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THE USE AND IMPACT OF 3D PRINTING TECHNOLOGY IN THE FUTURE: A REVIEW

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ABSTRACT
There is a growing consensus that 3D printing technologies will bring the next technological revolution through product and process innovation. This work by incorporating recent literature and research concentrates on the use and impact of 3D printing technology in escalating growth in the future. Firstly, this article studies the impact of 3D printing on forensic technology providing better visualization, interpretation, preservation, and analysis of evidence with further highlighting needs to boost its utilization in the future. Secondly, the impact of medical 3D printing applications is studied emphasizing new methods of regenerative technology, surgical planning, and tissue regeneration, as well as personalization of medical implants. Owing to the advantages of 3D printing in providing unique potential in creating personalized food with complex geometric structures and nutritional needs, the article also culminates the applications of 3D printing in the food industry paving way for future mass production. Finally, this article shows that in addition to enabling innovation, 3D printing technologies have the potential to change the way business model is perceived, by enabling a positive feedback loop between business model components through crowdsourcing and mass customization.
Key words: - 3D printing; Forensics; Medical; Food Industry; Business model.

INTRODUCTION:

3D printing a form of additive manufacturing technology involves the composition of a three-dimensional body through successive layers of printing per interval. This differs from the conventional subtractive manufacturing technology wherein an object is cut out from the raw material .3D printers involve a digitalized root of manufacturing using 3D modeling software which considers standard tessellation language (.STL) file format defining surfaces as a collection of facets. Computational programs like Catia, Autodesk Inventor, Solid Works, and UGS NX today are widely used to create the

.STL file format which is subsequently transferred to the 3D printer [Liacouras, Imanzadeh, Giannopoulas, Kumamaru,1958] Fig 1.Innovation capability has been a key factor for the creation of new technology, which has triggered the initial development of 3D printing technologies in more advanced countries in the last decade. The development of 3D printing technologies can be dated back to 1984 in the U.S., marked by the publication of the patent US4575330A,which proposed the Stereolithography technology [Lili Wang, Shan Jiang, Shiyun Zhang ,2020] Fig.1. Charles Hull, the inventor of this patent, co- funded -the first 3D printing company-3D systems in 1986. Moreover, research literature and patent families have increased at a rate of 23 percent per year, from 17 in 1985 to 6951 in 2015 globally.

According to Wohler's Report 2014, the global 3D printing market was valued at $2.3B in 2013 and is anticipated to reach $8.6B by 2020, attaining a compound annual growth rate of 20.6% [Research and Markets: Global 3D Printing Market 2014].3D printing (3DP) technology was introduced by engineers predominantly in the manufacturing and automotive industry to develop automated and easy manufacturing technology owing to efficient performance [Dodziuk H. 2016]. As a result of which the automotive industry's adoption of 3DP escalated from

$365.4M in 2015 to $1.8B in 2023, attaining a 19.51% CAGR. Today the technology has caught the attention not only in automotive and conventional manufacturing domains but shows huge potential to disrupt fields across applied health sciences, medicine, surgery, imaging, and anatomy.

Forensic Industry

Professionals in the domain of forensic investigation have recognized 3DP technology as an important tool to assist demonstrative evidence. Ebert [Ebert 2011] emphasized the importance of 3D prints and 3D imaging for proper visualization and assessment as a major tool to traction future forensic investigation. Moreover, in a series of literature, authors highlight the application of 3D scanning and printing in simulated forensic case scenarios [Jani G, Johnson A, Parekh U, Thompson T, Pandey A,2020]. Baier in 2018 [Baier 2018] demonstrated the decision-making process for the presentation of 3D prints in court. The case reports one of the first court trials in the UK incorporating 3DP for trial against two homicide accused, wherein a section of skull post-CT scan was 3D printed and presented in court as demonstrative evidence of pathological facts [Baier 2018]. In another murder trial in England, a 3D print of a child's head provided clarity in the investigation to conclude and present the cause of death [Scott ,2016]. The use of 3DP technology has also paved the way for efficient future anthropological studies. This can be inferred in the work proposed by Carew [Carew 2018] wherein a study was conducted to assess the accuracy of different 3D printers for producing the replicas of bone, making forensic anthropological evidence reconstruction easier Table 1.

Future researches are focusing on a smooth inclusion of 3DP technology leveraging the formers in the forensic domain. The fact that 3D printed models can be handled without restrictions enables the technology to serve pivotal in forensic evidence reconstruction. Owing to the non-destructive and non- invasive nature of the technology, 3DP in forensics is a humanitarian approach to analyze, investigate and visualize evidence without degrading the integrity of the evidence. Though limited research sets some drawback of utilizing 3DP in forensics due to lack of empirical data catering to the accuracy of 3D prints, documented legislation and legalization can lift the prospects of 3DP technologies in forensic discipline.

Medical Industry

With the development of biocompatible printable materials, today additive manufacturing technology permits advanced methods of surgical planning, regenerative medicine, personalization of medical devices and implants. Advances in 3DP have allowed the manufacturing of more complex structures for tissue regeneration, as a result, research confirming 3DP to especially construct and support scaffold for tissue growth has been on a rise [GargiJani, Abraham Johnson, Jeidson Marques, Ademir Franco ,2021]. Regenerative technology using 3DP involves the use of biocompatible material to form polymer chains which are reorganized into ribbon-like structures through shear. The resulting material can liquefy when traveling through a narrow opening due to local shear but solidify when spread over a surface [Cooke,2018].This caters to producing structures containing biological molecules, cells, and tissues, which can improve upon traditional tissue engineering techniques. Mohseni tested several medical-grade polymer filaments for printability, mechanical characteristics, and degradation, and determined that they were a promising technology for tissue engineering. Dinesh [Dinesh 2015] used 3D printing to develop a more affordable and precise alternative to pre-formed, individualized implants and bone cement by capturing a high-resolution CT scan of a patient's brain and generated a model of the skull and mold using software interface Fig 2. Fused deposition method was incorporated to print both the model and image and the pattern was used to shape an acrylic implant with 96.2% symmetry

Surgical guides can also be produced via additive manufacturing and contribute to more accurate work because they are designed for each patient's specific anatomy [Lador 2019]. Scaffolds for tissue regeneration can also be printed for use in orthopedic surgery .Demonstrating the accuracy of the molded implant Fig.3 shows the modeled spine fitted with a potential implant [Tan 2016]. In contrast to scaffolds, other types of maxillofacial implants can also be designed using 3DP designed to interact with patient tissues. For example, Bhargav [Bharghav 2017] in their work showed a metallic jaw implant printed by selective laser melting which was produced from powdered titanium, having non-reactivity characteristics upon interaction with bodily fluids.

Food Industry

The growing interest of consumers towards personalized food composition, food structure,

enable the large-scale application. Development of standards and quality control procedures would also be beneficial in escalating the adoption of 3D food printing in commercial applications [Tran 2017, Alain 2020].

Impact on Future Business model Innovation

and food properties has resulted in the emerging trend of customized nutrition [Sun 2018]. 3DP technology has enabled creating a large variety of meals on-demand, for instance, US Army has invested in 3DP for military food production, allowing them to produce meals in severe conditions using miscellaneous categories of food ingredients that can be conditioned in specific packages .This technology can produce food products focusing on nutritional intolerances and allergies such as gelled desserts without milk or eggs, which can be an alternative for vegan enthusiasts, or with a nutraceutical perspective. Different 'printing' technics used in the food industry have been adapted for future food applications. The major 3DP technologies applied to food production are illustrated in Figure 4 and is briefly discussed in Table 2.

Much remains to be explored in the field of 3D food printing and considerable challenges still need to be overcome to facilitate future developments, especially in terms of material properties, process parameters, and post-processing methods [Liu 2018]. To develop 3D food printing technology for practical consumption at the commercial level, additional improvements have to be made in printing time, food safety, and repeatability between batches. Speed improvements can be achieved by adaptive algorithms that adjust printing parameters to balance print quality with time, especially at a high resolution. Also, improvements of the feedstock material can improve the final properties of the printed material and

The last decade has been evident, concerning the disruptive impact of additive manufacturing technologies on the economy. 3DP will indeed paramount digital transformation through product and service innovation. As a result, it becomes imperative to question the impact the former technology is expected to have on business model innovation [Sher 2015, Lipton 2017].

As technological innovation leads to product and service innovation, value proposition is the principal business model component to be of concern .3D printing technologies have already led to product and service innovation and their main impact is more likely to relate to the value creation component and its value network subcomponent. It has enabled mass customization resulting in a co-creation process between customers and firms, thus escalating the value of the resulting product to a conventional mass- produced product. It also opens opportunities for crowdsourcing concepts by making them available to traditional manufacturers. For instance services such as Additer and MakeXYZ enable businesses to crowdsource the manufacturing of their products using various materials and finish qualities [Amit 2010]. Another key business model component affected by 3D printing is value delivery, enabling customers to manufacture at local levels, significantly altering supply channels and cutting off costs.

A potentially positive feedback loop between value creation, value proposition, and value delivery has allowed 3DP technologies to alter business model innovation Fig 5. Crowdsourcing and mass customization surge value creation, which, in its turn, enables to ameliorate value proposition and offer services which develop further crowdsourcing and mass customization.3DP in future is expected to make business models to modular and adaptable, allowing organizations to revamp and adapt to their market environment.

CONCLUSIONS:

3D printing technology was introduced less than 50 years ago, and in this relatively short time, it has set its root across mainstream industries enabling accessibility of largescale manufacturing at a personal scale. With its versatility and continued development, 3D printing has advanced in the medical industry, facilitating more precise and individualized interventions in the future, and playing an integral role in domains of forensic and food industry. 3DP technology shows immense potential to bring in disruption with its versatility in the fabrication of intricate food design providing personalized texture, appearance, and nutritional characteristics. However, much needs to be worked on and researched to capitalize the technology for commercialization and mass production. 3DP presents numerous advantages most important of which is the non-invasive nature which can prove to be of great advantage in forensics. However, given that this technology is in its early years of application, especially in the medical industry, there are limitations associated. With further exhaustive researches, utilization of newer methods of 3D printing, and sensitization the technology can transform the forensic and medical industry.3D printing technologies are a vector of business model innovation that can change the way of business model innovation. It has the potential to bring mass customization and crowdsourcing to the world of business model innovation and cause disruption through digital transformation. It also makes it easier to try new business models and minimize the cost for companies to change markets or even their place in the value chain. 3D printing technology will serve as instrumental to cater necessities for the poor with clean drinking water, food, and mean to low-cost energy sources, pushing the society to a better future.

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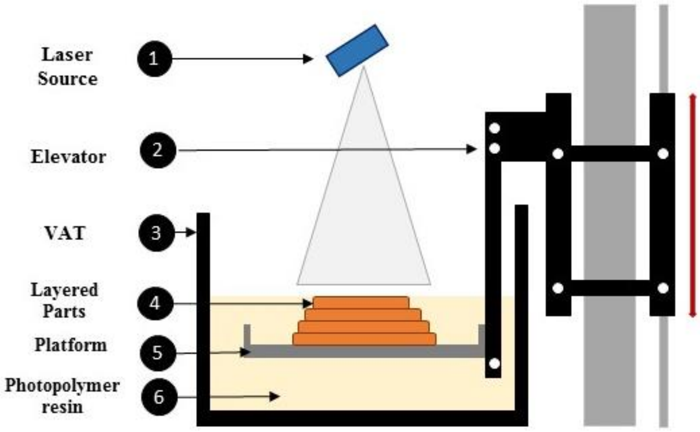

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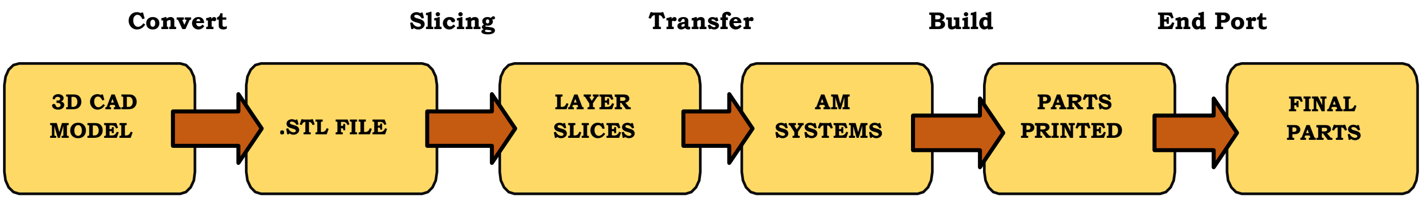
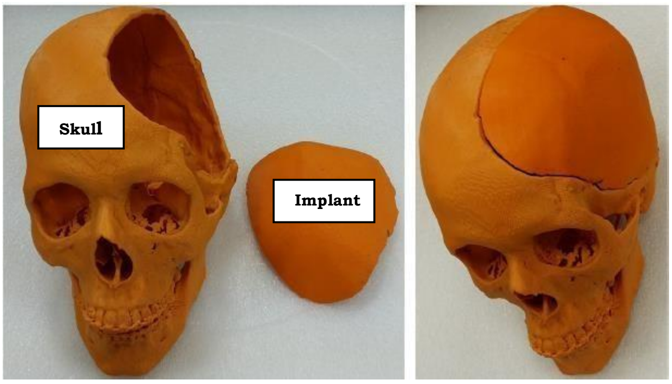


B)

Fig.1 A) Working of stereolithography and B) six conventional stages of the 3D printing process [3D Printing is a revolution 2015].

Application	Description	Reference
Documentation	3D printing can be instrumental to produce realistic three-dimensional replicas of human remains from facts that can serve to convey meticulous details to the jury, without causing bias.	[Liscio 2013,Vera 2017]
Human Identification	Age estimation through 3D modeling of dentition can be useful in age and sex determination overcoming drawbacks of traditional autopsies.	[Biggs 2019,Gargi 2021]
Dental Anthropology and Comparative Dental Anatomy	An accurately printed dental model could help improve the accuracy of population identification from the non-metric dental traits.	[Johnson 2019]
Forensic Anthropology and Archaeology	Printing skulls from computed tomography enables the reconstruction of faces multiple times without damaging the original skull providing potential anthropological/archaeological value.	[Kruth 2005,McPherron 2019]
Forensic Medicine	3D printed models of ruptured organs at both surface and volumetric levels would help demonstrate the relationship between the pathology and anatomical structure and facilitate the examining process.	[Ebert 2011]



A) **B)**

Fig 2. A) Fused deposition modeling used to produce model skull and implant B) and combined for fitting evaluation [Moiduddin 2017].

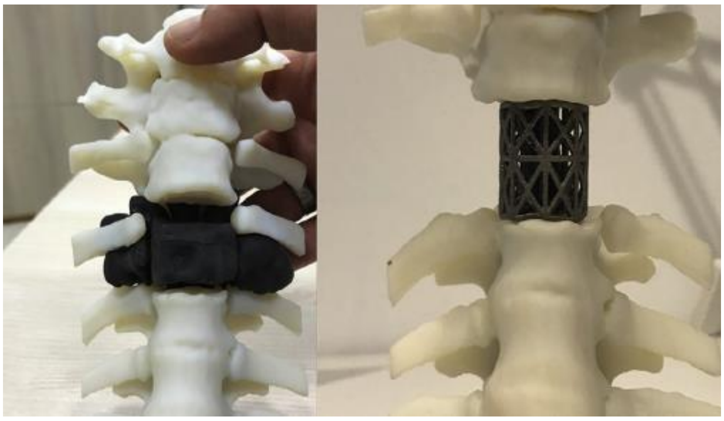


Fig 3. 3D-printed spine test-fitted with a variety of implants for surgical planning [Wong 2017].

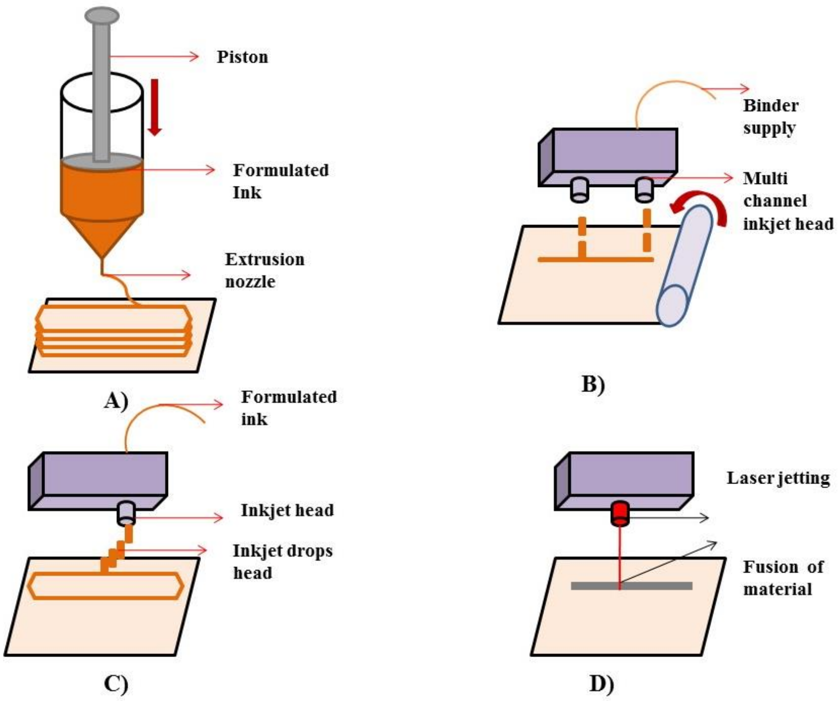


Fig 4. Schematic illustration of the different 3D food printing technologies: A) Extrusion, B) Binder jetting, C) Inkjet and D) Selective sintering

Table 2. Application 3D printing techniques in Food Industry [Amit 2010]

Technology	Description	Raw material	Major Findings	Reference
Extrusion	Caters production to the widest range of foods and is considered to be the easiest to develop. This system involves a syringe- supported robotic arm translating and extruding the pre-specified composition through a nozzle	Starch + milk powder + cellulose nanofiber + protein and oat	The authors inferred the best printing precision and shape stability in printing semi-skimmed milk powder paste, as a function of the yield stress of the paste.	[Yang 2019]
Inkjet printing	Utilizes an array of pneumatic membrane nozzle jets which lay tiny drops of food ink onto a moving object. A digital image in the format of a surface fill or cavity deposition is shaped by these drops.	Confectionary, decorations cupcakes, biscuits	Technique considered easiest to work with allows the production of innovative shapes of decoration.	[Holland 2018]
Binder jetting	Incorporates powdered material which is distributed evenly across the fabrication platform, with a liquid binder spray to bind two consecutive Powder layers.	Cellulose + xanthan gum + glucomannan	The addition of glucomannan for printing squares and complex stars resulted in a more cohesive material, which conventionally used only Cellulose.	[Holland 2018]
Selective sintering	Works on the principle of using a sintering source to fuse powder particles and form a solid layer.	Sugar	Capable to produce variable textures.	[Liu 2017,Tan 2018]

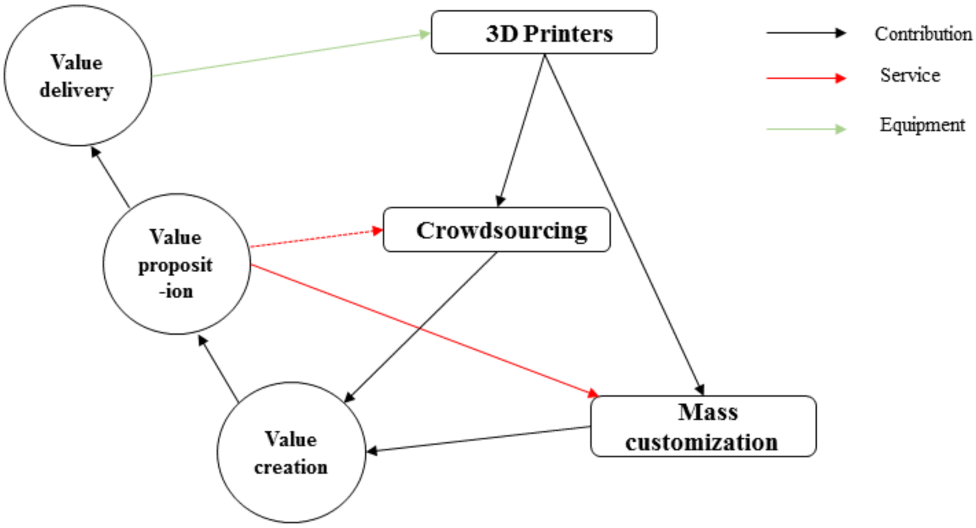


Fig 5. Positive feedback loop between business model components.