PRESCOUTER

HOW 3D PRINTING IS REDEFINING INDUSTRIES

PRESCOUTER

How 3D Printing Is Redefining Industries

2017

CONTENTS

INTRODUCTION

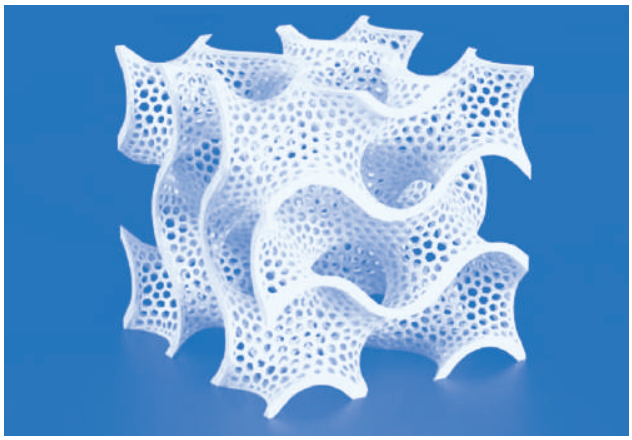
3D printing is a revolutionary technology, whose effects will be felt across multiple industries. It's part of a larger process called additive manufacturing. This white paper first explores additive manufacturing and how it progressed into the multi billion dollar industry it has become. Next, we delve into how this disruptive technology is impacting various industries, namely, healthcare, construction, packaging, and space. We break down 3D printing's impact on medical devices, pharmaceuticals and tissues and organs. Following that, we look at the impact of 3D printing on the construction industry and how it's impacting the speed of construction projects and lowering labor costs. Next, we move onto the packaging industry, where 3D printing will have both an environmental and economical impact because of rapid prototyping. Lastly, we look at how 3D printing is adaptive into new environments including space.

3D PRINTING – WHERE DID IT ALL START?

David Pollard

3D printing, a way of making objects directly from computer models, is growing in adaptability. Several industries are adopting 3D printing from customized medical devices to paintings to satellites. But, where did it all start?

Additive Manufacture (AM) is the general name for the processes which build the product up (additive), as opposed to cutting out of a solid block (subtractive). Using Additive Manufacturing, companies can create complex shapes that would be impossible to machine traditionally – think hollow and interlocking objects. Humans have been creating 3D shapes for millennia, but the modern automated additive methods are founded on two ideas from the late 19th Century – Topography and Photosculpture [1].



Gyroid, by Bathsheba Grossman.
Image courtesy of Bathsheba Grossman

AM – Older Than You'd Think

Topography was proposed to create 3D relief maps, depicting hills and mountain ranges in proportion. Using a series of wax plates, contour lines from a regular 2D map were cut out, creating stacks of surface cross sections. When smoothed, the surface was then covered with paper and annotated, a concept later becoming known as Laminated Object Manufacture.

Photosculpture was conceived to create realistic replicas of any object through multiple photos at different angles; a technique pioneered (and patented) by François Willème [2]. Using the silhouette extracted from the photos, the sculptor would carve out the intersection of the silhouette

and the material, before rotating the product to carve the view from the next angle. As a labor-intensive process, further automation would come with the onset of computing – the concepts of photosculpture carrying into the modern area of 3D scanning.

A similar process required just one photo to produce a 3D object; light was projected through a negative into a gelatin slab to achieve different cure depths based on the transparency of the negative. Hutchinson Frederick filed the patent in 1922 [3], and used this method for production of bas-reliefs. With the onset of computing, the level of complexity was about to increase again…

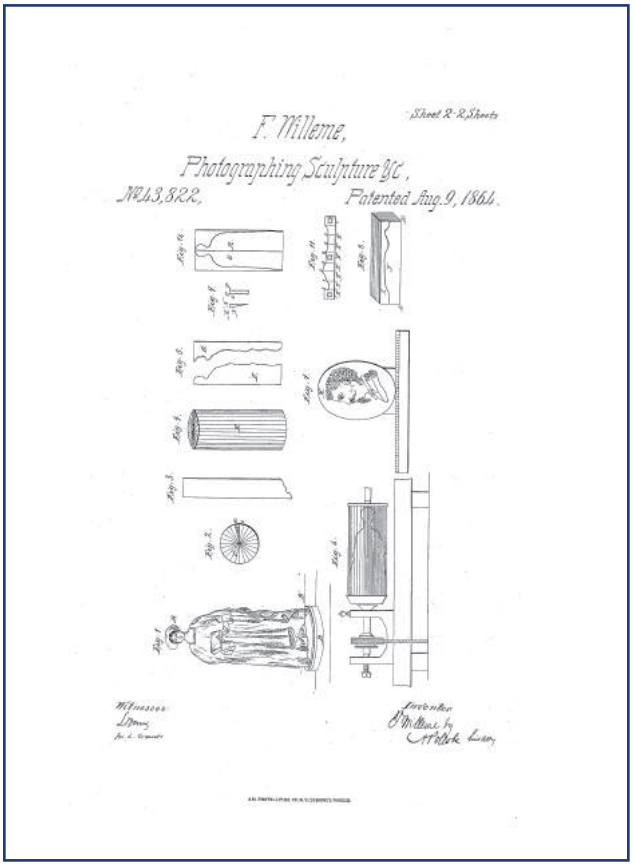


Image from [2] – The process of creating a photosculpture from photographs.

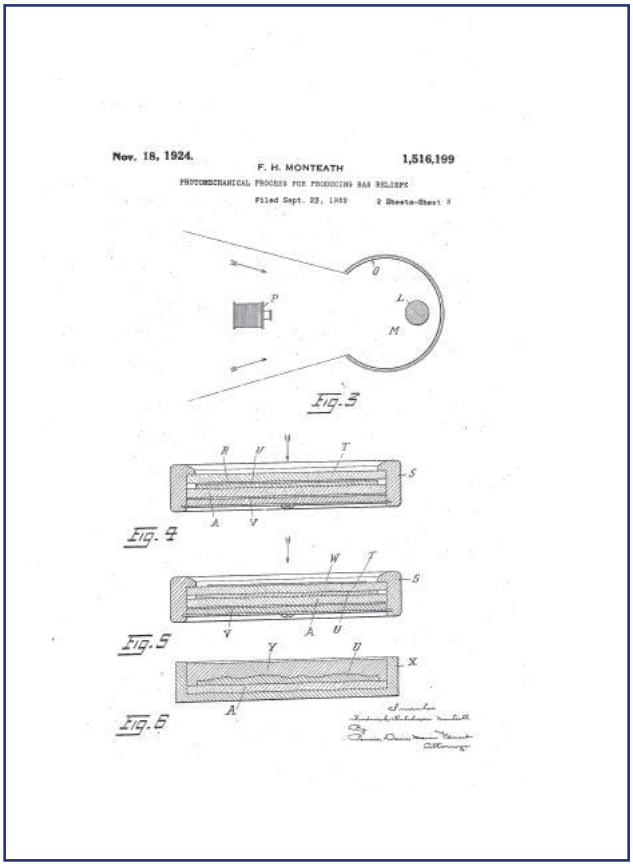


Image from [3] – Fig. 3 shows the process of taking the original image, and Fig. 4-6 depicts the placement of the production of the bas-relief

Moving Away From Analog

A patent in 1951 brought about the idea of stereolithography, where light (ingeniously controlled through a cathode ray tube and analog circuit) was projected to harden a photo-sensitive colloid. By ensuring the attachment to the layer above, successive layers would be added through increasing the vertical motion of the plate, with each layer hardened in a different shape [4]. This key patent for the stereolithography process was referenced in a large proportion of later patents.

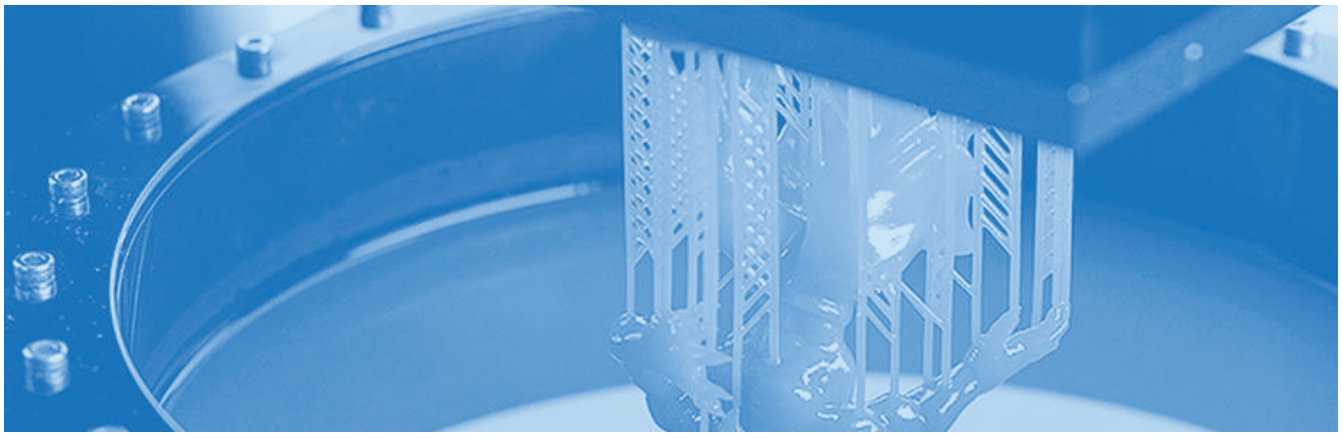
The next key development was a move away from resin-based systems, with a powder process similar to modern technologies; a localized heat source (e.g. a laser) was used to melt and fuse particles together [5], representing a move towards materials more suited for engineering, able to produce parts with more complex geometries and superior mechanical properties to the previous resins.

In 1992, Stratasys filed the original patent for Fused Deposition Modelling (FDM) entitled "Apparatus and method for creating three-dimensional objects" [6], embodying the idea of extruding molten plastic from a gantry system. Based on this work, the RepRap project began, bringing open source desktop printing to the world.

What's Available Now?

With AM technology being developed across many separate companies, there are different names for the same process (Stratasys had trademarked "Fused Deposition Modelling" The RepRap project used "Fused Filament Fabrication"). To help understanding of the different methods, an ISO/ASTM committee evaluated the current 3D printing technologies, and concluded there are seven process categories [7]:

Sheets of material are cut and then bonded together, based on the original idea of Topography. Also known as stereolithography, this uses light to solidify photosensitive resins to produce each layer. This process is based on the original Photo-glyph patent [4].



PROCESS	DESCRIPTION
Binder jetting:	Liquid bonding agents (glues) are applied to a powder bed to bond together for each layer.
Directed energy deposition:	Thermal energy is directed at the material as it is being deposited; similar to a welding machine.
Material extrusion:	A material is dispensed through a movable nozzle; this is the official term for Fused Deposition Modelling and similar methods.
Material jetting:	Using a style similar to inkjet printing, droplets of build material are deposited.
Powder bed fusion:	A bed of powder is selectively heated to fuse particles together. Subsequent layers of powder are then placed on top and then leveled. This process was originally patented in [5].
Sheet lamination:	Sheets of material are cut and then bonded together, based on the original idea of Topography.
Vat polymerisation:	Also known as stereolithography, this uses light to solidify photosensitive resins to produce each layer. This process is based on the original Photo-glyph patent [4].

Where Next for 3D Printing?

This brief history of key AM patents has shown the development has been mostly driven by commercial interests. The market for 3D printing has been rapidly expanding with the entire AM industry being valued at $1.2bn in 2008 [1], and $2.2bn in 2013 and still rapidly growing at a rate of 28.6% from the previous year [8]. The recent (2016) high profile acquisition of Arcam AB and SLM Solutions Group by GE to the tune of $1.4bn shows large companies are willing to get involved in this new technology [9]. While the ideas have been developing for over a century, the economic landscape of the industry has driven, and will keep driving, progress in 3D printing towards higher quality, increased variety of materials, and lower machine and operating costs.

DAVID POLLARD

David Pollard is a PhD candidate at the Bristol Robotics Laboratory, studying quality and control for 3D printing. His research includes modelling the quality of AM components, control of FDM nozzles, and multi-dimensional printing with a robotic arm.

REFERENCES:

[1]: Bourell, D.; Beaman, J.; Leu, M. C. & Rosen, D. A brief history of additive manufacturing and the 2009 roadmap for additive manufacturing: looking back and looking ahead Proceedings of RapidTech, 2009, 24-25

[2]: Me, F. W. (1864). U.S. Patent No. 43,822. Washington, DC: U.S. Patent and Trademark Office. *Hyperlink:* http://www.google.co.uk/patents/US43822

[3]: Frederick, H. M. (1924). U.S. Patent No. 1,516,199. Washington, DC: U.S. Patent and Trademark Office. *Hyperlink:* http://www.google.co.uk/patents/US1516199

[4]: John, M. O. (1956). U.S. Patent No. 2,775,758. Washington, DC: U.S. Patent and Trademark Office. *Hyperlink:* http://www.google.co.uk/patents/US2775758

[5]: Ciraud, P. (1973). Verfahren und vorrichtung zur herstellung beliebiger gegenstande aus beliebigem schmelzbarem material. German Patent Publication DE, 2263777. *Hyperlink:* https://www.lens.org/lens/patent/DE_2263777_A1

[6]: Crump, S. S. (1992). U.S. Patent No. 5,121,329. Washington, DC: U.S. Patent and Trademark Office. *Hyperlink:* http://www.google.co.uk/patents/US5121329

[7]: ISO/ASTM 52900:2015 *Hyperlink:* http://www.iso.org/iso/catalogue_detail.htm?csnumber=69669

[8]: Wohlers, T. Wohler's report 2013 status: published, 2013

[9]: GE Press release, accesed 10/2/17 *Hyperlink* http://www.genewsroom.com/press-releases/ge-plans-invest-14b-acquire-additive-manufacturing-companies-arcam-and-slm

3D PRINTING IN HEALTHCARE

Charles Wright

3D printing has generated huge interest in recent years. The most well-known uses are in manufacturing, but over the last fifteen years, 3D printing has slowly expanded into the healthcare industry. 3D printing has already been used to produce medical devices and instrumentation, but it's uses can expand further to personalized medicine through customized drug dosing, testing on patient-specific tissues, and even printing of tissues and organs.

What Is 3D Printing?

3D printing is a form of additive manufacturing, in which a three-dimensional object is built up from successive layers of raw material based on a digital model. Benefits of this approach include enhanced efficiency and flexibility. As compared to traditional processes, 3D printing wastes less raw materials and requires less manufacturing steps. Designers can easily make changes to 3D printed products without additional equipment or tools. The decreased cost of commercial 3D printers will also enable distributed manufacturing for at- or near-home printing of consumable products, dramatically restructuring the global supply chain.

3D Printed Medical Devices

By creating very complex internal structures, 3D printers can tailor medical devices to an individual's anatomy. Patient-specific devices follow a template model that is matched using medical imaging to an individual's unique anatomic features. Commercially available 3D printed medical devices include orthopedic or cranial implants (e.g., hip joints or cranial plates), surgical instruments (e.g., guides to assist with proper surgical placement of a device), dental restorations (e.g., crowns), and external prosthetics (e.g., hands). Dental implants have been particularly successful, with an estimated 50,000 custom-fit Invisalign braces printed every day.

The FDA regulates 3D printed medical devices through the same pathways as traditional medical devices. Currently, submissions for new 3D printed medical devices are evaluated for safety and effectiveness. Medical-grade PEEK plastic used to make Spinal Elements' Firefly surgical guides and Stryker's Tritanium metal lumbar cages achieved FDA approval in 2016, and many other 3D printing applications have now received 510(k) clearance.

One promising example for patient-specific devices comes from Spanish 3D printing startup Exovite, who uses a 3D scanner to precisely model a patient's limb and then 3D print a personalized splint in just 30 seconds. The system includes a rehabilitation module, which stimulates the muscles below the cast with electric signals to speed up recovery and prevent muscle atrophy.

Healthcare providers are also exploring the implications of 3D printing. US doctors can use a government-sponsored 3D-printing repository to share tool designs for surgeries and treatments. And, earlier this year, the Ottawa Hospital started Canada's first medical 3D printing program, which will seek to improve surgical planning and make 3D printed prosthetic limbs more accessible.

Finally, 3D printing can be used to create medical devices and supplies in areas that have limited access to healthcare. African organization ReFab Dar is recycling waste and turning it into 3D printable plastic filaments, and is running a design competition for 3D printed medical tools to create vital medical supplies in developing countries.

3D Printing of Drugs

Pharmaceutical companies are also embracing 3D printing, which will enable unique dosage forms, complex drug release profiles, and personalized drug dosing. In August 2015, Spritam (Levetiracetam) epilepsy medication became the first 3D printed pill to obtain FDA approval. It was developed by US-based Aprecia Pharmaceuticals, who gained the exclusive rights in 2007 to a computer-aided 3D printing technology developed at MIT for pharmaceutical purposes. Aprecia produces Spritam by sandwiching a powdered form of the drug between liquid materials and bonding them at a microscopic level. Due to their extremely porous nature, these high-dose drugs dissolve rapidly on contact with liquids, making them very effective for use in patients who experience sudden seizures.

3D Printing Can Control Drug Release

3D printing could be used to create many more unique dosage forms. In addition, by modifying a pill's surface area by printing complex shapes, drug manufacturers could control both the strength of a released dose as well as its timing. 3D printing would enable personalized drugs that facilitate targeted and controlled drug release, giving more control over how and when a specific treatment is released into the body. Another route involves 3D printing pills with inner geometries, for example, where one drug forms the outer shell

of a tablet and another fills the inside. Printing pills with a complex layered structure would allow us to create a combination of drugs to treat multiple ailments within a single pill.

Finally, 3D printed medications could aid in treatments for patients who respond to the same drugs in different ways. A healthcare provider could use an individual's information including age, race, gender, and medical history, to customize their treatment according to the optimal dosage.

Eventually, improvements in design and operational efficiency will enable deployment of 3D printers at locations that are convenient for patients, such as hospitals and pharmacies. The ability to manufacture prescriptions on-site would reduce inventory needs and potentially save patients a considerable amount of time.

3D Printing of Tissues and Organs

The production of 3D printed organs sounds straight out of science fiction, yet experts suggest that we are less than two decades away from a fully functioning 3D printed heart. Scientists are already researching 3D printed bones, as well as tracheas, ears, kidneys, skin, and so on. These technologies will address a major need for donor organs. But in the near-term, we are much closer to seeing small-scale applications of 3D printed tissue in humans. Scientists have successfully implanted 3D printed biological matter into animals, and a number of companies are working on applying this technology to human tissues.

Bioprinting startup BioBots is currently working to deploy small, low-cost desktop 3D printers to print living cells. Harvard researchers have already 3D printed human heart tissue on a chip with

Image courtesy of pixabay.com

integrated sensors. And, San Diego-based 3D bioprinting startup Organovo printed the first human liver-on-a-chip in 2014, and are now working to use their proprietary technology to build living human tissues that function like native tissues.

Such breakthroughs will allow us to study how a specific patient's tissues may respond to drugs and toxic compounds with an unprecedented level of throughput. This tissue-on-a-chip technology could let us replicate a patient's specific genetic disorder in the lab so that the properties of a disease or of an individual's cells can be matched to develop customized testing and treatment.

Barriers to Implementation

The FDA has issued guidance for 3D printing in medical applications for medical devices, biologics, and drugs, and is working with companies to better understand 3D printing technology and to improve its guidelines to better serve businesses and individuals using 3D printing for medical purposes. However, some experts believe that 3D printed drugs will eventually require a complete reassessment of classification systems, and regulatory authorities may need to establish new guidelines for the approval of mass-marketed 3D printed drug products.

When manufacturing can move closer to the end user, liabilities will also become less clear. Pharmaceutical companies will have to ensure adherence to their recipes and to regulatory norms, with foolproof processes that reduce the chances of human error. In addition, there is some concern about tampering with 3D printing methodologies, including the possibility of hacking machines to produce counterfeit medications or to mask illegal drugs as legitimate compounds.

A final barrier to consider is the massive level of investment needed to develop completely novel treatments using 3D printing. The concept of printing drugs is often simplified in the media. However, there is a significant amount of money and time that is invested in an actual large-scale implementation.

Outlook and Opportunities

Compared to other industries, the impact of 3D printing technologies in healthcare has a lot of untapped potential. It is estimated that healthcare accounts for less than 2% of all investments made into the $700 million 3D printing industry. However, this number is expected to grow to 21 percent over the next 10 years, with market research firm Markets and Markets projecting that the use of 3D printing applications within healthcare will have a value of $2.1 billion by 2020.

3D printing could provide the framework necessary to make personalized medicine an essential part of tomorrow's healthcare industry.

Devices and implants tailored to the individual patient are already becoming commonplace, and they will be followed by single, easy-to-swallow pills designed to release a customized drug cocktail at defined intervals throughout the day. 3D printed tissues will accelerate the pace of pharmaceutical research, and within a few decades, 3D printed organs for transplant could make the need for organ donors obsolete. Research and development of 3D printing applications for healthcare is continuing at a rapid pace. Stay tuned for future updates.

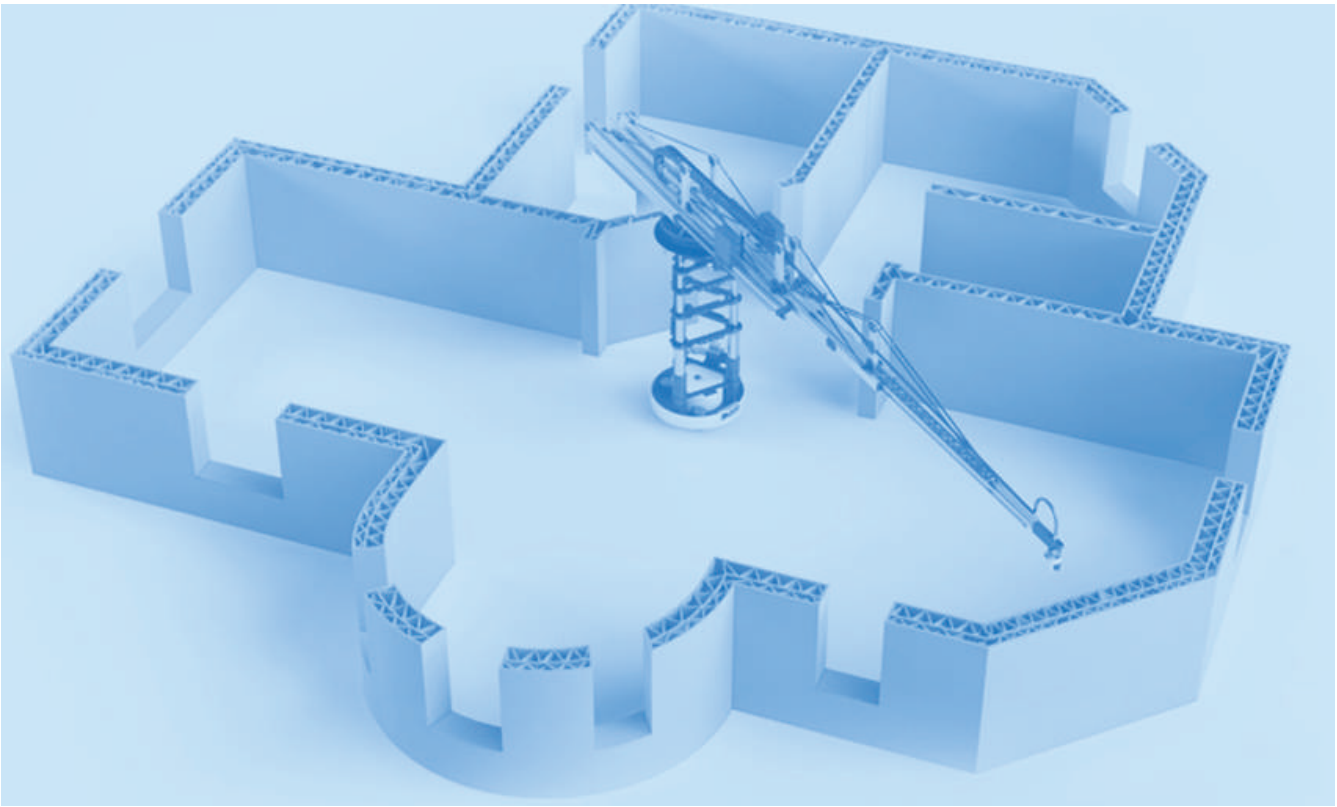
CHARLES WRIGHT

Charles Wright is one of PreScouter's Project Architects. He specializes in the medical industry. As an academic, he developed integrated microscopy and computational systems for high-throughput quantification of the behavior of single cells. Charles graduated with a BA in Physics, Molecular and Cellular Biology, and Spanish from Vanderbilt University, then earned his PhD in Biophysical Sciences from the University of Chicago before working as a Postdoctoral Scholar at Purdue University.

3D PRINTING AND THE FUTURE OF CONSTRUCTION

João Guerreiro

Earlier this month, Apis Cor announced the construction of a full building using its concrete 3D printer. The company joins a trend that has started to emerge ever since Chinese company, Winsun shocked the construction world with the announcement that they used 3D printing to erect 10 homes in a single day. With promises to lower construction times (printers can work 24/7), decrease raw materials use, eliminate waste, and improve safety in the workplace, 3D printing has plenty to offer.



An example of in-situ 3D printing using a crane system. *(courtesy of Apis-Cor – www.apis-cor.com)*

The Construction Industry Has a Labor Problem

The recession last decade particularly affected the construction sector. Plenty of projects were halted, companies went bankrupt and workers laid off. It is estimated that between 2006 and 2011, 2.3 million workers left the construction sector. The US Census published a study in late 2015 where they estimate that while 40% of these workers would eventually find their way back into the industry, 1/3rd moved to other industries and 1/4th never came back.

The construction industry has definitively bounced back and 2017 is expected to show the largest growth since the recession. While hundreds of thousands of new jobs were created over the past years, workers have not returned. Industry leaders have repeatedly brought up the difficulty in filling positions, and they fear this will lead to higher costs and extended timelines when completing projects.

Construction and Natural Resources

It is no secret that the construction industry exploits resources. It is estimated that the construction of an average home generates 2.5 to 4 tons of waste. Add to that the large energy requirements to operate the machinery necessary to erect such structures and transporting those to the construction site. There is an opportunity for the construction industry to conserve resources and at the same time, reduce construction costs through innovations like 3D printing.

MX3D metal 3D printer building a small model bridge through Wire and Arc Additive Manufacturing. The company is working on a full-size bridge that should be ready later this year in Amsterdam.
(courtesy of Adriaan de Groot, MX3D – mx3d.com).

How Is 3D Printing Helping Construction Projects?

Material Costs – 3D printing alleviates spending in key areas that are currently challenging the construction industry. 3D printers typically have very little waste as the materials are deposited only where needed. Furthermore, a common trend in 3D printing for construction has been the use of recycled and/or typical waste materials, further reducing construction costs. Estimates place construction project savings in raw materials can reach 50% in some cases.

An example of a 3D printed wall. The design saves material and provides insulation on load bearing walls. *(courtesy of Contour Crafting – www.contourcrafting.org).*

Complex Tailor Made Structures – Changes in design and complex elements can add cost and time to construction setting. Specialized equipment or personnel can sometimes be required to guarantee that structures are done per the specifications. 3D printers can read directly from the digital 3D model and print complex structures to the millimeter level in detail. This can be done either on-site or off-site and then assembled. Both cases typically result in more reliable construction and savings in time and resources.

Speed of Construction – 3D printers most immediate advantage remains one of its crucial ones. Walls can be erected 5 to 10 times faster when using a 3D printer. Winsur proved how efficient this is even when printing offsite by assembling 10 houses in a day. The costs are kept low with the 200 square meters' houses costing only $4,800 per unit.

Labor Costs – Labor costs are a big part of the construction budget. With the current labor shortage climate in the western world, 3D printing is estimated to result in up to 80% in savings on the labor cost per square meter. Even in emerging economies, the savings are significant.

Where Does It Still Need to Go?

While 3D printing offers clear operational advantages and savings, it is currently a considerable investment – higher than traditional construction. Very few companies have embraced this new technology. Finished projects are scarce, and materials are limited.

There is a misconception that manual labor isn't needed for 3D printing. New workforce training would need to be implemented. Additionally, 3D printing is not an all-in-one solution. Piping, electrical grid, reinforcements, and frames are

some of the elements that need to be manually installed. Furthermore, technical solutions need to be developed to allow an easy integration of construction elements or the deployment of different materials simultaneously.

One technical element that has received attention is the elimination of steel reinforcement altogether by employing new materials and design structures. This promises to make construction faster and more automated, but right now, no more than a few stories buildings have been successfully attempted.

Take Away

In the end, 3D printing must be able to emerge in an industry that can have a hard time accepting a new technology that will change the way it works at the worksite. One place where we see an easier adoption path is on the prefab / offsite construction setting that is on the rise as an answer to some of the challenges mentioned. Implementation of 3D printing here still provides many of the benefits discussed while not disrupting the worksite paradigm.

Ultimately, companies investing in 3D printing will be among a restricted number of innovators with all the advantages and challenges that brings.

Concept art of 3D printing use in an extra-terrestrial environment. *(Courtesy of Contour Crafting – www.contourcrafting.org).*

Keep an eye out for the next article on the topic where we'll highlight some of the main techs and the innovators in this field!

JOÃO GUERREIRO

João Guerreiro, Ph.D., is one of PreScouter's Project Architects. He specializes in the materials sector. As an academic, João performed research in Bio-Chemical Engineering at the Massachusetts Institute of Technology in the US, the University College London in the UK, and the University of Lisbon in Portugal.

HOW 3D PRINTING IS DISRUPTING THE PACKAGING INDUSTRY

Marija Jovic

In recent years, there has been a lot of interest and research in 3D printing and how it will change the packaging industry. Many parts of packaging from prototyping to manufacturing have been and will be affected and enhanced by 3D printing technology.

Rapid Prototyping

3D printing can accelerate early-stage product development through rapid prototyping. It helps companies design several molds so that prototypes can be manufactured quickly and economically. Thus, 3D printing technologies can rapidly expedite the time and cost it takes to bring a product to market.

Using 3D printing to fabricate single parts or a limited number of parts is cheaper than using standard plastic processing techniques like injection molding, thermoforming and blow molding. With 3D printing, one can go from a CAD blueprint to a complete part in a matter of days or, potentially, hours. As part count increases, however, standard technologies become much more economical compared to 3D printing.

Revolutionizing Packaging Machinery

3D printing will also impact packaging machinery manufacturers. For example, 3D printing can be used for printing robotic arms used in production. Additionally, the parts will be lighter than more traditional ones, and at the same time be more powerful with the right choice of material and printing method.

Making spare parts for machinery will be revolutionized as well, by making them on the spot, instead of being supplied all around the globe. Instead of shipping replacement parts, companies will be selling the packaging machine together with a software package for the end user to 3D print out any spare part needed on site at their manufacturing plant.

Custom and Personalized Packaging

With the current and future trend of making everything more custom-made (like personalized medicine for example), it is not surprising that manufacturing technologies such as 3D printing will be of high importance. The technique allows customers to design and make their own highly customized packages on request. Individual packaging designs can be manufactured specifically in accordance with customer wishes and various design prototypes can be produced running efficiently.

The trend of personalized packaging is particularly relevant for the food and beverage industry, where personalized gifts such as cakes and drinks are valued.

Reducing Plastic Waste Pollution

3D printing can also help companies make more environmentally friendly packaging. Plastic waste pollution is a huge problem, but with 3D printing, plastic waste can be cleaned, dried, shredded, extruded into a printable filament that can be recycled into a 3D printer for a new product. As more sustainable bioplastic materials are used, the adoption of 3D printing in packaging manufacturing may truly help save the environment. Generating less waste is not only environmentally friendly but economical as well.

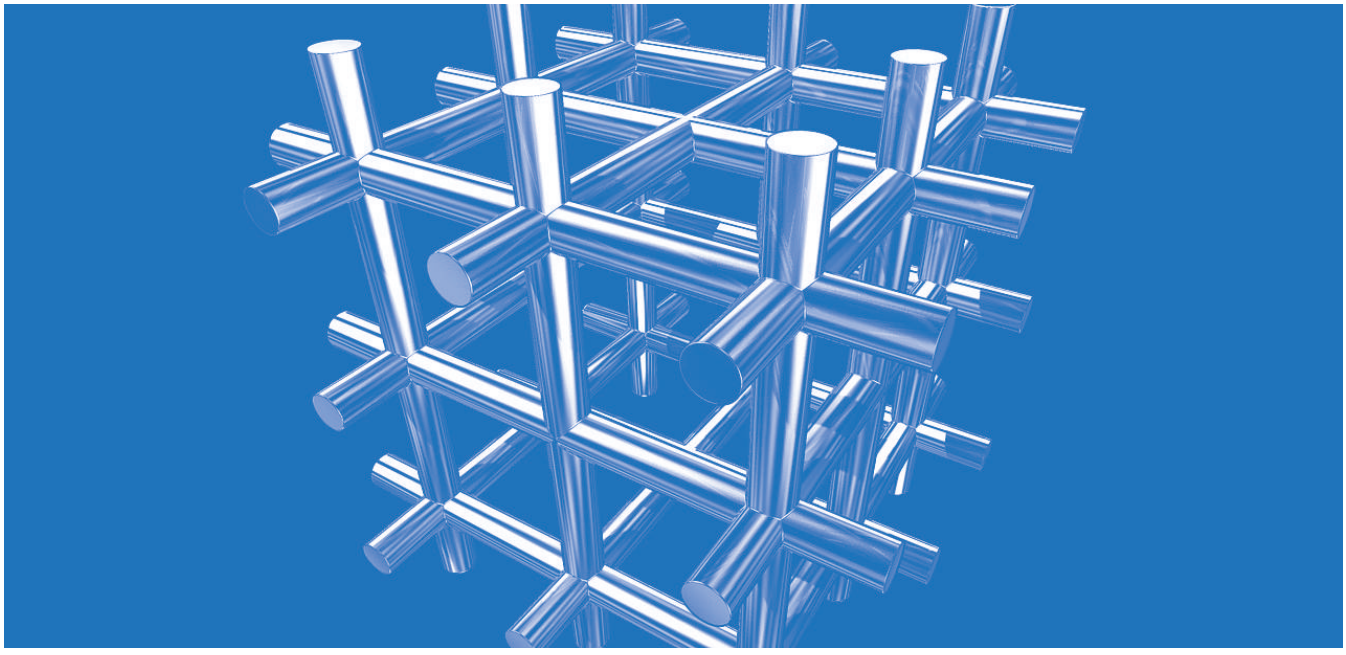


Image courtesy of pixabay.com

How Will 3D Printing Change the Market?

Trends like these will power the growth of the 3D printed market, which was valued at $5 billion in 2015 to a predicted $60 billion market in 2026. Per data cited by Packaging Digest and Smithers Pira, the market for 3D printing is set to reach $49 billion by 2025.

And according to a PWC's survey, 70 percent of companies surveyed believe that 3D printing will soon be used for obsolete parts and 57 percent believe it will be used for after-market parts. The study also revealed that 66.7 percent of manufacturers are adopting 3D printing in some capacity and that within the next three years, 24.7 percent plan to adopt 3D printing for some kind of use. Only 9 percent reported they had no plans to use 3D printing in any way. A similar 2015 survey was made by Packaging Digest, trying to understand the extent of incorporation of 3D printing in the packaging industry a year ago. They found that over one-third of respondents were already using 3D printing for product packaging and the others plan to do so in the near future.

Do you need help understanding how 3D printing can positively impact your business?

MARIJA JOVIC

Marija is one of PreScouter's Project Architects at PreScouter. She specializes in packaging. She finished her Master's degree in Chemical Engineering from Belgrade University and completed her PhD in Organometallic Chemistry and Catalysis at the Swiss Federal Institute of Technology (ETH Zurich). Marija's research was focused on understanding reaction mechanisms in order to rationally design catalysts for polymerization and metathesis reactions. Prior to her PhD, Marija worked in the industry on synthesis of new textile dyes.

A NEW MATERIAL IS FURTHERING 3D PRINTING IN SPACE

Sofiane Boukhalfa

3D printing, also known as additive manufacturing, has enabled many advancements in several industries, and it's about to make a significant impact in a new environment – space.

The International Space Station Uses 3D Printing

Last year, astronauts began 3D printing tools on the International Space Station using their advanced manufacturing facility (AMF). While this was an exciting development, their were some drawbacks to the 3D printed tool in space.

The harsh environment of space severely limits which materials can be used in the vacuum of space. Until now, there was no 3D printed material that could withstand these conditions. A few days ago, start-up Made in Space announced a new material and process to 3D print objects that could withstand these conditions. The new material is made from PEI/PC (polyetherimide/polycarbonate), and offers several advantages, including increased toughness and UV resistance. With this technological advancement, we can now bring tools to repair and build items in space.

3D printing can be used to create three dimensional objects by applying layers of materials on top of each other to create a final object. The layer-by-layer approach offers several advantages, including the ability to print complex shapes without the use of costly machining, the ability to use different materials for different layers, and to create complex 3D architecture to create functional objects.

Another large advantage of 3D printing is that it significantly reduces transportation costs. It gives individuals and organizations the ability to create a finished product at the location where this object will be used. There are few applications such as in construction, where this advantage will be more precious than in space, where the costs of transporting even the lightest objects are astronomical. 3D printing will allow astronauts to

create space parts and other useful objects directly in space, without the need to ship it from the Earth's surface. In fact, NASA intends to create the first 3D printed satellite to orbit Earth in 2018.

Such advancements in 3D printing that startups like Made in Space are working on, will help reduce the cost of space exploration in the years to come as we further explore building on Mars and space tourism.

SOFIANE BOUKHALFA

Sofiane is one of PreScouter's Project Architects. He specializes in the financial industry. His responsibilities include managing the overall project and scholar team to ensure successful project outcomes for our clients. Sofiane earned his B.S. in Materials Science and Engineering from The University of Illinois at Urbana-Champaign, and his Ph.D. in Materials Science and Engineering from the Georgia Institute of Technology. His research focus was in nanotechnology and energy storage. Since graduating from Georgia Tech, he has worked as an emerging technology and business strategy consultant at several firms and for his own clients.

"I don't know enough about X, and I don't have the time to research and learn it. Quickly get me up-to-speed on what I (specifically for my role and context) need to know, so I can understand my options."

Spend less time on tedious, tactical activities		Spend more time on high-impact, strategic activities
Calling external innovators for information		Collaborating with external innovators
Searching databases		Analyzing landscapes that are state of the art
Studying research journals		Road-Mapping internal programs
Mining large amounts of data		Making decisions

Have top tier advanced researchers work on your project

Our clients value the unbiased insights and innovative thinking that our network of over 2,000 researchers provides.

We take care of everything

Our proven system removes the stress of interviewing, selecting and managing talent to produce high quality results.

"PreScouter made us aware of 23 emerging technologies that we probably would not have become aware of (otherwise)"

Dr Richard Demke

SUNSTAR

PreScouter is trusted by over 400 clients - and counting

Micron · Coca-Cola · Afton Chemical · BD · Clorox · Aftron (True Value, True Quality)

EXPERIENCE IN MULTIPLE INDUSTRIES

Materials · Packaging · High Tech · Financial · Consumer Goods · Natural Resources · Medical · Food and Beverage · Transportation

PreScouter quickly gets Corporate Innovators up-to-speed on what they need to know to make informed decisions.

PreScouter, Inc. 1 N. Franklin St, Suite 1850, Chicago, IL 60606 • info@prescouter.com • (872) 222-9225

PRESCOUTER

PreScouter, Inc. 1 N. Franklin St, Suite 1850, Chicago, IL 60606

info@prescouter.com

(872) 222-9225

www.prescouter.com