Tech Insights: 3D Printing

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VA OFFICE OF TECHNOLOGY STRATEGIES

Introduction

What if you could build your own bones or car by printing the parts you need? Three-dimensional, or 3D, printing makes this possible by manufacturing materials that are deposited in layers, producing a three-dimensional object. This technology provides the capability to producing objects of different geometries or shapes, using different materials, such as polymers, free-standing liquid metals, solid metals, ceramics, clays, epoxy resin, and even living cells and organs.

In his book published in 2011, Jeremy Rifkin described how the use of 3D printing marked the beginning of a Third Industrial Revolution. This succeeded the production line assembly, which once dominated manufacturing, and the development of steam transportation systems. Economic historians argue that the onset of the Industrial Revolution was the most important event in the history of humanity since the domestication of animals, plants, and fire. So, what will be the significance of 3D printing? This Tech Insight explores the evolution of 3D printing, how the technology is used in current healthcare applications, its potential impact on the Department of Veterans Affairs (VA), and 3D printing's next evolution.

Evolution of 3D Printing

3D printing is a process that uses a digital file to make three-dimensional, solid objects. Because the creation of 3D printed objects is achieved using an additive process, it is also referred to as additive manufacturing. In essence, a 3D printer is a type of industrial robot.

Three-dimensional printing moved from science fiction to reality between the mid-1980s and the early 1990s when scientists such as Charles Hull, Carl Deckard, and Scott Crump independently developed different processes for printing 3D objects.

Charles Hull engineered the stereolithographic apparatus (SLA), a machine that created a tangible 3D object from digital data pertaining to its color, texture, layer thickness, and other features. The early 1990s saw the introduction of more 3D printing techniques, such as Selective Laser Sintering (SLS) and Fused Deposition Modeling (FDM). SLS uses a high-powered laser to fuse particles of plastic, metals, ceramic, or glass powders into a three dimensional object.

As early as 1991, FDM 3D printers, which lay down materials in additive layers, were fed with thermoplastic filaments. Thermoplastic filaments are materials that become malleable when heated, but harden when cooled. The filaments pass through an extruding nozzle and are heated above their melting temperature. The nozzle's motion is computer-controlled by a three-axis positioning system. While exiting the nozzle, the softened plastic filament cools, rapidly hardening and forming the 3D printed object via layer-by-layer deposition.

3D Printing in the Healthcare Realm

By the late 1990s, 3D printing became a strategic healthcare tool. The need to replace damaged or diseased bone is not new, so why not use 3D printing to manufacture body parts? 3D printing is an advancement that brings down cost and offers supply on demand.

In 1999, the Wake Forest Institute for Regenerative Medicine opened the door to applying 3D printing for engineering not only bones, but organs as well. With this development, 3D printing became vital for patients who needed organ transplants in a short period of time. Timely reception of these organs determined whether patients live or die. Further efforts include printing scaffolds of stem cells, cartilage, bone, disease cells, blood vessels, and human hearts. In 2008, a medical research firm, Organovo, printed functional blood vessels and cardiac tissue using cells obtained from a chicken. Today, researchers at the University of Rostock in Germany, Harvard Medical Institute, and the University of Sydney, are developing methods of heart repair, called "heart patches," made with 3D printed cells.

Additional Breakthroughs in 3D Printing

While 3D printing plays a major role in the healthcare sector, it has also impacted the automotive, architectural, aerospace, and jewelry industries. For example, the first 3D printed car, the Urbee, was created in 2011 through a collaborative effort between a 3D printing company, Stratasys, and a Winnipeg engineering group, Kor Ecologic. The car's entire body is created with 3D printed parts; it uses both gas and electric motors to achieve fuel efficiency of more than 200 miles per gallon (mpg) on the highway and 100 mpg in city, using either ethanol or gasoline fuel. In 2015, a Chinese construction company, WinSun Decoration Design Engineering Co., printed 10 houses, a five-story structure, and a mansion. Other contributions include the world's first 3D printed robotic aircraft designed and flown by engineers at the University of Southampton, and online 3D printing services which offer 14K gold and silver jewelry manufacturing.

4D Printing

A new form of printing has entered the market with even greater implications for industry; four-dimensional, or 4D, printing introduces transformative capabilities to the concept of printed manufacturing. 4D printing develops chameleonic materials, whose properties shift according to external stimuli, such as pressure, moisture or temperature changes. Whether synthetic or biological, these materials change shape on their own. MIT research scientist Skylar Tibbits predicts, "4D printing will allow us to print objects that can reshape themselves or self-assemble over time." Self-assembly is a process by which disordered parts build an ordered structure through only local interaction, such as a printed cube which folds by itself or a printed pipe which senses the need to expand or contract.

From a healthcare perspective, this type of technology can impact artificial organs and nanotechnology. For example, a throat illness that is temporarily treated with a static, 3D printed splint could instead be treated by implants that change shape and conform over time as the body moves or grows, using 4D printing. Thus, temporary implants have the potential to be replaced with more permanent implant solutions. According to Frost and Sullivan's analysis, healthcare applications may be slow to market due to stringent health and safety standards.

Conclusion

As further research and development continues to support 3D printing, it is important that VA leverage these technologies when possible. So far, VA has hosted a VA Innovation Creation Series Challenge, officially launched at the VA Palo Alto VA Medical Center in California, as a means to create "an open ecosystem of prosthetics and other assistive technologies" through the use of 3D printing and open source availability. It is an initiative that VA hopes will inspire the developer community to create new innovative prosthetics and assistive technologies that will improve the care and quality of life for our Nation's Veterans.

Read more technology-related topics in the Office of Technology Strategies' Tech Insights and Enterprise Design Patterns. If you have any questions about 3D printing, don't hesitate to ask TS for assistance or more information.

Note: As of September 14, 2016, the Office of Technology Strategies' (TS) white paper series known as "TS Notes" has been renamed to "Tech Insights." The new name has a stronger connection to the intent of the series, which is to provide readers with strategic insights on a variety of technology topics. The content and topics covered in Tech Insights will not change. If you have any references to these documents, please update them as necessary. Thank you!