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THE USE AND DEVELOPMENT OF ARTIFICIAL INTELLIGENCE IN ARCHITECTURAL DESIGN PROCESSES

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Abstract: Artificial intelligence is widely used as an interactive technology in various professional disciplines. The widespread use of these technologies, which we benefit from in most areas of our lives, in the education sector will provide important developments in the field of education. The main purpose of this study is to analyze the existing studies in which the use of artificial intelligence helps in architectural design processes. In the study, identification, screening, eligibility, inclusion, and data analysis processes were carried out in three search engines such as Web of Science, ScienceDirect, and ULAKBIM. While reporting the research, 'Systematic Literature Review' and 'Preferred Reporting Items for Meta-Analysis' protocols were followed and a total of 35 relevant articles were identified. In the research, three popular Artificial Intelligence applications used in architectural design processes were identified as Generative Adversarial Networks (GAN), Machine Learning, and Data Mining. In addition, Systematic Literature Review (SLR) outputs show that most researchers are supported by artificial intelligence applications in architectural design processes. As a result of the research, it was determined that artificial intelligence is widely used in architectural design processes, however, it has positive effects in 3D and animation parts.

Keywords: Artificial intelligence, Architectural design processes, Landscape architect

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1. Introduction

Today, artificial intelligence applications offer the ability to quickly and efficiently analyze the relationships between complex problems that require high computational power, thereby enabling the development of various strategies for the future. Due to these features, artificial intelligence applications are considered fundamental tools in many disciplines (Figure 1). Through various devices and applications, these technologies serve humanity in many fields. Examples of artificial intelligence technologies include chatbots, virtual assistants like Siri, Alexa, Google AI, and autonomous cars. Despite their widespread use in daily life, it can be said that the number of people who understand the applications and concepts behind artificial intelligence technologies is deficient. The widespread use of these technologies, which we benefit from in many areas of our lives, has led to significant advancements in the education sector (Tazefidan et al., 2022)

According to Teymur (1998), "Design is highly variable, multi-given, multi-faceted, multi-subjective, and therefore multi-disciplinary and multi-contextual." Due to the multifaceted nature of design, design-focused paradigms have begun to be developed.

In the field of design, designers often rely on their own experiences to solve the problems they encounter throughout the design process, and when they feel inadequate, they seek expert opinions to find solutions. This process can lead to a waste of time, as well as result in faulty decisions due to various shortcomings. However, a well-designed artificial intelligence application can significantly contribute to both speeding up the process and making healthier decisions for the future. With the developing world, it can be seen that the concept and field of design are becoming increasingly complex. Although there are countless indicators of design, it is quite difficult to define its boundaries. It is possible to see design in every area and every detail of life. However, it is difficult to define the boundaries of design. In this case, the question of what art is or is not may also bring along an approach to what design is or is not (Akdemir, 2017).

The use of artificial intelligence techniques in architectural design processes is not limited to accelerating thinking and reasoning processes; it also significantly contributes to the learning of various types and amounts of information that are desired to be achieved Austin et al. (1999). Methods such as machine learning and data mining, considered subfields of artificial intelligence, have paved the way for the emergence of the concept of big data, alongside the increase in computational power of computers and advancements in storage capacity.

Figure 1. Areas of application where AI methods are available (Tazefidan et al., 2022).

These methods have contributed to the formation of self-learning systems through algorithms developed by utilizing this data. Today, especially in fields such as computer science, engineering, medicine, and statistics, studies have popularized the use of these techniques in solving many problems and have enabled the discovery of new methods. In the international literature, over the past five years, the number of studies encompassing artificial intelligence-based applications such as data mining, image processing, machine learning, and fuzzy logic has been rapidly increasing across all disciplines. This trend is also clearly observed in the statistics obtained from the Web of Science, SinceDirect, and ULAKBİM databases in Table 4. the developments in artificial intelligence technologies have raised concerns that the need for human labor will decrease across many disciplines, leading to negative scenarios such as unemployment. Similar concerns are being expressed in the field of architecture, with suggestions that artificial intelligence (AI) could displace designers and architects from their jobs (Karslı, 2019).

However, AI and smart algorithms provide significant contributions across a wide range of areas, from generating building forms and plans to calculating construction costs, and from producing facade designs to making structural system decisions, thanks to the various solution alternatives they offer to designers. For example, AI can design facades using image processing methods and classify complex urban data with data mining techniques (Sönmez, 2018; Chaillou, 2019; Bingöl et al., 2020; Çalışır Adem, 2020). Additionally, machine learning methods allow for the creation of more user-friendly and effective architectural designs by analyzing user experience data (Şapcı and Taşlı Pektaş, 2021).

In this context, it is understood that AI applications play a significant supportive role in design processes, rather than completely sidelining human labor, and offer innovative approaches to solving design problems. It is observed that AI is positioned as a supportive tool for human creativity in creative disciplines such as architecture, thus enhancing human labor rather than replacing it, making it more efficient and effective. This situation suggests that AI can be seen as an element that will empower human designers in the field of architecture, rather than posing a threat to them in the future (Deveci, 2022).

In his work titled "Age of Design," Conklin (2001) argues that we are in a transition period from the age of science to the age of design. Conklin argues that for the past two centuries, we have focused on explaining the natural world through science and that we process and transform these explanations with technology, thus clearly living in a scientific era. However, it argues that the problems of time cannot be solved with scientific facts, definitions, and perceptions.

Hobday et al. (2012) argued for a reevaluation of the widespread applications of design theories, such as those of Hatchuel, and their relationships with the economy and innovation.

The stages of architectural action that can be traditionally defined consist of four phases: decision, design, implementation, and usage. One of these stages, design is a creative process carried out to find a solution to a specific need or problem. In this process, an objective and aesthetic formation emerges as a result of the interaction between sensory and mental information.

Design encompasses the transformation of ideas into a tangible product, structure, or system, taking into account criteria such as aesthetics, functionality, ergonomics, and innovation (Akdemir, 2017).

Predictions regarding architectural design processes are defined as challenging decision-making processes. In these complex problem areas where uncertain information is present, landscape architects increasingly need to adopt different methods from traditional design approaches to make quick decisions with a low error rate and to adapt to the dynamic changes in the parameters of the design problem.

The literature reviews on the subject are as follows;

The advancements in technology, the increase in environmental concerns, and the growing demand for speed driven by a fluctuating economy are leading to an increase in uncertainty and the expectations and requirements from designs are rapidly diversifying. Artificial intelligence programs can combine spatial and attribute information in such an environment, utilizing multiple spatial criteria to present the most suitable options for design.

AI provides countless benefits in architectural design decision support systems, design models (Bozdemir, 2005; Jaihar et al., 2020; Rego et al., 2021), smart spaces (Mueller and Ochsendorf, 2015; Bozdemir, 2017), environmentally sensitive structures (Güneş, 2016; Tushar et al., 2018), and product selections (Jin et al., 2016; Ding and Liu, 2007; Ireland and Liu, 2018; Das et al., 2019).

The use of AI in these areas provides significant contributions to supporting design decisions, ensuring energy efficiency, developing sustainable architectural solutions, and creating user-centered spaces. In particular, AI technologies provide significant advantages in areas such as environmentally friendly structures and smart spaces by optimizing energy consumption and minimizing environmental impacts (Baydoğan, 2013). In this context, AI technologies can process data from different disciplines using big data analysis and machine learning techniques, contributing to better design decisions.

Focusing on methodology in design research has become a priority to develop solution mechanisms for increasingly complex design problems. Studies that seek answers to the questions of how knowledge is created, used, and communicated have led to the systematic implementation of decision-making in the design process. These studies have enabled the development of methods that allow for decision-making based on the time and conditions in which the design problem exists. In conclusion, artificial intelligence offers a wide range of benefits for creating decision-support mechanisms in architectural design, developing design models, constructing smart spaces and environmentally sensitive structures, and making informed product choices.

The concept of artificial intelligence was first brought to the forefront at the Dartmouth Conference in 1956 and has been defined as encompassing all human abilities related to thinking, reasoning, perceiving objective realities, and concluding (Moor, 2006). Artificial intelligence refers to the efforts to create computer models that can think like humans, reason, perceive, move, learn, and produce results by utilizing the knowledge and experience they possess to solve problems. In this context, artificial intelligence has begun to play an important role by establishing a rational foundation for solving design problems and enabling more conscious, objective decisions regarding the products presented. The use of computer models, in addition to traditional systems in design, offers suitable solutions through algorithm-based methods for well-defined problems. Additionally, artificial intelligence is applied as expert systems to generate solutions and make recommendations in the resolution of poorly defined design problems and in areas that require specialized knowledge.

In the decision-making stages of architectural designs, various artificial intelligence algorithms such as artificial neural networks, expert systems, genetic algorithms, and fuzzy logic are utilized. Artificial intelligence programs are preferred more in the field of architectural design because they are algorithms that can produce results similar to those in human decision-making processes, unlike classical logic. In this regard, the literature examining traditional decision-making processes and artificial intelligence-based decision-making processes have been reviewed, and compared, and the advantages and disadvantages have been highlighted.

Design can be defined as the process through which something that is planned takes shape in the human mind as a result of various steps. This concept, in terms of its literal meaning, includes elements such as design, planning, shaping, and structuring, but it is difficult to provide a comprehensive definition of this concept. In various studies, design is defined as a solution plan or an idea aimed at addressing any problem (Demirarslan, 2006). In this context, the concept of architectural design is expressed as the determination and documentation of the structure that will fulfill specific functions based on a particular requirement, along with all the elements involved in the design (İzgi, 1999).

Louis Kahn, one of the famous architects of the 20th century (1901-1974), emphasizes with his statement, "Design is the production of form within a system," that the design process involves not only intuition but also a certain order (Conrads, 1991). As many designers have pointed out, the built environment that emerges as a result of the design process takes shape as a sequence in which events are repeated in chronological order, and although the products may differ, the process itself carries certain patterns. The understanding, development, and elimination of randomness in successful design products began with the first studies on the analysis of the design process through the Design Methods Movement. The members of this movement

have tried to examine how the designer thinks and acts by focusing on the organizational structure of the process. Jones, one of the pioneers of the movement stated that there are three fundamental stages in the design process (Jones, 1980):

- ➢ The "Analysis Stage," where the problem is defined
- ➢ The "Synthesis Stage," where the solution is created
- ➢ The "Evaluation Stage," where the developed solution is determined

These stages can be referred to as a flowchart of the design process, which is noted to be repeated in all design applications (Cooper, 1995).

The concept of design practice has evolved today, and designers no longer just create products; they have begun to design experiences, societies, and systems (Stewart, 2011). For this reason, designers are expected to solve complex design problems at a global or local level in a multidisciplinary and collaborative work environment, which requires them to be experts in many areas. As a result, the design discipline has become a multidisciplinary field, with designers starting to play a mediating and facilitating role among other disciplines (Trummer and Lleras, 2012). This situation has led to the collaboration of design with other disciplines.

Engineering and business have been integrated into design education, and collaborative programs have been established between design and other disciplines. For this reason, there has been an increase in pursuing graduate education in design, particularly in "business and design, design and engineering programs, or integrated undergraduate programs (such as design engineering) (Trummer and Lleras, 2012). For example, Rensselaer Polytechnic Institute (RPI) offers a Bachelor of Science degree in Design, Innovation, and Society (DIS), and Gazi University has an Industrial Design Engineering program, while Özyeğin University offers a graduate program in Design, Technology, and Society. These are a few of the interdisciplinary programs that encompass the field of design.

The interdisciplinary approach becoming a focal point in design education has also been observed in changes within educational institutions. Aalto University was established as Finland's first interdisciplinary university as a result of the merger of the Helsinki School of Economics, Helsinki University of Technology, and The University of Art and Design Helsinki (Restarting Britain Report, 2011). Therefore, interdisciplinary approaches in design education have been framed within the context of creating new programs, renewing curricula, or establishing institutions that provide design education with a different understanding.

The use of artificial intelligence (AI) in solving complex design problems like architecture can be evaluated from various perspectives. AI is a powerful tool for facilitating interaction among different stakeholders in design processes and managing large amounts of interdisciplinary information. For this reason, three research questions are presented below specifically aimed at assisting AI technology in architectural design:

- ➢ What types of Artificial Intelligence (AI) are used in the architectural design process?
- ➢ What types of technology are used in the architectural design process?
- ➢ What are the types of parameters for Artificial Intelligence (AI) in the architectural design process?

2. Materials and Methods

The research method has been determined as a Systematic Literature Review (SLR). The SLR method can be described as a process that, while reviewing the existing literature in a more organized manner employs systematic, transparent, and replicable techniques at every stage to fully explore and evaluate the relevant research (Higgins et al., 2011; Munn et al., 2018). A systematic literature review (SLR) validates existing practices, addresses methodological and conceptual differences, identifies emerging trends, explores and encourages future research directions, identifies and analyzes inconsistent findings, and develops recommendations that contribute to decision-making processes (Munn et al., 2018).

This study aims to determine the place of artificial intelligence, whose popularity has increased especially in recent years, in the architectural design literature, analyzes studies found in national and international literature, and systematically reviews existing articles related to the research subjects of Architectural Design and Artificial Intelligence (AI) learning. The current SLR has gathered primary literature by conducting literature reviews of articles published in journals indexed in SCI, SCI-Expanded, SSCI, and AHCI. Additionally, the ScienceDirect website, Web of Science, and ULAKBIM search engines have been identified as the materials for the research. The ScienceDirect website offers features that encourage visitors to explore the universe of scientific articles (Tober, 2011).

After formulating the research questions, keywords to be used in search engines to find relevant journal articles have been determined. To ensure that all relevant articles were included in the data, the query was performed without any time constraints. The appropriate keywords obtained from the title for conducting the review are artificial intelligence, architectural design, landscape design, and artificial intelligence in architectural design. Later, these keyword terms were combined with the Boolean operators "OR" and "AND" to create a search string for use in the definition process, and Table 1 summarizes the literature search plan. To facilitate the extraction of relevant journal articles, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol was implemented by following the flow diagram (Mohamed Shaffril et al., 2021; Ha-Mim et al., 2024).

It is a protocol aimed at explaining the purpose of a research study and summarizing its analytical and methodological strategy before conducting the research (Moher et al., 2015). PRISMA aims to enhance accuracy, and transparency, and reduce reporting errors in systematic review reporting (Liberati et al., 2009). The four stages of the protocol are identification, screening, eligibility, and inclusion.

2.1. Description

Three main search engines were used for scanning the relevant articles: Web of Science, ULAKBIM, and ScienceDirect. These databases offer many options to customize search results. While searching for articles related to the SLR title, the keywords in Table 1 were taken into consideration. At this stage, only keywords have been taken into account to generate search engine results. The first criterion in selecting the articles was the examination of the abstracts. The search results for Web of Science have been identified as 719, while the search results for ScienceDirect have been identified as 2141. A total of 2,860 results need to be examined. However, since the search engine provided a limited number of articles, a snowball strategy was employed to access as many documents as possible (Wohlin et al., 2022).

Table 1. Keywords used for AI application in architectural design

Keywords	Strings and combinations of keywords
Artificial intelligence	Artificial Intelligence or Yapay Zekâ
Landscape Architecture	Landscape Architect or Landscape
Architectural design	Architectural design or Mimari tasarım

2.2. Screening

This stage was carried out by removing duplicates from the results obtained in the identification phase. Out of a total of 2,860 results, 236 findings were identified as duplicates according to the PRISMA protocol technique and were removed (Figure 2).

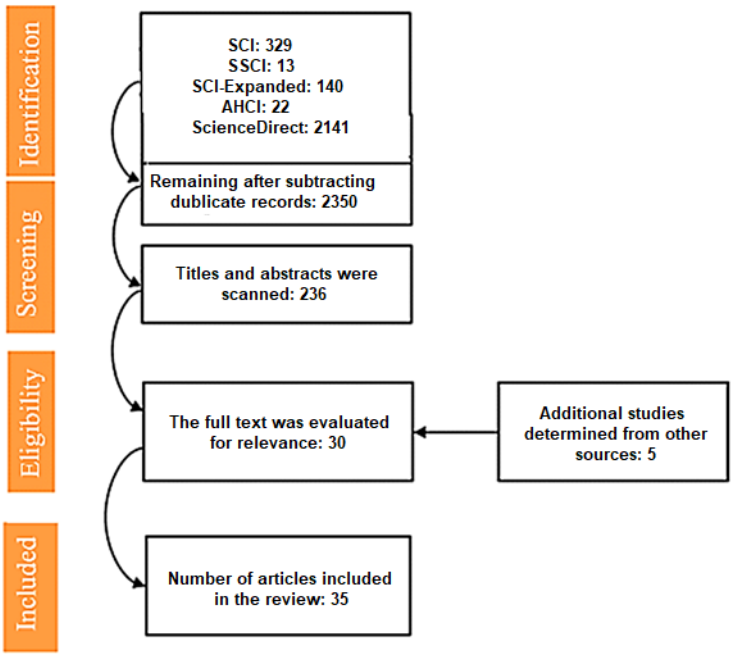

Figure 2. PRISMA protocol.

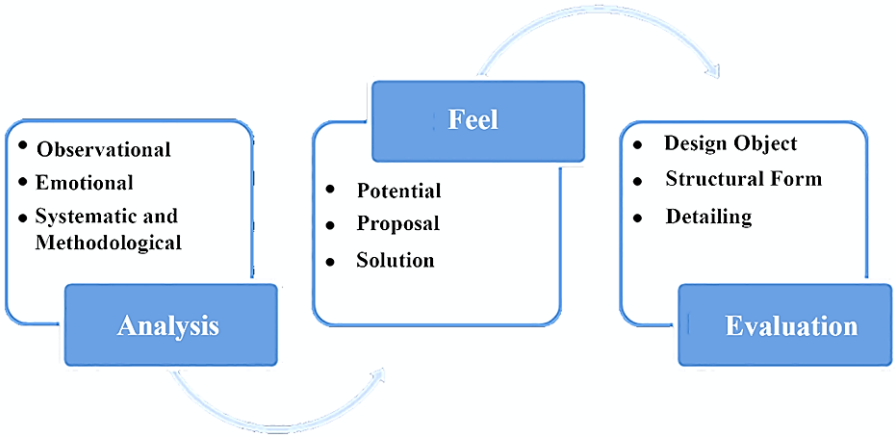

Figure 3. Flowchart of the architectural design process. (Jones, 1980, Baran et al., 2022).

Table 2. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Article title and content	Suitable title and met the requirements of the study	Irrelevant title and did not meet the requirements of the study
Publication Type	Original works and journal articles only	Reviews, editorials, and non-empirical studies
Language	English	Other languages
Article workspace	Architectural design	Fields other than architectural design
Accessibility	Full-text articles	Preview articles and those requiring payment or subscription

The remaining results were then reviewed, and those that did not meet specific criteria such as article title, publication year, document type, language, and accessibility of the articles were excluded. In terms of article titles, they should be related to artificial intelligence in the context of architectural design. Since the chosen topic is related to architectural design, a wider range of fields such as science, technology, engineering, or mathematics has been encountered as the main components of the articles. To ensure that the data is collected from the most recent studies, it has been stipulated that the articles must be published between 2020 and 2024, as artificial intelligence technology is continuously evolving rapidly. In terms of document type, only articles published in academic journals have been selected, while book chapters and conference papers have been excluded. Additionally, the selected articles are written in English, which is a universal language globally recognized as the language of science. Articles published in various languages have also been encountered in the literature. Only articles with full-text access have been selected. Therefore, at this stage, a total of 35 results have been obtained.

2.3. Elimination

This stage was carried out by removing articles that did not meet the criteria from the results obtained in the screening phase. Out of 2,860 results, 295 duplicate findings were identified and removed according to the PRISMA protocol technique (Figure 3). The remaining results were later reviewed, and articles that did not fully meet the requirements based on the article title, publication year, document type, language, and accessibility criteria were excluded. For the titles, it should be related to the use of AI in architectural design. Since the chosen topic is related to architectural design, a broader range has been found among architecture, technology, or design as the main components for the articles. Additionally, due to the rapid and continuous development of AI technology, the articles must have been published between 2020 and 2024 to ensure that the data collected from previous studies is up to date. As a type of document, articles published in scientific journals have been selected, excluding book chapters and conference reviews. In addition, the selected articles are written in English, a universal language, which has allowed access to articles written in various countries. Additionally, only articles with full-text access have been selected. The evaluation process has been carried out for all three search engines used. For this reason, a total of 2409 results have been eliminated at this stage.

2.4. Inclusion

During the process of scanning the full texts of the studies, a technique called backward and forward citation tracking was used, which led to the discovery of 8 additional relevant studies. These eight studies have been found relevant and have been added to the currently established pool of 35 studies. The data sources have been collected through secondary data sources. Examples of secondary data sources include journals, books, documents, reports, and similar items. Journal articles have been chosen as the data source for this SLR. The reason for this is that journals provide a more up-to-date perspective compared to other sources and therefore serve as a reliable source of information. Figure 3 summarizes the inclusion and exclusion criteria.

2.5. Data Analysis

To complete the literature review, relevant findings and information obtained from previous studies were collected and utilized to answer the research question. This review aims to combine and connect the findings of numerous articles, as well as to seek methods for advancing previous research. The inter-rater agreement was evaluated for the excellent coding of the reviewed articles to further support the validity of this SLR. Additionally, thematic analysis has been conducted; this is a technique for identifying patterns or themes in qualitative data. (Nowell et al., 2017). The Included studies have been sorted before being added to the total of 35 publications from which the data were selected. Research articles published in various parts of the world have been gathered to gain a broad perspective. Additionally, all summary sections such as the introduction, methods, results, and discussion have been carefully examined to obtain the desired information to answer the research questions. Such results have been labeled as qualitative data used in this SLR to evaluate summaries and explanations. Later, to validate the current study's validity, two separate authors categorized the themes by classifying them according to their partnerships or interests. A total of 35 articles related to the research were read, and three main categories were identified, followed by a coding process. These categories have been defined as types of artificial intelligence, the technology used, and enhanced parameters (Table 2).

3. Results

Architectural design is a dynamic discipline that continuously evolves and adapts to contemporary approaches, thanks to its deep-rooted traditions, diverse design methods, and the wealth of knowledge accumulated over the years. This flexibility also allows the design to be influenced by technological advancements. Artificial intelligence applications that model human behavior are increasingly offering new technologies that enhance, facilitate, and transform quality of life. The ability of artificial intelligence to quickly analyze complex design problems that require high computational power and to provide future solution alternatives makes significant contributions to the field of architecture. In this context, this study aims to provide a literature-based general review of artificial intelligence-based solutions in architectural fields and applications.

In the methodology section of the study, all scientific works focusing on the concepts of artificial intelligence, architectural design, and landscape architecture were obtained through a literature review method by scanning the designated databases. These studies have been classified into two different categories based on whether the topics examined are directly included in the title or addressed within the content of the study, and they are presented in Table 2 and Table 3. The purpose of creating these tables is to quantitatively highlight the importance of the concept of artificial intelligence in scientific studies conducted over the past five years. Table 2 presents the thesis studies conducted in the last five years regarding the use of artificial intelligence in the context of architectural design in Türkiye. These theses are categorized according to their objectives, based on the contributions and suggestions that artificial intelligence provides in solving structural design problems and addressing issues encountered in the architectural design process. Table 3 lists the studies categorized under artificial intelligence in architectural design within the Web of Science database.

Table 3. Categories of research questions

Research Question	Category
What are the types of Artificial Intelligence (AI) used in the architectural design process?	• Generative Design • Machine Learning • Neural Networks • Natural Language Processing • Computer Vision • Robotic Process Automation (RPA) • Computer Aided Design (CAD) • Building Information Modelling (BIM) • Rendering and Visualisation Technologies • Virtual Reality (VR) and Augmented Reality (AR) • 3D Printers
What are the types of technology used in the architectural design process?	• Artificial Intelligence (AI) and Machine Learning • Photogrammetry and Lidar Scanning • Cloud Based Collaboration Platforms • Drone Technology
What are the types of Artificial Intelligence (AI) parameters in the architectural design process?	• Design Parameters • User Experience Parameters • Performance Parameters • Cost Parameters • Environmental Parameters • Optimisation Parameters • Design Automation Parameters

3.1. Descriptive Results

Figure 4 shows the prevalence of AI topics related to architectural design as extracted from the literature. In this study, the researchers categorized AI topics into 11 different areas: Artificial Neural Networks (ANN), Game Theory and Simulation, Data Mining, Genetic Algorithms, Intelligent Systems, Image Processing, Deep Learning, Machine Learning, Generative Adversarial Networks (GAN), Natural Language Processing (NLP), and Project-Based Learning (PBL). Among the studies related to AI, GAN emerges as the most frequently studied topic (N=19 or 45%). Later, Data Mining (N=5 or 12%), followed by Machine Learning (N=4 or 10%), Image Processing (N=3 or 7%), Artificial Neural Networks (ANN) (N=3 or 7%), and Deep Learning (N=2 or 5%) come next. Finally, only a few studies have been conducted in the fields of Game Theory and Simulation, Intelligent Systems, and Genetic Algorithms with ANN, NLP, and PBL (N=1 or 2%). Image processing is another field of artificial intelligence that helps computers identify objects in videos or images, aiding in the perception of these objects.

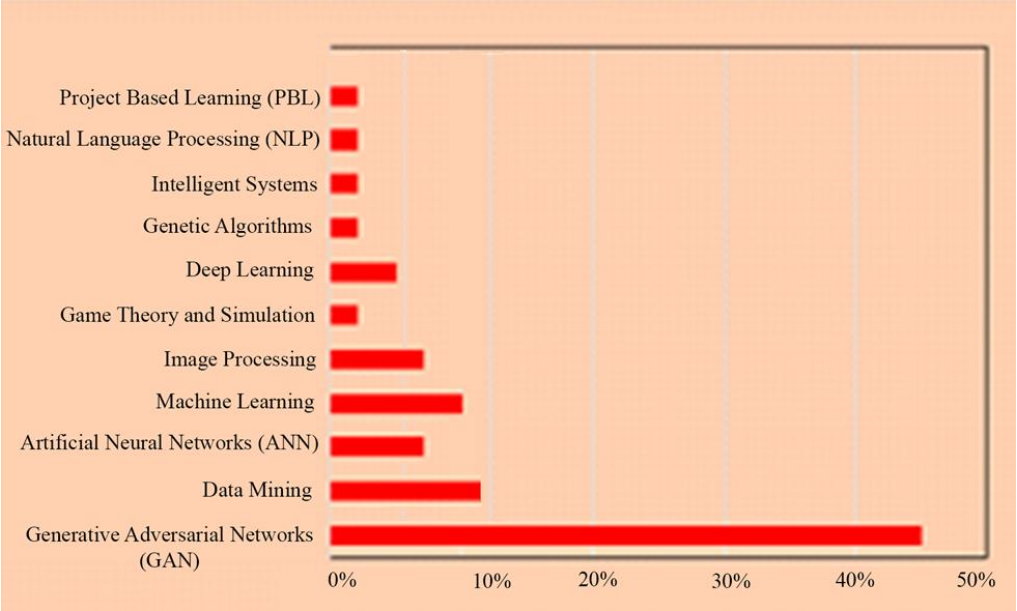

Figure 4. Distribution of AI topics.

This method aims to understand and interpret visual data by mimicking how humans perceive it. Image processing is widely used in various fields such as security, the military industry, medicine, robotics, art, and remote sensing. On the other hand, fuzzy logic is a field of artificial intelligence that aims to think like humans and process these thought processes by converting them into mathematical functions.

Fuzzy logic is a method that combines decision-making processes based on situations where clear predictions are not possible and where different aspects infringe upon each other's boundaries with artificial intelligence. This method aims to transform raw data in large datasets into meaningful insights and informed decisions. The integrating algorithm-based approaches from these artificial intelligence applications into architectural design processes will significantly enhance the analysis of data with intensity, diversity, and scale that designers may find challenging (Çeliker et al., 2020)

3.2. Types of AI Used in the Architectural Design Process

The distribution of articles according to the types of AI applied in the research is shown in Table 4. the table shows that 45% of the articles use Generative Adversarial Networks, indicating that designers are utilizing AI technology primarily for architectural rendering and to quickly present multiple design variations. Such AI applications are generally used to help the user save time and generate suggestions for the designer with a multitude of design options.

11 studies (31%) have used GAN; this means that the program used by the producer to generate more realistic images is directly related to the design of a model or algorithm, along with its own characteristics and technical knowledge. 5 articles (%15) have used Machine Learning; this means that these studies indicate the user's ability to prefer AI technology in terms of material selection and energy efficiency. This type of AI typically uses Decision Trees and Support Vector Machine (SVM) technologies. Five articles (15%) have utilized Data Mining with AI; this means that these studies have employed AI technology in topics such as Urban Planning and Building Placement.

This type of AI typically uses data analysis tools and clustering algorithm technologies. The remaining articles utilized additional artificial intelligence (AI) technologies represented by smaller percentages in the table: Artificial Neural Networks (12%), Image Processing (9%), Intelligent Systems (6%), project-based learning (3%), Game Theory and Simulation (3%), Genetic Algorithms (3%), Deep Learning and Natural Language Processing (NLP) (3%). Figure 4 shows the types of artificial intelligence used in design processes.

3.3. Types of Technology Used in the Architectural Design Process

These studies are very powerful and creative models capable of producing realistic data. This model uses AI technologies for image synthesis and enhancement. According to Table 4, 31% of the studies (11) used competitive producer network-based AI technology. This means that AI can quickly create architectural renderings and design variations in a computer environment using this method. 15% of the studies (5) used Support Vector Machines; this means that these studies made material selections and ensured energy efficiency. Support Vector Machines, characterized by a supervised architecture, are powerful classification and regression method. 15% of the studies (5) used data analysis tools or clustering algorithms; this is the task of obtaining useful data sets from large-scale data and ensuring their security. It is also recognized as part of the information discovery process. It can also be defined as the search for relationships that enable us to make predictions using computer programs within large data sets.

Table 4. AI summary

No.	Yazar	AI Türleri	Kullanılan Teknoloji Türleri	Parametre Türleri
1	Aeron et al. (2024)	Machine Learning	Decision trees, Support Vector Machines (SVM)	Material selection, energy efficiency, project forecast
2	Amer (2023)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
3	Başarır (2021)	Deep Learning	Neural networks, Convolutional Neural Networks (CNN)	Structural analysis, design optimization
4	Bingöl et al. (2020)	Image Processing	Image processing algorithms, camera technologies	Structural analyses, design evaluation
5	Ji and Levinson, (2020).	Game Theory and Simulation	Simulation software, game engines	Architectural design simulations, interactive design
6	Chaillou (2019)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
7	Çeliker et al. (2020)	Image Processing	Image processing algorithms, camera technologies	Structural analyses, design evaluation
8	Demirci and Yabanova (2019)	Image Processing	Image processing algorithms, camera technologies	Structural analyses, 9design e10valuation
9	Deveci (2022)	Machine Learning	Decision trees, Support Vector Machines (SVM)	Mat11erial selection, energy efficiency
10	Deveci, M. (2022).	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
11	Dym (1996)	Artificial Neural Networks (ANN)	Multilayer Perceptron, Recurrent Neural Networks (RNN)	Space analysis, user behavior
12	Goel et al. (2024)	Intelligent Systems	Rule-based systems, expert systems	Design advice, project management
13	Hayes-Roth, B. (1995)	Intelligent Systems	Rule-based systems, expert systems	Design advice, project management
14	Hornick et al. (2010)	Data Mining	Data analysis tools, clustering algorithms	Urban planning, building layout
15	Karahan et al. (2023)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
16	Kaya and İnce (2012)	Artificial Neural Networks (ANN)	Multilayer Perceptron, Recurrent Neural Networks (RNN)	Space analysis, user behavior
17	Kumar et al. (2023)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
18	Li et al. (2024)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
19	Mirakhorli et al. (2015)	Data Mining	Data analysis tools, clustering algorithms	Urban planning, building layout
20	Płoszaj-Mazurek, et al. (2020)	Machine Learning	Decision trees, Support Vector Machines (SVM)	Material selection, energy efficiency
21	Quan (2022)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
22	Sartipi et al. (2000)	Data Mining	Data analysis tools, clustering algorithms	Urban planning, building layout
23	Shao Zhang (2018)	Data Mining	Data analysis tools, clustering algorithms	Urban planning, building layout
24	Sohail (2023)	Genetic Algorithms	Genetic algorithms, evolutionary computation	Design optimization, configuration, various design alternatives
25	Şahin (2014)	Artificial Neural Networks (ANN)	Multilayer Perceptron, Recurrent Neural Networks (RNN)	Space analysis, user behavior
26	Şapcı and Pektaş (2021)	Natural Language Processing (NLP)	Language modelling, text analysis	Needs analysis, user feedback 27analysis, de28sign prop29osals
27	Tazefidan et al. (2022)	Machine Learning	Decision trees, Support Vector Machines (SVM)	Material selection, energy efficiency
28	Ünal (2023)	Machine Learning	Decision trees, Support Vector Machines (SVM)	Material selection, energy efficiency
29	Valls et al. (2018)	Data Mining	Data analysis tools, clustering algorithms	Urban planning, building layout
30	Weitz et al. (2021)	Artificial Neural Networks (ANN)	Multilayer Perceptron, Recurrent Neural Networks (RNN)	Space analysis, user behavior, Architectural design modelling, artificial design elements
31	Xi, and Wang (2022).	Project-Based Learning (PBL)	PBLs	User behavior, use of various tools and resources
32	Yıldırım and Demirarslan (2020)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
33	Zeytin et al. (2024)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
34	Zhang et al. (2023)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations
35	Zhang et al. (2024)	Generative Adversarial Networks (GAN)	GANs	Architectural rendering, design variations

12% of the studies (4) used Multilayer Perceptron technology, which is a type of Artificial Neural Network (ANN) AI. This structure is a mathematical model that attempts to mimic the way the human brain processes information and consists of artificial neurons that work together to solve a problem. This allows for spatial analysis and the examination of user behavior. 9% of the studies (3) used image processing algorithms and camera technologies powered by AI; this is a field of computer science focused on enabling computers to identify and understand objects and people in images and videos. Like other types of artificial intelligence, image processing algorithms also aim to perform and automate tasks that replicate human abilities. Other AI technologies were also included in the reported studies, such as simulation software, support vector machines (SVM), language modeling, and the use of PBL, with each being reported in only one study. Figure 5 shows the types of technology used in the architectural design process.

3.4. Types of AI Parameters in the Architectural Design Process

According to Table 4, 46% of the studies (15 studies) utilized architectural rendering and design variations, indicating that these studies employed AI technology that involves the integration of virtual images into the real world. 15% of the studies (5 studies) utilized 3D technology, and it is understood that these studies involved the overlay of virtual 3D objects or scenes onto the real project. 15% of the studies (5 studies) used a combination of images, 3D models, and animation clips, while the other 6% (2 studies) utilized a combination of video, images, 3D models, and scenes. This shows that these studies involve the layering of various types of visual media in the designed project. Other types of visual media have been reported in the remaining studies; these include the use of video and images (5 studies), objects that alter all or part of an image (1 study), animation clips (1 study), and the use of video (1 study). In general, it is observed that the studies included in the literature review utilize various types of visual media, particularly in AI applications related to 3D models and animation clips, as well as combinations of images, 3D models, animation clips, and videos. Figure 6 shows the types of augmented parameters applied in the architectural design process.

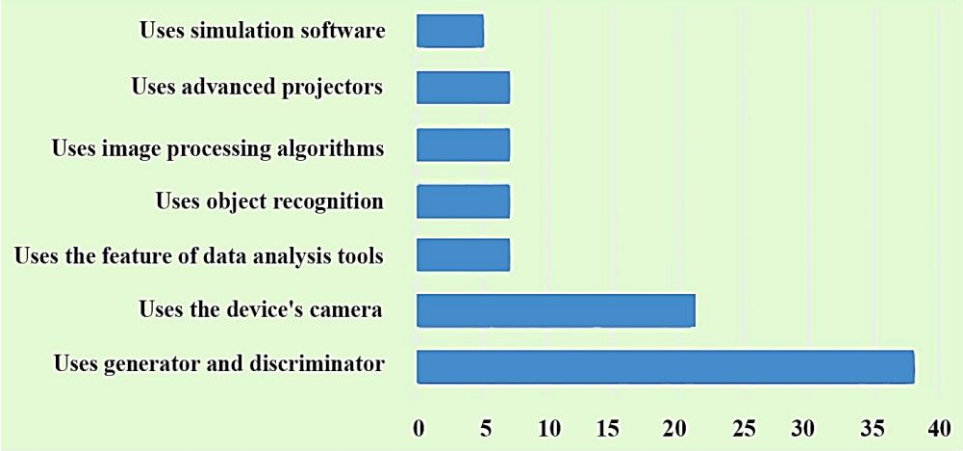

Figure 5. Types of technology used in the architectural design process.

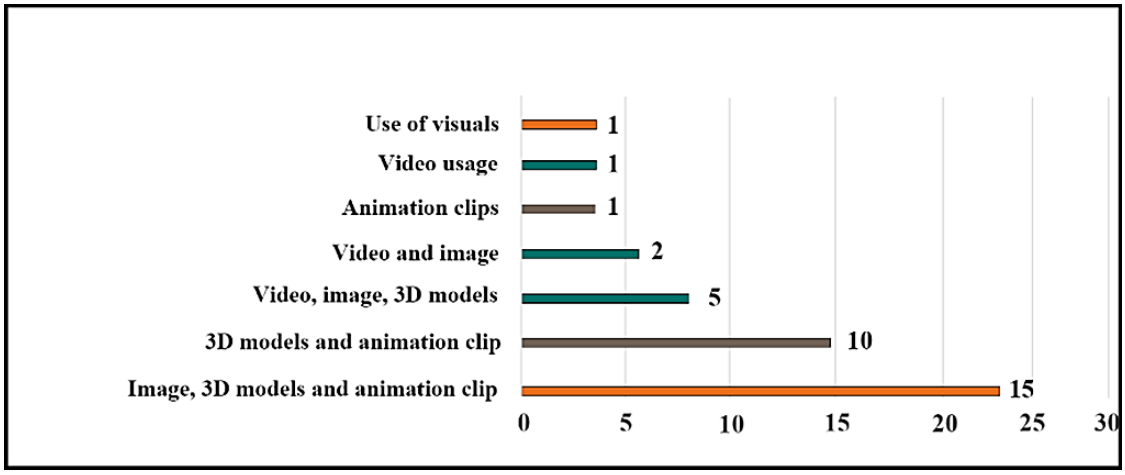

Figure 6. Types of augmented parameters applied in the architectural design process

4. Discussion

Artificial intelligence (AI) technology is advancing rapidly and has recently demonstrated significant potential. The main aim of this study is based on the analysis of existing works that demonstrate how the use of artificial intelligence assists in architectural design processes. In this context, the technologies used, the enhanced parameters, and the application areas have been reviewed.

In a systematic review conducted using three search engines, namely Web of Science, ScienceDirect, and ULAKBIM, a total of 35 articles related to AI in architectural design processes were found. Research results indicate that there are three main types of AI applications used in architectural design processes: Generative Adversarial Networks, Decision Trees, and Data Analysis tools. Generative Adversarial Networks and decision trees are popular in architectural design processes due to their significant advantages. Such AI designs are typically implemented during the 3D phase of the design to make the final version of the project more comprehensible. The generated visuals can convey the visual and auditory content of objects, experiments, and phenomena aiding in the understanding of complex subjects. On the other hand, data analysis tools have a wide capacity due to their advantages, such as demonstrating the possibility of obtaining and extracting valuable data and information to determine the different uses and architectural requirements of an area, including applications like urban planning and building placement. In this context, techniques such as data flow diagrams, design structure matrices, association diagrams, input-process-output diagrams and object-oriented modeling systems are used to provide the advantage of detailing a specific area of the design or modeling data that can be detailed during the design process (Austin et al., 1999; Smith and Jeffrey, 1999). Artificial Neural Networks (ANN) are gaining importance with their spatial analysis, user behavior, architectural design modeling, and wide range of applications. The integration of 3D modeling and animations significantly enhances the interaction and understanding of the parties involved. Using design suggestions with artificial intelligence applications can enhance the design experience by adding digital material to physical design. 3D and animated renders are commonly used components in architectural design. A 3D modeler allows designers to visualize objects and structures in three dimensions, enabling them to observe and manipulate them from various angles.

Animated clips offer the potential to explain complex processes and events that are not easily observable in reality. Device technology positively contributes to architectural design processes, and it is anticipated that the use of AI will be regarded as a fundamental design technology within the next decade. The interactive digital content of AI enhances performance by providing a more meaningful design experience. This situation suggests that artificial intelligence should be included in all design processes. The findings of this systematic literature review (SLR) indicate that the use of AI technologies in architectural design processes can provide significant benefits. For example, it guides designers in selecting the designs they will implement by identifying the AI program suitable for the project, encourages both designers and the commissioning party to overcome the confusion of meaning, and directs more researchers toward AI studies. Additionally, understanding the different classifications and functions of artificial intelligence can help designers choose the best AI variant suited to specific application requirements and create effective AI interactions. Understanding these differences can make it easier to choose the appropriate AI variant for a specific application and to create efficient AI experiences that achieve the intended goals.

The importance of this literature review lies not only in showcasing the existing reviews in AI technology but also in highlighting the types of AI applied in architectural design processes, as well as the research and potential application areas. Findings reveal that there are various fun and useful AI applications are available that will enable designers to create more interactive and innovative designs. Overall, AI is a promising technology in architectural design processes. Architectural rendering and design variations are the most commonly used AI technologies due to their simplicity and effectiveness. Additionally, designers need to understand the differences between the types of AI designs used in education, as this knowledge enables projects to be presented more effectively. Without sufficient knowledge about the types and features of AI, it will not be possible for designers to properly integrate this technology into their projects. Moreover, the findings related to the challenges encountered in architectural design processes with AI encourage improvements in areas where designers can enhance themselves. The main challenges encountered in the application of AI in architectural design processes include dependence on traditional methods, reliance on equipment, insufficient program knowledge, and the lack of awareness of many features of the programs, which leads to their underutilization. However, the use of these technologies is extremely limited, and there is room for their widespread adoption.

In response to the limitations of SLR, other researchers can conduct a more comprehensive literature review by using various database search engines such as ProQuest, Springer, and SCCI. Additionally, more suitable and accurate results can be achieved by using more specific keywords. Future researchers can obtain more comprehensive findings related to AI by examining a broader variety of documents, such as these, dissertations, and conference papers. Regarding paid documents, researchers can use alternative free databases that have been verified and approved by supervisors.

Finally, the current SLR has focused solely on three questions: the types of AI used in architectural design

processes, the types of technologies employed in architectural design processes, and the types of augmented parameters applied in architectural design processes along with the related fields. It might be more interesting to conduct an SLR examining the effects of each technology type on academic performance. Since the current SLR follows the framework of Hajirasouli and Banihashemi (2022), there is a significant need to expand research questions related to the use of AI in architectural design processes.

5. Conclusion

Among the most frequently used artificial intelligence applications, concepts such as machine learning, image processing, data mining and fuzzy logic stand out. When these concepts are briefly examined, machine learning can be defined as a sub-discipline that examines the learning processes of artificial intelligence algorithms and the development of these processes. Systems trained using large data sets are expected to both learn and continuously improve themselves. Machine learning can be used to understand user behavior in architectural projects and to create more user-friendly designs by analyzing how users react to spaces. Machine learning algorithms can also be used to evaluate the performance of different design alternatives. This allows architects to quickly identify the best options.

Data mining is the process of extracting qualitative and useful information from large databases. The main goal of this method is to uncover information that is valuable for decision support mechanisms. By analyzing data from previous projects, data mining can help determine which strategies are more successful in design processes. This information contributes to more efficient planning of new projects. In addition, by analyzing post-project user feedback, insights can be gained on what needs to be improved in future projects.

Nowadays, data mining methods and techniques are widely used in many fields, especially in companies. Image processing can be used to analyze existing structures and determine maintenance requirements. For example, surface cracks or other structural problems can be detected automatically. Image processing techniques enable more realistic visualizations in 3D modeling. This creates an immersive experience during the presentation phase of projects. These points help to better understand the potential of AI in architecture and the innovative solutions it offers. AI plays an important role by making architectural design processes more efficient, sustainable and user-oriented.

Author Contributions

The percentages of the author(s) contributions are presented below. The author(s) reviewed and approved the final version of the manuscript.

	M.D.	M.A.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author(s) declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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