THE FUTURE OF THE WESTERN CAPE AGRICULTURAL SECTOR IN THE CONTEXT OF THE 4TH INDUSTRIAL REVOLUTION

Review: 3D Printing

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1. What is 3D Printing?

Introduction

3D printing is a term that is used to describe a type of manufacturing that builds products from a 3D design by depositing materials layer by layer. 3D printing is technically called additive manufacturing. The term "3D printing" is increasingly used as a synonym for Additive Manufacturing. However, the latter is more accurate in that it describes a professional production technique which is clearly distinguished from conventional methods of material removal. Various materials are used in this process from plastics to metals. The type of additive manufacturing method will determine what material is able to be used, but almost anything that can be modelled in 3D and made of plastics, metals or even organic matter can be built using additive manufacturing.

How does 3D Printing work?

3D printing starts with a digital file derived from computer aided design (CAD) software. The 3D model is converted into a standardised format which 3D printers are able to use, and the model is sliced into many 2D layers - sometimes thousands. A 3D printer then reads the 2D slices and layers one on top the other, thus forming a three dimensional object. All design files, regardless of the 3D printing technology, are sliced into layers before printing. Layer thickness, the size of each individual layer of the sliced design, depends on the type of additive manufacturing technology, the materials used, desired speed of print and the level of detail required. Thicker layers result in faster builds but thinner layers equate to higher resolution and less visible layer lines. Thinner layers also have the benefit of needing less post-build processing to finish the project.

Types of Additive Manufacturing

There are seven types of additive manufacturing: Binder Jetting, Directed Energy Deposition, Material Extrusion, Material Jetting, Powder Bed Fusion, Sheet Lamination, and Vat Photopolymerization. Some of the more commonly used are described below:

Vat Photopolymerization

This high-end technology uses lasers to cure layer-upon-layer of photopolymer resin (polymer that changes properties when exposed to light).1 The build occurs in a pool of resin and lasers are fired at the pool surface to cure the resin in the shape required by the 3D model for a given layer. The model is then moved up and the lasers cure the next layer. This type of 3D printing is very accurate, but is also more expensive. Common uses are in aerodynamic testing of small models as well is in applications where high detail is needed, such as medical engineering.

Material Jetting

Material is jetted onto the build surface or platform, where it solidifies and the model is built layer by layer. Material is deposited from a nozzle which moves horizontally across the build platform. Machines vary in complexity and in their methods of controlling the deposition of material. The material layers are then cured or hardened using ultraviolet (UV) light.[2] A high accuracy can be achieved but materials are limited and only polymers and waxes can be used. Common use cases are in rapid prototyping. A major advantage is the ability of material jetting to use multiple materials on the same build. Much like your inkjet printer uses different inks for different colours.

Material Extrusion

Material is drawn through a nozzle, where it is heated and deposited layer by layer. The nozzle can move horizontally and a platform moves up and down vertically after each new layer is deposited. It is a commonly used technique used on many inexpensive, domestic and hobby 3D printers.[3] This technique is fairly inexpensive relative to other methods, however, the print quality is limited to the nozzle thickness, as such this method is not used for high accuracy tasks.

Powder Bed Fusion

Powdered material is selectively consolidated by melting it together using a heat source such as a laser or electron beam. The powder surrounding the consolidated part acts as support material for overhanging features. The model is moved to create the next layer.[4] This is typically used for metals or hard plastics. An advantage of powder bed fusion is that support structures do not need to be created during the print and it is relatively inexpensive. However, the process is very slow. Common uses are in prosthetics and even some bespoke jewelry.

2. Why is 3D Printing important now?

Accessibility

It is difficult to appreciate 3D printing without considering the manufacturing process and how a product goes from idea, to drawing, to prototype, to final product. It is the prototyping and production stage that has been revolutionised by additive manufacturing.

The driving force behind the technology is a decline in the cost of obtaining 3D printing devices and designs. As patents expire and designs become freely available and open source, the costs of additive manufacturing fall significantly. This allows more businesses the opportunity to use the technology and increases the level of development in the space. A key advancement in the design of products has been the increased capability of computers to produce and process 3D models. CAD software has advanced significantly and extremely complex 3D objects can be computed easily on modern hardware.

Emphasising the rapid growth in the industry is the number of producers of 3D printers. According to the Wohlers Report 2017, 97 manufacturers produced and sold additive manufacturing systems in 2016. This is up from 62 companies in 2015 and 49 in 2014.[5] From 2013-2015 the industry grew at a CAGR of 31.5% to reach a size of $5.165 billion. This growth is increasing competition and driving costs down.

Currently, a desktop 3D printer could be acquired for less than R5,000[6], which is comparable to other office equipment like conventional printers. With more businesses starting to manufacture products via 3D printing we can also expect the cost of materials used in 3D printing to fall. This will enable more applications of the technology to become feasible.

Rapid Prototyping

Prior to 3D printing, when an engineer or designer wanted to create a prototype of a product he had drawn up, it would have required a lengthy and often expensive process. The CAD model would have been sent to a machining shop where, through skilled (and expensive) labour, a mould could be created. This could take a number of days to weeks. Often a design needs to be quickly finalised and perfected through many minute changes, such as aircraft parts or racing car panels, where the aerodynamics hinge on extremely small changes in the shape of the part. This process of trial and error, with lead times in the weeks for a prototype to be ready, stalls projects and increases costs by an order of magnitude.[7] 3D printing has increased the speed of prototyping so significantly that where it used to take weeks to create a mould for a prototype, they can now be printed on-site within hours.

Design Freedom

3D printing has opened the doors for design complexity. Prior to the technology some designs or shapes would simply be too complex to feasibly manufacture via subtractive methods. Additive manufacturing has allowed amazingly complex and intricate designs to be produced at a low cost. This results in better designs and more creative products becoming feasible. Such intricacy can be seen in the image below.

Figure 1: An intricate 3D printed design: Source Stratysys.com

Cost

Costs are saved in a variety of ways through 3D printing, some of which have already been described above. There are 3 predominant areas of cost saving: zero-tooling, reduced labour and cost-free design complexity.[8]

Zero-tooling: 3D printed products do not need any tooling as they are built from a zero base to exact specifications. This saves on labour and tools needed to create different components which can be extremely costly.

Reduced Labour: labour is reduced due to the lack of tooling described above as well as less need for assembly, as many components can be consolidated into one unit for printing. Automation of the build process also saves on labour, as less input is needed during the production process as the entire design can often be produced without interaction from a person.

Cost-free Complexity: 3D printing removes the limitation on design complexity which would previously have determined cost. The limitations of the precision of tools and length of time to prototype designs for the production are no longer factors in the costing of a product. Thus, designs can increase in complexity without enormous increases in the cost of the product.

3. What are the applications of 3D Printing today?

Common Applications

The applications of 3D printing are so numerous that it would be impossible to detail all of these here, however, virtually anything that can be 3D modelled can be manufactured with a 3D printer of some sort. This ranges from aircraft parts to organs. Some of the most interesting applications are shown below:

Printed Buildings

Large 3D printers are already creating objects as large as apartment buildings in China, albeit in multiple parts which are later assembled and reinforced. Company,
WinSun, **claimed to have printed 10 houses in 24 hours**, using a proprietary 3D printer that uses a mixture of ground construction and industrial waste, such as glass and tailings, around a base of quick-drying cement mixed with a special hardening agent.[9]

Bio-organ Printing

Another interesting application of additive manufacturing which has significant implications is the ability to print biological material. 3D printing of human tissue and organs can revolutionise the healthcare industry. Organ recipients will no longer have to wait months or years for a donor with the correct blood type, and organ transplant rejection will not be an issue. Biofabrication uses 3D printing to perform a 3D culture of tissue. The cells are seeded into a 3D containment structure that facilitates the directed 3D growth and proliferation while also providing nutrients to the cells.

Other medical uses are in orthodontics and prosthetic limbs, where 3D scans of teeth or body parts can be used to print a perfectly customised replacement tooth or limb. This is more more convenient than a mould, and the 3D model can be modified as necessary by the physician.

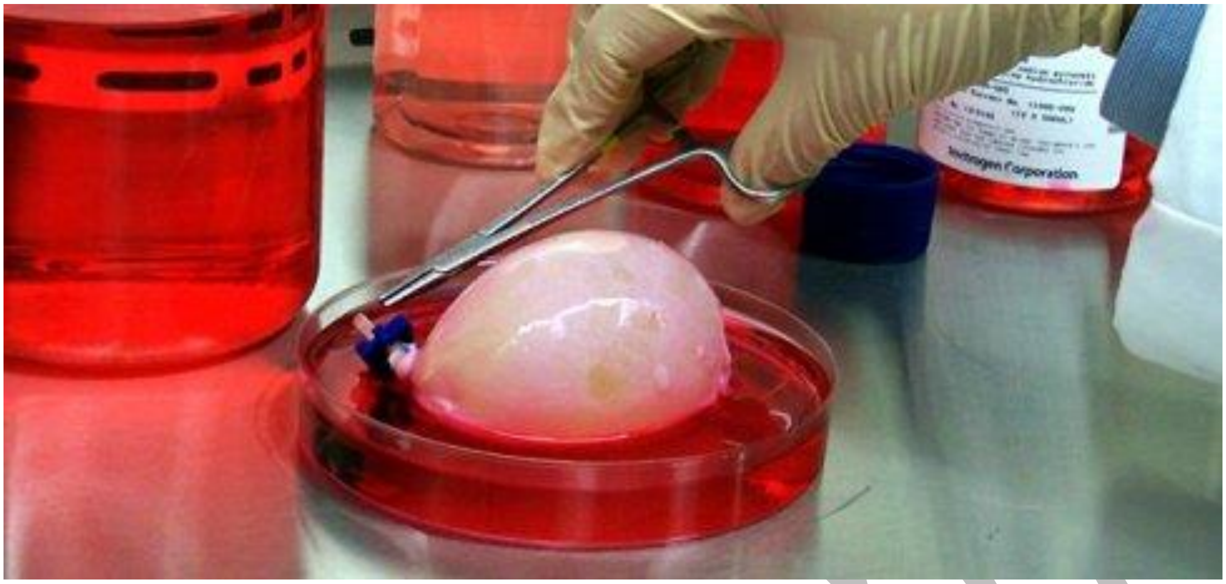

Figure 2: 3D printed bladder implanted with cells being placed in culture solution to grow.
Source http://www.3ders.org.

Agriculture

While 3D printing is not currently as directly applicable to farming as other technologies, such as robotics, 3D printing is being used in some agricultural operations. However, most additive manufacturing methods are used upstream in agricultural equipment manufacturing.[10] 3D printing and 3D printed foods, meats and vegetables could have a large impact on agriculture. We discuss this further in our report on biofabrication.

Equipment Manufacturing

Many OEMs (original equipment manufacturers) are using 3D printing in their manufacturing processes as described earlier in this review. This has brought down the cost of agricultural machinery and resulted in faster development of new equipment.[11] 3D printed equipment is emerging in the field of hydroponics. A company called 3DPonics is producing small and cost effective hydroponics systems which can be used on a small scale at present. The project is open source and the designs can be freely downloaded from their website.[12]

DIY Tool and Part Creation

Another direct application of the technology of additive manufacturing is the rapid prototyping of tools and replacement parts for farmers in remote areas. Farmers in Myanmar are currently using 3D printing to assist them in designing tools which they can use on their farms, this has assisted the farms in very rural areas in developing tools and parts which would otherwise need to be imported at great cost.[13] Farmers in undeveloped nations or those far from business hubs can use 3D printing to create the parts and tools they need on site. This can prevent farmers from having to wait weeks with a broken tractor or harvester for a part to arrive. Combining 3D-printed parts with virtual reality headsets will eventually allow farmers to print parts and then have an OEM expert talk them through a live installation remotely via virtual presence at a fraction of the time and cost of flying out parts and experts.

4. What is the Future of 3D Printing?

4D Printing

4D printing adds a fourth dimension to 3D printed objects: movement. 4D printing aims to produce objects which shift in shape or change tension in response to an energy source such as heat or movement.[14] It works by 3D printing with multiple materials and embedding movements into the 3D printed object so that with a bit of energy, it pulls itself into shape, much like proteins automatically folding in living cells.

Skylar Tibbits of MIT is one researcher leading the charge into 4D printing and is creating self-assembling technology through additive manufacturing methods inspired by the way the body manufactures its own parts.[15]

The technology would enable self-assembling and repairing products as well as smart materials that are able to perform basic computations. While this technology is not commercially available, good progress is being made in the field. Applications for 4D printed objects are numerous. Some of the exciting ones are: flat packing furniture which can self-assemble as needed, temperature-activated cardiac stents, and 3D printed underground pipes which contract and expand to control hydraulic pressure. As we perfect self-assembly, additive manufacturing will be of increasing use and smart buildings and other infrastructure could be created that reacts to changes in the environment automatically through its pre-programmed building material. As 4D printing becomes more accessible, the applications for agriculture or any other industry are only subject to human imagination.

3D Printing Application Life Cycle

3D printing is starting to gain widespread adoption as lowering costs make 3D printers more and more accessible to businesses and individuals. More users increase the market size for add-on products such as CAD designs and new materials. There are many issues with 3D printers at present, such as restrictions on the type of materials available and the time taken to print. However, solving these issues will result in large profits and so many businesses are working towards improving 3D printing. We believe that 3D printing will gain massive adoption across a wide range of industries, including agriculture, within the next 5 years.

Business Eco-System View

The international ecosystem for 3D printing is already large and growing exponentially. With equipment manufacturers, materials suppliers, designers and many others adding to the ecosystem. Locally there is less of a footprint. RoboBeast, based in Johannesburg, and UglyMonkey, based in Cape Town, are two of the few manufacturers of 3D printers in South Africa. Smaller organisations such as the MakerSpace are also involved in 3D printing. However, there are many 3D printer retailers selling foreign-made printers. This network of retailers are the driving force behind the industry in South Africa and form the backbone on the local ecosystem in terms of sales and after sales for 3D printing.

Benefits and Risks

3D printers have benefits in many areas of application. Being able to 3D print parts is a big benefit for a country that imports many parts from internationally based countries. The ability to rapidly prototype at a fraction of the traditional cost is also a huge positive for the existing and potential manufacturing industry in South Africa. This removes a barrier to entry typically faced by entrepreneurs who want to start a manufacturing plant. We will touch on risks in the section below.

Potential Economic, Social, Ecological and Political Developments and Impacts

3D printer may have a large impact on employment and trade internationally. Being able to 3D print parts on-site means that that part does not need to be made in a factor, stored, retailed, or shipped. The knock-on implications for 3D printing are colossal if the technology becomes widely adopted. South Africa, and Western Cape agriculture, is a net importer of goods. We (largely) rely on international companies to supply the parts for our tractors, irrigation systems, etc. Buying parts from other countries adds to our trade deficit. If we were able to 3D print much of these parts, the benefit in terms of reduced costs would be large for farmers in particular. The risk is the downside for logistics companies, service centres and retail outlets. Because 3D printing would essentially bring a great deal of manufacturing to local businesses, we believe the benefit to South Africa and Western Cape farmers would far outweigh the negatives.

End notes

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