Digital Fabrication in Architecture

Parinitha Kurmapu[1], Neeta Mishra[2]

[1,2]Amity School of Architecture & Planning, Amity University Chhattisgarh, Chhattisgarh, India

Abstract

Digital fabrication has emerged as a transformative force in the field of architecture, revolutionizing design, and construction processes.The paper begins by providing an overview of digital fabrication and its evolution within the architectural domain. It discusses the integration of advanced technologies such as computer-aided design (CAD), additive manufacturing (3D printing) into architectural processes. The advantages of digital fabrication, including increased design flexibility, enhanced precision, reduced material waste, and accelerated construction timelines, are highlighted.

Furthermore, the paper investigates various case studies showcasing the successful implementation of digital fabrication in architecture. Through these examples, the potential of digital fabrication techniques to enable complex geometries and facilitate sustainable design practices is underscored.

To conclude, this paper emphasizes the immense potential of digital fabrication as a tool for architectural innovation. It advocates for further research and development in this field to overcome the challenges and maximize the benefits. By embracing digital fabrication, architects can push the boundaries of design, create structures of unparalleled intricacy, and achieve sustainable and efficient built environments.

Keywords: digital fabrication, architecture, computer-aided design, parametric modelling, 3D printing, design flexibility, sustainability.

Introduction

1.What is digital fabrication?

In architecture, digital fabrication refers to the process of creating architectural designs and models using technologies. The most common method is to create physical objects from designs using computer aide d design (CAD) software, 3D printing, and other advanced manufacturing techniques.
Digital Fabrication is revolutionizing the way architects design and construct buildings. This ushered in a new era of architecture designed specifically for innovation, creativity, and efficiency.

Digital fabrication is also changing the way architects communicate design to clients and contractors.Usi ng 3D visualization and modeling software, architects can create accurate images and visualizations of t heir designs to better communicate their ideas.

Digital fabrication is changing the way architects design and construct buildings. It makes it possible to create images and documents that were not possible before while making the design process more efficie nt, sustainable and communicative. As technology continues to advance, digital design is likely to play a n important role in the future of architecture.

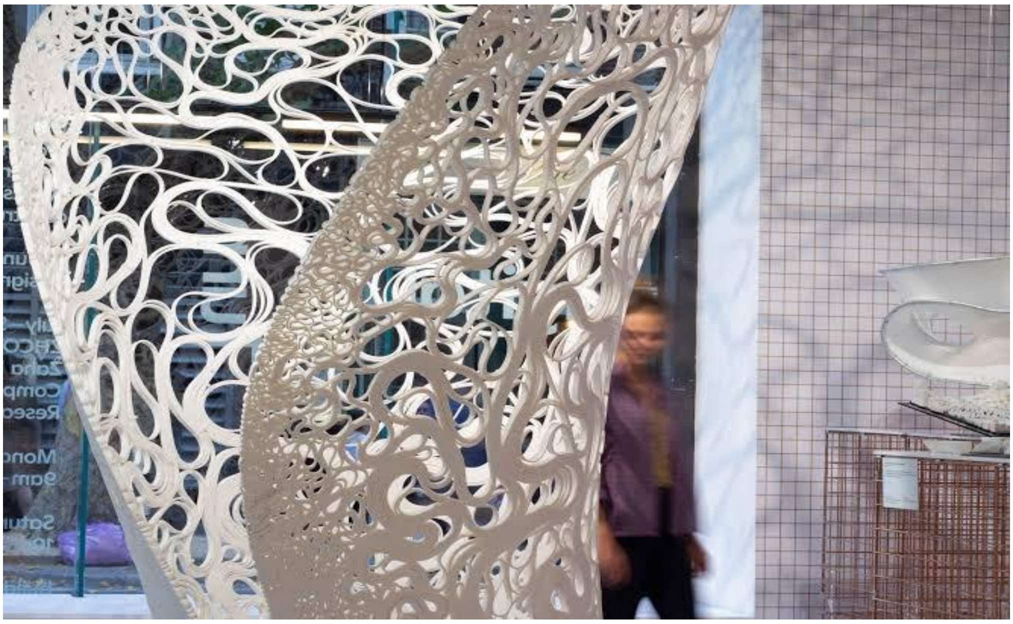

Figure 1.1
Source: archdaily.com

1.1 Aim of the study

The aim of this study is to use the computer-controlled machines to transform digital designs into physical objects with precision and accuracy.

1.2 Objectives

1. To understand the technology and manufacturing.
2. To study sustainability in digital fabrication.
3. To study the materials used in digital fabrication.
4. To study its role in architecture field.

1.3 Scope

This study's scope is to explore the potential of digital fabrication technology enhancing mass customisation efficiency, fostering innovative designs and promoting sustainability in manufacturing processes.

1.4 Limitations

1. The study is limited to complexity of fabrication products.
2. Cost estimates of overall project is not calculated in this study.
3. Scale of projects in not specified.

1.5 Research methodology

The research methodology of this paper involves defining the objective, conducting a literature review, collecting and analysing data with the help of case studies and presenting findings in relation to the objective and existing literature.

2 Introduction to digital fabrication in architecture

Digital fabrication in architecture refers to the use of digital tools and technologies to design and construct buildings and building components. This process involves creating digital models of buildings, structures, or components, which are then used to fabricate physical objects using computer-controlled machines and tools.

Digital fabrication has transformed the field of architecture in several ways. One of the most significant changes is the ability to design and construct complex and intricate shapes and structures that were previously impossible to build using traditional construction methods. With digital fabrication, architects can use 3D modelling software to design buildings that incorporate curves, angles, and other irregular shapes that are challenging to achieve with traditional construction techniques.

Another advantage of digital fabrication is increased precision and accuracy. By using computer-controlled machines and tools, architects can fabricate building components with a high degree of precision, ensuring that they fit together perfectly and reducing the need for on-site adjustments.

Digital fabrication has also improved efficiency and reduced waste in the construction process. With the ability to create precise digital models, architects can optimise the use of materials and minimise waste. Additionally, digital fabrication allows for rapid prototyping, allowing architects to test and refine designs before committing to full-scale construction.

Overall, digital fabrication has transformed the field of architecture by enabling architects to create buildings and building components that were previously impossible or difficult to achieve using traditional construction methods. The technology has increased efficiency, reduced waste, and improved accuracy, leading to more sustainable and innovative building practices.

2.1 Digital fabrication techniques commonly used in architecture:

2.1.1 CNC Routing

CNC (computer numerical control) routing involves the use of computer-controlled cutting machines to carve out shapes and designs from a variety of materials, such as wood, plastic, and metal. CNC routing is often used to create building components such as panels, mouldings, and decorative elements.

2.1.2 3-D Printing:

3D printing is a process of creating physical objects from digital models by layering materials on top of each other. In architecture, 3D printing can be used to create models and prototypes of buildings, as well as building components such as façade panels and structural elements.

2.1.3 Lazer cutting:

Laser cutting involves the use of a laser beam to cut and shape building components from a variety of materials, including wood, metal, and plastics. The laser is directed by a computer-controlled machine, allowing for precise and intricate cuts.

2.1.4 Robotic fabrication:

Robotic fabrication involves the use of robots to create building components and structures. These robots can be programmed to perform a variety of tasks, including cutting, shaping, and welding, and can work with a wide range of materials.

2.1.5 Digital Knitting:

Digital knitting involves the use of computer
controlled knitting machines to create materials and supplies. The process allows architects tocreate intri cate patterns and textures in a variety of materials such as wool, cotton and synthetic fibers.

These are just a few of the fabrication techniques commonly used in construction. As technology continu es to advance, new techniques and methods will emerge that further expand the possibilities of digital fa brication in construction.

2.2 Digital fabrication in manufacturing process

Digital fabrication is a manufacturing process that employs digital technologies to create physical objects. It involves stages of design, preparation, material selection, fabrication, finishing and quality control. With computer-aided design, materials are chosen based on requirements, and digital fabrication equipment like CNC machines or 3D printer's shapes and manipulates them. Finishing and inspections ensure the objects meets specifications, resulting in precise and customised creations.

Digital fabrication technology involves a series of steps that allow for the creation of physical objects from digital designs. The following is a general overview of the typical digital fabrication process:

2.2.1 Design:

The first step in digital fabrication is to create a digital design of the object to be fabricated. This is typically done using computer-aided design (CAD) software, which allows for precise and detailed designs to be created.

2.2.2 Preparation:

Once the design is complete, it must be prepared for fabrication. This may involve converting the design into a format that is compatible with the specific digital fabrication equipment being used.

2.2.3 Material selection:

The material to be used for fabrication is chosen based on the requirements of the design. Materials commonly used in digital fabrication include plastics, metals, ceramics, and composites.

2.2.4 Fabrication:

The digital design is then used to guide the fabrication process. This may involve the use of computer numerical control (CNC) machines, 3D printers, laser cutters, or other digital fabrication equipment. The specific process used will depend on the materials being used and the complexity of the design.

2.2.5 Finishing:

Once the object has been fabricated, it may require finishing or post-processing. This may involve removing excess material, smoothing rough edges, or applying a coating to improve the object's appearance or functionality.

2.2.6 Quality control:
Finally, the fabricated object is inspected to ensure that it meets the required specifications. This may involve using digital tools such as 3D scanners to verify the dimensions of the object.

2.3 Application of digital fabrication in architecture
Digital fabrication is being used in architecture in a variety of ways, from the fabrication of building components to the creation of intricate façade designs, and the use of digital tools for building analysis and simulation. Here are some examples:

2.3.1 Fabrication of building components:
Digital fabrication techniques, such as CNC routing and 3D printing, are being used to fabricate building components, such as walls, floors, and roof panels. By using digital models and computer-controlled machines, architects can create precise and intricate components that are difficult to achieve with traditional construction techniques.

2.3.2 Façade design:
Digital fabrication is being used to create intricate façade designs that incorporate complex shapes and patterns. By using digital tools and technologies, architects can create detailed digital models of façade designs that can be easily translated into physical components using computer-controlled machines and tools.

2.3.3 Parametric design:
Parametric design is a design method that uses algorithms and digital tools to create shapes and designs. Digital fabrication is used to fabricate parametrically designed components, allowing architects to create structures that are difficult or impossible to achieve with traditional construction techniques.

2.3.4 Building analysis and simulation:
Digital tools and technologies are being used to analyse and simulate building designs, enabling architects to optimise building performance for factors such as thermal performance and daylighting. By using digital tools, architects can create detailed models of building designs and simulate how they will perform in real-world conditions, enabling them to make informed decisions about design and construction.

2.3.5 Sustainable construction:
Digital fabrication is used to promote sustainable construction, such as the use of recycled materials and better use of materials. Using digital tools, architects can analyze and optimize building design for factor s such as energy efficiency and safety, resulting in sustainable construction.

2.4 Materials used in digital fabrication:
Digital fabrication involves a wide range of materials and processes, depending on the specific type of fabrication technology being used. Some common materials and processes used in digital fabrication include:

2.4.1 Plastics:

Plastics are commonly used in digital fabrication due to their versatility and affordability. They can be used in a variety of processes such as injection moulding, 3D printing, CNC machining, and laser cutting. Common plastics used in digital fabrication include ABS, polycarbonate, nylon, and PLA.

2.4.2 Metals:

Metals are commonly used in digital fabrication for their strength and durability. They can be used in processes such as CNC machining, 3D printing, and laser cutting. Common metals used in digital fabrication include aluminium, steel, titanium, and copper.

2.4.3 Ceramics:

Ceramics are used in digital fabrication due to their heat resistance, hardness, and durability. They are used in processes such as 3D printing, CNC machining, and laser cutting. Common ceramics used in digital fabrication include porcelain, clay, and alumina.

2.4.4 Composites:

Composites are materials that are made up of two or more different materials. They are used in digital fabrication due to their strength and durability. Composites can be used in processes such as CNC machining and 3D printing. Common composites used in digital fabrication include carbon fibre, fibreglass, and Kevlar.

2.4.5 Wood:

Wood is a commonly used material in digital fabrication due to its natural beauty and versatility. It can be used in processes such as CNC machining and laser cutting.

2.4.6 Foam:

Foam is used in digital fabrication due to its light weight and ability to be easily shaped. It can be used in processes such as CNC machining, laser cutting, and 3D printing.

2.4.7 Textiles:

Textiles can be used in digital fabrication to create complex and intricate designs. They can be used in processes such as 3D printing and laser cutting.

2.4.8 Glass:

Glass is used in digital fabrication for its transparency and aesthetic appeal. It can be used in processes such as laser cutting and engraving, and 3D printing using glass powder or filament.

2.4.9 Concrete:

Concrete is used in digital fabrication for its strength and durability. It can be used in processes such as 3D printing and CNC milling.

Comparison table of commonly used digital fabrication machines based on their different properties.

Common digital fabrication machines	**Materials used**	**Electricity consumption Approx..**	**Precision of production (standard +tolerance range)**	**Cost of production Approx. (value varies from brand to brand)**
CNC Router	**Metals:** aluminium, brass or steel **Plastics:** acetal, acrylics, polycarbonate, polypropylene **Wood:** hardwood, plywood or softwood. **Foam:** carving foam and rigid foam	Small to medium sized machine will consume approximately 3-10 kWh varying from brand to brand	More precise because they have higher tolerance for heat. 0.0004 inches or even better precision	150-3000/hr
Laser cutter	**Metals:** mild steel to stainless steel also non-ferrous metals. **Paper and cardboard** **Plastics:** acrylic, PMMA	25-80 watts	0.002 inches to 0.004 inches	450/hr
3D printer	**Plastics**: PLA (polylactic acid) ecofriendly option ABS (strength and safety) PVA **Metals:** stainless steel, bronze, nickel, aluminium, titanium	120-300 watts/h	0.004 inches	50-1000/hr

3 Case studies

3.1 India's 1st concrete 3D printing house, IIT Chennai

Figure 3.1.1

Source: https://tvasta.construction/projects

1. India's 1st 3D concrete house was built by a start-up called Tvasta Manufacturing Solutions. The house was built on the campus of IIT Chennai, India
2. Using a 3D printer, a 2,000 sqft home was built in less than a week, which is 1/8th of the time it takes using traditional methods and produced only 1/3rd of the waste materials.
3. The walls of the house are made of 3D printed concrete panels, which were printed in their factory and transported to the construction site for assembly.

The construction took place in following stages:

Stage 1. Design
Stage 2. Design development
Stage 3. Pre-production
Stage 4. Off-site 3d printing
Stage 5. Logistics
Stage 6. On site assembly

Figure 3.1.2Source: https://tvasta.construction/projects

Figure3.1.3Source: https://tvasta.construction/projects

3.2 COBLOGÓ Office, Brazil

Figure 3.2.1Source: archdaily.com

1. Parametric design, digital simulation and fabrication were used to create instructional guides for low-tech labour to build a rotating concrete block façade and wall panels using local materials.
2. Digital fabrication was used to create models and prototypes for structural and fabrication options during the initial design process.

3. Parametric scripts created comb like 'guides' made by laser cutting corrugated cardboard for on-site mounting of concrete blocks using digital model rotations.
4. A movable wood stand and track system were fabricated with a CNC route usingthe plywood.
5. The mason only needed to place blocks against the guides and add reinforcing bars in every other block for stability.
6. Parametric computation was used for generating geometric configurations and constructing the façade for optimal environmental performance.

Figure 3.2.2 Source: archdaily.com

Comparison between the case studies

COBLOGÓ Office, Brazil	**India's 1st concrete 3D printing house, IIT Chennai**
It is known for its use of laser cutting corrugated cardboard and 3D printing	Known for using 3D printers, it has a reputation for creating concrete walls

technology in creating architectural elements, particularly bricks, creating complex and intricate patterns.	through 3D printers.
Used CAD software to create 3D models, which translated into instructions for 3D printing	They are making their own 3D printers that utilizes a combination of robotics, concrete extrusion technology, and software control.
The printing involves layer-by-layer deposition of the material to build the final structure.	The printing process involves the precise deposition of a specially formulated concrete mix, which is then built-up layer -by-layer to create the desired structure.

Conclusion

Digital fabrication has revolutionized the field of architecture by providing architects with new tools and techniques to design and innovate.

Using technologies such as 3D printing, CNC routing and laser cutting, architects can create building materials with unprecedented functionality and efficiency.

All in all, digital fabrication is an exciting and transformative technology that has the potential to change the way we design and build homes. Digital fabrication opens new possibilities for architectural design by enabling architects to create complex shapes and structures more precisely and efficiently. As technology continues to evolve, it is likely to play an important role in the buildings of the future, enabling architects to create buildings that are functional and beautiful, yet sustainable and environmentally friendly.

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