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The impact of robotic technology in shaping the future of interior architecture (Implementation of a study on capsule housing units)

ABSTRACT :

Industries based on the intervention of robotics technology have become more sophisticated and able to advance countries at the present time, especially kinetic robots, which have the ability to move inside buildings and sites without human assistance, which help in carrying out tasks such as drilling and lifting heavy loads accurately and quickly, as this helped avoid human errors and improve the atmosphere of construction also helped reduce labor costs, which prompted the research to study the possibility of introducing robotic technology in Shaping the future of interior architecture and implementing projects easily, accurately and quickly in producing at the lowest costs, despite the lack of sufficient knowledge of robot technology as a result of the technological developments used recently, which prompted the possibility of implementing a robot-assisted design to highlight the features resulting from it and ensure projects already implemented using robotics technology, which follows the descriptive analytical approach, as it includes the statistics of the opinion of manufacturers about helping robots in manufacturing possibilities and discovering the advantages of robot-assisted manufacturing and how Its application in the furniture industry, which entails the importance of robot manufacturing technology to benefit from it in interior architecture.

Keywords:

Robotics – Robot-assisted manufacturing – Artificial Intelligence 3D printing

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العنوان : تأثير تقنية الروبوتات في تشكيل مستقبل العمارة الداخلية (تطبيق علي الحيزات السكنية الكبسولية)

الخلاصة :
اصبحت الصناعات المعتمدة علي تدخل تقنية الروبوتات اكثر تطورا و قدرة علي تقدم الدول في الوقت الحالي خاصة الروبوتات الحركية و التي لها القدرة علي التنقل داخل المباني و المواقع دون مساعدة بشرية و التي تساعد في تنفيذ المهام مثل الحفر و رفع الاحمال الثقيلة بدقة و سرعة حيث ساعد ذلك في تجنب الاخطاء البشرية و تحسين جوجة البناء كمان ساعد في خفض تكاليف العمالة مما دفع البحث الي دراسة امكانية ادخال تقنية الروبوت في تشكيل مستقبل العمارة الداخلية و تنفيد المشاريع بسهولة و دقة و سرعة في الانتاج باقل التكاليف بالرغم من عدم المعرفة الكافية بتقنية الروبوت تنيجة للتطورات التكنولوجية المستخدمة موخرا مما دفع ذلك الي امكانية تنفيذ تصميم بمساعدة الروبوت لتسليط الضوء علي المميزات الناتجة عنة وتضمن مشاريع منفذة بالفعل باستخدام تقنية الروبوتات و التي تتبع المنهج الوصفي التحليلي حيث يشمل احصائية راي المصنعين حول مساعدة الروبوتات في امكانيات التصنيع و اكتشاف مميزات التصنيع بمساعدة الروبوتات و كيفية تطبيقها في صناعة الاثاث مما يترتب علي ذلك مدي اهمية تقنية تصنيع الروبوتات للاستفادة منها في العمارة الداخلية

الكلمات المفتاحية :
الروبوتات – التصنيع بمساعدة الروبوتات – الذكاء الاصطناعي – طباعة ثلاثية الابعاد

المنهج العلمي للبحث :
المنهج الوصفي التحليلي : استخدام هذا المنهج لوصف مراحل التنفيذ للعملية التصميمية باستخدام الروبوت وطرق تطبيقها في مراحل مختلفة .
المنهج التحليلي و الاحصائي : دراسة اهم تقنيات الروبوت التي يمكن الاعتماد عليها في مجال العمارة الداخلية

مشكلة البحث :
دراسة التحديات والفوائد المرتبطة باستخدام الروبوتات في العمارة الداخلية ، حيث يواجه المهندسون والمصممون صعوبات في التكيف مع هذه التكنولوجيا الحديثة. على الرغم من الإمكانيات الكبيرة التي توفرها الروبوتات في تحسين كفاءة وجودة عمليات التصميم والبناء، إلا أن هناك تساؤلات حول تأثيرها على سوق العمل، والتكاليف المرتبطة بتبنيها، بالإضافة إلى التحديات التقنية التي قد تعيق تطبيقها في مواقع البناء.

اهداف البحث :
- دراسة التطبيقات الحالية للروبوتات في العمارة الداخلية .
- تحليل الفوائد و التحديات المرتبطة باستخدام الروبوتات .
- تحليل تاثير الروبوتات بيوق العمل .
- استكشاف الابتكارات المستقبلية في هذا المجال .

فروض البحث :
- هل استخدام الروبوتات في العمارة الداخلية يودى الي تحسين كفاءة العمليات و زيادة الانتاجية في مراحل التصميم و البناء ؟
- تفسير مدي تاثير اجهزة الروبوتات علي التقليل من الاخطاء البشرية في عمليات البناء
- ما هي التحديات التى تعيق استخدام الروبوتات في العمارة الداخلية؟

عينة البحث :
اختيار مجموعة من المشاريع التي استخدمت الروبوتات في تنفيذها مثل المباني السكنية و التجارية .

النتائج المتوقعة للبحث :

- الأستفادة من التفاعل بين الانسان والالة .

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- تحسين جودة البناء من خلال دقة التنفيذ و تقليل الاخطاء البشرية .
- دراسات حالة لمشاريع تم تنفيذها باستخام الروبوتات

Scientific method of research :

Descriptive and analytical approach: Using this approach to describe the stages of implementation of the design process using the robot and the methods of its application at different stages.

Analytical and statistical method: studying the most important robotic techniques that can be relied upon in the field of interior architecture

Search problem:

Study the challenges and benefits associated with the use of robots in interior architecture, as engineers and designers face difficulties in adapting to this modern technology. Despite the great potential that robots offer in improving the efficiency and quality of design and construction processes, there are questions about their impact on the labor market, the costs associated with their adoption, as well as the technical challenges that may hinder their application on construction sites.

Research Objectives:

- Study the current applications of robotics in interior architecture.
- Analysis of the benefits and challenges associated with the use of robots.
- Analysis of the impact of robots on the time of work.
- Explore future innovations in this field.

Research hypotheses:

- Does the use of robots in interior architecture lead to improving the efficiency of operations and increasing productivity in the design and construction stages?
- Interpret the impact of robotics devices on reducing human errors in construction processes
- What are the challenges that hinder the use of robots in interior architecture?

Research Sample:

Selecting a group of projects that used robots in their implementation, such as residential and commercial buildings.

Expected results of the research:

- Benefit from the interaction between man and machine.
- Improving the quality of construction through the accuracy of implementation and reducing human errors.
- Case studies of projects implemented using robotics

1- Introduction:

In the age of advanced technology, robotics have come to play a pivotal role in the transformation of many industries, including interior architecture. Robots are innovative tools that contribute to improving efficiency and accuracy of implementation in the design and construction of interior spaces. The history of robots dates back to ancient times, where they were conceived in myths and tales, but the first actual use of the concept of robots came in the twentieth century. In 1956, engineer Georges Devol developed the first industrial robot known as Unimate, which was used in car production lines. Since then, robotics has seen remarkable advances in the fields of artificial intelligence, In the seventies and eighties, robots began to gain popularity in heavy industry, where they were used for repetitive and dangerous tasks. As technology advances, robots have become smarter and able to learn and adapt to different work environments. With the beginning of the twenty-first century, robots began to enter new fields, including architecture, introducing technologies such as

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three-dimensional printing and mobile robotics.Today, robots are used in design and construction processes, allowing engineers and designers to focus on creativity and innovation, thus producing more complex and unique architectural designs. . Robots open up new horizons for the development of smart spaces that interact with users, enhancing the housing experience and achieving comfort and multifunctionality. With the increasing adoption of this technology, professionals in the field are required to acquire new skills related to interacting with robotics and their applications. Thus, the impact of robotics in interior architecture is not limited to improving efficiency and quality, but extends to redefining how spaces are designed and built that reflect the needs of modern society.

Figure (1) shows the first robotic machine (uinmate), which is a robotic arm connected to a giant steel cylinder that casts metal into molds, welds car bodies and lifts cars weighing 500 pounds.

2- What is robotics:

The robot is a human invention that works as a machine programmed to implement commands, designed in a specific way that facilitates it to perform various functions in many fields, interacts with the environment around it and responds in a fast and intelligent way to commands, and robots were made by Karel Kabeck in 1921 AD to show the first model of it, to spread now in our time and enter into the completion of many difficult tasks such as the manufacture of smart devices Robots are also characterized by artificial memory that simulates the human mind in the processes of thinking and perception, and produces About this realization act intelligently and provide the best responses and solutions.

2-1 The development of robotics:

The field of robotics has witnessed a great development in recent years[1], and this is due to advances in other fields of science and technology in improving the performance of robots, making them more efficient. For example, the advent of big data science helped connect different devices together, and the innovation of new sensors and the emergence of the Internet of Things allowed them to better monitor and interact with the surrounding environment. As a result of these developments, we have a new generation of robots with complex capabilities and can be used in fields as diverse as industry, healthcare, security, and helping people in their daily lives.

2-2 Fundamentals of Robotics:

Robotics are considered one of the leading technological innovations that have revolutionized many fields, from industry to other fields, including architectural engineering and Delhi design, where robots consist of a set of basic elements that contribute to their effective performance. There are three basic elements that make up the basic structure of the robot's look and design.

- Mechanical construction: Each type of robot is characterized by a specific structure or design commensurate with the task attributed to it

[1] علم الروبوتات وتخصصاته الحالية ومجالاته المستقبلية (for9a.com)

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- The electrical element: It is the energy element that provides the robot with the necessary energy and controls it.
- Programming element: All types of robots must contain a type of programming that enables them to make certain decisions or carry out specific tasks

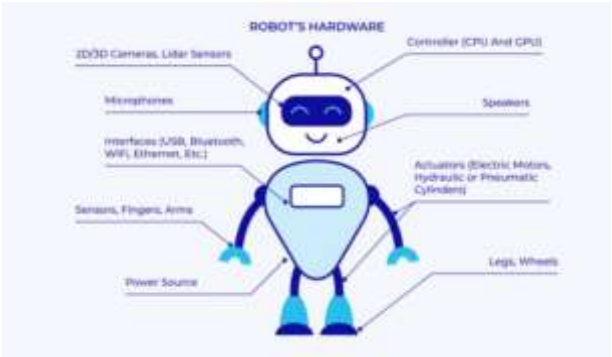

Figure (2) shows the basic structure of the robot's shape

3- The role of robots in construction and design:

Although it is a modern field, the use of robotics in architecture is nothing new. There are many areas in which robotics applications can expand, such as construction, design processes, interiors, furniture and landscaping, in addition to manufacturing, production, materials, methods, structural and mechanical systems, and robots help create three-dimensional models with extreme accuracy, enabling designers to fully visualize the project before starting construction. Engineers can also test the properties of different materials within these models to determine their strength and flexibility and choose the most appropriate according to the requirements of the project, in addition to the widespread use of robots in manufacturing units to produce the parts necessary for the construction of buildings. Long cranes and robot arms facilitate assembly operations on site, while drones have become a popular option for placing small pieces in place, previously requiring the use of complex hydraulic elevators or scaffolding.

Figure (3) shows the working robot and a robot that performs work in construction sites where it can stack bricks to complete construction operations

4- Types of robots used in interior architecture:

Interior architecture is one of the areas that has witnessed remarkable development thanks to technological innovations, as robots play an increasingly important role in the design and implementation of interior spaces. The uses of robots in this field vary[2], from design and planning, to implementation and installation. This technology improves efficiency and reduces time spent on projects, as well as providing innovative solutions that better meet customer needs. Through the use of robots, engineers and designers can achieve high accuracy in work, contributing to the creation of comfortable and attractive indoor environments.

4.1 Mobile robots:

They are automated machines that navigate and perform tasks within internal environments. These robots are known as machines controlled by software, using sensors to determine their surroundings and move independently.

[2] الروبوتات في العمارة | ARCHCOD

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Practical examples include RoboFold, a robotic arm that can bend materials in furniture, and mobile robots that help organize rooms by analyzing human-object relationships to improve usability.

Figure (4) shows the design of the Roomba Robot, which is one of the most powerful cleaning robots

4-2 robots specialized in finishing and painting:

Manual finishing methods often face challenges as a result of the variation in the amount of paint used, when a person slows down during the movement of paint, he may use a larger amount of paint than required, which leads to waste of materials and reduces the quality of finishing, so paint robots are an ideal option to improve the efficiency of the furniture painting process, as different robotic models have been designed specifically for this purpose.

The use of industrial robots in painting furniture arouses great interest and offers wide possibilities where the best possible quality can be achieved when the paint is implemented by fully automated robots, however, wood, especially hardwood, is a more complex material, as it is difficult to deal with because of its sensitivity to moisture, in addition, determining the position of the raw materials that are delivered is critical to the success of the painting process, and examples of finishing and painting robots are robospray, Maverick

4-2-1 robot robospray:

It is an industrial robot that can paint or spray glue. Teach to Easy technology has been developed to train the relatively simple and programming-free robot in which human movements are recorded during the implementation of the process[3], which is then depicted in a graph on the robot program that allows each point to be modified separately or part of the graph as required, and once any modification is completed, the graph is converted into a robotic language, while tracking human movements, A record of the coordinates of the place, angle of the instrument and the timestamp is recorded. This allows human movements to be repeated or modified as required so that the robot performs tasks to the fullest.

Figure (5) illustrates the robot robospray

4.2.2 Maverick robot:

The IST team, consisting of an engineering student at the University of Waterloo, Canada, created a new intelligent robot called maverick, which can touch the wood used in the walls of homes with amazing accuracy, it is equipped with sensors that make it a fully independent robot, and the team indicated that the traditional manual painting process is very slow, expensive, inefficient and dangerous

[3] IDJ_Volume 13_Issue 2_Pages 389-406_2 (1).pdf

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Figure (6) illustrates the Maverick robot

5- Robots supported by artificial intelligence:

AI-powered robotics technology refers to the integration of robotic systems with AI algorithms, enabling robots to learn and adapt to their environments. The technology relies on techniques such as machine learning, neural networks, and computer vision, allowing robots to analyze data and make autonomous decisions. Through these capabilities, robots can improve their performance over time, making them more efficient and effective in carrying out complex tasks. This technology contributes to enhancing the ability to interact with and understand the environment, opening up new horizons in multiple fields.

5-1 Its positive impact on shaping the future of interior architecture:

- **Reduce human error:** Since artificial intelligence takes aggregated decisions using designed algorithms, errors are reduced and accuracy is increased
- **Finding ways to save time** by making faster decisions is always valuable, AI can do this as AI works in tandem with various technologies to help machines make these decisions faster than many human workers.
- **Increasing efficiency:** It helps speed up design processes, which results in reducing the time spent for the implementation of design projects
- **High accuracy:** reduce human errors and the resulting work is at a high level of efficiency and accuracy as it measures space spaces accurately
- **Data analysis:** analyzing customer ideas and proposed design trends and providing auxiliary and appropriate solutions for the same topic
- **Improve the customer experience:** Three-dimensional applications provide a design vision before implementation that helps customers visualize the design

6 – Three-dimensional printing:

Augmented reality allows for the enhancement of AI capabilities in the field of interior design. The importance of this technology lies in the fact that it relies on mixing digital information with information gleaned from the surrounding environment, and then presenting it together through a composite image rich in information. Through augmented reality, interior design companies can display furniture items in a three-dimensional way, and help customers, by producing a virtual home. By seeing the display, customers can check if furniture items fit where they are, or if they need something else. They can also visualize how the design will look with the selected elements even before making a purchase decision. AI therefore helps simplify the selection method for consumers while enhancing their chances of buying for any design.

6-1 The beginning of three-dimensional printing technology:

The use of this technology began in the eighties of the last century by the American engineer (Chuck Hall as a first), which is the first technology to achieve the goal of rapid printing of three-dimensional models, which implements printing in the form of successive layers, but its use has spread in the last ten years, despite that, it has affected many industries, but this effect has swelled with time and increased its speed as it has passed

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and is still going through many successive developments

6-2 The development of three-dimensional printing:

The concept of three-dimensional printing was invented in the eighties of the last century by an American engineer named Chuck Hall as the first technology that achieves the goal of fast printing of three-dimensional models, which performs printing in the form of successive layers. Although 3D printing technology has been widely commercialized for less than a decade, it has had a huge impact on many industries. Rather, this effect has been amplified with time and its speed has increased, as it has gone through and is still going through many successive developments, and there is no doubt that three-dimensional printing has had a remarkable and pivotal impact on the industries in which it has been listed so far.

6-3 Advantages of three-dimensional printing technology:

- Reduce the cost: The use of this technology led to a significant reduction in construction costs and it is expected that this technology, if used extensively, will solve the housing problems for low-income people by a large percentage, as a house has been built in China at a cost that did not exceed $ 5,000, eliminating the cost of molds used in traditional construction methods is the main economic driver of construction because they are built using materials such as wood, as the cost of molds drops significantly by 60% of the total cost of construction.

- Reduce the duration of construction: The use of this technology in building homes helps reduce the time required by projects, as three-dimensional printing can produce housing units in much less time than what traditional construction methods require. An American startup called (Icon) was able to use a three-dimensional printer to build a house consisting of one floor extending to an area of 650 square feet in a period that did not exceed twenty-four hours, and there are other successful examples such as the Chinese company Huashang Tingda Another Chinese company called Win Sun Engineering Design and Decoration built ten complete houses within one day through a three-dimensional printer. Certainly, with the continuous and rapid development witnessed by this technology

-Strong structures: 3D printing has developed to [4]a large extent that allowed the use of concrete as one of the printing materials, which led to the production of homes that can withstand natural disasters such as earthquakes and hurricanes

Freedom of creative design: Three dimensional printing that is not restricted to certain shapes or templates for construction will allow architects to unleash their creativity and designs, which will open the door to picturesque and creative building designs.

Figure (7) shows the method of building huge structures using three-dimensional printing

[4] Gallery of Dubai Municipality to Become the World's Largest 3D-Printed Building - 31 (archdaily.com)

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Figure (٨) shows the method of building huge structures using three-dimensional printing

Figure (11) shows the façade of the largest building in Dubai designed by three-dimensional printing technology

Figure (9) shows the implementation of the largest building in Dubai by three-dimensional printing technology

Figure (١٢) shows the façade of the largest building in Dubai designed by three-dimensional printing technology

Figure (١٠) shows the implementation of the largest building in Dubai by three-dimensional printing technology

٦-4 Ways to use 3D printing:

٦.4.1 Extrusion method:

Materials used

Cement – wax – foam – polymers

Method of implementation

- The building material is melted [5]or diluted to make it easier to print on layers
- Through the extruder of the printing machine, small grains of material are extruded that immediately harden to form layers and the extruder is connected with

[5] الطباعة ثلاثية الأبعاد (تكنولوجيا البناء الحديث) - بعدسة معمارى (byarchlens.com)

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thermoplastic filaments or metal wire[6], which are used to heat the printing material before the extrusion process

Extrusion lines can process recycled materials, contributing to sustainability efforts by reducing waste and energy consumption. Recycled yarn is used in environmentally friendly production lines and initiatives.

Figure (13) shows the method of extrusion in three-dimensional printing

An example of the TECLA extrusion method is designed by Mario Cucinella Architects and designed and built by WASP 3D printing specialists.

TECLA will be the first home to be fully three-dimensional[7] printed using locally sourced clay – a biodegradable and recyclable material that will make the building waste-free.

TECLA was built using a WASP crane, named after a fictional city described by writer Italo Calvino - it will be the first habitat to be built using several collaborative 3D printers, offering greater scope than ever before.

Figure (١٤) showing the implementation of the TECLA house by three-dimensional printing

Figure (١5) showing the implementation of the TECLA house by three-dimensional printing

Figure (16) showing the interior design of the TECLA house

[6] الطباعة ثلاثية الأبعاد (تكنولوجيا البناء الحديث) - بعدسة معمارى (byarchlens.com)

[7] TECLA Technology and Clay 3D Printed House / Mario Cucinella Architects | ArchDaily

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Figure (17) showing the interior design of the TECLA house

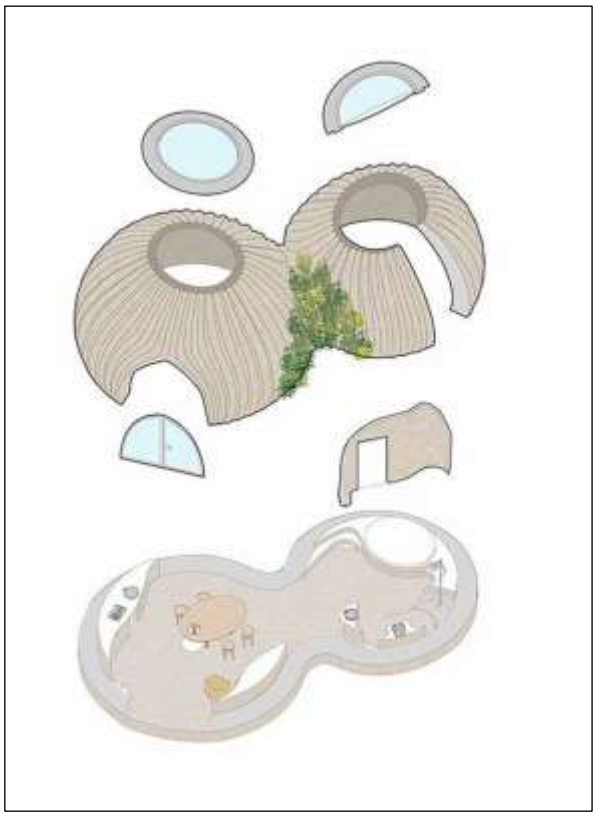

Figure (18) illustrating the isometric design of the TECLA house

6.4.2 Bonding powder method:

Materials used:

Polymeric binder – Reaction binder –

Welding additives

How to implement:

- Each layer is built by scattering the raw material powder and a layer of powder prepared as a basis
- These layers will serve as binder for the ores to bind the granules, so the model is formed
- Piston compression of the base layer to stabilize it and then rises to compress the next layer that has been scattered and then bind its granules using a binder
- The construction of each layer is repeated until the formation of the required block is completed

Figure (19) showing the method of pressing in three-dimensional printing

6-5 Construction method:

Construction is done on-site or off-site and then transported

You will serve a 6.6-meter-high[8], 10-meter-wide printer that casts cement ink in a stiff, interlocking Z-shaped arrangement, giving the printed walls strength and rigidity, and making them unbreakable or archable

The design to be built is entered into printing and the printer will work automatically and when it is finished it will stop automatically

It also prints innovative and new building designs.

[8] الطباعة ثلاثية الأبعاد (تكنولوجيا البناء الحديث) - بعدسة معمارى (byarchlens.com)

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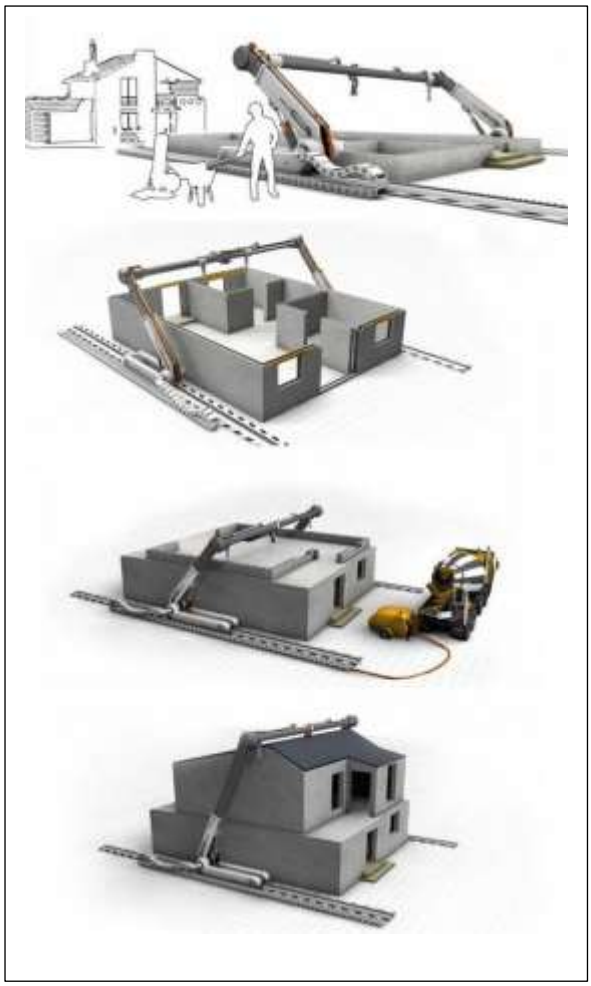

Figure (20) shows the method of construction gradua

Dubai has opened a new project, Office of the Future, the world's first 3D printed and printing building, which is the temporary building of the Dubai Future Foundation and is located on the Emirates Towers campus in Dubai. The building is the first of its kind in the world, as it is ready for practical use through the integration between the design of the building and its printing, in addition to providing the main services within the building such as electricity, water, communications and air conditioning.

The office is located on an area of 250 square meters and features [9]a modern and innovative design that suits a future work environment, taking into account moving away from the traditional form in work environments to provide greater opportunities to stimulate innovation, communication between work teams, allowing joint work with networks of experts and innovators from around the world, drawing inspiration from ideas, developing relationships between employees, and establishing new methods in brainstorming sessions by providing a healthy and happy work environment. The design also provides diverse work environments to meet all needs, providing opportunities for interactive meeting between the Foundation's employees, in addition to providing spaces for holding exhibitions and workshops so that members and partners of the Foundation can hold their meetings and hold various events.

A printer with a height of 20 feet, a length of 120 feet and a width of 40 feet was used, and a robotic arm was used to carry out printing operations and the use of a mixture of cement and a set of special materials that were designed between the UAE and the United States and underwent a series of tests in both China and the United Kingdom to ensure their quality, in addition to adopting designs with arches to ensure the strength of the building structure. The building is characterized by an innovative insulation system that helps reduce energy consumption, where umbrellas have been used over the windows aesthetically and provide protection for the building from direct exposure to direct sunlight to save energy consumption and the building includes the latest technologies for information

[9] " أول مبنى مطبوع بتقنية الطابعة – "مكتب المستقبل ثلاثية الأبعاد في دبي - مجلة البناء - Albenaa Magazine

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systems management by providing integrated wireless solutions for the Internet

The construction of the total office took only 17 days to print[10], after the approval of the interior and exterior designs and was installed on site within two days. The building saved more than 50% of the cost of labor compared to traditional buildings with similar construction area, as the printing process required one worker to monitor the workflow of the printer, a team of 7 people to install the building components on site, and a team of 10 electricians and specialists in the implementation of mechanical and electrical engineering works.

The project is part of the Dubai 3D Printing Strategy, a unique global initiative that aims to harness this promising technology to serve people and strengthen the position of the UAE and Dubai as a leading regional and global hub in the field of 3D printing. The Dubai 3D Printing Strategy focuses on 3 main sectors: building and construction, medical products and consumer products, depending on Dubai's competitive and future advantages.

Figure (٢١) showing the entrance area- the office of the future, which is the first building made using three-dimensional printing technology

Figure (٢٢) showing the shape of awnings for windows to save energy - the office of the future, which is the first building made usin three-dimensiona lprinting technology

Figure (٢٣) shows the design of a cafeteria space in the outdoor space of the office - the office of the future, which is the first building made using three-dimensional printing technology

Figure (٢٤) shows the design of the reflective glass of the sun - the office of the future, which is the first building made using three-dimensional printing technology

[10] أول مبنى مطبوع بتقنية الطابعة – "مكتب المستقبل" ثلاثية الأبعاد في دبي - مجلة البناء Albenaa Magazine

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Figure (٢٥) shows the interior design of the meeting room surrounded - the office of the future, which is the first building made using three-dimensional printing technology

Figure (٢٦) showing an interior design with flowing lines that match the external shape of the office - the office of the future, which is the first building made using three-dimensional printing technology

Figure (٢٧) shows the interior design of the office - the office of the future, which is the first building made using three-dimensional printing technology

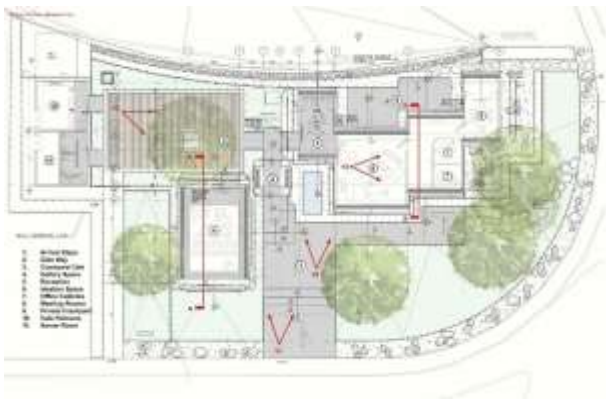

Figure (٢٨) shows the horizontal projection of the office of the future which is the first building made using three-dimensional printing technology

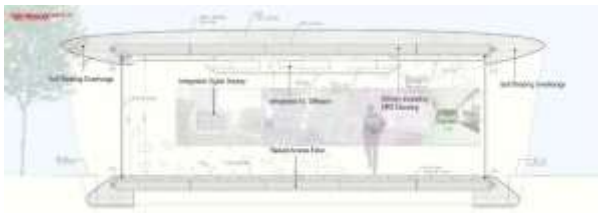

Figure (٢٩) showing a vertical sector (A-A') for the office of the future which is the first building made using three-dimensional printing technology

Figure (٣٠) showing the future office model which is the first building made using three-dimensional printing technology

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7- The importance of three-dimensional printing in achieving sustainability :

3D printing technology is a revolutionary tool that plays a vital role in promoting sustainability in interior architecture[11]. By enabling the design and implementation of innovative and efficient architectural elements, this technology contributes to reducing environmental impact and improving resource efficiency. The following are the most prominent points that illustrate the importance of three-dimensional printing technology in achieving sustainability in interior architecture

-Reduce material losses

In traditional construction processes, large amounts of waste are produced as a result of material overcutting. In three-dimensional printing, elements are stratified according to a precise design, reducing unused materials, thus contributing to reducing waste and increasing resource efficiency.

-Use of sustainable materials

Three-dimensional printing can use sustainable materials such as recycled plastic, clay or biocement, contributing to reducing environmental impact. New materials can also be developed that meet sustainability standards and enhance the performance of buildings in terms of thermal insulation and energy efficiency.

-Providing innovative architectural solutions

This technology enables the creation of unconventional and sustainable architectural solutions, such as designing multifunctional furniture or walls with **built-in storage** systems, enhancing the utilization of spaces.

-Recycling and use of renewable resources

Some 3D printing technologies allow the use of recycled materials from previous construction processes, and environmental materials such as clay or plant fibers can be used, supporting the idea of reusing natural resources.

-Produce faster at a lower cost

Three-dimensional printing saves a lot of time in producing architectural elements compared to traditional methods, which makes the construction process faster and less expensive, and helps reduce time and financial waste.

٨- A proposal to apply three-dimensional printing technology to capsule spaces:

Eco Capsule Home:

It is a sustainable mobile tiny home that is designed to fit into energy-efficient environmental life. It features a compact capsule design that provides all basic living needs in a small space, and works independently using solar energy

Thanks to its smart design, the home can be installed in remote locations and rely on renewable energy

It can be easily modified and developed using three-dimensional printing technology. This technology allows interior walls to be remodeled, such as changing the zoning of spaces or adding new rooms, providing greater flexibility to meet the changing needs of residents. Walls and furniture can be printed using sustainable materials such as recycled plastic or bio-concrete, enhancing the efficiency of heat and sound insulation. In addition, windows or power systems such as

[11] ثورة في التصميم الداخلي باستخدام الطباعة ثلاثية الأبعاد - Goldsupplier

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built-in solar panels can be improved, enhancing the sustainability of the home. Printing can also be used to develop internal systems such as sanitary facilities or storage more integrated with the design

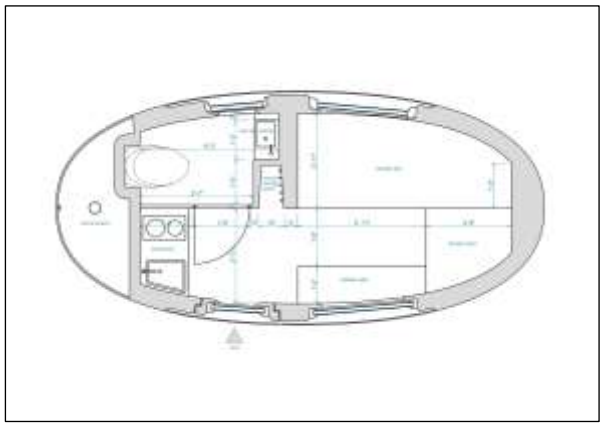

Figure (٣٠) shows the horizontal projection of an Eco capsule house

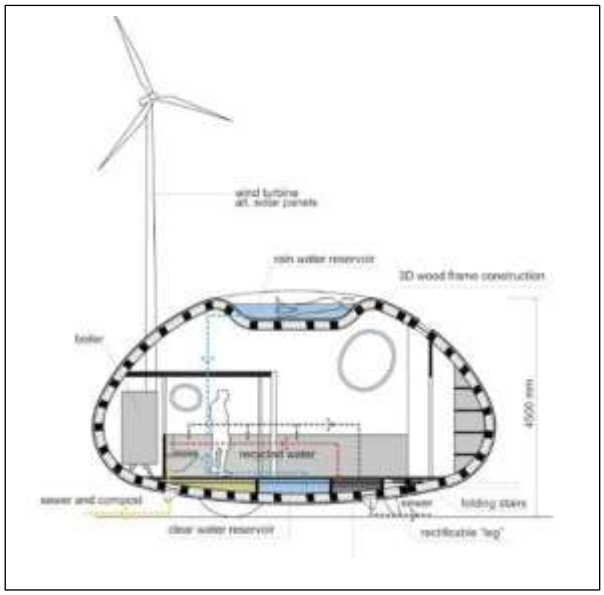

Figure (٣١) shows the vertical projection of an Eco capsule house

Figure (٣٢) shows the entrance and the extent to which the capsule is related to Nature

Figure (٣٣) shows the interior design of the Eco capsule house

٩. Conclusions:

Robotics are one of the basic elements that redefine interior architecture, as they contribute to revolutionizing how spaces are designed and built and through their ability to carry out tasks with extreme accuracy and high speed, robots allow reducing human errors and enhancing the quality of work, which leads to improving the overall efficiency of projects.

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When robots are combined with 3D printing technologies, these technologies allow the production of custom architectural elements that accurately meet customer needs, which contributes to reducing material losses and increasing sustainability. 3D printing has contributed to reducing the time and costs associated with traditional construction processes, making projects more cost-effective.

These innovations contribute to improving the energy efficiency of buildings leading to a reduction in energy consumption in the long run. The integration of robotics, artificial intelligence and three-dimensional printing into interior architecture represents a radical shift towards a more sustainable and innovative architectural environment, which opens new horizons for the design of spaces that meet the needs of modern society and contribute to preserving the environment.

١٠. Recommendations

Making the most of the impact of AI-powered robotics and 3D printing in interior architecture requires a set of strategic recommendations First, research and development in this area should be encouraged to explore new applications that enhance the efficiency of design and construction. Specialized training programs should be provided to engineers and architects to enhance their skills in using these modern technologies. It is also necessary to establish clear standards and guidelines for the use of robots on construction sites to ensure the safety of workers and reduce risks. In addition, materials should be explored New usable 3D printing that is sustainable and environmentally friendly It is important to conduct environmental impact assessment studies for the use of these technologies, which help guide policies towards sustainability. Investments in this area should also be encouraged by governments and the private sector and public awareness of the benefits of these innovations should be promoted.

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