ABOUT 3D PRINTING LATEST DEVELOPMENTS

Prof.PhD Cătălin Iancu,

Constantin Brâncuşi University of Târgu-Jiu, ROMANIA

ABSTRACT: *In this paperwork is presented a documentary research on one of the latest developments in 3D printing technology, the so called volumetric 3D printing. The 3D printing that commercially exists today is actually 2D printing, repeated layer after layer in the Z dimension. The new volumetric 3D printing technology creates the 3D object inside the entire volume of a photo-polymerizable resin that is solidified at the same time, in less than a minute. There are presented also the actual limitation and the bright future perspective of this technology.*

KEY WORDS: *3D printing, volumetric 3D printing, photosensitive resin*

1. Introduction

In 2010, meaning about 10 years ago, in [1] it has been presented the situation regarding 3D printing using STL file format, as the most common and well known format and therefore supported by most software and hardware for 3D printing.

Also it has been concluded in [1] that "3D printing and 3D printers have become financially accessible to small and medium sized business, thereby taking prototyping out of the heavy industry and into the office environment. The technology of rapid prototyping also finds use from industrial design to dental and medical industries".

In 3D printing, depending of the complexity of the model, by using the so called "additive layer manufacturing" it took hours or even days to obtain the final item.

In this paper will be presented a documentary research regarding a new development of 3D printing technology, named "volumetric 3D printing". This technology was presented in the end of 2017, explained and developed in 2018, and with new applications in 2019. Some researchers even concluded that "volumetric 3D printing" could mean the end of additive layer manufacturing.

Further will be discussed the technological background, features, limitations and future perspective of this technology.

2. Volumetric 3D printing

In [2] there is a definition: "**Volumetric printing** is a three-dimensional digital-to-physical imaging technology developed in 2013 that uses ink or other pigments suspended in a volume to form a full-color volumetric scene in physical space". The researchers have concluded that the 3D technology and transfer data from CAD package to 3D printers have a series of limitations and therefore new formats and even new technologies will replace it [3]. The actual 3D printing technology, commonly known as *additive manufacturing* (AM), "is enabling engineers and scientists to build parts in configurations and designs never before possible, the impact of the technology has been limited by layer-based printing methods, which can take up to hours or days to build three-dimensional parts, depending on their complexity" [4]. "In other words, all 3D printing that commercially exists today is actually 2D printing, repeated layer after layer in the Z dimension" [5].

Progress moves fast in the 3D printing industry, and new technologies are announced every few month. When a

truly disruptive new approach to 3D printing is announced it may go somewhat unnoticed – or fully understood for its importance. That is the case when Lawrence Livermore National Laboratory (LLNL) researchers first announced and presented volumetric 3D printing in the end of 2017.Researchers at Lawrence Livermore National Laboratory (LLNL), along with collaborators at UC Berkeley, the University of Rochester and the Massachusetts Institute of Technology (MIT), have discovered they can build complex 3D parts in a fraction of the time of traditional layer-by-layer printing. The novel approach is called volumetric 3D printing, and is described in the journal Science Advances published online on Dec., 2018.The principle of volumetric 3D printing is shown in figure 1, and was explained by researchers from the Ecole Polytechnique Fédérale de Lausanne in late 2018[6].

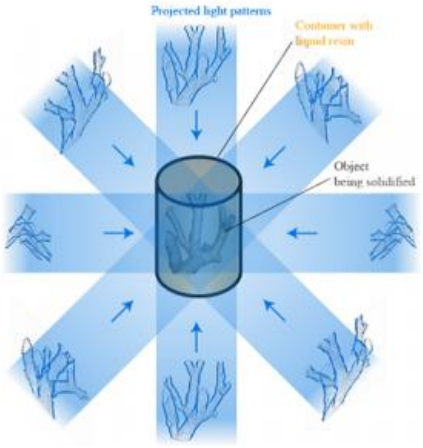

Figure 1. Principle of volumetric printing [5]

Computed tomography (CT) scans actually inspired tomographic 3D printing. A tomographic algorithm is used to process radiographic projections of an object, so that cross-sectional images of the scanned object can be reconstructed. These images represent how the absorbed X-ray dose is distributed inside the object itself. "Basically, the process of tomographic 3D printing can create a solid object inside a photopolymer's volume" [6].

The abstract of mentioned paper [6] is relevant: "Most additive manufacturing methods such as fused-deposition modelling, selective laser melting or stereolithography create objects sequentially one layer at a time. This type of process imposes limitations on the shapes and the materials that can be printed. For example, overhanging structures need additional supports during printing, and soft or elastic materials are difficult to print since they deform as new layers are added. … we use a volumetric 3D printing method based on tomography, where the entire volume of a photo-polymerizable resin is solidified at the same time. We demonstrate very rapid (<30s) printing of a variety of complex structures with acrylates and silicones.""The technique does have limitations", researchers said in [4]. Because each beam propagates through space without changing, there are restrictions on part resolution and on the kinds of geometries that can be formed. Extremely complex structures would require lots of intersecting laser beams and would limit the process, they explained. Additional polymer chemistry and engineering also would be needed to improve the resin properties and fine-tune them to make better structures [4].

3. Latest developments on volumetric 3D printing

The researchers at Lawrence Livermore National Laboratory (LLNL) in California together with collaborators from MIT, the University of Rochester, and UC Berkeley to develop this method, which flashes laser-generated, hologram-like 3D images into photosensitive resin.
The researchers from LLNL and UC Berkeley just published another paper about volumetric 3D printing, titled "Volumetric additive manufacturing via tomographic reconstruction." Co-authors of the paper are Brett E. Kelly, Indrasen Bhattacharya, Hossein Heidari, Maxim Shusteff, Christopher M. Spadaccini, and

Hayden K. Taylor [7], in which they described a new 3D printer nicknamed "the Replicator", after the fictional *Star Trek* device that's able to materialize any object at the push of a button, and filed a patent application on their method The printer is schematically presented in figure 2, and in figure 3 can be seen the real 3D printer.

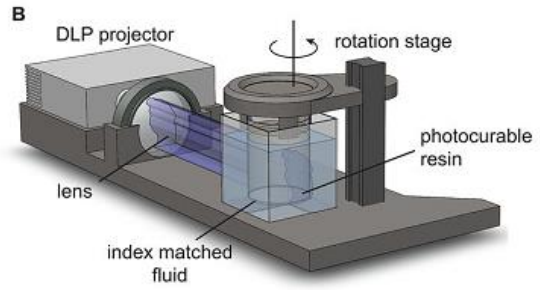

Figure 2. The principle of new 3D volumetric printer [8]

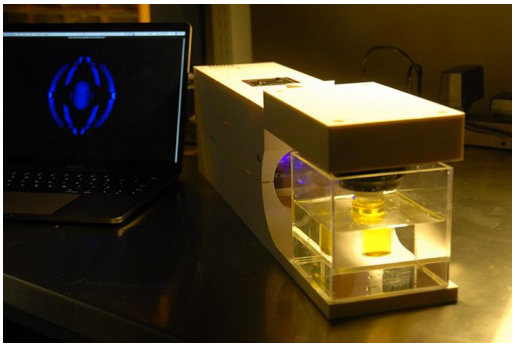

Figure 3. The real 3D volumetric printer [8]

The team has developed a brand-new high-speed 3D printing method called Computed Axial Lithography (CAL)."

The 3D printer works by changing patterns of light through a rotating vial containing photo-polymerizable resin.

As seen in figure 2, a projector beams 3D images into a container of viscous photosensitive resin, which briefly rotates and then lets the fluids drain, leaving behind a complete, fully formed 3D object in minutes.

A computer algorithm calculates the exact patterns of light needed to shape the specific model, as shown in figure 4.

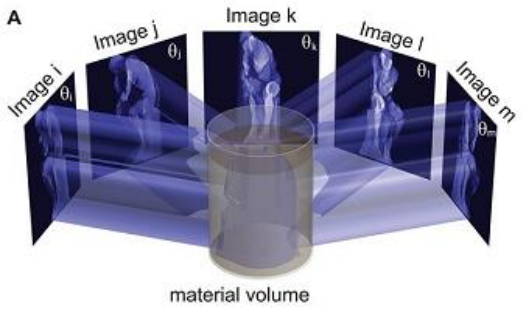

Figure 4. Projected images from various angles of 3D object [8]

The time in which the 3D object forms itself is less than a minute, as seen in figure 5:

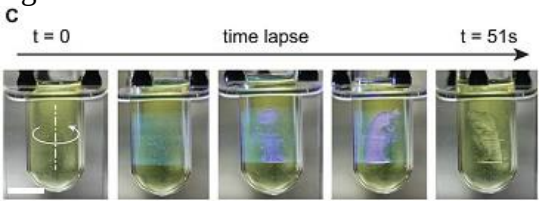

Figure 5. Time formatting 3D object [8]

This "technique generates almost no material waste and the uncured material is 100% reusable. This is another advantage …", mentioned the authors in [8].Although this technology is definitely an exciting development, it's important to note that "further engineering and polymer chemistry need to be completed in order to improve the resin properties, so more stable structures can be fabricated" [8]. The Lawrence Livermore National Laboratory (LLNL) and University of California Berkeley team can only 3D print objects *up to four inches in diameter* at the moment, so large-scale objects cannot be printed right now.

4. New developments of 3D printing in medical field [9]

Swedish bioprinting company CELLINK has entered into a partnership with organ and tissue engineering company Prellis Biologics, Inc. with the goal of commercializing high-resolution holographic bioprinting technology for micro-scale printing.The printer costs 1.2

M USD and it's available since early 2019 (figure 6).

Figure 6. First holographic printer [9]

This printer can be used for or bioprinting pre-vascularized tissue structures that support tissue growth 10x larger than more conventional spheroid cultures.
The high-end system is compatible with any CAD file, enabling researchers to set their own goals for organ and tissue cultures. The bioprinter can also be used for in-lab manufacturing of capillary-containing organ structures and tissues for transplantation, therapeutics screening and complex 3D culture development.
Although is not cheap this system will provide scientist a tool "to advance their research in the field of 3D bioprinting of human organs." [9]

5. CONCLUSIONS

At this point "all 3D printing that commercially exists today is actually 2D printing, repeated layer after layer in the Z dimension" [5].
In 3D printing, depending of the complexity of the model, by using the so called "additive layer manufacturing" it took hours or even days to obtain the final item. In this paper was presented a new development of 3D printing technology, named "volumetric 3D printing". This technology, brand new (2018-2019) may be the end of additive layer manufacturing.
The principle used by 3D printer for volumetric 3D printing is changing patterns of light through a rotating vial containing photo-polymerizable resin.
This technique does have limitations on part resolution and on the kinds of geometries that can be formed. Extremely complex structures would require lots of intersecting laser beams and would limit the process. Additional polymer chemistry and engineering also would be needed to improve the resin properties and fine-tune them to make better structures [7].There are also commercial applications, such as the first holographic printer, presented before, that's not cheap but being able to 3D print/producing complex organs in the future.

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