

3D Printing in Architecture

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Abstract:

3D printing or additive manufacturing is the process of creating physical items by layering materials based on the requirements of a digital model. The technology has become increasingly popular in recent years, and it is now used in various industries. One area where 3D printing is making a significant impact is architecture. Manually curating physical architectural models can be tedious and time-consuming. 3D printing is poised to revolutionize the architecture industry. There is no doubt that 3D printing is a disruptive technology set to change how we build our cities. This paper examines the use of 3D printing technology in the architecture industry.

Keywords: 3D printing (3DP), additive manufacturing (AM), 3D printing in architecture.

INTRODUCTION

Traditionally, a printer is used at home or in the office to print out text and images on paper. This conventional printer prints in a flat two-dimensional (2D) space using the dimensions length and width. A three-dimensional (3D) printer uses length and width but also adds depth to the print. A 3D printer has more manufacturing capacity than a traditional manufacturing machine. It is regarded as a disruptive technology that will change manufacturing. It has been used for decades in the automotive and aerospace industries. The 3D printer is also used by hobbyists, small businesses, creatives, manufacturers, architects, and most importantly contractors to instantly create a variety of products.

Since the time of the Pharaohs, architectural models have served as physical representations to help sell a project, support fundraising efforts, and solve construction challenges. Traditionally, model-

making is a manual craft that involves working with materials such as wood, ceramic, cardboard, or clay and is extremely time-consuming. Today, architecture studios and practices today have access to a wider range of tools, including CAD software, Building Information Modeling (BIM) solutions, and 3D printers that can reduce labor needs and save time [1].

WHAT IS 3D PRINTING?

3D printing (also known as additive manufacturing (AM) or rapid prototyping (RP)) was invented in the early 1980s by Charles Hull, who is regarded as the father of 3D printing. Since then it has been used in manufacturing, automotive, electronics, aviation, aerospace, aeronautics, engineering, architecture, pharmaceuticals, consumer products, education, entertainment, medicine, space missions, the military, chemical industry, maritime industry, printing industry, and jewelry industry [2]

A 3D printer works by “printing” objects. Instead of using ink, it uses more substantive materials—plastics, metal, rubber, and the like. It scans an object—or takes an existing scan of an object—and slices it into layers, which can then convert into a physical object. Layer by layer, the 3D printer can replicate images created in CAD programs. In other words, 3D printing instructs a computer to apply layer upon layer of a specific material (such as plastic or metal) until the final product is built. This is distinct from conventional manufacturing methods, which often rely on removal (by cutting, drilling, chopping, grinding, forging, etc.) instead of addition. Models can be multi-colored to highlight important features, such as tumors, cavities, and vascular tracks. 3DP technology can build a 3D object in almost any shape imaginable as defined in a computer-aided design (CAD) file. It is additive technology as distinct from traditional manufacturing techniques, which are subtractive processes in which material is removed by cutting or drilling [3].

3D printing has started breaking through into the mainstream in recent years, with some models becoming affordable enough for home use. Many industries and professions around the world now use 3D printing. It plays a key role in making companies more competitive. The gap between industry and graduating students can be bridged by including the same cutting-edge tools, such as 3D printing, professionals use every day into the curriculum. There are 3D printed homes, prosthetics, surgical devices, drones, hearing aids, and electric engine components. As shown in Figure 1, 3D printing involves three steps [4]. A typical 3D printer is shown in Figure 2 [5].

3D PRINTING IN ARCHITECTURE

Architectural models are conventionally assembled with a variety of materials and components. Modern CAD platforms have dedicated 3D printing modules to help architects convert a CAD design into a printable model. 3D printers help fuse these components into as few individual parts as possible. The size and geometry of different components within an architectural model are key considerations when preparing an architectural model for 3D printing.

How does 3D printing work in architecture? Architects must first create a digital model of the desired structure. Once the model is complete, it is sent to a 3D printer. Operating as a layer-by-layer additive manufacturing process, 3D printing uses digital models to create customized 3D objects with a remarkable level of precision and efficiency, saving time, generating zero waste, and reducing labor costs. The printer uses materials such as plastic, metal, or concrete. This process can take anywhere from a few hours to several days, depending on the size and complexity of the project. Post-processing differs depending on your specific 3D printing technology, but generally includes sanding, bonding, and painting models [1]. Figure 3 illustrates the 3D printing process in architecture [6], while Figure 4 shows how 3D printing works in architecture [7].

Materials play a vital role in conveying the underlying concept of a design. Parts can be produced with various 3D printing materials, or individually painted with different colors. Some printers only print with their own proprietary materials, while others work with a wide range of materials. One of

the most exciting developments in 3D printing is the use of more natural materials that allow for more environmentally conscious building techniques.

3D-printed homes have the potential to revolutionize construction and reduce the intensive carbon footprint of that industry. Key innovators in the industry include ICON, MOBBOT, and COBOD. They intend to expand into other markets to make their materials not only residentially available but also widely commercially available. If these innovators can show that their designs are safe, durable, and sustainable when compared to traditional homes, 3D-printing may become a viable and sustainable construction building method. Figure 5 shows a typical 3D printing building [8]. Figure 6 depicts the largest 3D-printed structure in Europe [9]. It is called Wave House and is used as cloud-computing data center in Heidelberg, Germany.

BENEFITS

Construction and architecture, which are often wasteful professions responsible for about 40% of greenhouse gas emissions, are the two key domains where 3D printing can be beneficial. 3D Printing is highly advantageous since it can create new products very quickly and precisely. Architects are increasingly using 3D printers to produce beautiful and highly-detailed architectural models. They are saving time and money by utilizing 3D printing to create impressive and durable designs straight from CAD data. 3D printing can be used to produce architectural models of entire buildings. Other benefits of using 3D printing in architecture include the following [10-12]:

1. *Your Clients Can Visualize Better:* One of the main goals of 3D architecture models is to simplify communication between architects and to make it easier to showcase plans to clients and impress them with tangible model of any structure. Being able to physically see something tangible creates a lasting impression. As illustrated in Figure 7, a 3D printed object makes your design easy to visualize [13]. So a detailed scale model of the final project can be a valuable way of communicating your design idea to your colleagues or clients.
2. *Reduce Design Time:* In today's fast-paced construction industry, designers have to use the shortest time possible to develop 3D models. With 3D printers, you can produce complex building in hours rather than weeks or months. With a 3D printer you can make your design come to life while saving yourself the hours of creating a scale model. Time is money. So saving hours of work ultimately means saving expenses.
3. *Models In Great Quality:* Professional 3D printers now print architectural models with great quality and a great level of detail architects.
4. *High-Quality Prototypes:* 3D printers can produce high-quality architectural prototypes to clarify the details of exterior. The equipment may use different types of raw materials to deliver complex, color objects.
5. *Easily Re-Edit And Re-Print:* 3D printing allows you to be more flexible with your models since it is easy to re-edit and re-print your architectural 3D models. If the client requests a change, you can simply edit the file, and print the object.
6. *Saving Costs:* Architectural firms can acquire 3D printers for on-premises deployment, which is way cheaper than outsourcing to a provider. The equipment helps them enhance overall productivity and cut production costs.
7. *Saving Time:* 3D printers can operate overnight to save time. We can launch the printer in the night, and when we come back in the morning, we find the model done.
8. *Collaboration:* 3D printing opens up numerous avenues for collaboration. A 3D modeling software using the cloud will allow you to optimize your team's collaboration and communication. Your work will be accessible to anybody, and you will all be able to work on the same model.

9. *Labor Force Reduction:* 3D printing technology involves low use of the labor force and saves a lot of time. While a set of labor is involved in one project, having a 3D printer allows them to distribute it in different other projects.
10. *Financially Beneficial:* As the architecture industry is a million-dollar industry, money is the game-changer. With in-house printers, it becomes an effortless modeling process. It is financially sustainable and impactful in the design method.

CHALLENGES

3D printing does not allow us to print entire structures simultaneously, such as a building. The whole unit will be fabricated in parts at a manufacturing unit and then combined to create the final design at the construction site. Other challenges of 3D printing in architecture include the following [14]:

1. *High Cost:* 3D printing in architecture is still a new technology in the market. It requires a high initial cost of buying the necessary machinery and equipment. The additional cost of materials, experimentation, and maintenance poses one of the greatest barriers for anyone willing to try this technology.
2. *Lack of Known Materials:* Materials that can be printed and constructed in real time are essential for getting the best outcomes from 3D printing. Sophisticated printers can also work with metal, ceramic, and glass. Yet, the selection of materials that supports additive manufacturing is limited, restricting the widespread use of this technology.

CONCLUSION

The architectural designing community has embraced 3D printing with open arms and harnessed its limitless potential. Architects have been using 3D printers for years. 3D printer manufacturers offer a wide range of resources covering printers, technologies, software, and troubleshooting to make you an expert in no time. To fulfill the enormous demands of customers, companies are really pushing their limits hard to offer something out-of-the-box concept to their clients.

3D printing is revolutionizing the field of architecture, and it is poised to change the way we build our cities and towns in the future. This technology covers the way towards a bright future full of opportunities. Several universities are now offering courses in 3D printing for architects. Figure 8 shows a futuristic architecture class [15]. More information about 3D printing technology in the architecture industry can be found in the books [16-18].

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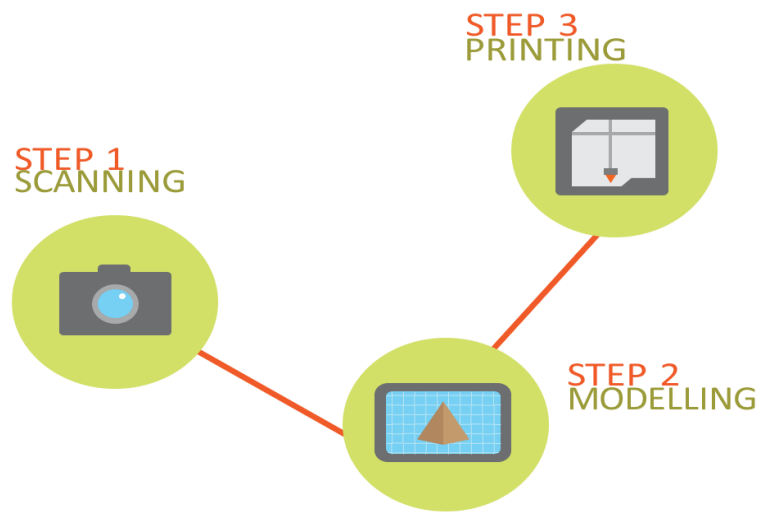


Figure 1. 3D printing involves three steps [4].

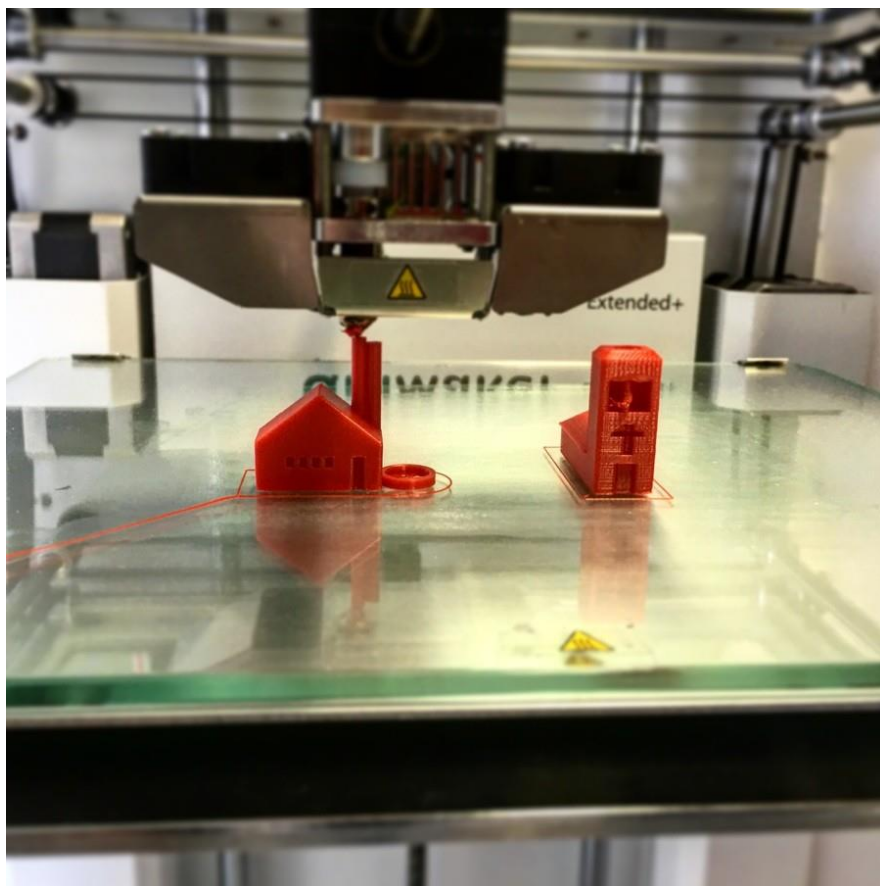


Figure 2. A typical 3D printer [5].

3D PRINTING PROCESS IN ARCHITECTURE

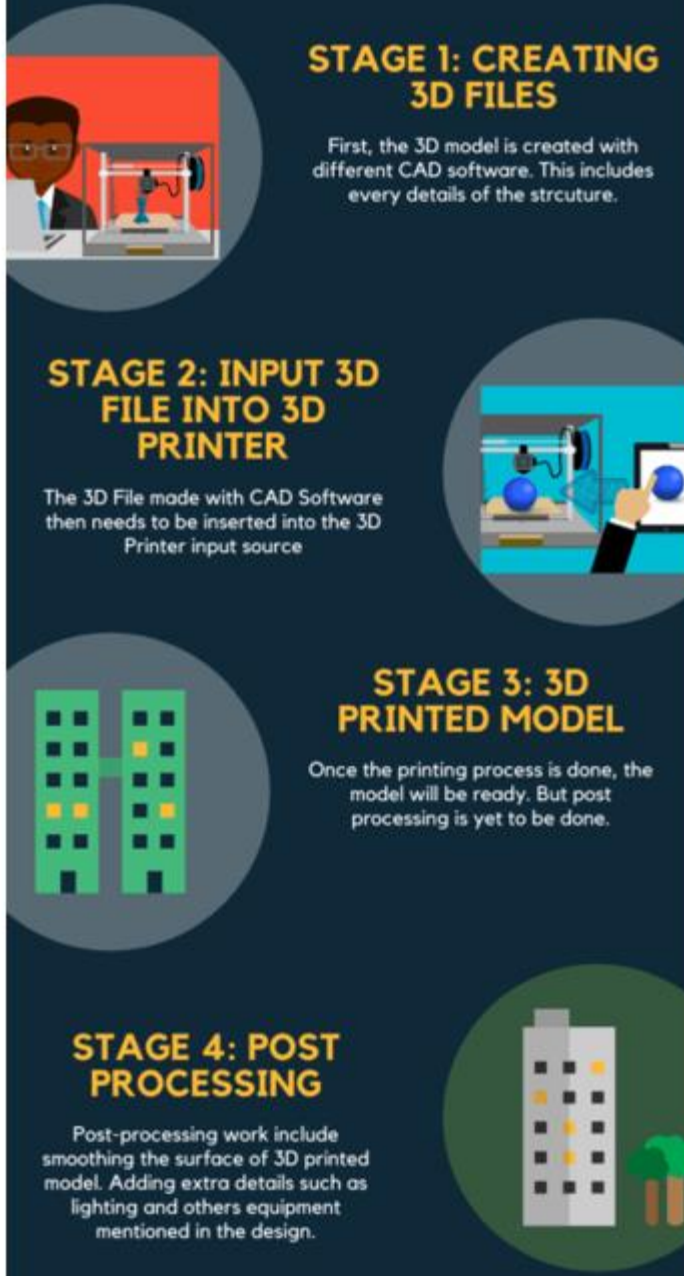


Figure 3. 3D printing process in architecture [6].

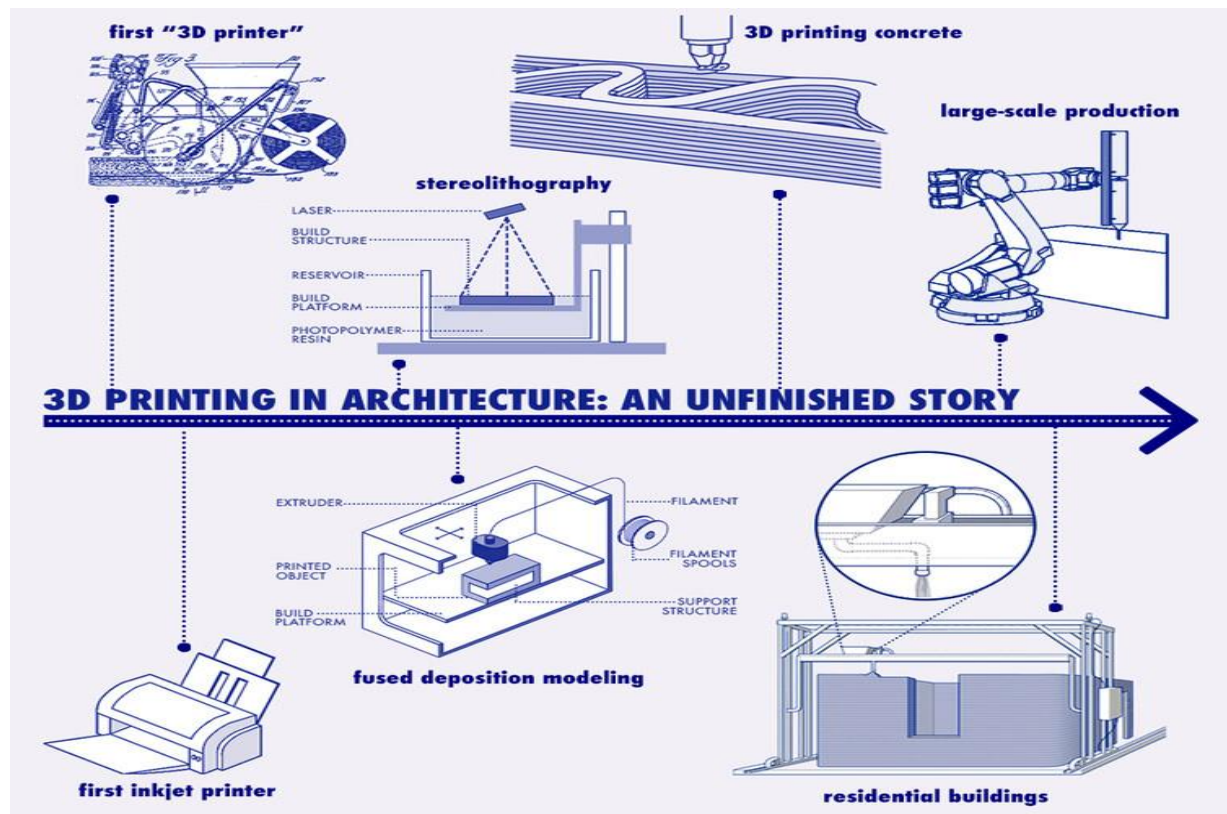


Figure 4. How 3D printing works in architecture [7].



Figure 5. A typical 3D printing building [8].



Figure 6. The largest 3D-printed structure in Europe [9].



Figure 7. 3D printed object makes your design easy to visualize [13].



Figure 8. A futuristic architecture class [15].