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Artificial Intelligence and 3D Printing Creating the Future in Pharmaceutical Field: A Review

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Abstract: ***The healthcare industry has undergone a paradigm change thanks to three-dimensional (3D) printing. A platform technology called 3D printing enables the creation of complicated items using fewer ingredients. An advantage over traditional methods is provided by the simple development procedure. Each patient requires a unique dose of medication. The conventional "one size fits all" technique is now in use, but 3D printing has the potential to become more individualised. In this, we discuss several viewpoints on the choice of medicine, polymer, and technological considerations for 3D printing. In terms of clinical use, legal issues, and business opportunities Future 3D-printed implantable organs will likely be available, lowering waiting lists and increasing the number of lives saved. Research into the benefits and drawbacks of 3D printing's use in the medical field is ongoing and how powerful technology***

Keyword: Personalized medicines, automation, computer drug design

I. INTRODUCTION

It's been foreseen for a long time that AI and 3D printing would combine. The elements of a 3D model that won't come together properly can be identified by AI analysis of the model. Moreover, 3D printers have the ability to take out materials from problematic areas and apply AI to produce an alternative design[1]. Using geometry analysis, AI may even spot possible issues with a part's design and suggest a different way to make it. One advancement in manufacturing paradigms is the blending of artificial intelligence and 3D printing. One of the most significant uses of 3D printing is in the creation of prosthetics, for example. As technology develops, 3D printers can be controlled by artificial intelligence, which will also increase the number of materials that can be utilised in the process. This two-pronged approach combines Manufacturers are able to develop fresh and enhanced goods and manufacturing techniques. The development of improved prosthetics by humans will eventually be aided by artificial intelligence and 3D printing. With the development of 3D printing, it is now possible to produce intricate objects without using a human. Despite the manufacturing process's complexity, AI can contribute to its improvement. New applications will be produced by combining AI with 3D printers. Here are a few uses for which the convergence of these technologies will be advantageous. The manufacturing sector will undergo a revolution once this technology is more widely used. Even new surgically usable prosthetic limbs could be made with it. Whereas AI and 3D printing are frequently linked, it can also be employed to produce better products and objects[2]. AI can assist reduce human error and improve 3D printing performance by automating operations. Manufacturing and quality control stand to gain from the combination of AI and 3D printing. Also, it hastens the development of Industry 4.0 and the Industrial Internet of Things. A technique known as machine learning, or AI, can examine a data stream and identify hidden links. For instance, artificial intelligence assists in the maintenance of the material properties of complicated alloys, such as titanium, carbon, and other metals, during the 3D printing process. Predictive maintenance can employ the models that are produced. Machine learning can even assist manufacturers in improving spare parts .This new finding is intriguing for both producers and researchers[3]. Machine learning is being utilized in the developing field of bioprinting, also known as 3D bioprinting, to enhance the creation of organoids. With this method, a scaffold is built specifically to facilitate cell development and function. The functionality of the printed organ can be significantly impacted by the complexity of the scaffold. In order to maximize the process, scaffolds should be carefully and accurately built .Machine learning can be used in 3-D bioprinting to find flaws including misplaced cells, curved layers, and microstructure faults. Additionally, it has the ability to monitor the entire bioprinting procedure and spot issues early on[4]. Artificial intelligence and 3D printing are two emerging technologies that have the potential to transform the future of many industries. The combination of these technologies could lead to even more advanced and innovative solutions in various fields.Artificial intelligence, or AI, involves the development of algorithms that can learn and make decisions based on data. 3D printing, on the other hand, is the process of creating physical objects layer by layer using a digital model[5] .When AI is integrated with 3D printing, it can provide several benefits. For example, AI can be used to optimize the design of a 3D printed object by analyzing its performance and suggesting modifications to improve its functionality.

This can lead to faster and more accurate production of complex geometries, reducing the need for costly and time-consuming human intervention. The way AI can be used with 3D printing is through predictive maintenance. AI systems can spot patterns and forecast when maintenance is needed by analyzing data from sensors on 3D printers. This can help to prevent malfunctions and reduce downtime, resulting in more efficient and cost-effective manufacturing.

AI may also be used in quality control, detecting flaws in 3D printed goods by analyzing pictures or 3D scans. This can lead to higher product quality and a lower danger of faulty products reaching the market[6].

Furthermore, AI may be utilized to optimize the materials used in 3D printing. By examining data on the qualities of various materials and their performance in various applications, AI algorithms can recommend the optimal materials for a certain 3D printing job.

Overall, the combination of AI with 3D printing has the potential to change manufacturing and many other industries. 3D printing can become an even more powerful tool for generating future layers by integrating AI to enhance design, production, and quality control.

The purpose of discussing the synergies between AI and 3D printing in this article is to demonstrate how these two technologies can work together to increase production efficiency, accuracy, and quality[7.]

Artificial intelligence algorithms have the potential to improve the 3D printing process in a variety of ways. They can, for example, aid in the design process by providing more efficient designs, decreasing material waste, and eliminating the requirement for support structures. AI algorithms can also improve the production process by regulating the printing process, monitoring the temperature and humidity, and making real-time adjustments to the conditions. 3D printing, on the other hand, can be used to create components for AI systems such as sensors, actuators, and robots. These components can be tailored to unique demands and requirements, enhancing the AI system's overall capability.

Overall, combining AI and 3D printing has the potential to significantly improve the manufacturing process, making it faster, more efficient, and more accurate. It also has the ability to generate new business models and product offerings, thereby providing organizations with new markets and revenue streams[8].

II. SYNERGIES BETWEEN AI AND 3D PRINTING

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Overall, the combination of AI with 3D printing has the potential to significantly improve the manufacturing process, making it faster, more efficient, and more accurate. It also has the ability to establish new business models and product offerings, so opening up new markets and revenue streams for businesses.

III. APPLICATION OF AI AND 3D PRINTING

The third goal of a piece on the subject of artificial intelligence and 3D printing is to give examples of how these two technologies are combined in different fields of endeavor.

The healthcare sector is one area where AI and 3D printing are being used. Medical models, implants, and prosthetics can all be made specifically for each patient using 3D printing technology. After then, AI algorithms can be employed to enhance these goods' designs, enhancing their functioning and decreasing the likelihood that they would be rejected[10].

AI, 3D printing, and the aerospace sector can be utilized to optimize aircraft component designs and reduce weight, resulting in higher fuel efficiency and fewer emissions. Airbus is investigating the use of AI to optimize the design of airplane parts, while NASA has been employing 3D printing to produce parts for rocket engines.

Complex automobile parts that are challenging to build using conventional techniques can be produced utilizing 3D printing. AI algorithms can be used to optimize these parts' designs, making them more durable, lightweight, and effective. For instance, Tesla has been utilizing AI to optimize the design of its electric automobiles, while BMW has been employing 3D printing to produce metal parts for its vehicles[11].

AI and 3D printing can be utilized in the consumer goods sector to produce individualized goods that are catered to the preferences and requirements of specific clients. Adidas, for instance, uses 3D printing to create personalised shoes, and Nike uses AI to create individualized training programs for its clients[11].

These are just a few instances of how AI and 3D printing are used in different fields. The fusion of these technologies has the power to completely transform manufacturing, making it more streamlined, effective, and individualized.

A. Technique

1) *DoE:* Design of experiments (DoE) is a non-learning mathematical technique extensively used in pharmaceutics. DoE is a systematic model for process optimisation that studies how input parameters (e.g. drug loading) relate to each other and the desired output (e.g. tablet strength) . For example, 30 variables that could impact tablet breaking force include binder content and excipient porosity and friability . DoE allows mapping of the extent that variables affect the experimental outcome, alone and in combination. DoE projects generally follow a similar structure[12]
2) *FEA:* Similar to DoE, finite element analysis (FEA) and computational fluid dynamics (CFD) are another standard optimisation techniques used in both academia and industry, applied in fields such as aerospace, electronics and biomechanics. In fact, the FDA is actively investing in CFD for medical devices and biological fluids . The wide adoption of both techniques can be attributed to the high degree of accuracy that can be achieved, which in some instances has been found to be more accurate than results obtained from experimental measurements. An additional appeal is that simulations can be performed that are experimentally challenging to conduct[13]
3) *Mechanistic Modelling:* Mechanistic models are mathematical models built using physical laws to explain process variables, and have been applied to 3DP . These types of models require domain expertise, which depending on the model developed, will require knowledge of thermodynamics, particle physics, and fluid dynamics . A salient advantage of mechanistic models is that they can be regarded as 'white-box' modelling since the dependent variable is clearly explainable. Mechanistic modelling has been explored for 3DP, with relevant models covering filler impregnation, predicting mechanical properties, photopolymerisation kinetics, and heat absorption in powder-bed technologies[14]
4) *MI:* There are several subclasses of ML, of which supervised learning is one. Supervised learning involves directing an algorithm to solve a specific question. The algorithm is presented with data that has been labelled, describing the question of interest. For example, labels could be medicine 3D printability, or optimum 3DP temperature . The former label in printable, or alternatively, not 3D printable[15]

Technique	Benefits	Limitations
DoE	In common use by pharmaceutical industry	Restricted to small datasets
FEA	Physical phenomenon extrapolates well to new designs	Restricted data formats
Mechanistic modelling	Pk modelling is used and can reduce the number of animal experiments	Complex experiments needed
Ml	No commercial software required, models can be developed for end -to end applications	Pre-processing data can be time consuming with unstructured data

Table 1 summary of the advantage and drawbacks of each optimisation technique

IV. FUTURE TRENDS

The fourth point of an article on the intersection of artificial intelligence and 3D printing is to discuss the future trends of these technologies and how they will continue to shape the world in the years to come. The growing application of AI and 3D printing in the healthcare sector is one trend that is anticipated to continue. Implants, prosthetics, and medical models will increasingly be produced via 3D printing, and AI algorithms will continue to improve the design and manufacturing process, improving patient outcomes. The growing usage of 3D printing to create industrial parts and components is another trend. 3D printing is anticipated to be used increasingly frequently in sectors including aerospace, automotive, and construction as the technology and material options progress. Additionally, the design of these components will be optimized using AI algorithms, which will result in higher effectiveness and cheaper prices[16]

For the production of customized items, a growth in the application of AI and 3D printing is anticipated. Businesses must use these technologies if they want to stay competitive as consumers get accustomed to individualized products. These objects will be produced via 3D printing, and AI algorithms will be employed to streamline the design and production processes.

The usage of AI with 3D printing to produce food and other organic materials is also anticipated to grow. Artificial intelligence (AI) algorithms can be utilized to enhance the flavor and nutritional value of food, while 3D printing technology can produce complex food designs that are challenging to achieve with conventional techniques[17]

In conclusion, it is anticipated that 3D printing and AI will develop further and continue to change the world in the years to come. These technologies could transform the industrial industry, resulting in improved goods, lower costs, and higher efficiency. As these technologies spread, new business models and product offers will emerge, presenting both business owners and customers with fresh opportunities and difficulties.

V. CONCLUSION

The fifth and final point of an article on the intersection of artificial intelligence and 3D printing is to discuss the potential challenges and ethical considerations that arise from the use of these technologies.

The potential for employment displacement is one difficulty. As AI and 3D printing develop, certain manual labor occupations might be eliminated. For people who work in the sectors most impacted by these technologies, this could result in job loss.

A. Conclusion and Future Outcome

In conclusion, the convergence of artificial intelligence and 3D printing holds great potential for revolutionizing various industries and transforming manufacturing processes. By combining AI algorithms with 3D printing technology, we can expect increased production efficiency, improved product quality, and enhanced customization capabilities.[18]

The future outcome of this integration is promising. We can anticipate advancements in the healthcare sector, where personalized medical models, implants, and prosthetics can be created using 3D printing, while AI algorithms optimize their design and functionality. In aerospace, AI can help optimize component designs, leading to lighter aircraft and increased fuel efficiency. The automotive industry can benefit from optimized, lightweight parts produced through 3D printing, enhanced by AI algorithms. Consumer goods will see a rise in personalized products tailored to individual preferences and requirements, thanks to the combination of AI and 3D printing.

However, along with the opportunities, there are challenges and ethical considerations that need to be addressed. Job displacement due to automation is a concern, as certain roles may become redundant with the increased use of AI and 3D printing. It will be crucial to focus on reskilling and upskilling the workforce to adapt to the changing job landscape.

Ethical considerations include ensuring data privacy and security when using AI algorithms and protecting intellectual property rights in the digital design era. There will also be a need for regulatory frameworks to address potential risks and ensure responsible and ethical use of these technologies.[19]

Overall, the future outcome of integrating AI and 3D printing is likely to reshape industries, create new business models, and provide innovative solutions. It will be important to navigate these advancements with careful consideration of the associated challenges and ethical implications, ensuring a balance between progress and societal well-being.

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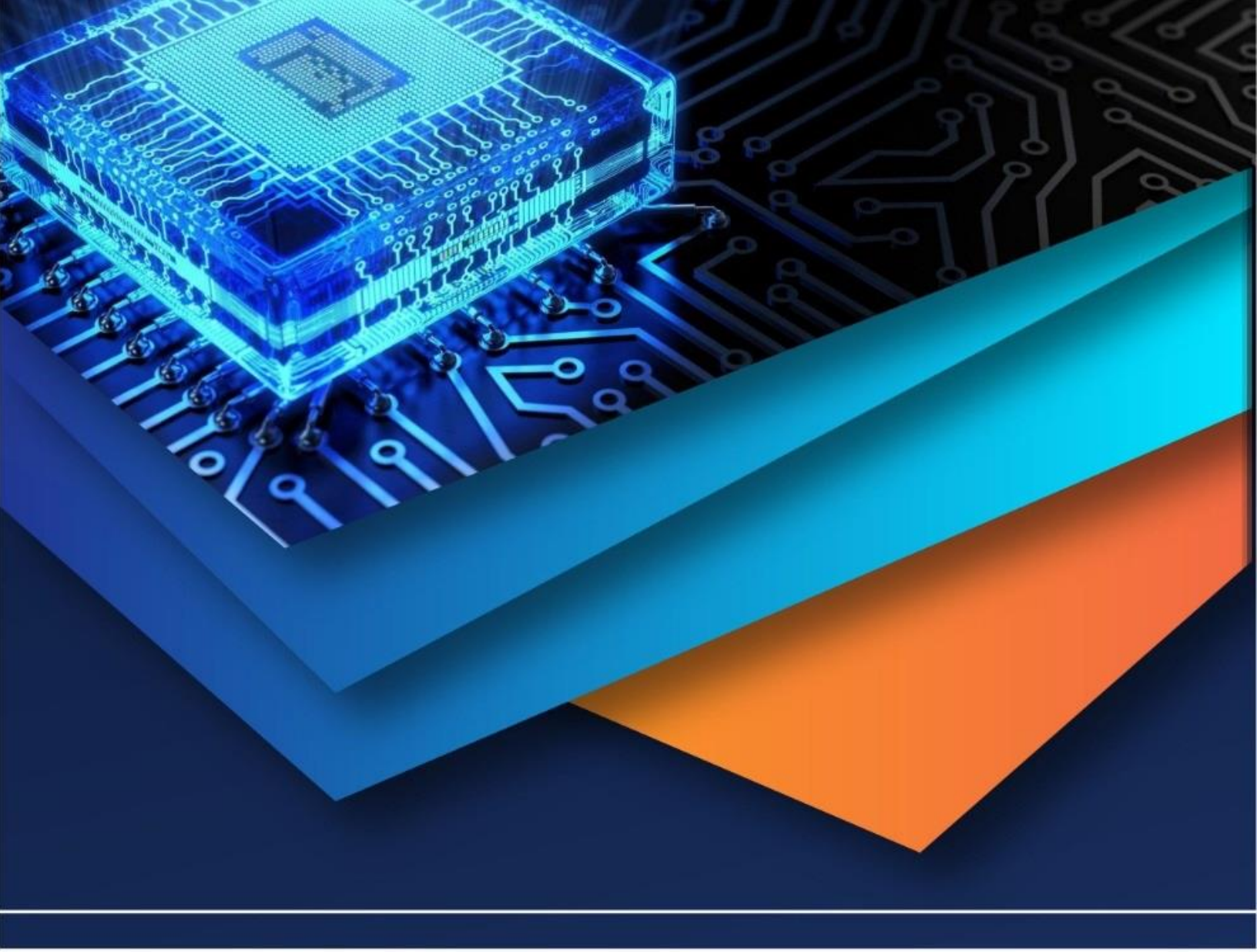

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