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AI-Driven Furniture Design: Bridging Creativity and Manufacturability in the Digital Age

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Abstract

Design is an innovative process that originates in mind and is directed by the designer to appear in a physical form. Recently, the development of design technologies and the emergence of artificial intelligence (AI) applications in furniture design raised many questions in designers' society. These applications have triggered a new approach to design that is even available for amateurs and non-specialists. The beta version launched by (Midjourney)- a self-funded computer research laboratory working on innovative design and artistic creativity tools- was a starting point for a creative design approach that creates images from text.

Research Problem: The research was a result of artificial intelligence applications in furniture designs today. The research question is (Can designers rely on designs produced by artificial intelligence technology or they are just tools to help the designers present their ideas?). This question leads us to other sub-questions as the following: How can designers benefit from this technology in the near future? What is the impact of this technology on the future design practices?

Research Objectives: The research aims to study the use of artificial intelligence in furniture design and to investigate whether it is possible to rely on the designs produced by AI for manufacturing or if the designs need a reformat.

Research Significance: The research significance shows the applications of artificial intelligence technology and its contribution in the field of furniture design in addition to providing an understanding of technology aspects and its impact on futuristic practices.

Research Methodology: The research applied an experimental approach by using AI online platforms to generate furniture designs. The research also applied a descriptive-analytical approach through a questionnaire of furniture designers on their opinions about AI designs and their insights on the influence of this technology on the profession's future.

Results: The questionnaire results for the designers were Collected, summarized, and presented as shown in Table 1. The level of experience ranged from one year up to more than five years as the following: From 1 but less than 3 years (30%)., From 3 but less than 5 years (60%), From 1 but less than 3 years (10%). According to their job responsibilities, 60% of the questionnaire sample worked in the design office, while 30% worked in the technical office. Only 10% worked in quality control.

Keywords

Artificial Intelligence, Furniture Design, Furniture Manufacturing, Machine Deep Learning, Futuristic Design.

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Introduction

Design is an innovative process that originates in the mind and is directed by the designer to appear in a physical form. It is all about recognizing the

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needs and creating an entity that meets a set of goals.

A process of innovation starts by collecting elements from the environment and placing them in a specific format for a meaningful result. The design process originally depends on the designer's experiences in solving the design problem and achieving its functional and technical aspects.

Recently, with the development of design technology and computational design that support the design process. Virtual models were introduced and emerged to facilitate the designer's idea. Computer programs like Auto CAD - 3ds max - Revit - Rhino and else more have accelerated the design and preparation of technical drawings for them (El-fayoumy, 2022). These programs do not perform the design process, but they serve as tools that help the designers to present their designs. These designs must be prepared as preliminary drawings and sketches, which he uses to work on his ideas.

With the emergence of artificial intelligence technology (AI) applications in the late nineties, according to the definition of John McCarthy an American computer scientist and the father of this technology defined it as the science and engineering of making intelligent machines, especially intelligent computer programs that have specific features enabling them to know and learn by analyzing and interpreting data (McCarthy et al., 2006). This concept was used to achieve specific goals and tasks or make decisions, it is linked to the mechanisms and techniques of using computers to understand and simulate human intelligence (Shi et al., 2024). Since then AI applications have been introduced in many aspects even in the education sector (Suidan et al., 2022). In general, the term (artificial intelligence) is used when the machine simulates the functions performed by humans, such as learning and solving problems (Liu et al., 2024).

Research Problem:

The research was a result of artificial intelligence applications in furniture designs today. The research question is (Can designers rely on designs produced by artificial intelligence technology or they are just tools to help the designers present their ideas?). This question leads us to other sub-questions as the following:

- How can designers benefit from this technology in the near future?
- What is the impact of this technology on the future design practices?

Research Objectives:

The research aims to study the use of artificial intelligence in furniture design and investigate whether it is possible to rely on AI-produced designs for manufacturing or if they need reformatting.

Research Significance

The research significance shows the applications of artificial intelligence technology and its contribution in the field of furniture design in addition to providing an understanding of technology aspects and its impact on futuristic practices.

Research Methodology

The research applied an experimental approach by using AI online platforms to generate furniture designs. The research also applied a descriptive-analytical approach through a questionnaire of furniture designers on their opinions about AI designs and their insights on the influence of this technology on the profession's future.

1. Theoretical Background

Artificial intelligence is considered the fourth industrial revolution that improved productivity and reduced operating costs by integrating manufacturing processes (Javaid et al., 2022). In the furniture market industry, IKEA launched a service by Ingka Group – one of the retailers- in April 2020, which is an application that helps the company's retailers provide a new experience for their customers. The idea was to apply augmented reality within a mobile application to allow customers to try different furniture items within their living spaces (IKEA, 2022), as shown in Figure (1).

Fig. 1 – Augmented reality using mobile application

Recently, what was presented by (Midjourney) as a self-funded computer research laboratory working on innovative design and artistic creativity tools using artificial intelligence was a high-tech approach (The Economist, 2022). This research lab launched a beta phase of its application that has the same name (Midjourney AI) starting in July 2022 and ending in June 2023 (Claburn, 2022). This technology creates images from text descriptions

and is similar to other previously introduced applications like OPEN AI, Stable Diffusion, and DALLE 2 (Wang et al., 2024). This technology was first launched to the public on the 14th of March 2022, through the (Discord) website. Discord was considered a communication platform for game lovers in 2016. At the beginning of August 2022, "David Holmes" – founder of Midjourney - began to make profits out of this service (Curry, 2024).

Many designs that appeared through "Midjourney", whether artistic, architectural, or even industrial products triggered many designers about the future of their professional practices. To understand AI workflow designers need to get a baseline knowledge of the concept of this technology.

Artificial intelligence is an umbrella term that includes different machine learning methods, based on a set of data, whether the data is image, text or audio it is used as a database on which the machine learns how to organize depending on their features (Ramzan et al., 2022). The data is classified and arranged according to data science, which is an independent science that helps artificial intelligence learning models classify the inputs and recognize them in categories for easier processing (Zhu & Xiong, 2015). The intelligent model starts to learn the patterns in the data and the best way to solve problems using that data. The machine learning approaches are supervised, unsupervised, semi-supervised, and reinforcement presented in Table 1 (Sarker, 2021b).

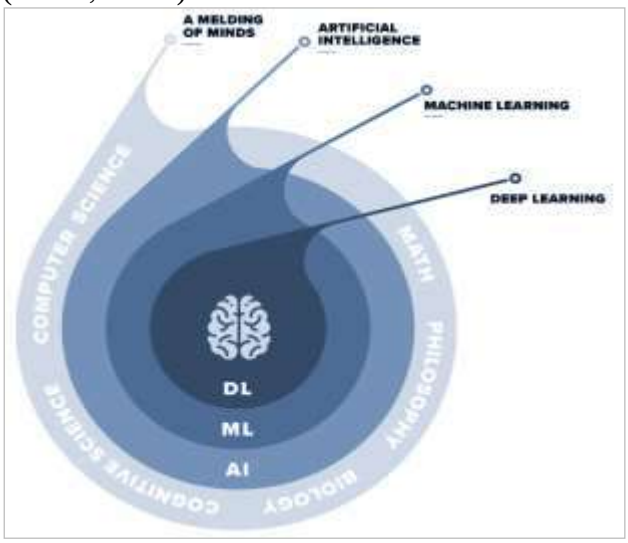

Fig. 2 – Relation between computer science, Artificial intelligence, and machine learning.

Table 1 – Machine Learning Approaches

Machine Learning Approaches (Udousoro, 2020)	
Supervised	Supervised learning relies on data that is added to the system as an input. This data is pre-specified and classified in order to obtain a classification for other similar data. Therefore, the model has data to rely on, which makes it supervised, given that we control its classification reference.
Un-supervised	This kind of machine learning depends on discovering patterns and relationships between data without human intervention or assistance instead the machine classifies the data and discovers the links between them. It is effective when dealing with a large data set that needs to be arranged and organized according to its features.
Semi-supervised	This kind of machine learning depends on discovering patterns and relationships between data with human help by providing some of the data that has been classified to be used as a reference for further and more complicated classifications. This kind can handle the classification of large data sets.
Reinforcement	This model of machine learning is based on the concept of distinguishing between right and wrong. The model is provided with a data set to classify and arrange. The feedback for this classification will inform and guide the learning model or specifically the learning algorithm through its mistakes to be a reference for its database.

There are many other methods of machine learning, including deep learning, which simulates the human brain's neural network also known as (Artificial Neural Network - ANN), which simulates the neural structure of the cerebral cortex, but on a much smaller scale (Hao, 2019). In this method, the neural nodes are connected in a network to simulate the billions of cells that make up the human brain, as each neuron processes information in the neural network. These neurons have a numerical value that contributes to the final decisions (Mishra & Gupta, 2017). Deep machine learning differs from other learning methods as it relies on unstructured data, which is completely different from structured data as the structured data is arranged and classified (Singh & Hooda, 2023). Structured data can be used directly unlike unstructured data, which is difficult to classify and needs processing time to be arranged (Al Ka'bi, 2020).

In deep learning, there are different models like generative, diffusion, variational, and transformers that learn automatically from a little data and discover the links between them, which is considered an effective model in arranging image

databases(Du et al., 2024). This model will greatly reduce time and effort for data classification. After the learning model is trained and tested to ensure its ability it can be released as a beta version (Sarker, 2021a). The methodology for the learning model depends on a conditional flowchart that utilizes binary decision-making as shown in Figure 3.

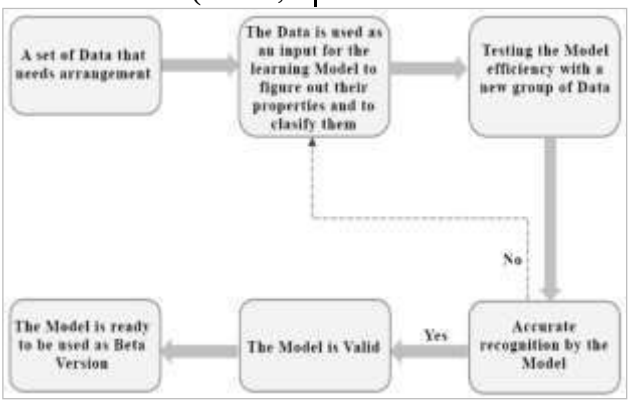

Fig. 3 – Machine Learning – Binary decision making

The inner architecture behind the deep learning model is the interconnected neurons (Neural Network). This network is divided into layers where the input layer receives inputs and data of various types, which are processed by other hidden layers to reach the final result (Output Layer). Usually, one or more hidden layers are placed. Each connection between these neurons has a relative weight that affects the output, and each neuron has a specific value that contributes to the results (Taherdoost, 2023).

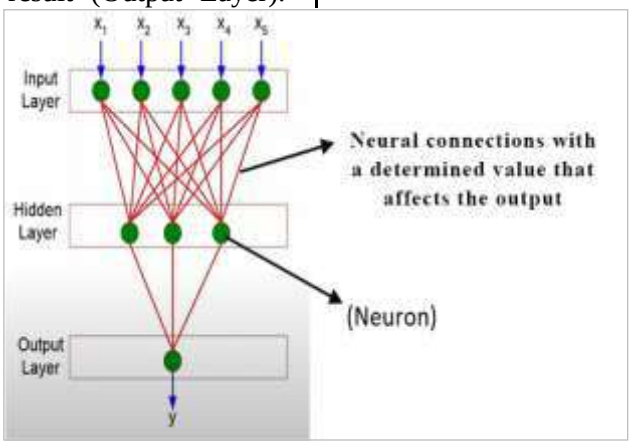

Fig. 4 – Neural network Explanation.

These neural networks differ in their processing of unstructured data. One of the most important deep learning algorithms that help identify and classify images is (CNN-Conventional Neural Network), which is a kind of deep learning algorithm used to recognize the features in images. Simply it converts the pixels of the image - the simple parts that make up an image – to a numerical digital value to deal with. The algorithm detects image features such as edges, textures, and shapes. As the network deepens, it identifies more complex patterns (Purwono et al., 2022).

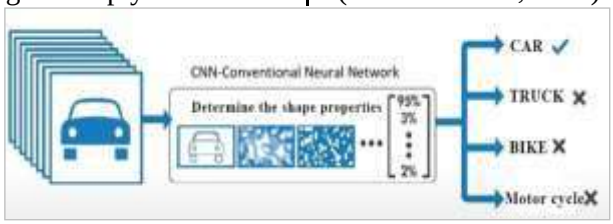

Fig. 5 – Image recognition concept by CNN-Conventional Neural Network

3. Converting text to image

The (DALLE-2) model is responsible for converting a text prompt to an image as explained in Figure 4. The conversion concept depends on two phases. Firstly, coding the written text by assigning digital values for each word (Text coding). Secondly, converting image pixels into digital values (Image coding) and then linking the two codes that have numerical values to each other (Marcus et al., 2022). Achieving this link is performed by another learning model called

(CLIP), which works to link text coding to image coding (Feng et al., 2024).

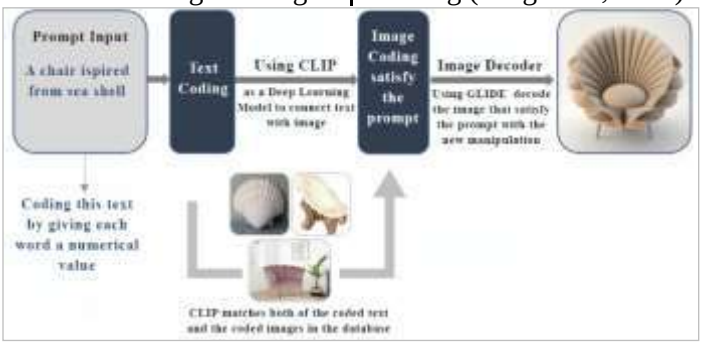

Fig. 6 – Text to image workflow

CLIP model is an abbreviation for (Contrastive Language–Image Pre-training) and was released in 2021(Feng et al., 2024). It is one of the deep learning models that rely on neural networks and was trained using a large number of data that is available online. This data was derived from the captions on photos as these were used as a database for this model to learn through (Sarker, 2021a)

All of these learning models were provided by (Open AI), which is an American non-profit organization for artificial intelligence aiming to develop and direct artificial intelligence in a way that benefits humanity (Mhlanga, 2023).

4. Experimental AI Designs

These design experiments were held through a session as two users entered the website at the same time and applied the same design style option. The same written text was used as an input at the same time. The generated images were different from the following figures.

4.1 First Trial

In the first trial, the written text was a general description consisting of two words (Parametric armchair). The results are shown in Figure 7.

Fig. 7 – AI-generated designs for the first trial

The analysis for this trial is presented within two aspects functional and aesthetic.

• On the functional aspects, the design proportions are acceptable and close to the common. There is a lack of stability for both designs. They need to be modified to achieve balance. Considering the mass production, these designs can manufactured after modifications concerning the design outline to be stable on the floor. Molding injection is the recommended production technique for such a form. The molding injection depends on granules of resin that are fed through a hopper to the injection piston to fill in a clamped mold cavity as shown in Figure 8 (Czepiel et al., 2023).

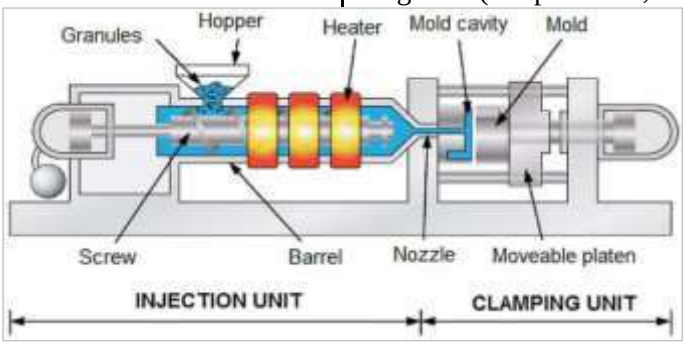

Fig. 8 – Molding injection process

• On the aesthetic aspects, the design lines are fluent and dynamic providing a visual harmony that creates a sense of elegance and fluidity, contributing to the overall beauty of the chair. They often evoke feelings of comfort and sophistication, making the chair visually appealing in various settings.

4.2 Second Trial

In the second trial, the written text consisted of two words (Biomimicry armchair). The results are shown in Figure 9.

Fig. 9 – AI-generated designs for the second trial.

• On the functional aspect, the design does not support sitting properly, especially the support for the lower back area. As for mass production, it is difficult to keep up with other highly mass-produced seats because of the crafted form. Overlapping fine details are possible through bamboo weaving craft. The bamboo basket chair sample is similar to these ideas. It emerged from a collaboration between the Japanese-American sculptor (Isamu Noguchi) and the Japanese industrial designer (Isamu Kenmochi). Noguchi drafted the ideas that were incorporated into the design shown in Figure 10 (Schwendener, 2007).

Fig. 10 – Noguchi and Kenmochi chairs

• On the aesthetic aspect, symmetry prevails in both designs, especially in design (A), while the lines for design (B) need to be refined and connected properly. The designs have a monotonous rhythm.

4.3 Third trial

In the second trial, the written text consisted of three words (Contemporary modern armchair). The results are shown in Figure 11.

Fig. 11 – AI-generated designs for the third trial.

- On the functional aspects, the design proportions are acceptable. The designs are familiar and the form is a pre-existing design. The capabilities of AI to have a new unexpected form are intangible, these designs can be easily manufactured.
- On the aesthetic aspects, the design lines are straight with a chamfered wooden structure giving a simple and contemporary feeling with no sophistication, making the chair visually appealing and authentic.

5. Designer's questionnaire

Through the previously presented theoretical background and the design experiment and analysis of the 3D models. A questionnaire for (100) designers who worked in Damietta and Cairo governorate's industrial market with at least one year of experience. The questionnaire presented AI

designs as shown in Figure 12. The questions mainly focused on:

- Designer's opinion on the form.
- Technical aspects for the designs.
- Influence of AI on designer's capability.
- Profession future concerning AI.

Fig. 12 – Questionnaire presented Ai designs.

6. Results

The questionnaire results for the designers were Collected, summarized, and presented as shown in Table 2. The level of experience ranged from one year up to more than five years as the following:

- From 1 but less than 3 years (30%).
- From 3 but less than 5 years (60%).
- From 1 but less than 3 years (10%).

According to their job responsibilities, 60% of the questionnaire sample worked in the design office, while 30% worked in the technical office. Only 10% worked in quality control.

Table 2. Questionnaire results.

Question	Statistics	
	Agree/ I do	Disagree / I do not
Do the AI designs need refinement and reformat?	75%	25%
Are all the presented designs able to be manufactured?	80%	20%
Does the AI technology replace the designer's skills at the moment?	5%	95%
Do you use AI as an inspiration for your designs?	15%	85%
Do you think that AI can help designers to present their sketches?	70%	30%

7. Conclusion

Through the presented application and questionnaire results about the technology and its applications concerning furniture design practices and the future of the profession for the designer, we can conclude the following:

- Artificial intelligence is a technology that is incorporated in design practices today mandating the designer to understand its potential and capabilities.
- Many platforms support the design service by relying on artificial intelligence technology. These designs are initial ideas that need further

design studies and refinement to be manufactured.

- Through the questionnaire, we find that designers are fully aware of the value and importance of design sciences related to furniture design and the importance of these sciences for manufacturing furniture products.

8. Recommendations:

Finally, the presented results provided up-to-date insights about AI applications and advantages. The recommendations for designers and academic institutions are as follows:

- The designer needs to start learning AI tools to facilitate the design process and push the boundaries as it will soon be a thriving need, not an option.
- Follow up on AI technologies and their impact on the industry to get ready for a new era of design technologies.
- Educational institutions must adopt and apply AI technology with an approach that does not compromise the designer's skills and innovation. Students at level four can make use of the technology as they already have gained and practiced design basics. The tool is used for visual studies and not for imitation and copying.

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