Digital Fabrication Systems between Theory and Practice "Application on Metal Roofing Systems"

Prof. Medhat Mabrouk Zidan
Professor, Faculty of applied arts – Helwan University
Assist. Prof. Dr. Mohamed Mohamed Yehia
Assistant Professor, Structure Department, Helwan University
Assist. Lect. Ahmed Salah Abd El-Azim Mohamed
Teaching Assistant - Faculty of Applied Arts - Helwan University
ahmed_salah@a-arts.helwan.edu.eg

• Introduction to the research:

Design and productivity trends in the information age have been influenced by technical, economic and political factors... The technical factor of the tremendous advances in computer technology, communications technology and information trading through Cybernetic systems, which are currently an intermediary containing all other print and audio-visual communications media.

The world is getting smaller due to digital technology, digitalization has destroyed barriers between the remote and the near as they have fallen down, and digital digitization with its results from virtual reality has almost dropped the barrier between reality and illusion, and between the present and the absent.

In a new phase of development, a new generation of intelligent machines and systems based on the representation of knowledge in a symbolic form, and its experimental treatment, in which human intelligence is in harmony with the machine system in a "dynamic automated" mix through superior technology dealing with non-material elements such as numbers and symbols, potential reality, virtual and imaginary, and the emergence of smart systems that distinguish, analyze, demonstrate theories and help make decisions, all the way to systems with self-development capabilities to progress themselves to match developments.

Digital manufacturing is one of these nascent technologies for the development of computer science and its applications in manufacturing and production processes, which is the result of the emergence of automatic control engineering, which aims at digital simulation through the interaction of digital, mechanical and automatic systems with high-sensitivity technology, and digital manufacturing techniques rely on translating digital data into mechanical action through digital manufacturing machines.

This research is therefore concerned with the study of digital manufacturing systems between theory and the work of a pilot study by being applied to metal roof systems through a repetitive hierarchical unit.

• Research problem:

The research problem stems from the need to keep pace with the technical development of design and manufacturing processes to achieve the most quality and performance-effective methods that can be achieved through digital manufacturing systems.

• Research goal:

The research aims to explore the role of digital manufacturing systems in construction systems and architecture with application to metal ceilings.

DOI: 10.21608/MJAF.2021.80726.2368

- **Research hypothesis:**

A scientific approach to digital design and manufacturing will lead to the effective advancement and development of the metal roof manufacturing process.

- **Research approach:**

Theoretical and applied studies go within the scope of a specific methodology through: -

A- The descriptive approach in theoretical studies.

B- The experimental approach in applied studies.

- **<u>The concept and intellectual construction of the theory:</u>**

The concept of theory indicates the personal intellectual vision and individual judgments that a particular person may adopt on an issue. The theory is therefore required to be linked to practice and action. From this we conclude that the concept of theory in common significance carries a pragmatic dimension.

Theory is therefore an intellectual building that links principles to results. The theory is based and constructed on a set of hypotheses that in turn guide the experience. It should be noted that theory is also led by particular logical mental principles: causality and inevitability. The first states that no phenomenon has a cause, and the second means that the same causes always yield the same results. The results often result in what is termed the law, which is the sum of the constant relationships between certain phenomena, and has characteristics.

From this point of view, we can say that if laws are formed among themselves, they constitute a coherent theory. The functions of theory may vary depending on the objectives guiding the scientific law. The function of theory may be descriptive if the laws are merely descriptive. Its function may be interpretative if the laws are aimed at providing causal relationships that are a framework for certain phenomena. When the theory aims to embrace future phenomena with interpretation and analysis, their function is predictive. It should be noted that the theory with an interpretive function is also predictive.

It turns out, therefore, that determining the scientific function of the theory is an issue that depends not only on the nature of the theory, but also on the nature of the approaches used and the areas in which the theory is adopted. From this point of view, we ask: What is the nature of the relationship between theory and reality?

- **<u>Design philosophy for manufacturing:</u>**

In the field of research by design science theorists about its cognitive structure, meaning and purpose, theorists have resorted to the field of philosophy using its intellectual foundations and thesis, trying to interpret the design process and subject it to logic through these intellectual orientations, as a result of which the design trends borrowed the apparent thought, structural and Marxist thought and other philosophies — especially in the 20th century — and this design orientation towards different philosophies did not lead to a clear and consistent knowledge structure but led to a kind of pluralism and lack of clarity that characterized the trends. Design in the second half of the 20th century, structural philosophy, for example, is an intellectual approach based on the fact that the truth of things does not exist in the same things but in the relationships we create and recognize between these things, through the existence of preconceived cognitive structures in man based on the beliefs and concepts of the person, and

the structural concern with linguistics and semantics semiotics, and emphasizes the existence of code and agreed concepts, and how there is agreement among members of society on what words carry of semantics, and how to install sentences and meanings.
The concept of ideology has moved to design to explain it, as design has become not only a utilitarian or technical role, but also a cultural and social role, and the design task becomes to express the layers of society and their vision of life, which amounts to other intellectual activities. Thus, these diverse philosophies have confirmed the multiplicity of design thought and the multiplicity of its dimensions through its various entries, each philosophy provided a different perspective of design from its intellectual and philosophical basis, whether the designer follows his own idea or uses the prevailing intellectual and philosophical orientations, we find that there is a multiplicity and diversity in the handling of design art and manufacture, a tool for benefit and aesthetic expression, which is also a vacuum expression and social expression, and other metaphors and analogies that the philosopher or designer tries to explain what the design is. From previous knowledge inputs, it can be explained that the design philosophy of manufacturing depends on the creation of solid inputs for a continuous design and manufacturing system, a decentralized top-down network of design, manufacturing, distribution and assembly processes that use digitally controlled tools and resources to produce a design piece (may be a piece of furniture, a building façade or a building ceiling) according to a specific design at a specific location, time and cost. This assembly is complex for custom parts delivered by a network of compatible manufacturing and assembly processes, and the costs of the digital supply chain depend on the flow and distance travelled in the distribution network at the design, manufacturing and assembly level: the higher the cost of design and production. In addition, the wider the supply chain network and the more phases it stages, the more vulnerable they are to errors because they are slower to respond. Thus, improving the supply chain means reducing the number and length of stages and coordinating operations to avoid delays and accuracy.

- **The concept of digital manufacturing in the light of technological development:**

Advanced industrial societies in our contemporary world are characterized by what we call technology and science technology, and the science of technology means that technological development has become dependent on the absorption of natural sciences, but the technology of science means that scientific research has become dependent on tools and devices that are very complex and need tremendous technical development, which confirms that the development of technology is greatly linked to the development of science, which led to the emergence of new digital manufacturing tools that contributed to a radical change in the way products are designed and manufactured. If the initial industrial revolution provided man with muscular capabilities of cranes, machines and the second industrial revolution exempted him from routine work, the third industrial revolution, the atomic energy and space revolution, imposed the economic, military and political sovereignty of the States that monopolized the facts of the elements of this revolution.
The digital revolution, which resulted from the introduction of an increasingly weighty new dimension, the new value such as the creation of electronic slides of sand silicon and the subsequent means of communication, information and robots, also imposed the characteristics of the new digital system and new manufactured materials technology, computer

manufacturing, micro electrics, renewable energy, lasers and fiber optics. The digital revolution arose from the escalating convergence of several paths of technical development when it was integrated through a single technology communication medium, where in the last two decades of the last century the field of communications and information witnessed successive booms, first the Internet revolution, and then the multimedia revolution (Info media), the second and third peaks in the march of the digital revolution, after the first peak of the emergence of computers, this revolution inherited by our new century is escalating in the pace of its achievements since the early 1990s, where information technology has produced many mechanisms of the knowledge industry and information transfer such as network search sites and engines, email communication and distance learning systems, and news group information exchange system that helps to exchange views on a topic, and generates new ideas through friction between different cultures.
As for the Fourth Industrial Revolution, it can be said that the Fourth Industrial Revolution (4IR) arose in the wake of the digital revolution, also called the Second Digital Revolution, and can be defined as the revolution resulting from the use of a modern set of means that facilitated the inclusion and activation of the work of advanced technologies in human societies and even implanted them into human bodies if possible. This revolution was marked by the emergence of a range of techniques:

- Innovative robotics techniques.
- Artificial intelligence techniques.
- Nanotechnology.
- Quantum computing technology.
- Biotechnology.
- Internet of Things.
- 3D printing technology.
- Self-driving vehicle technology.

Digital Fabrication or Computer Integrated Manufacturing relies on the idea of computer aided process planning and abbreviated (CAPP) combining CAD and CAM systems.

- **The use of digital manufacturing processes and methods is the result of a range of reasons that can be explained in the following points:**

1- The rapid technological development of new materials and alloys characterized by rigidity, cruelty, heat resistance and corrosion.
2. The production of composite shapes, fragile parts that are easy to break, short, thin fish and need inexpensive and economic formation and the precise formation of high-durability ores such as carbon solid, which are difficult to produce, requiring scientists, engineers and technicians to look at new techniques that have the potential to provide an effective solution to these problems.
Complex forms that cannot be finished and completed by traditional industrialization.
4- Avoid deformation of the surfaces to be produced, which are often accompanied by stresses resulting from normal formation.
5-Accuracy and speed of results compared to traditional manufacturing.

- **<u>Applications of digital manufacturing in architecture:</u>**

The rapid development of parametric tools for architectural design has led to a major challenge to contemporary architectural design. Mathematics and engineering play an important role once again in understanding these new tools, in recent years, many universities have introduced digital design and manufacturing into their curricula to provide and learn a broader

understanding of parametric design, in order to create virtual models that can be built and architecturally used, a great deal of knowledge and skills are needed, leading to a great task and a great challenge for architects.
The role of digital manufacturing in architecture and design has increased in the past decade. Digital manufacturing is a very rare subject in architectural work at the beginning of the twenty-first century, but it has become a common point of view in design practice due to the fact that it can be used as a catalyst for design rather than merely as a means of production, despite this fact, in many architectural trends, digital manufacturing has an impact only on increasing the number of physical models produced, the reason for the fact that promoting design innovation through digital manufacturing can only be achieved through digital manufacturing. Integration with other areas of design such as computer science, engineering, mathematics and mechatronics, moreover, experiments with different materials in the manufacturing process are also of paramount importance in order to achieve different physical effects and change our common way of thinking. This interaction between materials design and digital manufacturing has recently been defined as a new architectural phenomenon called digital physicality, or a new materials or structural environment, while there are many design manufacturing experiences that are conducted in many academic institutions.
The first digital manufacturing laboratories emerged in the late 1990s, and fast prototypes and CNC routers were the first machines to be used to manufacture models in architecture. In the following years, technologies and strategies that drive digital manufacturing-based design experiences have been rapidly expanded.
At present time, the digital manufacturing technologies now available provide a direct embodiment of virtually perceived designs: either by creating small-scale models or by building real structural elements.
The transition from virtual to real mode, implemented after the design process is completed, with the help of CAD/CAM software tools, which allow computer-assisted conversion from cad to cam with the help of a computer, as the use of CNC technology requires digital models to convert to certain file types if implemented (e.g. 3D printing or any other manufacturing method), digital manufacturing tools are extremely necessary in architecture because of the decline in construction costs in the case of high design complexity. The free-form designs, which at the design stage consist of countless unique components, require some kind of structure rationalization, before they become real buildings.
The Greater London Town Hall, built by Foster & Co. is an example of such an approach, the initial design of the spherical-shaped building had to be changed in order to enable the physical perception of the building, the oval shape was reconfigured using four-sided flat segments (PQ) to meet manufacturing standards, demonstrating the parallel search of the compositional system and shape that affect each other.

- **<u>B- Applied study of digital manufacturing in metal ceilings:</u>**

Digital manufacturing technologies generally fit into four main categories: cutting, bending, combining, and configuring. These are similar to the traditional processes used in the metal roof industry, where traditional machinery and equipment are used to achieve the desired results.
Catia V5 has been used to draw the proposed design where through this program we will be able to achieve the CAD/CAM relationship and therefore it will equip the design parts for digital

manufacturing processes, and it allows for the achievement of the barometer design of the ceiling in cases of future extension or the desire to change shape or ratio.. etc.

The following shapes illustrate skylight's repeated quad-faced pyramid-shaped metal roof design to cover an area of 2x2 meters, and the iteration unit has been applied only to the cost and time factor.

References:

- Elbanna, Mahitab Hasan: Athr Nazariat Eltasmim w Alnozom Alma3refia 3la tanmeit elshakhsiia elebda3ia le mosamem alathathat w elensha2at elma3dania – resalet doctora – koliet elfenon eltatbikia – gam3et helwan – 2010.

- Hasan, Walid Ibrahim: eltasmim bel tagrouba kamadkhal lelertekaa belfekr alebda3y le mosamem almonsha2at alma3dania alkhafifa - resalet doctora – koliet elfenon eltatbikia – gam3et helwan – 2009.

- Mohamed, Raghad Mofied: alnakd walnazaria fe el3omara - resalet doctora – koliet elhandasa – gam3et elqahera – 2000.

1. Papanikolaou, D. :Digital Fabrication Production System Theory: Towards an Integrated Environment for Design and Production of Assemblies. . In Proceedings of the 12th Iberoamerican Congress in Digital Graphics - SIGraDi (Havana, Cuba, 1-5 Dec. 2008.

2. Guzik, A,: Digital Fabrication Inspired Design Influence of fabrication parameters on a design process, New Design Concepts and Strategies - eCAADe 28 , 2010 .

3. Stavric, M., Wiltsche, A., Tepavčević, B., Stojaković,V.& Raković, M.: Digital Fabrication Strategies in Design Education, 4th ECAADe International Regional Workshop: Between Computational Models and Performative Capacities,2016.

4. L. Corsini, C. B. Aranda-.., J. Moultrie: Using digital fabrication tools to provide humanitarian and development aid in low-resource settings, Technology in Society 58, 2019.

5. Jabi, W.,: Parametric Design for Architecture. Laurence King Publishers, London, 2014.

6. Afify, H., Abd Elghaffar, Z.,: Advanced digital manufacturing techniques (CAM) in architecture. ASCAAD Conference Proceedings, Section 2, Alexandria, 2007.

7. Kolarevic, B.,: Architecture in the Digital Age: Design and Manufacturing. Taylor and Francis, London, 2005.

8. R.C. Sobrosa Neto, J. Sobrosa S. N., Samara D. S., Michael, B. S., José: The fourth industrial revolution and the coronavirus: a new era catalyzed by a virus, Research in Globalization 2, 2020.