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(Review)

Digital manufacturing technology using computer systems

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ABSTRACT

In recent years, there has been a surge in development in computer-assisted manufacturing (CAM) programs. CAM technology saves time and cost in commercial production, as computer CAD designs have become very precise, and it also allows products with complex, fine details to be made quickly. They are also still able to create complex designs that were, until recently, of a high standard for some reason, but they are highly effective in execution using traditional techniques.

Producing an environmentally friendly building with light weight, structural strength and distinct design. The historical relationship between architecture and design to achieve production is much greater than the challenges before the design, manufacturing, and creation of the outlet through the use of digital means.

Keywords: Digital manufacturing ; Computer aided Manufacture ; Cam Procedures

1-Introduction

The digital revolution has brought challenges not only related to how to design interior spaces, but also to how to implement them and manufacture their components. The creative

possibilities provided by digital design techniques in the field of interior design and furniture open new horizons for us to reformulate the mechanisms of producing and implementing fractal designs with the help of computers. Manufacturing has become Digital is a medium that allows narrowing the gap between digital practices in the field of digital design and the construction process, and also works to provide a seamless connection between them.

2. Digital manufacturing techniques

NURBS-non-uniform rational-B-Splines have been raised , It is one of the models for generating and representing curves that provides a great deal of flexibility and accuracy in dealing with free shapes in computer programs - the question of how to implement them - is what raised a lot of criticism about the extent of its realism. But they were able to implement the digital revolution and its technologies through what is known as digital manufacturing.

From here we can define digital manufacturing as: a method of processing building materials using digital data output from computer-aided design programs to control the manufacturing process based on computer-driven machines and machines in what is known as CAM Computer-aided Manufacture, in order to build or cut raw materials. Through digital industrial operations, including cutting, deletion, and addition operations.[1]

2-1. Cutting Fabrication

It is one of the most widespread digital manufacturing techniques. It is done using computer-aided drawing programs and two-dimensional manufacturing techniques (2D Fabrication), through the use of a plasma arc, a water jet, or a laser beam (Figure 1). The technology relies on the use of two-axis movement (horizontal and vertical) in order to cut Raw material slices connected to the double-axis milling cutting head.

A  B 

Figure 1. (**A**) Demonstrates water-jet cutting technology ; (**B**) Explains the cutting technique using laser beams. The two figures show cutting using the biaxially moving cutting head.[2]

2-2. Formative Fabrication

In it, mechanical forces are used to form shapes, such as heat, steam, or pressure, which is concentrated on the material to form it according to the desired design. This is done through reshaping and deformating processes in a flat or axis way. For example, metals are compressed beyond their modulus of elasticity, or heated and bent while they are still soft, or plates are bent using steam. Using plastic manufacturing, we can produce molded glass panels, curved stamped metal tiles, and complex bending plastic panels, by dividing the bi-curved composite surfaces. To bend individual parts using CNC numerically controlled bending processes.[3]

This is what appeared in the external coverage of the BMW display pavilion called the Bubble Pavilion, designed by Bernhard Franken in Frankfurt, Germany, Figure (2). Inspired by the shape of a drop of water, plastic manufacturing technology was applied to thin aluminum rods carrying the external covering panels composed of curved acrylic units in what is known as the monocoque structure system, which does not require the construction of vertical supports or columns to carry the covering (Figure 3).

Figure 2. BMW's display pavilion called The Bubble Pavilion.

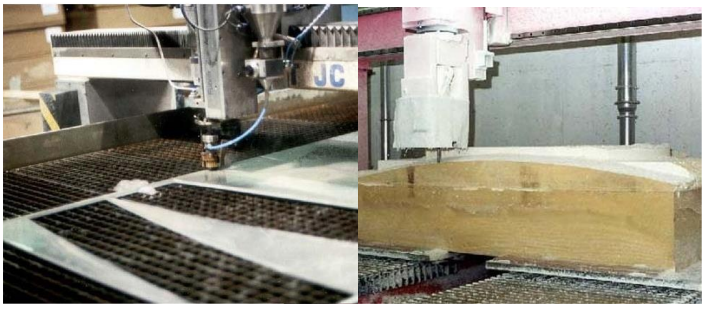

Figure 3. The manufacturing process of the external structure of the exhibition stand.

2-3. subtractive Fabrication

It is done by removing a specific size of raw material of different types from the model. Modern digital design programs set the main control tasks in the movement of the machine tools using a set of codes, which use multi-axis milling cutting technology using digitally controlled cutting machines Using Computer Numerical Control. [4]

Computer Numerical Control (CNC):

It is a technology that appeared in the early seventies, and it means a series of coded instructions in the form of numbers, letters, and symbols that are produced by digital design programs to be absorbed by the machine control unit and converted into electronic signals that direct the electric motors and multiple cutting axes to carry out the required operations on the material after introducing it to the cutting machine and in technology. Manufacturing by deletion using CNC. The machine begins by removing an amount of material from molds or panels of various materials through controlled movements in accordance with directions, measurements, and coded instructions issued by digital design programs. Cutting machines have developed through computer numerical control using CNC until they have become huge robots with a number of cutting axes reaching up to 7 axes, 7 axes milling robot, Figure (4), which enables it to work with the utmost precision and in the shortest possible time, which performs bending and spray painting operations, in addition to high-precision cutting. [5]

Figure 4. The robot and its 7 cutting axes perform bending and spray painting operations, in addition to high-precision cutting. [6]

During the past fifteen years, many forms of assembly based on digital manufacturing techniques and digital cutting machines have appeared in several axes using computers, the most important of which are:

Digital Fabrication Techniques Using Tessellation:

It depends on dividing the design into pieces that are assembled in a contiguous manner (similar to the tessellation technique) to form the design. This allows the design to take complex shapes

using double-curved repetition, providing more contrast and formation through non-standard manufacturing of the compact pieces that make up the design. Its characteristics include repetition and symmetry, meaning maintaining shape and composition across a point, line, or plane. Figure (5). Therefore, it is of great importance for architecture and interior design based on fractal geometry. It is considered a mathematical design based on a geometric shape, whether regular or irregular. [7]

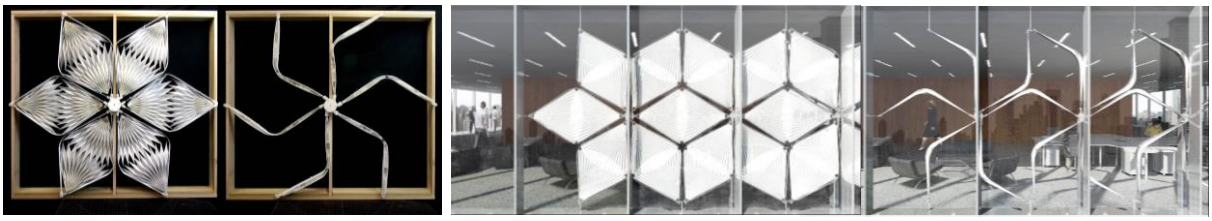

Figure 5. Example of non-periodic tessellation in an architectural facade design Snapping Facade to open and close openings, providing shading to the building. [8]

Tessellating technology is demonstrated through the following projects:

A- Ismaili Jamatkhana & Community Center Project in India in 2021, Figure (6).

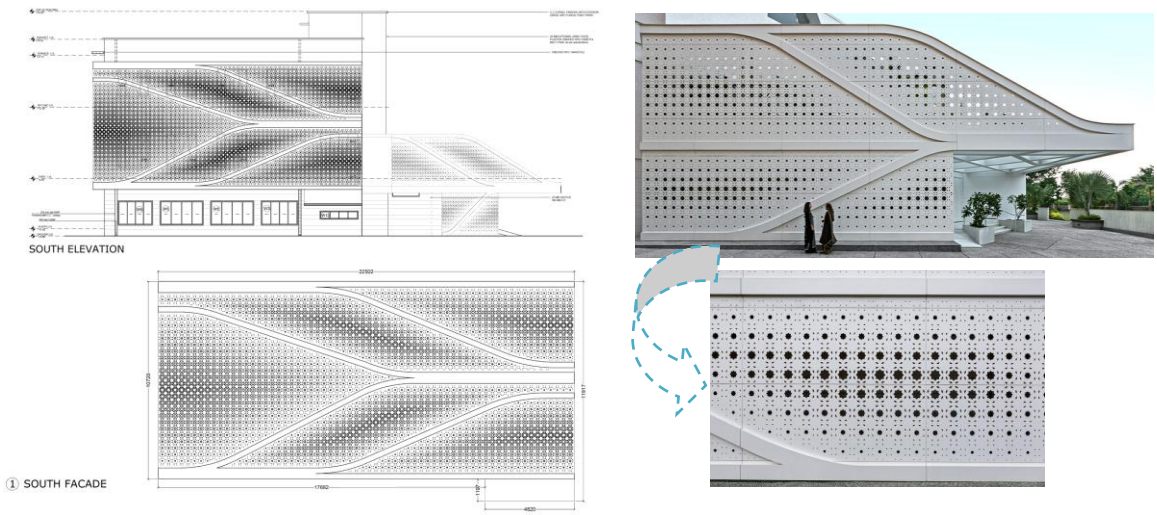

Figure 6. The Ismaili Jamatkhana & Community Center project in India is an example of periodic symmetrical tessellation.

B- Facade design project for Noida factory, India. To tessellate and repeat a pattern to create a plane, the unit chosen here is the triangle , Figure (7).

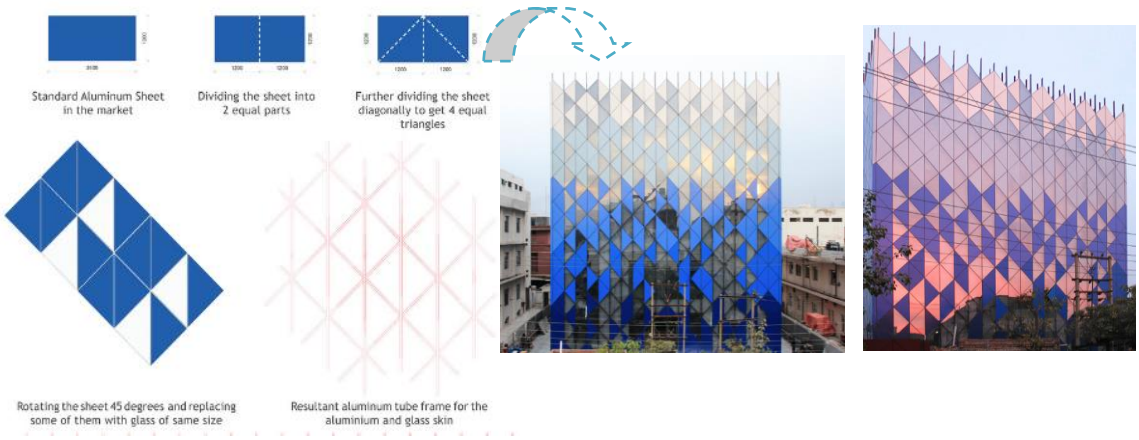

Figure 7. Facade design project for Noida factory, India.

Digital Fabrication Techniques Using Contouring:

It is the reshaping of the surface to form a three-dimensional object by removing successive layers of raw material by deletion. It is a type of sculpture, but in digitally organized patterns. However, digital sculptural shaping can produce various shapes with complex curvatures at a lower cost, with greater accuracy, and in less time using digital manufacturing techniques and digital cutting machines. In multi-axis CNC milling (more than 5 axes), relying on data output from modern digital design programs to determine the sculpting path of the machines in the form of curves in parallel, spiral, chain, beaded, or sloping paths, and controlling the speed and depth of the sculpting arm, for internal processors with different configurations.

Applications of contour lines in architectural, interior and furniture design using the computer in design and implementation:

A-Zaha Hadid's project, which was inspired by the contour lines (Figure 8).

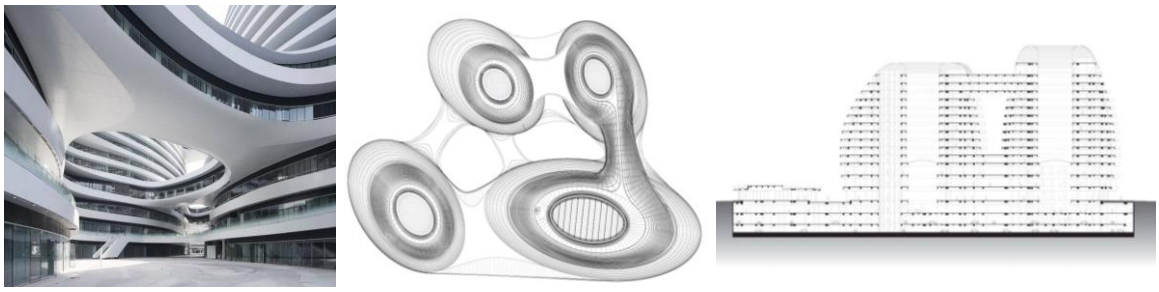

Figure 8. Demonstrates the accuracy of the manufacturing process based on sculptural shaping using CNC milling machines. [9]

B-Yuyuan Station Project on Shanghai Metro Line (Figure 9).

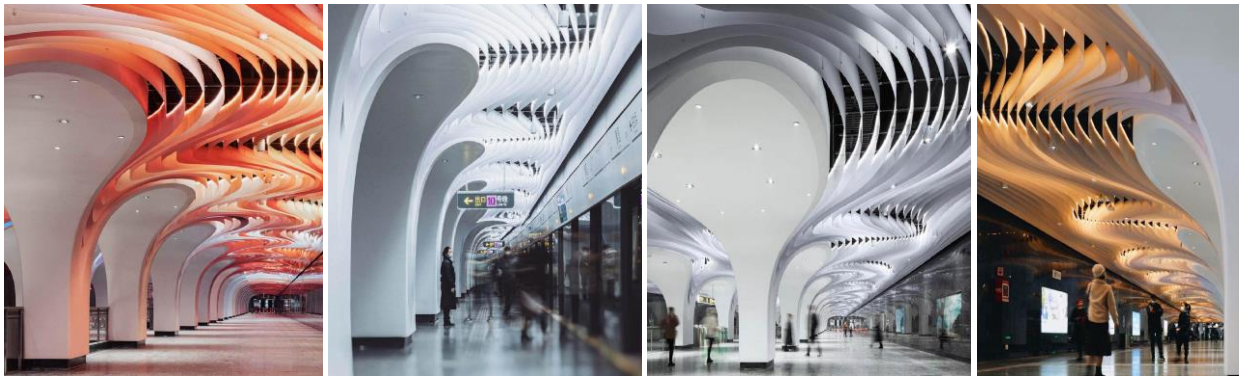

Figure 9. Interior design of Yuyuan Station Project on Shanghai Metro.

Digital Fabrication Techniques Using Folding:

The process of folding material is also a creative design tool resulting from digital manufacturing processes. The origami principle is based on transforming a plane surface into another three-dimensional one. It also allows new spaces and regions to appear without losing the original characteristics of what is being folded. It is an important principle not only for creating a shape, but also for creating a geometric structure. In the manufacturing process, the applicable manufacturing process is introducing folds into flat materials so that these materials gain rigidity and durability and often become self-supporting depending on their folds. This is why the trend to use applied manufacturing has increased in the era of digital design and manufacturing because it is physically economical and visually attractive in addition to its structural effectiveness, as the structural rigidity resulting from introducing folds into materials is an important advantage for this type of manufacturing. [10]

Folding applications in architectural and interior design and furniture using the computer in design and implementation:

A- Temporary chapel of St. Loup Loup in 2008 (Figure 10).

This temporary wooden church is the first full-scale structure that incorporates fractal design to generate new geometric shapes. Inspired by origami, the shape is created using computer software to calculate the load-bearing structure, determines the dimensions and transmits this information to the machine that cuts the 6cm-thick wooden panels, which are joined by Folded metal panels. Each fold of the facade reflects light differently and thus emphasizes the development of volume. Transparent fabric-covered plastic panels in the gable side facades also allow natural light into the church. [11]

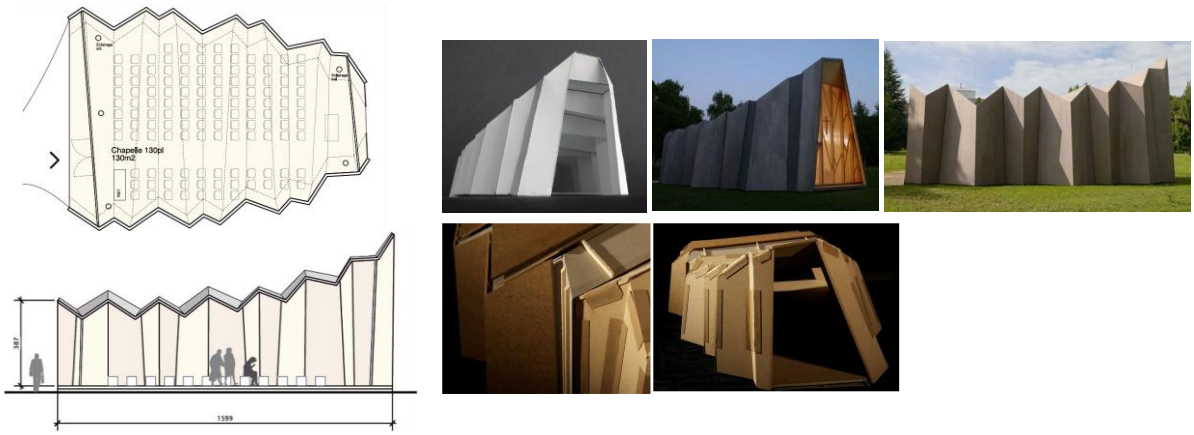

Figure 10. Illustrates horizontal and sectional projections, perspectives, and methods of fabrication and installation of the temporary saint's church, whose 7-meter-high wooden walls can be folded to support a roof up to 12 meters above the nave. [12]

B- Bengt Sjostrom Starlight Theater in the United States in 2003(Figure 11).

Rock Valley College wanted to develop a new regional performing arts facility in the Starlight Theatre. Expanded facilities and a roof enclosure were needed so that performances could continue without the risk of rain. At the same time, there was a strong desire to maintain an outside feeling. [13]

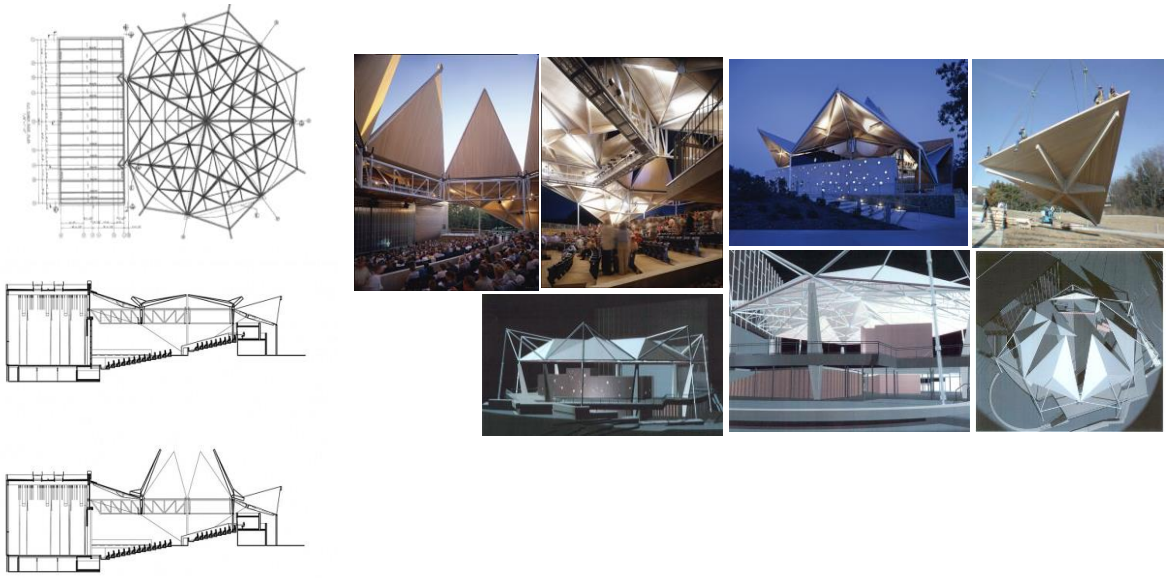

Figure 11. Sections, Plans, internal and external perspectives of Bengt Sjostrom Starlight Theater in the United States.

C-Use of applicable manufacturing in folding furniture (Figure 12).

As foldable furniture has been around for a long time, but with the new digital technology and digital manufacturing, it has become easy to manufacture and carry in addition to saving space.

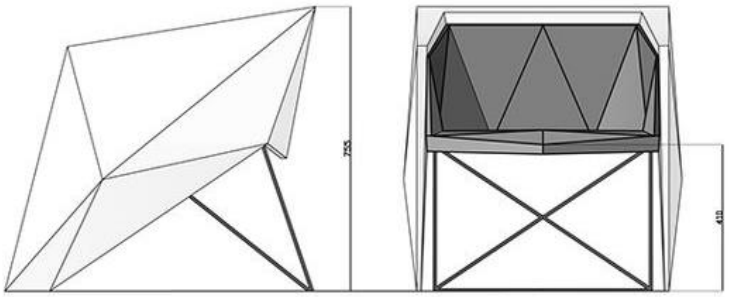

Figure 12. It is a stunning and very comfortable lounge chair that demonstrates the repeated folding method and the use of applied manufacturing in the furniture. [14]

2-4. Addictive Fabrication

This is also known as layered manufacturing, which is widely used in the field of interior design, as it is used to create block models with complex curvatures, in which the digital model of the model is dissected into two-dimensional layers and slices through design programs, and then the dimensions of each layer are transferred. To the processing head of the manufactured machine, which is known as the 3D printer D Printer3, the model is produced by adding one layer after another. The 3D printing technology is a breakthrough in the field of digital manufacturing, as pieces are manufactured by dividing their 3D designs into very small layers using design programs. They are then manufactured by printing one layer on top of another until the final shape is formed, transforming them into three-dimensional tangible objects. The first three-dimensional printer was developed by the 3D System company in 1988 AD, then it spread widely, and its development is still continuing until now [15] . The most important forms of assembly based on additive manufacturing techniques are:

Digital Fabrication Techniques Using waffling:

Waffle structures - technically known as solid geometry fractals - date back to industrial design for their utility in rapid prototyping of complex surfaces and volumes. They are used in architecture and interior design for large surfaces and spaces. Among the most important existing projects are:

A-Metropol Parasol project in Seville, Spain, 2011(Figure 13).

Recognized as one of the largest and most innovative wooden structural constructions, the Metropol Parasol project is part of the redevelopment of Plaza de la Encarnacíon, designed by J.MAYER H. [16]

Figure 13. Metropol Parasol project in Seville, Spain.

B-French Pavilion - at Expo Milano 2015 (Figure 14).

Figure 14. A structural canopy was demonstrated by WEsearch Lab using the programs Grasshopper and Rhinoceros.

3- The foundation of advanced technology in design and manufacturing

The digital manufacturing process based on computer fractal design techniques has many advantages that pushed it to achieve great spread in the twenty-first century, the most important of which is Overcoming the difficulty of implementing complex multi-curvature designs,

The ease of making modifications to the design in the early stages after reviewing the rapid prototype design blocks, which helps in continuous development ,and Providing all information related to the production cost accurately, according to design and manufacturing information, in the shortest possible time, and reducing production costs. [17]

A- Computer numerical control (CNC).

B-Modeling through 3D printing and 3D scanning.

3-1. Computer numerical control (CNC).

It is a form of deletion manufacturing technology, as it is a term used to take advantage of stored computer information and create a three-dimensional model using a special machine. The computer is connected directly to the cutting or engraving machine through CAD drawings, so the shaping takes place in the material. Assembling large-sized models after manufacturing their separate parts and making several copies. It is also used in rapid prototype technology, evaluating its quality and price, discovering its defects, and marketing it. [18]

CNC is an abbreviation for computer numerical control. It began around the early seventies and was preceded by what was called NC for short. NUMERICAL CONTROL.

Digital control means a series of instructions recorded or encoded in the form of numbers, alphabetical letters, and symbols that are absorbed by the machine’s control unit and converted into electronic signals that direct the electric motors and cutting tools of the machine and then carry out the required operations.

CNC Description:

With the beginning of the use of CNC, there was a development in manufacturing, which relied on workers in work that consumed a lot of time, money, and human errors, and so the technology contributed to Reducing the time required for the product while reducing costs and quality required . [19]

And the possibility of producing complex products, and with development this has become Systems are part of an industrial system that uses industrial integration methods The manufacturing mechanism, in all its stages, is carried out with high precision (up to micrometer control), as is the case with controlling the position of the cutting tool Using a stepper motor.

Features of CNC machines:

1- Saves time spent in the process of controlling and preparing work compared to traditional machines.

2- Provides high accuracy in producing parts.

3- The ability to repeat the produced parts with the same accuracy for all parts.

4- Reduce the fixing points used in the production process as much as possible.

5- Eliminate the produced parts that have production defects compared to traditional machines.

6- The ability to control appropriate cutting conditions.

7- Ease of moving between different forms of products

8- Reducing the time in the process of changing the tools used in the operating process during the cutting process.

Disadvantages of CNC machines:

1- The large cost of the machine.

2- Labor must be provided with the highest level of training to handle this type of machine.

3- Lack of specialists in maintaining this type of machines.

CNC components:

This machine, like most machines nowadays, falls under a specialty that combines mechanics, electricity, control, and computers in one thing and makes them work together in complete harmony. [20]

- Mechanical parts:

It is the chassis of the machine, the table, and the mechanism for converting rotational motion into linear motion in the three directions x, y, z .

- Electrical parts:

These are the main motor and stepper motors, in addition to the electrical connections, original point switches, and end switches.

- Control:

It is an intermediate interface card between computer parts and electrical parts.

- Computer:

It is the output of the bar from which guidance signals are taken, and the program that outputs these signals, organized according to the shape or drawing to be implemented (Figure 15).

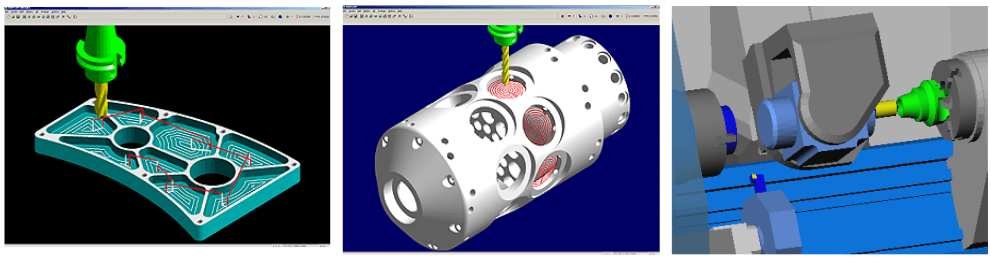

Figure 15. It shows the CNC components of the barrel output from which guidance signals are taken [21].

3-2. 3D Printing.

It is a form of additive manufacturing technology in which a three-dimensional object is formed by placing successive thin layers of a material on top of each other.

3D printers are usually faster, more economical, and easier to use than other manufacturing technologies. 3D printers allow developers the ability to print complex, interconnected parts. Parts can also be made from different materials with different mechanical and physical specifications and then assembled with each other.

Advanced 3D printing technologies produce models that closely resemble the look, feel and function of a prototype product [22].

In recent years, it has become financially possible to implement 3D printing at the level of small-medium enterprises, so modeling has moved from heavy industry to the office environment, with prices reaching up to $5,000 per 3D printer. It can now also be applied simultaneously to different groups of materials.

Types of 3D printing:

Since the manufacture of the first 3D printer that used the technology of dissecting the model into layers, many competing technologies have emerged that use many materials and processing processes based on light, heat, or chemicals, including:

-**Stereo Lithogarphy (SLA)**: It is based on the use of liquid polymers that solidify when exposed to a laser beam.

- **Selective LASER Sintering (SLS)**: The laser beam melts the metal powder layer by layer to form solid products.

- **Laminated Object Manufacture** (**LOM):** In it, strips of material are glued together before cutting and then cut using a laser beam.

- **Fused Deposition Modeling (FDM)**: The hologram is produced by melting polymer filaments that harden by heat.

- **Multi-jet Manufacture (MJM):** A modified print head is used to deposit a thermoplastic and molten wax material in extremely thin layers to form the three-dimensional object.

Three-dimensional printing is mainly used in the production of structural components that are characterized by the presence of a large, sequential and identical number of them, and in the rapid manufacture of miniature prototypes of complex curvature designs in what is known as rapid prototyping, which enables the designer to see the details and make all the necessary adjustments in the early stages. [23]

3D printer applications:

3D printing technology is widely used, mainly in the field of medicine and pharmacy, but it has applications in other fields such as architecture, interior design, furniture, industrial design, ceramics, metals, and the formation of casting molds. Emmanuel Sachs, the inventor of 3D printing, says that the basics of 3D printing technology are the same in every case. [24]

The 3D printing method unites powders and binders with unprecedented engineering flexibility. 3D printing shortens the time required to market a new product in many fields by improving the quality of the product, by combining design and manufacturing directly, and reduces the cost of the product by reducing the cost of the development and modernization phase.

The production rate can also be increased by allocating each machine or printer to produce one type of product. Therefore, 3D printing is the next revolution in manufacturing because it is the leader in the rapid production of prototypes as well as the final parts of the product (Figure 16).

Figure 16. It Shows models of modular furniture manufactured using 3D printing**.**

Advantages of 3D printing technology:

1- Ease of modifying the design.

2- The possibility of copying designs using a digital scanning system for the first model by Computer. The data is then converted into a three-dimensional product of the chosen material.

3- The possibility of obtaining large parts, protruding parts, overlapping parts, and interlocking parts

At an angle of less than 5 degrees, which is difficult or impossible to obtain by traditional forming methods. (Figure 17).

4- More than one material can be used.

5- Do not use many tools or devices, thus saving time and cost.

6- There are no limits to the complexity of the design.

7- Lower cost for complex shapes.

8- Very short production cycle.

9- Obtaining a product that conforms to all standard specifications

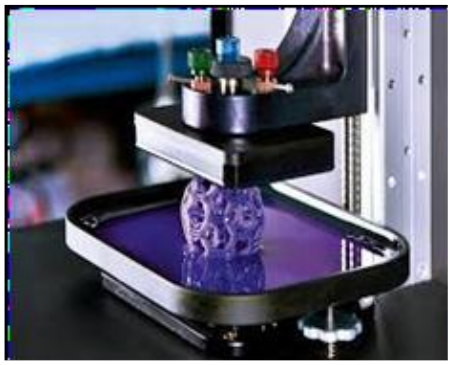

Figure 17. Explains the evolution of printers into 3D printing robots.

The term printing has been associated in the minds of many with 2D products and decoration techniques, whether on paper, fabric, or even photo printing, but for the term printing to be associated with one of the methods of formation, this is not what those working in the field of industrial design are accustomed to. The 3D printing method is still under development by some international companies, with the aim of achieving rapid and flexible production of the prototype parts as well as the final parts of the product directly from the model designed on the computer with the help of the AutoCAD program. [25]

This method has unprecedented flexibility, as any part or geometric shape can be produced from a number of materials such as ceramics, metals, polymers, and many other compounds. Emanuel Sacks invented 3D printing technology in 1993, and its development continues to this day.

4-Results and Discussion

In light of the above study, the interior designer must arrive at design solutions for interior spaces using digital design technology and develop new, non-typical design ideas that carry with them fluency and innovation in accordance with the principles of digital interior design through the use of advanced computer programs as an assistant in design and manufacturing. figure (15).

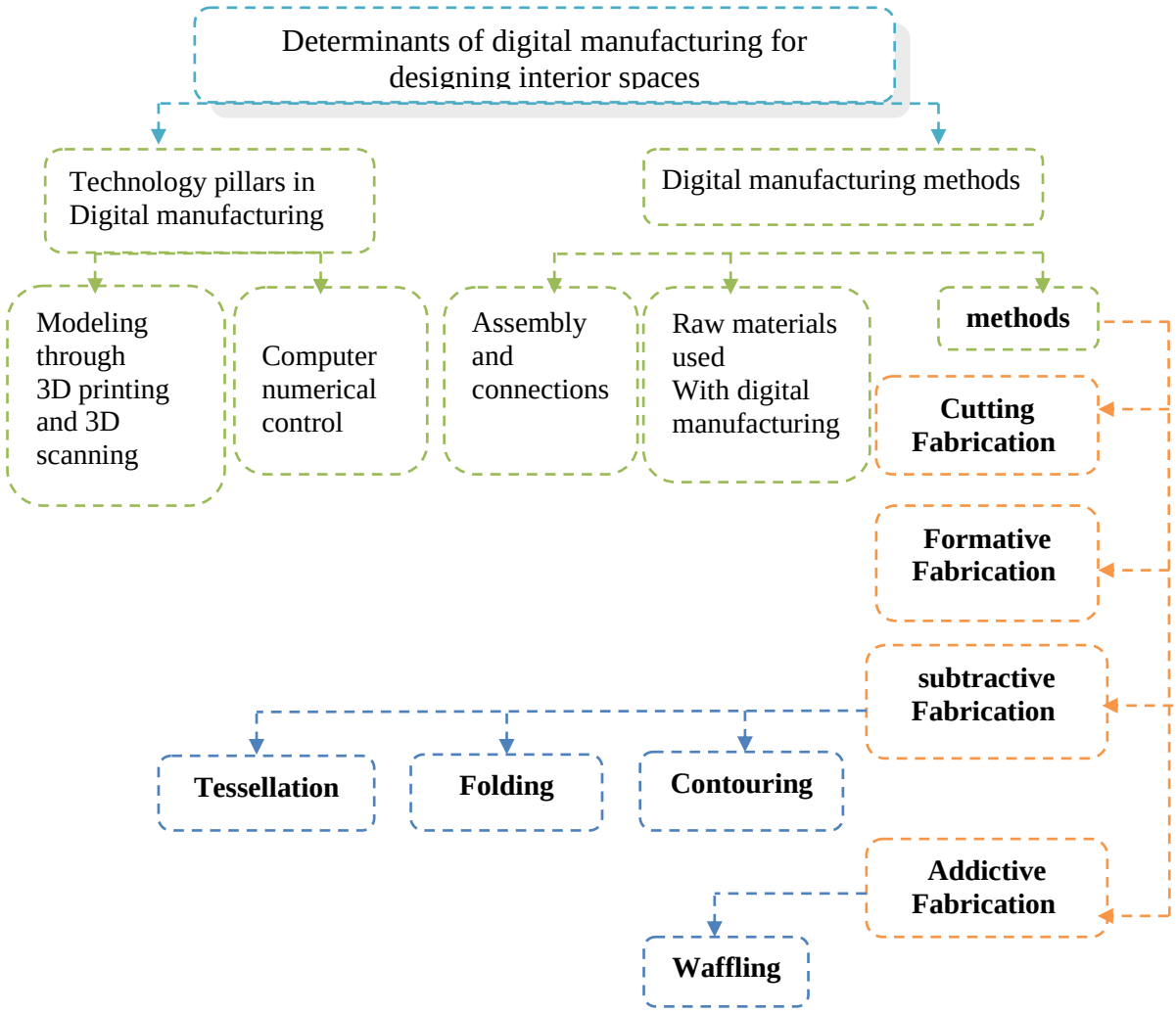

Figure 15. Determinants of digital manufacturing for designing interior spaces.

5. Conclusion

This paper has presented a detailed review of Digital manufacturing techniques. Based on the reported observations, the following major conclusions can be drawn:

1- The connection in the workforce is highlighted among the architectural workers of the General Directorate, and is not deeply defined in the practical way of fractal art as none of them can be separated from the others. This connection is often influenced by the CNC digital design and manufacturing process.

2- I contributed to the use of digital data used in Microphone with computer systems in the way of dealing with recognized vocabulary and elements of form, and this appears clearly in the design product in both internal agricultural engineering.

3- It is possible to get rid of the rigidity and similarity of some manufactured elements, as three-dimensional printing provides the possibility of the appearance of different elements while eliminating the need for special molds, which resulted in the monotony of pre-fabricated buildings. It also provides the possibility of using reconsumed products such as plastic and glass.

4- The topography varied, including:

A- Manufacturing parts microphone

B- Plastic composition

C- Microphone by deleting subtractive fabrication: (by the method of sculptural contour formation - by means of an applied folding microphone - by the method of segmental composition (mosaic) by tessellation)

D- Additional composition for manufacturing addiction: (about the modular cutting method for solid waffle geometry)

5- The fusion of the two design processes as it develops until it reaches the stage of complexity. This topic has brought about major transformations in the process of designing internal spaces with fractal electronics.

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