, the following was established. 3D printing technologies offer a quick and high-quality path from the idea to the final product: 1) the duration of the production process of prototypes and the workers employed in it (and the cost) is reduced; 2) the complexity and quality of products (integral parts of complex shape); 3) environmental friendliness of production improves (non-waste production, production from secondary raw materials, the use of materials quickly decompose into safe substances in natural conditions); 4) the possibilities for the designer are expanding (regarding the creation of prototypes and small series of high quality without involving industrial production) [1; 2; 3].

Keywords: 3D-printers, 3D printing technology, object-spatial environment, furniture design, design objects.

1. Introduction

1. It has been established that 3D printing technology is a complex multifaceted tool in the hands of a designer who has already opened and continues to open up new possibilities and takes environmental design to a new level when the environmental assessment of products is of great importance.

2. As a result of the study of the means of ecological formation of an artistic and spatial image of space using objects created using 3D printing technology, environmental principles and means of 3D printing technologies were discovered.

3. Based on the analysis of the scientific works of a number of researchers and the study of design and factual material, the founding principles of the ecological shaping of the spatial environment using 3D printing technologies and their basic theoretical foundations are found.

4. It has been established that 3D printing technologies are a combination of all existing technologies of traditional production, development of computer technologies (in particular 3D modeling), environmental safety, experiments of scientists, designers, artists, art practices, conceptual art. The author's suggestions on the use of 3D printing technologies, environmental tools and principles of shaping the subject-spatial environment, the creation of new objects using 3D printing technology are presented.

2. Objective

Identify the means, methods, materials of environmental production and balanced nature management, propose a classification of these tools, determine the principles and methods of nature management and production of objects created using 3D printing technology.

2. Material and Methods

Background. When stereo lithography was invented and patented for the first time in the 1980s of the 20th century, in all developed countries of the world and in Ukraine growing interest in innovative technology of three-dimensional virtual 3D-printed models has been observed. Unique products in a single copy (art objects, musical instruments, houses, cars, furniture, clothing) appeared, they were wholly or partly made using 3D-printer and they have the shape that was previously impossible and extremely difficult to perform in conditions of existing modern equipment. Due to 3D-printing technology fast and qualitative way from idea to final product is implemented, namely, the duration of the production process of prototypes is reduced and the number of employed workers (and therefore cost) is also reduced; But complexity of form parts and product quality is increasing; the ecological production (waste-free production and production of secondary raw materials) is improving; variability of design concepts (the ability to create prototypes and small series of high quality without the involvement of industrial production) is increasing. Modern 3D-printers offer product developers the ability to print parts and mechanisms of several materials with different mechanical and physical properties at a time of drafting process.

The paper uses a comprehensive methodology that summarizes the existing research experience, is based on bibliographic and design materials and uses both general scientific and special research methods.

3D printing technology is one of the main innovations of recent years. Their use is associated with the need: 1. reduction of environmental pollution while increasing the efficiency of production of high-tech products from various materials; 2. the use of the principles of recycling in the design of the subject-spatial environment and the disposal of waste products; 3. production from secondary raw materials, the use of materials quickly decompose into safe substances in natural conditions; 4. growing demand for updating the subject-spatial environment and reducing environmental pollution; 5. The

availability of quality and environmental products for the general population.

Due to its features, 3D-printing technology makes the shaping of the spatial environment ecological, economical, technological, allowing you to create new forms of virtually unlimited complexity from environmentally friendly materials in an environmentally friendly production, while attracting a minimum of resources. 3D printing technology is implemented in a spatial environment in the form of furniture, interior items, and architecture. Due to the features of this technology, all elements of the subject-spatial environment can be environmentally friendly while having a low cost. Such a property opens up a new level of ecological culture of society.

Forming of the spatial environment using 3D printing technology can occur:

– by creating environmental objects (furniture, fixtures, interior items)

– by creating various mechanisms to complement (or provide a new quality) objects of traditional production;

– by creating objects with the necessary qualities (softness, hardness, electrical conductivity, thermal conductivity what)

– by applying and combining various materials in one single object; – printing directly on objects; The advantages of 3D printing are speed (the creation of a real model using traditional technologies, depending on the complexity of the work, can take up to one month or more). 3D printing technology allows you to do this in one day)

– price (pricing policy depends on the complexity of the model, as well as the material used). We can say with confidence that 3D printing will cost an order of magnitude cheaper than manual or automatic production of a prototype and small-scale objects;

– functionality (an object made by a 3D printer can be used immediately after manufacturing);

– all the shortcomings of the model identified at the stage of its prototyping can be quickly and cost-effectively eliminated; and also create several variations of prototypes of the same product at once;

– the ability to set the properties of the material at the design stage (environmental friendliness, strength, flexibility, thermal conductivity, electrical conductivity, etc.);

– the ability to print with various materials at the same time; – 3D printing technology makes possible the so-called "teleportation", (a real object made of material can be reproduced on the other side of the earth).

4. Results and Discussion

Analysis of various objects created using 3D printing technology showed the main means of ecological shaping of the spatial environment:

– design the environmental properties of the material that will print objects;

– take into account that 3D technologies have the ability to create infinitely complex forms that can be more or less ecological (to be in harmony with or resist the environment)

– design textures and textural properties of the material, which will be printed objects that also affects the environment;

– low knowledge of 3D technologies makes practical experiments with the form relevant, identifying new methods and approaches for the search for environmentally harmonious solutions;

– use of objects created by means of 3D technologies together with existing technologies that are not harmful to nature;

– when designing, lay down the principles of environmental friendliness of construction for all objects created by 3D technology, and use only environmentally friendly materials for 3D printing;

– to create objects of large sizes (3D-wall, decorative partitions, large furniture, etc.), apply modulation, designer, and scaling techniques to make it easier to work with them without heavy equipment, which reduces the resources involved;

– realize objects created by means of 3D technologies recommended as safe for the environment;

– to reduce the printing time and cost of objects to design a mesh structure;

– take into account the place where it is necessary to apply 3D objects, the author at the design stage must lay down the environmental properties and appearance of the material.

The use of these means of shaping the spatial domain can make a significant contribution to environmental safety.

1. It has been established that 3D printing technology is a complex multifaceted tool in the hands of a designer who has already opened and continues to open up new possibilities and takes environmental design to a new level when the environmental assessment of products is of great importance.

2. As a result of the study of the means of ecological formation of an artistic and spatial image of space using objects created using 3D printing technology, environmental principles and means of 3D printing technologies were discovered.

3. Based on the analysis of the scientific works of a number of researchers and the study of design and factual material, the founding principles of the ecological shaping of the spatial environment using 3D printing technologies and their basic theoretical foundations are found.

4. It has been established that 3D printing technologies are a combination of all existing technologies of traditional production, development of computer technologies (in particular 3D modeling), environmental safety, experiments of scientists, designers, artists, art practices, conceptual art. The author's suggestions on the use of 3D printing technologies, environmental tools and principles of shaping the subject-spatial environment, the creation of new objects using 3D printing technology are presented.

Different objects of 3D printing technology have different physical properties and each of them has its own advantages depending on the situation.

Due to its physical and aesthetic properties, objects and materials of 3D printing technology can be used: in urban space; public areas; in the living space [1; 2].

The aesthetic and physical properties of objects created using 3D printing technology are a complex multifaceted tool in the hands of the designer.

Ecological production and balanced nature management using the technology of 3D printer printing reaches a fundamentally new level. Actually explore the possibilities of application and development prospects of 3D printing technology as a form of environmental production and balanced environmental management. 3D printing technology is associated with the fourth industrial revolution, which means the merger of automated production, data exchange and production technologies into a single system. The rapid development of 3D printing technology requires the study of both theoretical and practical capabilities of this technology in the environmental field. 3D printer technologies use the latest technologies and materials, many of which are ecological: they quickly decompose in nature without harming the environment; from secondary raw materials that can be processed and used in production.

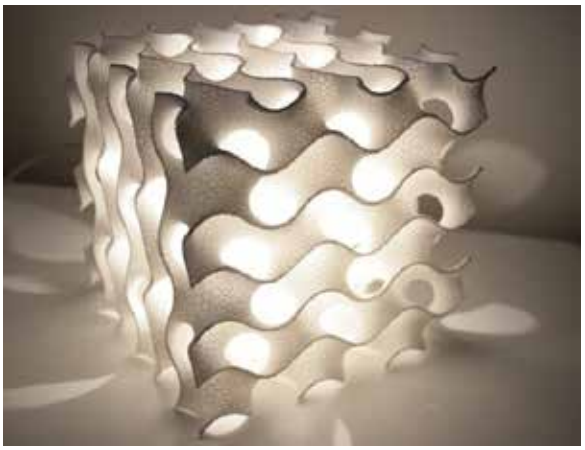
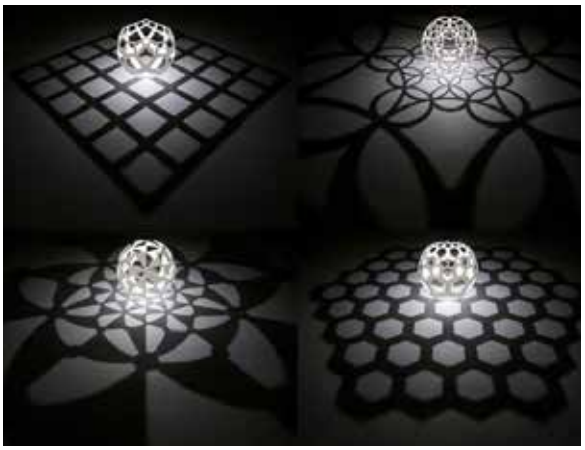
3D printing is often referred to as "magic" technology. For printing, you only need a printer with consumables and a 3D model. For example, to manufacture an item weighing 1 kg, you need a 3D printer and printing material weighing 1 kg, after printing there is no production waste left. Since the advent of 3D printing technology, the 3D printer market has grown rapidly, there are new types, new technologies that allow you to print faster, more economically, and from more complex materials. There were houses, cars, furniture, rockets, clothes, and other items made entirely or partially on a 3D printer [1; 2; 3].

The scientific novelty of the work is the author's determination of the means, techniques, materials of environmental production and balanced environmental management, the proposed classification of these tools, the principles and methods of environmental use and production of objects created using 3D printing technology are defined.

The author offers a new look at the prospects and directions of the application of 3D printing technol-

ogy in environmental production and balanced environmental management: over time, 3D printing technology will replace the main types of industrial production as more environmentally friendly, advanced, and greatly simplify human life.

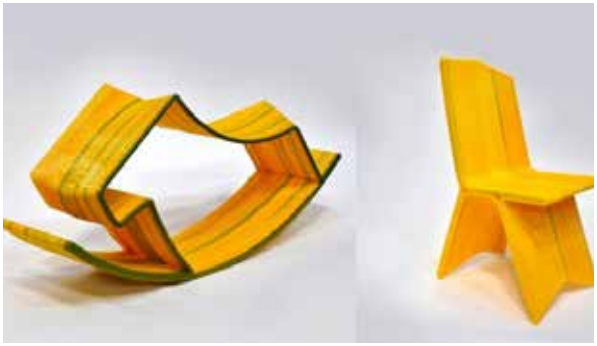
Table 1. – Examples of application of 3D technologies in residential interiors and in interiors of public buildings

Examples of 3D objects	Description
 	1) Designer Bathsheba Grossman, a first-time mathematician, uses 3D printing technology to create lamps with a high complexity of geometric construction, using the technology of electroforming, stereolithography. Its 3D objects are based on symmetry and balance, origin and infinity. MGX Studio presented the unique Flame, Quin, and Torus lamps (pictured) that she created. Amazing plasticity and mesh texture have become a reality thanks to Materialise, a world leader in rapid prototyping technology [5]. Creation method: Stereographic projection Dimensions of the printed detail: 200×200 mm Material of the printed detail: paper Date of creation: 2013 Technology: Laser stereolithography (SLA)
	2) Mathematician Henry Segerman creates three-dimensional 3D and 4 D mathematical models [6]. Dimensions of the printed detail: 100×100 mm Material of the printed detail: PA 2200 plastic Date of creation: 2014 Technology: Selective laser sintering (SLS);

3) Author: Joris Laarman (born October 24, 1979) – Dutch designer, artist and entrepreneur known for his experimental design, inspired by the latest technology. In 2004, Laarman, together with his partner Anita Star, founded the Joris Laarman Laboratory in Amsterdam, the Netherlands. The laboratory collaborates with masters, scientists and engineers, using new technologies, including 3D printing. The object designed by Laarman is in permanent collections and exhibitions at institutions such as Moma, New York; V &, London; Central Pompidou, Paris [7].
Dimensions of the printed part: x mm
Material of the printed part: plastic
Date of creation: 2013
Technology: Selective laser sintering (SLS)

4) The design company Freedom of Creation (FOC) from the Netherlands has added to the list of printing materials for a 3D printer ordinary sawdust, which can be purchased at any home store. The material is mixed with a connecting base of glue and looks like natural wood. FOC calls it the Tree-D printer [8].
Dimensions of the printed detail: 50x400 mm
Material of the printed part: wood shavings
Date of creation: 2011
Technology: 3D Printing, 3DP

5) Designers Sebastian Misurek and Arianna Lebid designed a modular wall system that was printed on a SuperMod 3D printer. This system creates a multifunctional storage item that combines functionality and beauty. The wall consists of modules of different sizes, for different needs, for books, gadgets, bottles, etc. The modular wall dividing the room serves as a shelf and a decorative element. By filling in the modules it is possible to adjust the degree of transparency [9].
Material of the printed part: plastic
Date of creation: 2015
Technology: Selective laser sintering (SLS)

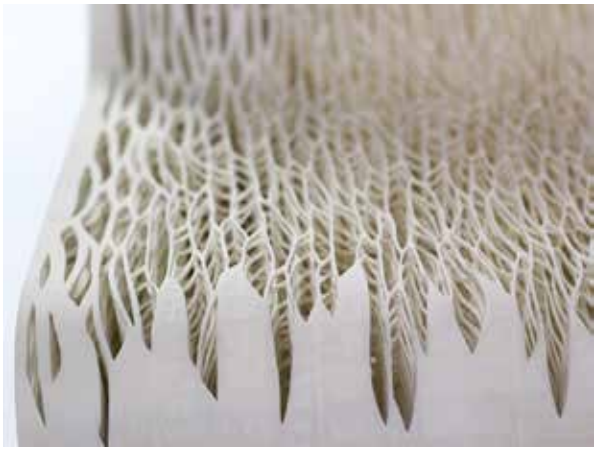


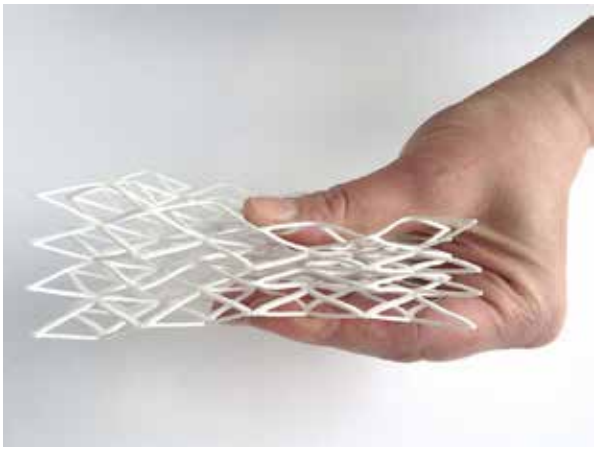
6) The ultimate goal of Drawn is to release custom collections of 3D – printed furniture. Galatea 3D printer, developed by the founders of Drawn, Sylvain Caprio and Samuel Javell, and named after them in the sculpture of Pygmalion, is able to print objects of fairly large sizes. It can be used primarily for printing furniture. The first samples of 3D-printed furniture items from Drawn were shown at the Maker Faire exhibition in Paris. Despite the fact that the 3D printer prints on the basis of FDM technology (simulation by the method of deposition of molten filament), we can note the smoothness and uniformity of the surface. Of course, the layers of material on the subject stand out quite strongly, but the developers used this «disadvantage» in order to make the furniture truly unique and aesthetically appealing. In addition, the Galatea 3D printer can print in multiple colors at once [10]

Dimensions 1.2×1.2×1.2 m
Material of the printed part: plastic
Date of creation: 2014
Technology: FDM (molten filament deposition simulation)

7) The "Endless" chair from waste in the Netherlands hosted the Lowlands pop festival. The festival presented an interesting project The Perpetual Plastic Project, which gave visitors the opportunity to recycle used plastic cups and make something on a 3D printer (Ultimaker) [11].
Processing stages:
- The glasses are washed
- to dry
- are ground
- melted into a bar for the printer
- something is printed on a 3D printer

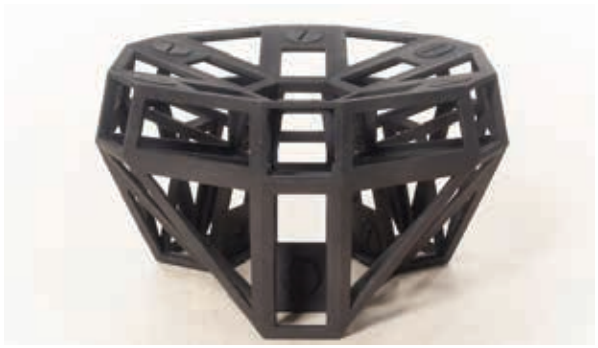
Material of the printed part: plastic
Date of creation: 2014
Technology: FDM (molten filament deposition simulation)





8) Dutch designer Lilian van Daal has managed to develop a sophisticated and simple way of making furniture using a conventional 3D printer. The designer's invention is based on a special focal structure of furniture. You can see it in the photos. The cells can be of different shapes without differing from each other functionally. The multilayered structure of such furniture makes it surprisingly strong, but at the same time very soft and convenient. The chair literally takes the shape of the body of the person who sat on it. Lillian drew inspiration from wildlife when creating her furniture. She was inspired by some marine inhabitants with their spongy structure, which directly affected her work. Given that the furniture is made of only one type of plastic – its production is much easier than creating similar interior items, which are assembled using dozens of different materials and parts made in many unrelated plants and factories. Another plus of plastic furniture is its environmental friendliness. Nowadays, it is much easier to recycle plastic using modern techniques than any sofa, which contains wood, metals and many other materials. [12]
Material of the printed part: plastic
Date of creation: 2015
Technology: Selective laser sintering (SLS)

9) Minale-Maeda has introduced Keystones special connectors for various folding furniture parts that can be printed at home on a 3D printer. These plastic connectors connect standard wooden parts, so only the main parts need to be ordered from the manufacturer, and other people can make their own at home using a 3D printer. The goal is to change the design process itself and ensure interaction with customers.



The Minale – Maeda studio project explores the potential of new ways of designing and modeling, forms and ways of selling, as well as implementing concepts and ideas.
Keystones greatly simplify the design of furniture to a single connector – a compact part that you can print yourself [13].
Material of the printed part: plastic
Date of creation: 2014
Technology: Fused deposition modeling (FDM) or Selective laser sintering (SLS)

10) Hungarian designer Olli Gellert, in his Eco-Friendly Furniture project, printed compounds that help people without tools, nails, glue or professional skills create a multifunctional, storage item that can also serve as a partition.
Different combinations of connections allow you to create options for shelves for different interiors and for different items. 8 mm thick plywood sheets can be at different angles (90, 45 and 120 degrees), and the special design of the joints allows you to fasten them without screws and glue [14].
Dimensions: 150×150 mm
Material of the printed part: plastic
Date of creation: 2015
Technology: Fused deposition modeling (FDM) or Selective laser sintering (SLS)

11) Author: Alexandrina Rizova & 3DPrintUK created a table whose elements are printed on the principle of the structure of a walnut

Using the ability of 3D technology to design works of infinite complexity without additional costs, Alexander Rizov brought 3D printing technology to the forefront in both art and design. Using a 3DPrintUK printer, which offers professional printing, allows you to create a high quality object with a unique printed legs consisting of 7 different parts, and the table top is milled from solid walnut wood. There were 5 attempts to print before the desired result was achieved. It took three separate workstations to try to print on a 3D printer, nylon material, using the electro-optical SYSTEM P100 SLS. As a result, it took about a week to print the final details. After printing, all 7 parts were glued together using 2-component epoxy resin adhesive. Although the supports are made of nylon, a few millimeters thick, they easily support a heavy countertop. No other technology can create anything like this [15].

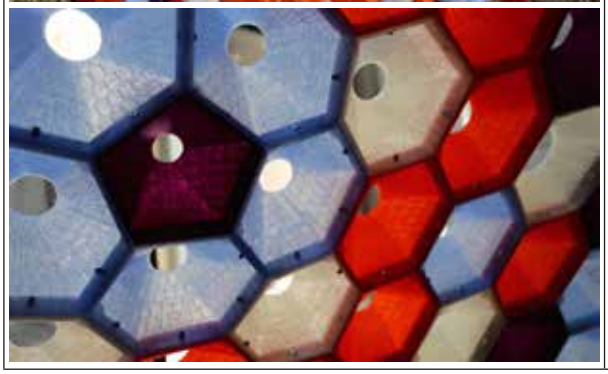
Dimensions: 300×300 mm

Material of the printed detail: nylon

Date of creation: 2015

Technology: Selective laser sintering (SLS)

	12) The KARO COFFEE TABLE coffee table is printed on the Zortrax M200 3D3D printer. It consists of square modules measuring 300×300 mm The time for which the table was printed – 268 hours 32 minutes [16]. Material: polymer thread Date: 2014 Weight 7kg. Technology: Selective laser sintering (SLS)
 	13) Emerging Objects – an American company specializing in the creation of architectural and construction projects using 3D printing, presented the concept of residential interior, the elements of which are printed on an industrial 3D printer. The project called 3d Printed House 1.0 is a hybrid of modern and futuristic architecture. Part of this concept is implemented in one of the buildings of the lake resort Jin Hai near Beijing [17]. Dimensions of the module: 200×200 mm Material of the printed part: plastic Date of creation: 2015 Technology: Fused deposition modeling (FDM) or Selective laser sintering (SLS)
	4) The Star Lounge project is a demonstration of the architectural potential of 3D technologies. Each of the modules is printed on a desktop 3D printer MakerBot Replicator 2. The smallest pavilion consists of 2073 multicolored hexagonal blocks that transmit light, and it is possible to create a pavilion of much larger size. The Star Lounge project demonstrates that it is already possible today to create printed architectural groups, environments, and objects for zoning. Using more than 100 3D printers simultaneously, the team was able to create a structure that maximized print time and print efficiency. 2 modular elements per hour were printed on one printer.



To facilitate the assembly of the pavilion on each element on the inner surface was printed (during printing) the corresponding number. Rivet holes were also printed.
1 Such a pavilion can be installed both in the interior of a public space and in the exterior [18].
Dimensions of the module: 200x200 mm
Material of the printed part: plastic
Date of creation: 2015
Technology: Selective laser sintering (SLS)

When analyzing publications relating to 3D printing technology, the following was established. 3D printing technologies offer a quick and high-quality path from the idea to the final product: 1) the duration of the production process of prototypes and the workers employed in it (and the cost) is reduced; 2) the complexity and quality of products (integral parts of complex shape); 3) environmental friendliness of production improves (non-waste production, production from secondary raw materials, the use of materials quickly decompose into safe substances in natural conditions); 4) the possibilities for the designer are expanding (regarding the creation of prototypes and small series of high quality without involving industrial production) [1; 2; 3].

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