Artificial Intelligence in Architecture: Integration into Architectural Design Process

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Abstract: Recently, Artificial Intelligence (AI) has permeated diverse sectors, revolutionizing various aspects of human's life by automating tasks traditionally performed by humans. This includes manufacturing automation, certain educational methodologies, and the dynamics of social media. However, despite these advancements, there are still domains where AI struggles to fully emulate human capabilities, notably **creativity**, a unique human attribute. Architects can leverage AI technologies to streamline their work, handling non-creative tasks efficiently and allowing more time for innovative processes. Despite the wealth of data AI generates within seconds, many architects and designers remain unfamiliar with integrating AI into their processes. Through a comprehensive study of AI, including its patterns, decision-making processes, data-related predictions, and event presentations, it becomes clear that AI can significantly contribute to various phases of architectural design process, benefiting from its continuous learning capabilities, self-evolution, and performance enhancement.

This research aims to formulate a framework that delineates the integration of AI and its patterns in reshaping and enhancing the different phases of the architectural design process, focusing on accomplishing non-creative tasks, ultimately saving valuable time and effort. This, in turn, can support architects within the creative process, idea development, and achieving optimal results while presenting innovative designs.

That, grounded in a theoretical framework that illuminates relevant literature related to AI, its diverse types, and patterns. Additionally, it delves into a meticulous examination of the design process stages within the context of AI's capabilities, boundaries, and its impact on the architect's role. Highlighting culminates for the proposal of conceptualized AI system designed to function as an architectural assistant. This system utilizes various AI patterns based on their specific goals and capabilities, thereby providing comprehensive support throughout the architectural design process.

Keywords:

Artificial Intelligence (AI)- Creativity- Architectural Design Process- AI Patterns.

1- Artificial Intelligence (AI):

Artificial Intelligence (AI) is characterized by the capability of digital machines and computers to execute specific tasks that mimic the cognitive functions of the human mind and intelligent entities. These tasks encompass a range of abilities, including thinking and learning from past experiences, emulating various mental processes. The overarching objective of artificial intelligence is creation of systems endowed with intelligence, mirroring human-like learning and comprehension. Such systems aspire to offer diverse services to their users, spanning education, guidance, interaction, and beyond. (wenjun & malaeb, sep 2019)

1-1-Definitions and Concepts in the Field of Artificial Intelligence:

- **Artificial Intelligence:**

Artificial Intelligence (AI) is succinctly defined as "a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Haenlein, Kaplan, Tan , & Zhang , 2019). Artificial intelligence emerged in the 1950s, marking its evolution as a vital branch of data science with the overarching goal of constructing machines capable of emulating human thought processes. This journey ranges from basic expressions to intricate models, showcasing AI's capacity to progressively think and adapt like humans.

- **Machine Learning:**

Machine Learning is a specialized field within artificial intelligence that endeavors to empower machines with the capability to "learn" and autonomously enhance their performance. This is accomplished through the implementation of algorithms designed to discern patterns and generate insights from the data provided to them. It finds application in decision-making processes, future predictions, and problem-solving, eliminating the necessity for explicit programming.

Fig (1) Difference between artificial intelligence, machine & deep learning, data science
Source: https://www.datacamp.com/blog/how-to-learn-ai

Positioned as a subset of both artificial intelligence and data science, machine learning exemplifies the evolution of intelligent systems capable of independent learning and adaptive problem-solving. (Campesato, February 13, 2020).

- **Deep Learning**:

It is a subset of machine learning, representing one of the most advanced branches within the realm of artificial intelligence. This sophisticated approach empowers machines to emulate human learning and cognition, necessitating a complex structure that mirrors the neural networks
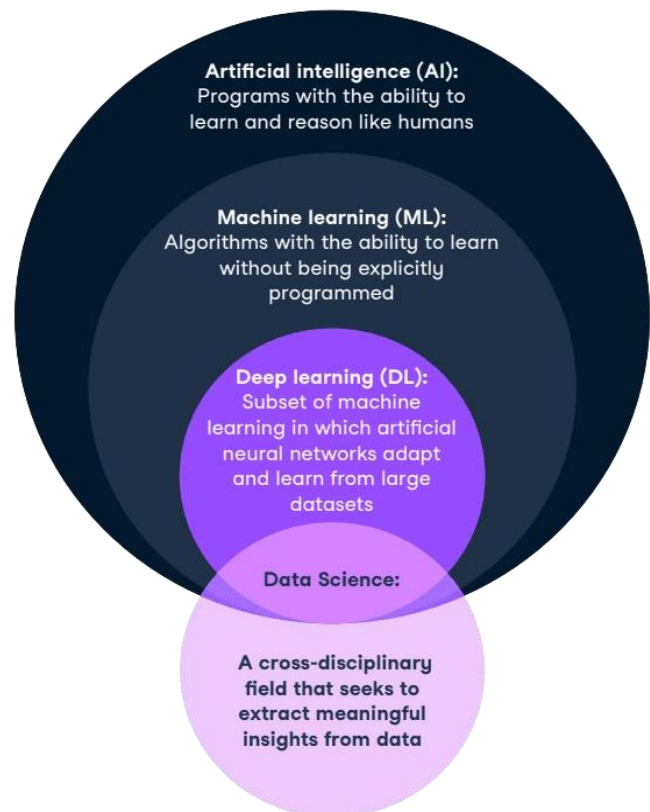
found in the human brain. The primary objective of deep learning is to comprehend intricate patterns, even when faced with noise and incomplete details.

- **Data Science:**

Data Science is a discipline focused on extracting valuable insights from available data. Employing rigorous analytical methods, data science engages with both structured and unstructured data. It serves as a vital tool for uncovering essential information from vast datasets, often stored in repositories, by processing and analyzing the data. (Campesato, February 13, 2020).

1-2- Types of Artificial Intelligence:

Artificial intelligence is classified based on its capabilities and the functions it performs, it can be classified into three different types based on its capabilities, as well as into four types based on the functions it performs and its decision-making abilities (Khan, 2021), as shown in figure (2).

BASED ON CAPABILITES

BASED ON FUNCTIONALITIES

NARROW AI

This type of AI is designed for specific tasks and is limited in its abilities. It excels in one domain or task but lacks general intelligence.

GENERAL AI

General AI, in contrast to narrow AI, possesses human-like intelligence and can perform a wide range of tasks and understand information in a manner like humans.

SUPER AI

This type of AI may surpass human-level intelligence and perform tasks better than experienced human experts. It is characterized by the ability to learn, communicate autonomously, and make judgments. However, Super AI does not currently exist.

REACTIVE MACHINES

That type of AI has no memory, and the task is specific. It does not tell previous experience and works only with predefined single logic. they do not store previous memory to implement previous experience. Moreover, it is purely reactive and does not utilize pest experience.

LIMITED MEMORY

That type of AI system has limited memory that can be referenced to future decisions. It is one kind of machine learning model that especially learns from facts and events.

THEORY OF MIND

This is psychological terminology. This social intelligence is applied to understand emotions. It predicts the behavior of human reactions. Computers are equipped with all types of emotions to read the human mind. It does not exist.

SELF - AWARENESS

This is the application of common sense by the machine. All the predefined data is stored in the system, so whenever it needs action, it works automatically. This type of AI does not exist.
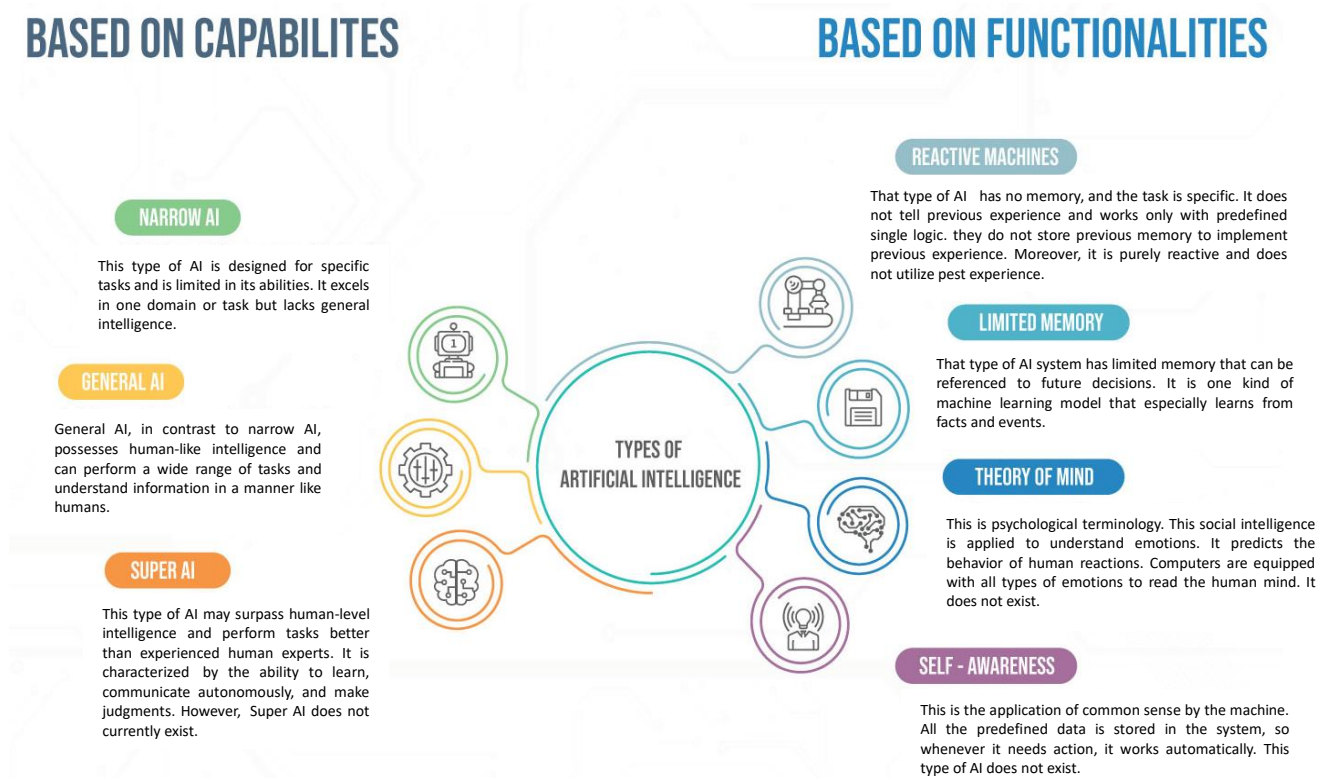
TYPES OF ARTIFICIAL INTELLIGENCE

Fig (2) Artificial intelligence is classified based on functionalities and capabilities
Source: Khan, Hanif. (2021). Types of AI | Different Types of Artificial Intelligence Systems fossguru.com/types-of-ai-different-types-of-artificial-intelligence-systems. 9. 50.

1-3- Applications of Artificial Intelligence:

AI applications often rely on the application of heuristics, which is essentially a "rule of thumb" for solving a problem. In other words, it is a set of guidelines that often works to solve problems. Such problems tend to be large and computationally complex, and frequently they cannot be solved via straightforward algorithms. Additionally tend to embody a large amount of human expertise, especially if tackled by strong AI methods. Some types of them are better solved by using AI technique, whereas others are more suitable by traditional computer science approaches

involving simple decision making or exact computations to produce solutions. (Campesato, February 13, 2020) . Here we are some few examples:

- **Genetic Algorithms:** They are a specific methodology from the general field known as evolutionary computation, which is a branch of AI wherein proposed solutions to a problem adapt similarly as animal creatures adapt to their environments in real world. Prescribed sets of rules to solve a problem and whose output is entirely predictable.
- **Knowledge representation:** AI systems that acquire and store knowledge to process it and produce intelligent results also need the ability to identify and represent that knowledge considered as an issue of representation becomes important when we consider AI related problems. The choice of a representation is intrinsic to the nature of problem solving and its understanding.
  - Logic- based solutions: AI researchers have used a logic-based approach for knowledge representation and problem-solving techniques. These applications encompassed issues of understanding language and scene analysis as well as other AI aspects.
  - Semantic networks: Another graphical representation of knowledge. Much of the work employing semantic networks has focused on representing knowledge and structure of language.
- **Expert Systems:** Designed to solve complex problems by emulating the decision-making abilities of a human expert in a specific domain. They use knowledge base and inference engine to make decisions.
- **Neural Computing Networks:** it's a subset of AI that mimic the structure and function of the human brain, used in deep learning and pattern recognition tasks.
- **Evolutionary computation**: It is not solely concerned with optimization problems; it relies upon the use of heuristics and representational paradigms. It allows machines to interpret and understand visual information from the world, such as images and videos.
- **Natural Language Processing (NLP):** NLP focuses on enabling machines to understand and interact with human language. It is used in chatbots, language translation, and voice recognition systems.
- **Reinforcement Learning AI:** This application of AI learns through trial and error, receiving feedback and rewards for its actions. It is commonly used in applications like game playing and robotics.

These different types and applications of AI serve various purposes in architectural design and can be applied to tasks ranging from data analysis to generative design and decision-making processes (Zheng & Yuan, 2021).

2- The Patterns of Artificial Intelligence (AI):

Artificial Intelligence (AI) manifests through seven recurring patterns that are employed in various combinations within its systems. These patterns are leveraged either individually for specific use cases or in combination to achieve desired outcomes in AI and machine learning systems. Understanding these seven patterns provides insights into how to effectively apply

them, contributing to the realization of ultimate goals in the realm of artificial intelligence and machine learning. As shown in figure (3)

The seven patterns are diverse and adaptable, reflecting the multifaceted nature of AI applications. By comprehending and strategically applying these patterns, developers and practitioners can navigate the complexities of AI systems, tailoring their approaches to specific needs and objectives. The versatility of these patterns allows for innovation and customization, paving the way for advancements in AI and contributing to the realization of its full potential.
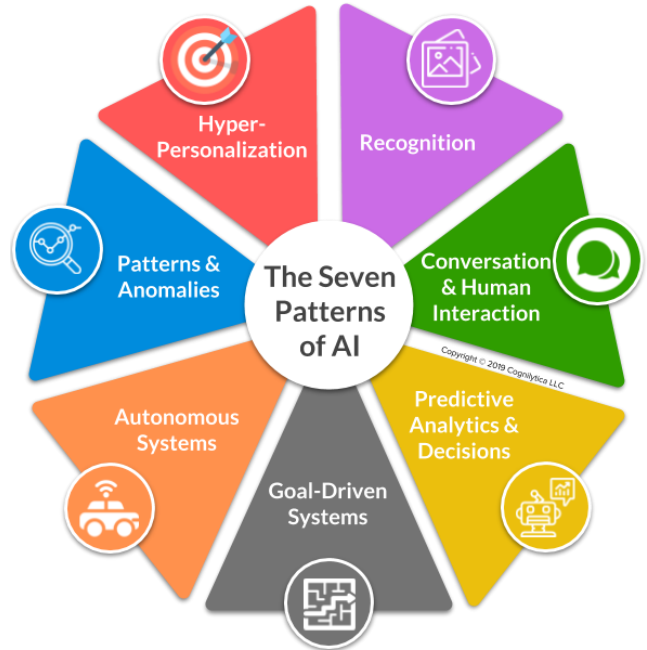
Fig (3): The seven patterns of Ai

Source: https://www.forbes.com
accessed oct 15, 2023.

2-1- Hypersonalization Pattern: Treat each customer as an individual:
The Hypersonalization Pattern involves utilizing machine learning to construct an individualized profile for each user, enabling the profile to continuously learn and evolve over time. This pattern serves various purposes, such as presenting tailored content, suggesting related products, and providing personalized recommendations.

The main goal of the Hypersonalization Pattern is to treat each person as a seperate and unique individual. This approach users machine learning algorithms to analyze user behavior, preferences, and interactions, allowing the system to understand and adapt to each user's specific needs and interests. (Walch , 2019)

2-2-Autonomous Systems Pattern: Reducing the need for manual labor:
The Autonomous Systems Pattern involves the integration of software, hardware, and virtual systems with the ability to complete tasks, interact with the environment, and achieve goals with minimal human intervention. This pattern is based on the application of machine learning processes, allowing the system to autonomously understand its environment, predict the future behavior of external elements, and plan how to navigate and interact with these variables.

The overall goal of the Autonomous Systems Pattern is to leverage technology and automation to reduce reliance on manual labor and promote efficiency and autonomy in accomplishing of tasks and goals. (Walch , 2019).

2-3-Predictive Analytics & Decision Support:
Predictive analytics and decision support patterns use machine learning and cognitive techniques to analyze past or current behavior, predict future outcomes, and help people make decisions based on those patterns. The emphasis is on Unlike the autonomous systems pattern, where machines perform tasks and decisions independently of each other, this pattern relies on human input in decision-making, but provides important support to improve the decision-making process. This approach, often referred to as "intelligence augmentation," aims to improve human efficiency without replacing human participation.
The overarching objective of the Predictive Analytics & Decision Support pattern is to empower humans with advanced insights derived from data analysis, fostering improved decision-making across various domains while leveraging the adaptive capabilities of machine learning. (Walch , 2019).

2-4-Conversational Pattern: Machines that can communicate as humans do:
Conversation patterns revolve around the interaction between machines and humans through various forms of conversation and communication such as voice, text, illustrations, and images. This pattern involves two-way interaction, where both machines communicate with humans and vice versa. The overall goal of Conversation Patterns is to bridge the gap between humans and machines in terms of communication. This fosters more natural and effective information exchange, supports applications such as automated chatbots, content generation, and language translation, and improves human-machine interaction. (Walch , 2019).

2-5-Pattern & Anomaly Detection:
Patterns and Anomaly Detection Patterns harness the power of machine learning to identify patterns in your data and detect anomalies. "Pattern matching" is a widely used technique in artificial intelligence projects, and its effectiveness is increasingly recognized. Pattern and Anomaly Detection The overall goal of patterns is to leverage machine learning capabilities to efficiently identify patterns, differentiate between anomalies, and derive meaningful insights from data. It has wide applications in various fields and contributes to improved decision making, improved risk management, and detection of fraud in large datasets. (Walch , 2019).

2-6-Recognition Pattern:
The Recognition Pattern represents a significant stride in machine learning, particularly with the integration of deep learning to enhance accuracy in tasks related to recognition or the identification of objects. This pattern involves the use of machine learning and cognitive methods to discern meaningful entities within unstructured content, spanning images, videos, audio, text, or other forms of data.
The Recognition Pattern stands as a testament to the capabilities of machine learning, particularly deep learning, in enhancing accuracy and expanding the range of applications in diverse recognition tasks. (Walch , 2019).

2-7-Goal-Driven Systems:
Goal-driven system patterns leverage the power of reinforcement learning and other machine learning techniques to equip systems with the ability to simulate scenarios, address recurring problems, and provide real-time offers and auction bids. Although not as widely used as other

patterns, it is rapidly gaining traction due to its potential to be applied to learning through experience and trial and error.

Goal-oriented system patterns contribute to the evolving landscape of AI implementation with a focus on experiential learning and optimal solutions. (Walch , 2019). Although the patterns above identify different goals for using AI, each project or implementation is likely to exhibit one or more of these patterns. In fact, most advanced AI applications combine patterns to achieve desired results. It is important to be aware of which patterns are being used because they determine how projects are executed and managed to achieve these goals. (Walch , 2019).

3- Artificial Intelligence and Architectural Design Process:

The integration of Artificial Intelligence (AI) into the architectural design process represents a transformative approach, empowering architects with advanced tools and capabilities. In architectural design, AI serves as a valuable ally, facilitating the creation of diverse design variations and generating unique concepts by leveraging algorithms and inputs defined by architects. This partnership with AI positions it as a supportive tool that architects can employ to address the ever-evolving demands of their work.

3-1- Impact of Artificial Intelligence on the Role of the Architect in the Design Process:

Inarguably, advanced artificial intelligence (AI) design systems can learn design behaviors, yet the architect's role remains vital in selecting the most suitable solution among numerous alternatives (Cudzik & Radziszewski, 2018). While AI can generate various creative design solutions, discerning between good and bad results poses a challenge. Evaluation involves two stages:

- Objective evaluation: Depends on mechanical laws and self-logic based on culture and aesthetics. Strict mechanical laws allow the AI to evaluate this.
- Subjective Experience Rating: Requires human intervention initially. Results can be added to a database and AI evaluation tools can be created by applying AI algorithms. (Wang, Cai , & Tian, 2018)

It is premature to assert that AI will replace the architectural profession. Architects continue to control the design process at every stage, choosing alternatives and posing questions AI should answer. Designers' roles remain crucial as they are responsible for balancing various factors in the design process (Borglund , 2022).

Soon, AI's role will be that of an assistant to architects, capable of solving specific problems defined by the architect. Advanced AI systems cannot replace humans as architects; they can assist in creating varied solutions but cannot make final decisions. The architectural engineer's aspirations for creativity and control over the design environment are limitless. Hence, designers must embrace significant differences between previous digital technologies and the new AI methods applied in architectural engineering. (Gallo & wirz, 2020).

3-2-Limitations of Artificial Intelligence in Architectural Design:

Artificial intelligence (AI) can serve as an invaluable tool for architects due to its capacity to analyze vast datasets (Borglund , 2022). Researchers recognize the evident constraints imposed on AI in creative endeavors. Given that AI learns from input data, any errors in the data directly impact the results (Wang, Cai , & Tian, 2018). Thus, while AI can assist humans in swiftly understanding the world and predicting possibilities based on this foundation, it remains incapable of true creativity and innovative thinking within the realm of architectural engineering.

This is primarily because architectural engineering is an intricate practice, unlike a specific question with a single correct answer or choice. The architectural process encompasses numerous factors such as human elements, politics, social sciences, engineering constraints, environmental standards, and art, all contributing to design choices(Gallo & wirz, 2020), These factors infuse buildings with a soul, a quality that cannot be solely created by AI but relies on the practices and visions of architectural engineers.

Therefore, it can be asserted that AI has a role in the design process, simulating various design alternatives and processing vast amounts of data to retain and verify required parameters like material use, energy consumption, exposure to light, noise exposure, and more (Borglund , 2022). However, it cannot achieve the essence of buildings on its own. Consequently, it remains crucial to consider creativity in the development of artificial intelligence applications (Haenlein & Kaplan, 2019)

4- Architectural Design Process Stages in the Light of Artificial Intelligence:

The role of artificial intelligence (AI) in the redesign and execution of the architectural design phase can be formalized by building AI systems. The system helps architects complete the design process with expected efficiency while saving time, effort, and resources. It is particularly characterized by continuous learning, which enables self-improvement and improves performance and results.

However, it is essential that the architect leverages relevant domain expertise and actively participates as an integral member of the team building this system.

4-1-Pre-design Stage:

This stage can be defined as the architectural programming phase, where the research and decision-making processes shape the scope of the intended design work. It involves outlining project requirements and goals, identifying stakeholders, and creating a roadmap for the design process. The utilization of artificial intelligence in architectural programming aids in saving time, obtaining more accurate data, and consequently, crafting a superior product.

- **Stage 1 (Defining the Design Problem):** During this stage, the problem and the primary goal of the project are identified, followed by a comprehensive understanding of all its aspects. This involves grasping the nature of the project, discerning client requirements, determining the project's scale, and detailing all tasks until project completion.
- **Role of Artificial Intelligence:** Artificial intelligence can identify, aggregate, and categorize various data types, discovering possible relationships between datasets and issuing recognizable results (Borglund , 2022). By employing a combination of integrated artificial intelligence patterns, this stage can be efficiently completed, encompassing the following:
  - ➢ **Hypersonalization Pattern**: This pattern provides comprehensive information about the project, similar projects, user preferences, customer needs, and available technology.
  - ➢ **Pattern & Anomaly Detection**: This pattern searches for relevant references to the project and identifies recurring patterns for such projects, assisting in determining recurring advantages and problems.
  - ➢ **Predictive Analytics and Decision Support**: This pattern assists in creating data models for project parameters (environmental, natural, urban, economic, social, etc.). It aids in exploring missing data and predicting future outcomes, facilitating better decision-making and optimal selection.

- ➢ **Recognition Pattern**: Utilizing natural language processing (NLP), this pattern helps provide comprehensive information about proposed solutions to the studied problem.
- **Stage 2 (Data and Information Documentation):** In this stage, the study of existing buildings, structures, and designs takes place to gather information, inspiration, and ideas beneficial for the design process of a new project. This type of research involves examining the work of other architects, analyzing design decisions that have been made, and understanding the various factors that influenced those decisions to create an enlightened new design that meets the specified needs and requirements of the proposed project. This stage is crucial, as architects utilize it to develop a design rooted in the context of the surrounding environment, responsive to user needs, and enlightened by the latest technological and material advancements.
- **The Role of Artificial Intelligence:** Artificial intelligence contributes by analyzing vast amounts of project-related data, employing machine learning algorithms to make design choices based on real and reliable data (Cudzik & Radziszewski, 2018). Through the integration of various artificial intelligence patterns, this stage can be accomplished seamlessly. These patterns include:
  - ➢ **Hypersonalization Pattern**: Using this pattern, architects can streamline the architectural programming process and gain deeper insights into their clients' needs and preferences.
  - ➢ **Pattern & Anomaly Detection**: This pattern provides an analysis of relationships between different architectural program elements, identifying potential conflicts or contradictions. For example, an artificial intelligence system may be capable of pinpointing instances where the size or location of a specific area conflicts with the requirements of a particular function or activity. This assists designers in making better decisions regarding building configurations, unit mixes, and other key aspects of building design.
  - ➢ **Recognition Pattern**: Artificial intelligence and machine learning aid in providing comprehensive information about similar architectural projects, their elements, and the technologies utilized. It also simplifies the process of gathering architectural precedents by classifying and sorting all images. This makes it easier to efficiently categorize images and leverage them later in the design process.

4-2- Design stage:

The design phase constitutes the second stage in the architectural design process. It involves the development of conceptual plans for the building layout, form, and function. During the design phase, expectations encompass creating design alternatives, evaluating precedents, and existing designs, refining the design, and generating a foundational set of architectural drawings. The information extracted from the preceding stages serves as inputs for this phase.

- **Stage 3: Design Requirements (Development of Design Idea):** In this stage, the design concept is refined, and detailed design drawings are prepared to illustrate both 2D and 3D design solutions. Additionally, space allocation, design patterns, and the selection of construction systems and materials are specified and allocated.
- **The Role of Artificial Intelligence:** A set of artificial intelligence patterns can be relied upon to accomplish this stage. This is achieved by integrating script-based artificial intelligence programs into generative design tools, creating detailed conceptual images, and simulating various design alternatives. (As, Pal, & Basu, 2018). This allows architects and

designers to convey their ideas more effectively to clients, facilitating decision-making regarding all details early in the design process. this stage can be accomplished seamlessly. These patterns include:

- ➢ **Pattern & Anomaly Detection**: This pattern aids in recognizing recurring patterns from previously input parameters in the results of the preceding stages. It utilizes this data, transforming it into parameters to generate various types of outputs, allowing architects to select their design outputs.
- ➢ **Predictive Analytics and Decision Support**: This pattern assists in simulating and analyzing design alternatives, comparing them based on criteria such as efficiency, functionality, and aesthetics. This makes it easier for architects to filter the best decisions and choose promising options for further improvement.
- ➢ **Recognition Pattern**: This pattern provides simulation of numerous design alternatives in a short time. Artificial intelligence can be used to create detailed 3D models of buildings and environments, extending to integrate time, cost, environmental analysis, and building lifecycle management. This facilitates architects in envisioning and evaluating design options, as architects need inspiration through exploring multiple choices—an essential element in the creative process.

- **Stage4: Design Development Stage:** At this stage, the review and approval of the design plans take place, along with the preparation of executive drawings and detailed specifications that will be used for the construction of the building or project.
- **The Role of Artificial Intelligence**: In this stage, two patterns of artificial intelligence are employed. This involves creating more detailed and precise drawings of the design concept that was developed during the previous stage, as follows:
  - ➢ **Goal-Driven Systems:** This pattern assists in ensuring that the proposed design achieves the required goals and standards.
  - ➢ **Recognition Pattern**: This pattern provides the necessary data and information to create detailed schematics of the proposed design. Subsequently, the machine learning model can be trained on a large dataset of floor plans and corresponding features. This enables the model to generate new floor plans based on a set of input parameters.
- **Stage 5: Planning Stage (Review and Approval of Design Plans):** In this stage, ensuring that the proposed design complies with all relevant regulations and laws is carried out. Additionally, it involves addressing the needs and requirements of the client, reviewing the documents, and obtaining approval from the relevant authorities and stakeholders.
- **The Role of Artificial Intelligence:** Like the mentioned uses in the pre-design stage, text-based artificial intelligence can assist in tasks such as scheduling, document management, and project progress tracking (Chaillou, 2019), This is achieved by leveraging a variety of its patterns.
  - ➢ **Goal-Driven Systems:** This pattern aids in analyzing data from previous projects to determine cost, timelines, and predict the requirements of future projects. This helps ensure the accuracy and completeness of specifications, saving a significant amount of time.
  - ➢ **Recognition Pattern**: This pattern assists in completing design documents by recognizing similar details in the database and utilizing them.
  - ➢ **Autonomous Systems Pattern:** Self-operating systems help in finalizing design documents, starting from hand-drawn sketches and data, transforming them into detailed execution drawings and comprehensive design documents.

> ➢ **Predictive Analytics and Decision Support**: Machine learning algorithms can be utilized to provide estimates for project duration, resources, and expected budget requirements.

The three previous stages together form a critical part of the architectural design process, where artificial intelligence can significantly enhance efficiency, creativity, and the decision-making process.
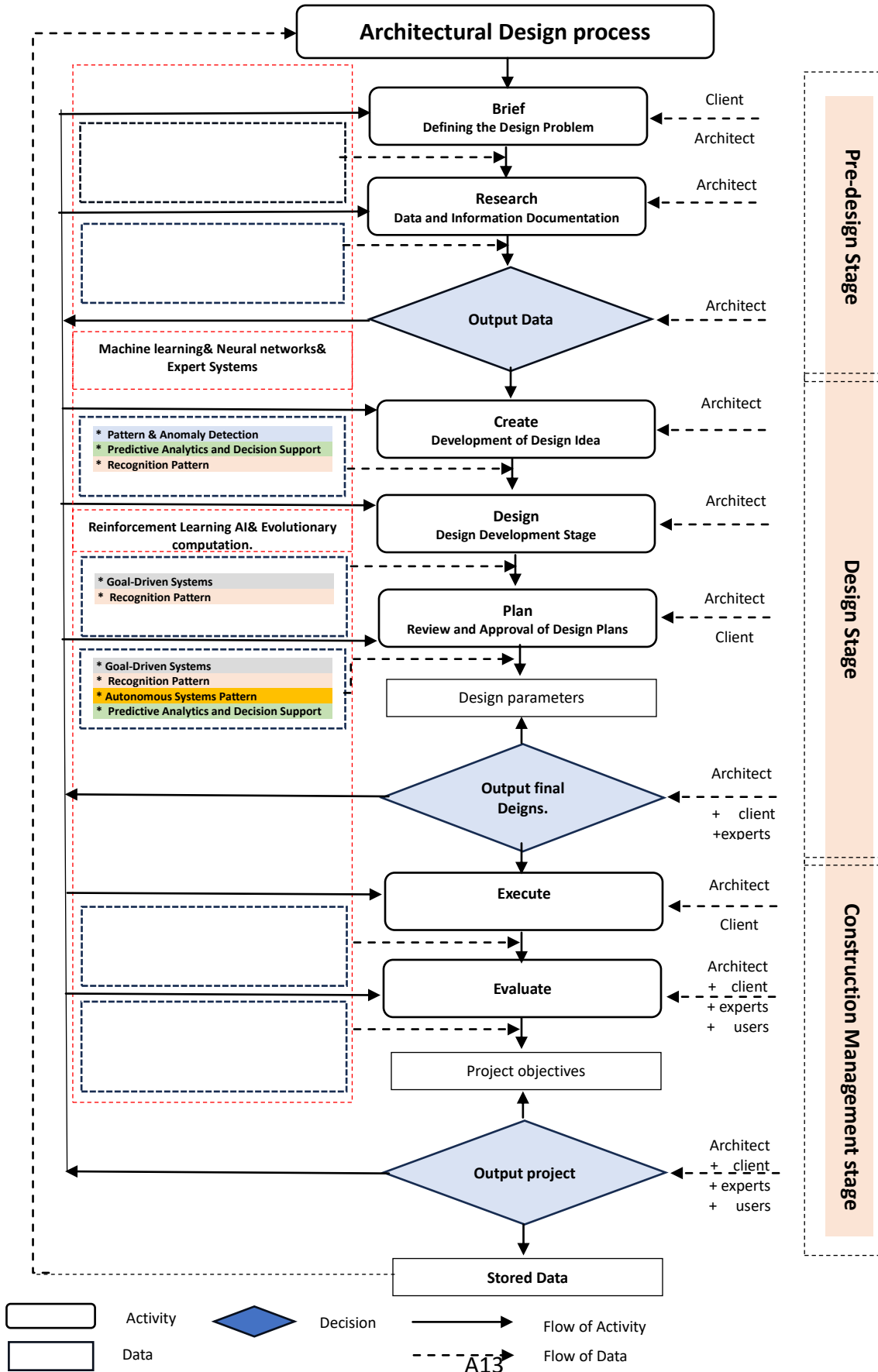

4-3-Construction Project Management:

The Construction Management phase is the final stage of the architectural engineering process, involving supervision of the construction of the building or project to ensure it is built according to the plans and design specifications. During the Construction Management phase, the architect will regularly visit the construction site to monitor progress, ensuring it aligns with the design plans and specifications. They review and approve the execution drawings and material samples, addressing any problems or conflicts that may arise during construction.

In general, the Construction Management phase aims to ensure that the final project meets the design intent and fulfills the needs and requirements of the client.

- **Stage 6: Execution Stage**: In this stage, everything previously planned is put into action, and work schedules are sequenced correctly. Potential and anticipated problems are identified and addressed before they arise.

- **The Role of Artificial Intelligence:** Artificial intelligence can be utilized in this stage by analyzing data from previous projects to make predictions about the feasibility and execution capabilities of the proposed project. It can also help identify potential risks that may be encountered during the implementation process, such as the possibility of construction delays or cost overruns (Rao, 2022), by leveraging a variety of its patterns.:

  > ➢ **Autonomous Systems Pattern:** This pattern enables the monitoring of construction errors, production issues, and on-site safety concerns. For instance, robots can routinely capture three-dimensional images, compile site assessments, and generate quick, accurate reports that can be automatically linked to the project plan. This saves time, money, and effort. Moreover, self-driving construction equipment can be employed to perform repetitive tasks such as drilling, bricklaying, concrete pouring, rebar bending, welding, and more.

  > ➢ **Goal-Driven Systems:** This pattern can be utilized by simulating workplace scenarios to manage various construction components and in the human resource management of the project. Using data recorded from previous projects helps estimate the workload, facilitate workflow, update project sequencing, and manage tasks while keeping all project stakeholders constantly informed about the project status.

  > ➢ **Predictive Analytics and Decision Support**: This pattern enhances foresight into future projects, allowing for the early detection of risks and faster responses to emerging challenges during the implementation process. Dealing with these challenges promptly ensures that they do not impede project completion or compromise its quality.

- **Stage7: Evaluation Stage:** In this stage, a post-occupancy evaluation is conducted, gathering all data related to the end-users of the building (feedback loop).

- **The Role of Artificial Intelligence:** Artificial intelligence can be utilized to aggregate extensive data on the actual usage, needs, and behaviors of end-users in the building. This aids in developing new algorithms that can be applied in future projects, (Navarathna & Malagi, 2018). This is accomplished using a range of integrated AI patterns:

- ➢ **Hypersonalization Pattern**: This pattern determines the impression formed by users about the project through a series of surveys directed at the end-users of the building.
- ➢ **Conversational Pattern:** This pattern aids in building communication programs with users to understand their opinions about the building, its usability, and how well it meets their needs.
- ➢ **Autonomous Systems Pattern:** This pattern can conduct assessments through images and videos captured using mobile devices, drone footage, security sensor data, Building Information Modeling (BIM), and other sources to identify deficiencies and features.
- ➢ **Predictive Analytics and Decision Support**: This pattern provides the aggregation and analysis of extensive data on the actual usage, needs, and behaviors of end-users in the building. This helps build new algorithms that can be used in future projects. Each construction site becomes a potential source for artificial intelligence data. This provides an opportunity for clients and professionals in the construction sector to study and benefit from insights derived from the use of artificial intelligence and machine learning systems.
- ➢ **Recognition Pattern**: This pattern, through advanced analytics and artificial intelligence-supported algorithms, helps form useful insights about the operation and performance of a building. As a result, artificial intelligence can be used to identify problems before they become serious and predict the necessary preventive maintenance schedules.

Fig (4) Shown the Framework for integration the role of AI and its patterns in reshaping and practicing the phases of architectural design process.

Architectural Design process

Brief
Defining the Design Problem
Client
Architect

Research
Data and Information Documentation
Architect

Output Data
Architect

Machine learning& Neural networks&
Expert Systems

Create
Development of Design Idea
Architect

* Pattern & Anomaly Detection
* Predictive Analytics and Decision Support
* Recognition Pattern

Reinforcement Learning AI& Evolutionary
computation.

Design
Design Development Stage
Architect

* Goal-Driven Systems
* Recognition Pattern

Plan
Review and Approval of Design Plans
Architect
Client

* Goal-Driven Systems
* Recognition Pattern
* Autonomous Systems Pattern
* Predictive Analytics and Decision Support

Design parameters

Output final Deigns.
Architect
+ client
+experts

Execute
Architect
Client

Evaluate
Architect
+ client
+ experts
+ users

Project objectives

Output project
Architect
+ client
+ experts
+ users

Stored Data

Pre-design Stage

Design Stage

Construction Management stage

Activity
Data
Decision
Flow of Activity
Flow of Data

A13

5- Conclusion:

In summary, incorporating AI into the architectural design process represents a paradigm shift in which technology collaborates with human creativity. Architects benefit from synergies by using AI as a tool to explore, optimize, and overcome design challenges in dynamic and innovative environments. The result is a harmonious fusion of human ingenuity and technical ability in the field of architectural creativity. Integrating artificial intelligence (AI) into architectural design has led to many achievements, including:

- **Assisting Architects with Data Processing:** AI helps architects collect and process large amounts of data, generate multiple variables, and extract thousands of unique models and designs through architect-specified algorithms and inputs. However, the creative process remains only in the realm of the human mind.

- **Contribution of AI Algorithms to Design Interpretation:** AI algorithms contribute to interpreting the behavior patterns and preferences of architects through stored data, producing unique and non-repetitive designs to create a customized experience for each architect.

- **Enhancing Efficiency Across Architectural Design stages:** AI patterns and applications can help architects complete various stages of the design process with desired efficiency, saving time and effort from pre-design to design, construction, construction management, and post-occupancy evaluation., save costs.

- **AI Patterns Enhancing Efficiency in Architectural Design stages:** While AI patterns enhance the efficiency of architectural design phases, the continuous evaluation by design process stakeholders (architects, owners, users, experts, etc.) is essential at decisions and control are necessary at every stage of the project.

- **Significant Role of AI in Architectural Design stages:** AI plays a key role in all stages of the architectural design process. However, it cannot serve as an assessment tool or decision-making aid. These aspects remain the domain of the human mind.

- **AI Will Not Replace Architects:** AI will not replace architects but can be used as an assisting tool throughout the design process.

6-Recommendations:

- Integrating AI learning into architecture curricula: It is recommended that AI learning and the study and use of AI applications related to architectural design be integrated into the curriculum of architecture universities and institutes of architecture in Egypt.

– Promoting a culture of AI use. It is essential to spread the culture of using AI as a tool in the architectural design process to students and practitioners.

– Architects must learn and leverage new AI technologies to maintain their professional reputation.

– Using AI in design firms allows design and engineering consulting firms to integrate AI patterns and applications into the design process of each project to save time and effort and avoid run-time errors., thereby significantly facilitating and controlling all design process activities.

– It is essential to build an integrated AI strategy for architectural design by developing a comprehensive strategy for the use of AI technology in architectural design through complementary research that takes into account all relevant details.

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الذكاء الاصطناعي في العمارة: التكامل في عملية التصميم المعماري

ملخص: في الآونة الأخيرة، تغلغل الذكاء الاصطناعي (AI) في قطاعات متنوعة، وأحدث ثورة في مختلف جونب الحياة واستبدال البشر بالآلة من خلال أتمتة المهام التي يؤديها البشر تقليديًا. ويشمل ذلك أتمتة التصنيع، وبعض طرق التعليم، وديناميكيات وسائل التواصل الاجتماعي. وعلى الرغم من هذه التطورات، إلا أنه لا يزال هناك الكثير من المهام لم يستطع الذكاء الاصطناعي السيطرة عليها: وعلى رأسها **الإبـــــداع،** الذي يتفرّد به الإنسان. يستطيع المعماريون الاستفادة من تقنيات الذكاء الاصطناعي في تسهيل عملهم، وإنجاز المهام غير الإبداعية بمساعدة تلك التقنيات، وذلك لتوفير الوقت والجهد لإتمام العمليات الإبداعية من ابتكار وتطوير. على الرغم من ثروة البيانات التي يولدها الذكاء الاصطناعي في غضون ثوانٍ، إلا أنه لا تزال هذه العملية غير مألوفة لأغلب المعماريين والمصممين والمخططين. وبدراسة الذكاء الاصطناعي وأنماطه، واجراءات عمله واتخاذه للقرارات، والتنبؤ بالنتائج والتطورات المرتبطة بالبيانات والأحداث المعروضة عليه؛ اتضح أنه قد يُساهم بدور فعّال ومساعد للمعماري في ممارسة أغلب مراحل عملية التصميم المعماري. حيث إنه يتميز بالتعلم المستمر، مما يجعله يتطور ذاتيا ويحسن من أدائه.

يهدف هذا البحث إلى صياغة إطار لتقنين دور الذكاء الاصطناعي وانماطه في إعادة صياغة وممارسة مراحل عملية التصميم المعماري، وإنجاز المهام غير الإبداعية مما يوفر الكثير من الوقت والجهد. ويساعد المعماري في عملية الابداع وتطوير افكاره، والوصول لأفضل النتائج وتقديم تصميمات مبتكرة.

يرتكز البحث على إطار نظري يسلط الضوء على الأدبيات ذات الصلة بالذكاء الاصطناعي وأنواعه وأنماطه المتنوعة، ودراسة مراحل العملية التصميمية في ضوء الذكاء الاصطناعي وحدوده وامكانياته وأثر ذلك على دور المعماري، حيث توصل البحث إلى وضع تصورُ مقترح لتقنين دور الذكاء الاصطناعي كمساعد للمعماري في تأدية عمله، يعتمد في المقام الأول على تطبيق أنماط الذكاء الاصطناعي المختلفة- تبعا لأهدافها وقدراتها، وبالتالي توفير الدعم الشامل طوال عملية التصميم المعماري.

الكلمات المفتاحية: الذكاء الاصطناعي – الإبداع – عملية التصميم المعماري – أنماط الذكاء الاصطناعي