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Review

Enhancing Smart Home Design with AI Models: A Case Study of Living Spaces Implementation Review

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Abstract: The normal development of "smart buildings," which calls for integrating sensors, rich data, and artificial intelligence (AI) simulation models, promises to usher in a new era of architectural concepts. AI simulation models can improve home functions and users' comfort and significantly cut energy consumption through better control, increased reliability, and automation. This article highlights the potential of using artificial intelligence (AI) models to improve the design and functionality of smart houses, especially in implementing living spaces. This case study provides examples of how artificial intelligence can be embedded in smart homes to improve user experience and optimize energy efficiency. Next, the article will explore and thoroughly analyze the thorough analysis of current research on the use of artificial intelligence (AI) technology in smart homes using a variety of innovative ideas, including smart interior design and a Smart Building System Framework based on digital twins (DT). Finally, the article explores the advantages of using AI models in smart homes, emphasizing living spaces. Through the case study, the theme seeks to provide ideas on how AI can be effectively embedded in smart homes to improve functionality, convenience, and energy efficiency. The overarching goal is to harness the potential of artificial intelligence by transforming how we live in our homes and improving our quality of life. The article concludes by discussing the unresolved issues and potential future research areas on the usage of AI in smart houses. Incorporating AI technology into smart homes benefits homeowners, providing excellent safety and convenience and increased energy efficiency.

Keywords: smart home design; AI technology; human environment; living space; ubiquitous computing

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1. Introduction to the Thematic Area

1.1. The Advancements and Benefits of Smart Home Technology

A smart home is a residence outfitted with cutting-edge technology that allows for the remote automation and management of various household systems and equipment. The development of smart home technology has been given top priority in national energy strategies and strategic planning. However, smart home technologies (SHTs) will only catch on with the public if potential buyers see only upsides while accepting some risk [1]. This type of housing is also referred to as a connected house.

Artificial intelligence (AI) is a term used to describe a group of computerized systems that carry out jobs typically done by humans. As it attains human-like levels of sensing, reasoning, interaction, and learning, it approaches or surpasses human intelligence. Answering complicated issues that call for intelligent involvement is attainable using AI as a science [2]. Artificial intelligence takes standard smart home technology to a whole new level. Artificial intelligence can create a behavior model from data collected from connected devices. Put another way, it can automate chores according to the homeowner's preferences. Integrating artificial intelligence and technology for smart homes will result in improved living circumstances, increased levels of work automation, and even the ability to make judgments [3].

"Intelligent building" is where the term "smart house" started. In this sense, the idea of "vehicle" need not change to make sense of the unit "home." Interactivity is emphasized here. Several networks comprise this interactive system, including the electricity grid, telephone and television networks, and the Internet. As it stands, networks are being integrated to provide a more efficient interface between the network and the end device and, more crucially, an interface between a human and a machine in the form of a graphical user interface, a touch screen, and voice or gesture identification [4]. A "smart house" is a contemporary dwelling with state-of-the-art automation technology. A "smart" home is one where artificial intelligence (AI) redefines the design process and innovation management structure to increase safety, comfort, and efficiency. An inquiry such as this appears: Can AI truly replace human beings? [5]. Thanks to AI advancements and increasingly capable tools and systems, "intelligent" room management is no longer just a pipe dream. Examining the setup of an intelligent dwelling that can change its behavior in reaction to its surroundings is called a "smart house." Today's innovative home technologies are all built on innovations from the turn of the XX century. As technology has improved, these technologies have gradually changed. A modern appearance of a residential structure has resulted from outfitting homes with the appropriate technical equipment: a kitchen with built-in equipment, including a gas or electric stove and a refrigerator, a bathroom and toilet with modern plumbing, etc. The English term "intelligent building" is where the phrase "smart house" first appeared. Interactivity is prioritized. The Internet, telephone, and television networks make up the interactive system of today [6]. As a result of networks' existing connections, an ideal interface between them and the end device already exists. This interface, which makes use of of a graphical user interface, touch screen, voice recognition, or gesture recognition, facilitates human–machine interaction.

The administration of the following systems is one of a smart home's primary tasks:

– Support systems for human habitation (electricity, water, and air conditioning);
– Safety (intrusion detection, an alarm, shutters to cover windows and doors, a dummy intercom system, and an alert system for in-house crises);
– Home electronics (TV, fridge, tea/coffee maker, etc., with Internet-enabled administration and control functions);
– Maintenance (surveying the functionality of automated devices and individual parts of the smart home and issuing fault notifications (messages and letters), as well as monitoring and management);
– Energy (controlling alternative energy sources and interactions via the Internet).

Think about a few different control kinds. The first form of management is done manually or using profiles of inhabitants with various priorities. The purpose of this article is to examine how artificial intelligence helps develop smart home model subsystems that meet the demands of inhabitants in terms of convenience, comfort, and security in a way that strikes a compromise between these competing priorities [7]. The optimal sources management strategy, which must accommodate many and often competing purposes, is one of the most difficult challenges of running an intelligent home [8].

On the other hand, the primary concept underpinning the idea of a smart home is the creation and upkeep of a human habitat that is simple, risk-free, resource-efficient, and, if possible, cost-effective. This is the goal of the smart home movement. To accomplish these goals, high-tech solutions revolving around electronics, data transmission lines, and sensor networks are integrated into the design of the architectural space being constructed or the existing architectural area. In addition, the variety of problems that need to be resolved for each user is included in several architectural aspects.

1.2. A Review of the Role of AI Models in Enhancing Smart Home Design

AI models have contributed significantly to the utility and convenience of modern homes, and creative home design has come a long way in recent years. This investigation examines how AI models improve smart home design, focusing on living areas. Living spaces highlight the importance of smart home design because they are a crucial component of modern residences and are used for various activities such as socializing, unwinding, and working. According to Raz Kamaran Radh (2022), extensive work regarding spatial design modifications accommodating the lifestyle requirements of smart home inhabitants remains to be conducted. The opportunity to change scale, form, relation, and configuration becomes more straightforward and faster, with more possibilities for arranging rooms in smart homes with the help of hypothetical prototypes [9]. AI models are critical in allowing breakthrough home solutions to improve the usability and comfort of living spaces significantly. One of the primary benefits of incorporating AI models into the smart home design is the ability to automate multiple tasks such as changing light levels and colors, temperature and humidity, and home security systems. Elkholy et al. (2022), on the other hand, believe that one of the most challenging difficulties associated with the operation of smart microgrids is determining the ideal home energy management system with various competing objectives [10]. Furthermore, depending on user behavior and preferences, microcontrollers, intelligent control systems, and sensors may be automated to boost convenience and efficiency. Moreover, AI models can manage and control smart home devices. An intelligent control system, for example, can alter device settings depending on user behavior, such as changing the thermostat to the homeowner's preferred temperature levels. However, according to Marco et al. (2015), many home users need clarification regarding how thermostats manage and control their energy usage in general [11]. AI models may be used in smart home design to maintain energy. For example, machine learning algorithms may evaluate data gathered from sensors and other home devices to develop personalized energy management systems. These systems may learn from user behavior and preferences to improve energy usage and lower costs. Another area where AI models are helpful in the construction of smart homes is security. AI models can recognize and respond to possible security risks using monitoring systems, sensors, and other devices to monitor the home environment, where Gengyi Xiao (2021) suggests solving the insufficiency of the existing intelligent home energy monitoring system in autonomous adaptability by implementing a smart home energy monitoring system based on machine learning and embedded technology [12].

The living spaces case study demonstrates how AI models might be used in smart home design. Furthermore, it underlines the method's advantages and disadvantages. A case study of a living space shows how AI models may be used to improve the development of a smart house. Artificial intelligence (AI) technology, which can learn from user behavior and automatically change home gadget settings, has contributed to this revolution. As demonstrated in the case study for living spaces, AI models might be used to create a smart home design. According to Diraco, G., Leone, A., and Siciliano, P. (2019), in today's intelligent settings, numerous heterogeneous sensors are being increasingly deployed to give more and more value-added services. This abundance of sensor data and new artificial intelligence (AI) approaches for big data analytics can generate a wide range of actionable insights to assist consumers in maintaining a pleasant lifestyle [13].

A smart home's multiple appliances and systems make it a perfect environment for testing AI software. This highlights how embedding AI models into smart homes may increase usability, practicality, and energy efficiency while providing homeowners a more peaceful and pleasurable living experience. Personalization is an essential aspect of applying AI models to improve the design of smart homes. Since AI models learn from human behavior and adjust device settings as needed, intelligent home systems may be tailored to each homeowner's specific needs and preferences. This might include using natural language processing (NLP) technology to execute voice commands and other customized interactions with smart home devices. Yet, incorporating AI models into the architecture of intelligent houses is also a challenge. Nevertheless, Alexakis et al. (2019) confirm that IoT agents can contain chatbots that use natural language processing to interpret text or voice commands (NLP). As a result, home gadgets are more user-friendly when NLP is used. Furthermore, managing them is easier since the system knows the user's wants and responds accordingly, even when a command or question/command departs from the presets [14].

One of the significant difficulties is the demand for compatibility and interoperability between diverse systems and devices. Several manufacturers develop smart home appliances, which causes compatibility issues and makes it difficult to incorporate other methods. AI models' complexities can also make setup and maintenance onerous for professionals and homeowners. Industry standards and protocols are being developed to address these difficulties and ensure high compatibility and interoperability among smart home systems. Furthermore, setting these standards would make smart home systems easier to install and maintain and extend their accessibility to a broader range of users. Furthermore, utilizing AI models in smart home design benefits homeowners by improving safety, convenience, and energy efficiency. However, Chang, S. and Nam, K. (2021) assert that despite the numerous advantages of smart homes they have yet to be generally accepted by mainstream users [15]. However, a case study that concentrated on living areas offers a practical illustration of the advantages and drawbacks of this strategy. Moreover, it emphasizes the significance of system and device compatibility and interoperability. Therefore, AI models will probably take on a more significant role in improving the ease and usefulness of smart homes as the market expands and changes over time.

2. Materials and Methods

The method was based on the rules for assessing the level of a working smart home environment, functions comfort and safety, general recommendations, how to calculate intermediate indicators, how to form a scale, and how to calculate the final result. First, these rules and suggestions were used to develop the method. Then, using the AI models, the approach evaluated the level of comfort and safety and all aspects that may be engaged. To ensure smart home rules and adequate assessment levels are the best and most effective, it is crucial to evaluate the quality of the working environment. There are several guidelines or suggestions for determining the functional domain of a smart home, namely objectively assessing compatibility and interoperability [16]. The compatibility and interoperability across various systems and devices are crucial factors to consider while analyzing a smart home's operational environment. When testing deep levels of connectivity, it is essential to evaluate how connected the home is. To assess the degree of automation and control in the home, it is vital to check the automation and control systems that are critical components of smart homes [17]. Considering the security situation is very important for smart homes. Hence, assessing the amount of security the residence provides is essential. Another crucial aspect of intelligent houses is energy efficiency. A smart home should be customized to the owner's unique requirements and preferences. Finally, the usability of smart home technologies must be evaluated. These guidelines can quantify the quality of an intelligent, good living space and point out opportunities for enhancement and improvement [18].

2.1. New Rules for the Enhanced Smart Home

The user will need many rules for several devices to create smart behaviors in smart homes. In addition, the user may need more time or technical knowledge to develop good device control practices. An innovative home system can automate the tedious task of rule creation using machine learning. Machine learning solutions can find patterns in data from smart home devices and automatically create rules to control the connected devices.

The specifications of the system's features and capabilities and the relevant regulatory framework will determine the rules and regulations for determining the operational level of an upgraded smart home environment. A thorough assessment should consider the criteria above to ensure that the smart home environment is risk-free, secure, and simple for people to use. In addition, the following important considerations must be respected:

- Even nontechnical people should be able to utilize and navigate the user interface easily. Moreover, people with disabilities such as hearing or vision impairments should be able to use the interface without difficulty.
- Smart sensors and automation should be included in the system's design to decrease energy waste and maximize energy consumption.
- Innovative home settings should be able to operate seamlessly with various hardware and software, including third-party apps.
- To avoid data loss or system failures, the system has to be dependable, robust, and equipped with backup and recovery features.

Although cutting-edge home automation systems are becoming increasingly common, there is still a need to investigate the concerns preventing their widespread adoption. For example, further study is required to determine what factors influence user adoption, such as perceived utility, convenience, and privacy concerns [19]. Regarding some of the essential gaps in smart home research, which vary depending on the topic and area of focus, such as interoperability and how to improve interoperability and create a more seamless smart home experience for users, security and privacy, where it is needed to develop adequate protection and privacy measures to protect users and their data, etc., this article attempts to create a set of rules for the objective of integrating AI models in intelligent homes. Pleasant human–machine interaction is necessary to enhance the connection between humans and machines by increasing the accuracy of speech recognition systems [20] and a need to drastically reduce energy usage through an energy efficiency procedure.

2.2. AI and Smart Home Interaction

The term "artificial intelligence" (AI) refers to the process of recreating human intellect in computers by teaching them to learn and reason in the same way that humans do [21]. Problem solving, decision making, and pattern identification are all examples of activities that fall under this. Artificial intelligence is constantly heading towards new developments, and recent innovations have resulted in the incorporation of AI technology into a variety of sectors, including the industry of a smart homes. AI technology appeared in the early 2000s when the term "smart building" was trendy [22]. Still, it only reflected the level of performance of building automation systems, not having a direct bearing on its "intelligence". Today, we can already talk about optimizing the functioning of building engineering systems based on offline data analysis achieved through AI. The system implements automated building functions, covering a broad set of home functions for inhabitants. For example, the change in the Sun's position during the day can be considered when controlling lighting, curtains, heating, and air conditioning [23]. The operation of ventilation systems can be based not only on sensors' signals of the presence of CO_2 but also on the occupancy schedules of specific premises, cleaning, and sanitation, which is especially relevant in recent times [24]. Moreover, forecasts based on accumulated data on the operation profiles of engineering equipment in the previous period can be used. This proactive building management can be applied to almost any system, reducing energy consumption and operating costs, increasing space efficiency, and more. Intelligent assistants are among today's smart homes' most crucial artificial intelligence applications. These virtual assistants can be controlled by voice commands and perform various functions. Some examples include playing music, making reminders, and managing other smart devices in the home.

- Control of a Smart Home Through the Use of a Touch Control Panel

Controlling a smart home via a touch control panel is one of the most straightforward methods. The touch panel in Figure 1 is outfitted with a little liquid crystal display. With the help of this display, it is possible to activate all the essential communication systems and program their functioning.

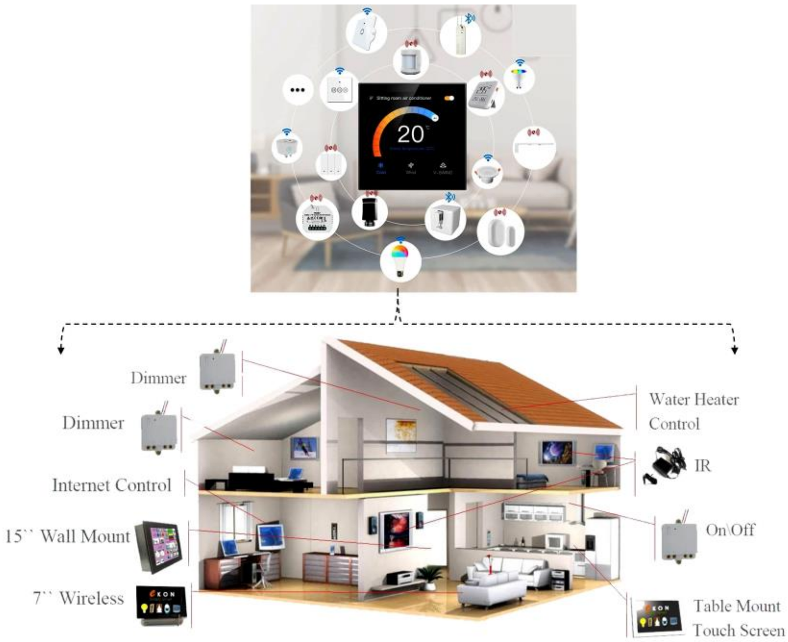

Figure 1. The smart home control system**.**

2.3. Ubiquitous Computing

This alludes to numerous information technologies that enable the integration of computing and communication capabilities across consumer electronics. Mobile phones, home appliances, and other daily goods are examples of such gadgets (dishes, furniture, etc.). Many new terms, including "smart environment" with "smart objects", "ambient intelligence" (enveloping intelligence), "pervasive computing" (sensing computing), "proactive computing" (active computing), "intelligent space", etc., have recently emerged because of the deeper integration of various social applications and networking services into our daily lives [25]. For example, "ambient intelligence" refers to a system's primary objective of assisting a person in everyday tasks.

2.4. Environment—Smart Technologies

A "smart environment" with "smart objects" is, in general, an information system made up of a wireless sensor network, a server for centralized data collection and control, a network of "smart objects" with built-in intelligent systems, and a collection of mobile devices to the system that provide a user interface with built-in services [26]. Sensors include temperature, light, touch, proximity, video sensors (microvideo cameras), and sound sensors fitted on furniture. Simple objects with intelligence can be utilized as "smart objects". These academic fields are all relatively autonomous. Innovative sensor technologies are used in lifestyle, healthcare, fitness, manufacturing, and everyday life for various purposes. Due to the robustness of the wireless connection, they have been simultaneously incorporated into the central control system of the smart home. Thanks to their sensors, they can provide information on their state and other things [27]. Examples of the behavior of smart objects are as follows:

- When the user asks, "Where is my x?" the bookmark, tied to a cabinet with items in the living or bedroom, responds, "I'm here", and the LED blinks.
- The local light and the computer on the desk switch on when a person sits in a chair in front of it [28].

- The system controls the lighting in the space or the amount of fresh air necessary for a particular room with a function by the state guidelines while keeping track of the number of people present.
- A person's preferred music or television channel is activated if they visit a space for leisure around lunchtime.
- The light intensity and hue will vary once the system analyzes the room user's facial expression to determine their feelings [29].
- If a person lies down on an intelligent bed, it will automatically dim the light, turn on the local light if the person picks up a book to read (turning off the TV), detect the body's position on the bed, turn it over, and, using this information and the sound of breathing, determine whether the person is sleeping or not.

Merging neural networks and expert systems in a hybrid approach is the most promising method for structuring an intellectual environment [30]. Moreover, it offers the ability to formulate understanding at a certain level in a straightforward manner conducive to perception (both for entering the system and for deriving knowledge to explain or debug the plan)—the fact that artificial neural networks are the most closely related to natural mechanisms for data processing and knowledge acquisition explains their prospects in comparison with other methods of representing and processing knowledge.

2.5. Environment—Smart Architecture

A wireless sensor network, intelligent devices, and a server constitute the foundation of the information system that supports the intellectual environment. A design such as this enables the integration of electrical circuits with free-form plastic sensor housing in situations where managing home functions and quality of life calls for complete monitoring systems with user-friendly features [31,32] (see Figure 2). The most straightforward sensors, such as tactile signals indicating whether a person has sat in a chair or if a door is closed and microvideo cameras, which may function as a distributed technological vision system, are connected to the touch wireless network. Several noncontact sensor technologies include motion, pressure, video, object contact, and sound sensors. In addition, smart and multicomponent technologies (combinations of ambient and wearable sensors) were found [33]. Doors, windows, furniture, courts, and books may all be wired into the wireless network of intelligent things, including lights, home appliances, mobile robots, cell phones, and standard personal computers. Remember that although these two networks are one wireless LAN physically, they might vary logically. Activity recognition, glory recognition, and honor recognition of people and objects are three critical functions of the recognition subsystem. However, apart from utilizing data from conventional sensors, these systems cannot offer automated activity detection due to a lack of contextual knowledge [34].

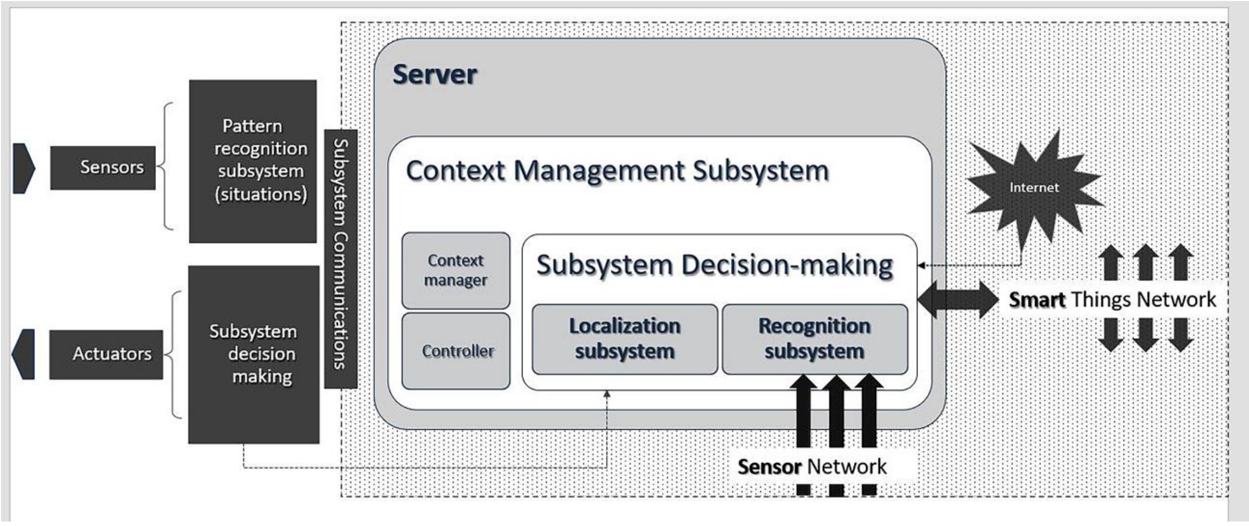

Figure 2. Structure of the information system of the smart environment.

The system uses neural networks, probabilistic models, and a hybrid approach with knowledge-based decision making. The localization subsystem must use information from numerous local sources, such as visual input from many cameras, to establish the positions of objects and people. The system can locate itself in an unfamiliar area and create a scene map, which we can be used to track and find the locations of essential things worldwide [35]. The application of neural-network-proposed coordinate recognition by the vector of the intensity of signals (electromagnetic or ultrasonic) from many beacons helps locate the problem. The context management subsystem gathers, archives, and updates the text the decision-making subsystem utilizes. The context of circumstances identified and actions conducted relates to the time, location, problem-solving task, solution state, and other critical components. The system, in which all the services and jobs solved by the system are incorporated, includes the decision-making subsystem.

In contrast to other subsystems, which are frequently built as middleware, this subsystem is generally regarded as application software. This subsystem implements interaction with the user through sensors (or input devices) and actuators of intelligent objects, such as cell phones, personal computers, or robots. Applications that carry out tasks, including device control, control over a multimedia device, item search, communication, cheering up loneliness, and question-and-answer systems, maybe a part of this subsystem [36].

Consider personal matters, a reminder of business, ensuring the home is secure, keeping an eye on the child's position, and work, as well as offering aid to visually impaired people with orientation challenges. Many of these applications include a question-and-answer system for locating accurate information, and a technique for tracking a kid's contact when contacting the homeowner who has lost a child is essential. A hardware and software board is integrated into an intelligent device to enable communication with other intelligent objects and the perception of significant external events or states through sensors and actuators. It is necessary to use a smart environment server via a wireless network. The number of devices linked to the Internet has substantially expanded during the past few years. Through various sensors that perceive reality by digitizing some critical criteria of interest, these gadgets may communicate with humans and the outside world, gathering vast amounts of data [37]. The hybrid expert system architecture shown below can build a decision-making subsystem on a server or as a component of an intelligent item. In this case, a built-in hybrid expert system is suggested to produce the "intelligence" of smart objects.

2.6. Expert System and Neural Network Communication

Many significant advances have been made in the design of knowledge-based intelligent systems (KBIS), most notably expert systems [38]. These advances may be categorized into one of many direct modeling techniques. In the knowledge base, a neural network is characterized as a frame-like source data structure that describes the parameters for choosing how the expert system will interact with other sources of information and communicate with the user. Consider the following scenario: the logic inference interpreter finds a specific frame in the rule's executed condition. In such a scenario, the system stops and utilizes the socket to submit a request for the relevant fact to another software (a neural network). The process of interpreting the rule continues once the truth has been ascertained. The neural network results may be understood using logical reasoning. Making judgments based on gathered observations and uncertain domain knowledge is essential in various everyday circumstances, from investment opportunities and lighting suggestions to music and weather predictions. With a straightforward logical output, the neural network may provide precise information while pinpointing a specific thing or situation [39,40].

The neural network results may be understood using logical reasoning. Symbolic representations, such as words or phrases, are created from the vector signals from the neural network using a dictionary. For example, the dictionary may include the following terms: item, kitchen cabinet, a package of chips, bowl, bottle, window, parallel-pipped, complicated shape (for the dispersed position/state of a person), condition, standing, lying, and sitting (for the recognized form or for a recognized object). Furthermore, the verified fact has previously been received from the neural network and is already in the database of facts. In that case, it is utilized without the neural network's request until its obsolescence period has passed. The suggested hybrid expert system's knowledge representation and utilization levels are depicted in Figure 3.

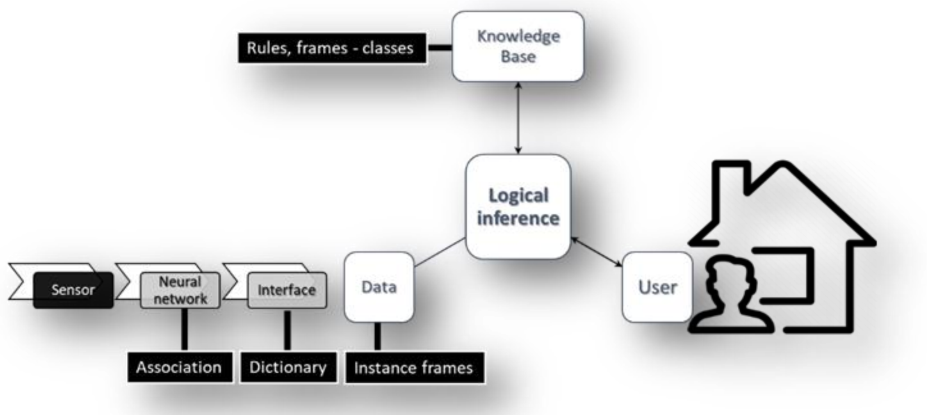

Figure 3. Levels of information processing.

3. AI Patterns in Smart Home Design Features, Interactions, and Control

Many home appliances are on the market today, where there are popular device models that successfully use artificial intelligence for smart homes (see Figure 4).

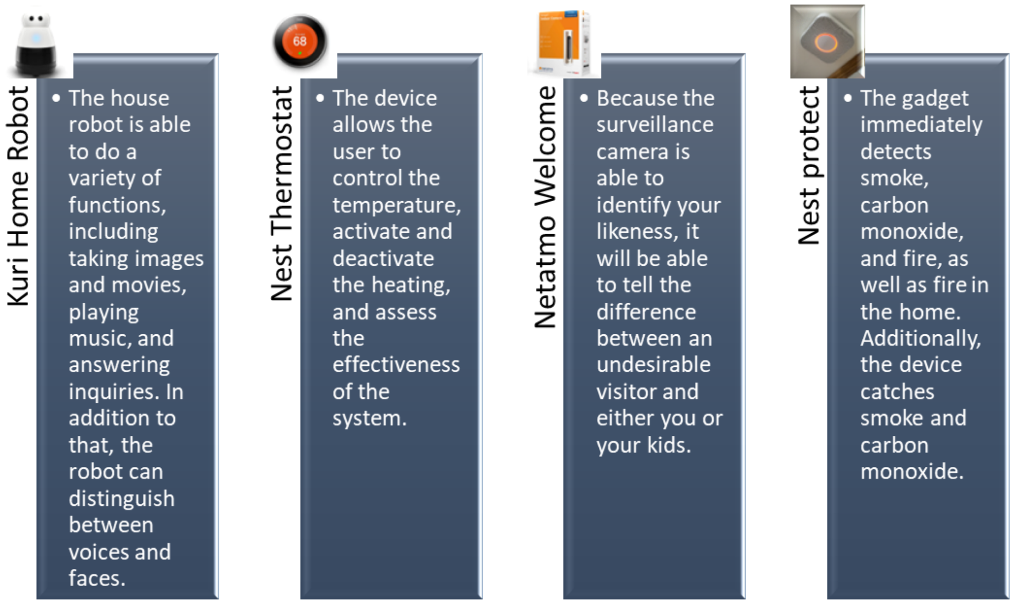

Figure 4. The AI applications on a smart home.

The interaction between artificial intelligence simulation models and smart home design is essential in creating efficient, sustainable, and individualized living places. The following is a list of some of the most critical needs and responsibilities involved in these interactions.

3.1. Constant, Preemptive Safety Warnings and Security Functions

Compared with their analog counterparts, smart home security systems provide several advantages, including real-time warnings, motion detection, video monitoring and analytics, and protection against fire and other hazards to life. This system employs advanced multiple-frame motion detection technology to achieve high-compression video data transmission in real time [41]. These apps are made to work with existing infrastructure. They can be used from any mobile device, making it possible to monitor utilities and energy consumption, as well as health and well-being [42]. According to several studies, security considerations, including smart alarms, different sensors, smart locks, and cameras, are the main factors behind the design of smart homes. Modern technology can protect people's lives, businesses, homes, schools, and other establishments by deploying an active protection system to monitor them [43]. Modern security systems can also act as a conduit for other intelligent technologies. Most common security systems only sound an alarm after a breach. When a break in, fire, or carbon monoxide leak occurs, you will receive a warning once it is too late to do anything about it. These technologies do not deliver proactive, real-time notifications. Smart locks and contact sensors send an alarm if a door or window is left unlocked or ajar, keeping intruders out. Thanks to smart motion sensors and detection, parents and carers may rest easier knowing their children are not getting into trouble.

AI simulation models can create personalized living spaces by analyzing data about the occupants' preferences and habits [44]. For example, in modern architecture, an AI algorithm could analyze data about an individual's sleep patterns and use this information to adjust the lighting and temperature in the bedroom to create the most comfortable environment for sleeping.

3.2. Voice-Activated Control System

Users can control the lights, electric draperies, gates, and door locks in their home simply by using their voices, and they may even launch complicated situations with a single phrase, such as "I am at home" or "I left home." The lighting in the home represents an important issue in housing design; according to Natalia et al. (2022), indoor lighting can influence people's well-being, mood, behavior, and several other functions. This is an issue that should be taken into consideration when designing a home [45]. For voice control of the light, the user needs the Internet, a voice assistant, and a connected smart home system; see Figure 5.

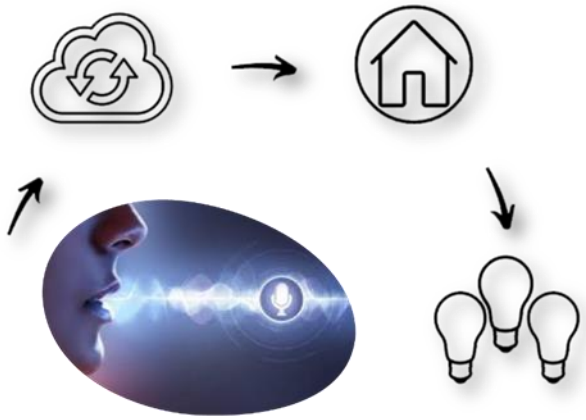

Figure 5. The voice control of the light in the smart home system.

Valera Román et al. (2021) affirm that Siri, Google Assistant, and Alexa are just a few examples of virtual assistants' growing popularity. They are helping people across all demographics bridge the digital gap and access resources previously out of reach [46]. However, no mass-market technical solutions allow for autonomous and high-quality voice command recognition without an Internet connection. Hence, a fast Internet connection is necessary for this capability. Siri is Apple's pioneering voice assistant, accessible by Iphone, iPad, or headphones. This is useful since it ensures that something is always nearby that can hear the orders being given. Apple's HomePod makes it even easier to control. Apple's Home Kit is a suite of gadgets designed to communicate with and be governed by the built-in home app on iOS devices. All Home-Kit-enabled gadgets are easily linked to your Apple ID and may be controlled by app and voice commands. As a bonus, they also offer device operation scenarios in which devices are instructed to carry out predefined tasks in response to predefined triggers (such as time or state changes). Installing a server home that agrees with installed devices and voice assistants is the key to making a smart home system with voice control far more functional than utilizing the devices compatible with Home Kit and Alice. Khan et al. (2022) consider that home automation has gained much popularity due to the rapid development of technology and its subsequent improvement of people's quality of life. Automation and digitalization have permeated nearly every industry. With the IoT, home automation may be made more widely available and famous [47]. It is recommended that you install Open Hab, the most commonly used program of its kind, on the server. Open Hab is a free program that links various cutting-edge home devices. In this context, "server" refers to any machine, from a Raspberry Pi to a brand-new laptop, and Open Hab software must be regularly run on it. Smart homes can range from the simple and inexpensive, such as those based on Fibarom equipment or an EasyhomepLC controller, to the complex and advanced, such as those found on Backhoff industrial controllers; these are ideal for large apartments and country houses, and their features can even be expanded upon. By utilizing voice recognition technology, a software agent known as a voice assistant can carry out activities or provide services on behalf of an individual. Voice-activated home automation systems have the potential to make people's lives easier and more pleasant, while also streamlining routine activities. Furthermore, voice control in environmentally friendly houses benefits persons with disabilities, since this technology allows them to live a lifestyle that was not conceivable in the past [48] (see Figure 6).

Figure 6. Different software for voice-activated control systems.

Using voice command systems might result in significant benefits, including providing support in the workplace. The widespread use of smart speakers has made it possible for well-known virtual assistants such as Google and Alexa to become an integral element of home operations, where the use of smart speakers (SS) is becoming increasingly common in today's culture [49]. They can link to various domestic systems, which allows us to automate many of our day-to-day responsibilities and allows us to manage certain equipment specific only to our voices.

3.3. Options for Remote Observation and Video Surveillance

During the past two decades, the number of houses with HD cameras has increased steadily. These houses' vision-based systems assist in users' activities, change detection, and object detection categorization. However, for most of these activities, artificial intelligence algorithms often need to know beforehand what to search for and recognize, or comprehend [50]. As a concrete illustration, owners who can monitor their property even when not present can receive notifications on their phones when the kids arrive home from school. They may also "peek in" to check on activities such as homework, meal preparation, and medication administration via an interior camera. Likewise, front-door cameras that provide two-way audio and video transmission are a terrific way to communicate with people even when they are not there in person.

4. Experience Integrating AI Technologies with the Human Environment

Today, the most practical way to care for the environment is to adopt ecological solutions that take advantage of the latest technological innovations and consume fewer resources. The implementation of digital technologies contributes to increasing the quality of life. It must invest in new practices integrating pedagogy and technology, with pedagogy being the driving force. The task of a new stage on the horizon of the current decade is to ensure the mass introduction of artificial intelligence; it should cover all sectors of the home and all our life spheres. Smart homes and artificial intelligence technology are advancing quickly, and numerous smart home solutions using artificial intelligence (AI) have enhanced the quality of life for residents [51]. It is essential to agree on what people mean when discussing "smart homes. The systems may be divided into six categories:

- Equipment for relaxing oneself at home;
- Light modulation apparatus;
- Connected home appliances;
- Command of water heaters and radiators;
- Safety measures and rights management;
- Plants, watering, and other garden needs.

These layers are added to this: the home network and its connection to the Internet and the apps, programs, and services that control gadgets and functions or are accessible via the smart home devices.

Machine learning approaches and artificial intelligence are finding more and more applications in the field of smart home technology. Various AI-based methods, such as machine learning, have already been formed in the industry to achieve sustainable manufacturing thanks to significant research efforts in artificial intelligence (AI). These efforts have been made possible by the rapid advancement of AI and machine learning [52]. For example, the Nest thermostat was the first product to start this trend, since it considered user preferences and behavior when setting temperatures. There is a computer science subfield that focuses on developing intelligent machines that can carry out activities that would ordinarily need human intellect, such as visual perception, speech recognition, decision making, and the translation of languages. In the context of "smart homes", artificial intelligence (AI) technology may regulate and automate various processes within the home, including temperature, security, and lighting. For instance, homeowners may use voice commands to manage the lighting and temperature, while intelligent security systems can employ AI to detect and respond to possible breaches via voice commands. In addition, artificial-intelligence-driven virtual assistants, such as Amazon's Alexa and Google Assistant, may be included in smart homes to aid with various activities, including scheduling reminders, playing music, and managing other smart devices [53]. Overall, artificial intelligence technology has the potential to make smart homes significantly more convenient and functional, as well as more productive and tailored to the specific requirements and tastes of the occupants.

4.1. Refusal of Cloud Technologies

Cloud technology has become increasingly popular as more individuals turn to the cloud for data storage and processing. Through the use of various computer and storage systems that are connected over the Internet, the practice of "cloud computing" makes the processing of data more effective. These new imaginative and novel computing approaches have allowed for the advancement of these strategies, which now support the database and network systems vital to Internet operation [54]. The decision to refuse can be based on various reasons, including security concerns, lack of control over data, and cost. One of the main reasons for refusing cloud technology is security.

The operation of the Internet is gradually shifting from the "Internet of Computers" (IoC) to the "Internet of things" (IoT). Massively linked systems, often called cyber-physical systems (CPSs), are also emerging due to the incorporation of many aspects such as interest, embedded devices, smart objects, humans, and physical surroundings [55]. Cloud computing is linked to the Internet of Things (IoT) and smart homes. Because it is not economical to construct an energy-consuming information storage system in the home, most of the information acquired by smart devices and that is necessary for their operation is retained remotely. This is because it is required for their functionality. On the other hand, the tendency is shifting in the opposite direction, and more and more information is being saved locally. One of the causes is the worry that the system's operation would suffer due to disruptions in the connection. Therefore, once more, information processing is delegated to individual end devices or hubs within the home. At the very least, users and developers anticipate that such a system will be more susceptible to hacking and provide higher security [56].

4.2. Smart Homes within New Standards

As the usage of smart technology in residential settings grows more popular, new standards are being established to guarantee that all of these different devices and systems can smoothly communicate with one another. The creation of standards for the Internet of Things (IoT), which attempts to create a common language for connected devices to interact with one another, illustrates this trend. Zigbee is an example of a standard that has seen widespread adoption [57]. One of the causes is that it enables easy integration of various devices such as lightbulbs, thermostats, and security cameras; it is frequently utilized in smart homes and building automation systems. As a result, these two types of systems are becoming increasingly popular [58]. Z-Wave is another type of standard. It is a wireless communication protocol explicitly designed for build-on plans and smart homes. It makes integrating various devices, including thermostats, light switches, and security systems, among others, simple. Consequently, the development of new standards for smart homes is essential if one wishes to guarantee that the various equipment and systems included inside these houses can communicate with one another smoothly, making the homes more productive and user-friendly. Once more, information processing is delegated to individual end devices or hubs within the home. At the very least, users and developers anticipate that such a system will be less susceptible to hacking and provide higher security.

4.3. Smart Home System within Alternative Approaches

A system for a smart home may be constructed in several ways. It is feasible to incorporate many devices made by various manufacturers and to take advantage of them—however, there is the danger of compromising security and losing a consistent user experience. Keeping the system safe may also be accomplished by selecting just items made by one firm and the businesses with which it works. Every strategy has advantages and disadvantages that the user should be aware of. There are many different options available when it comes to putting in place a smart home system, which depend on the market adoption of smart home technologies (SHTs) and rely on prospective users perceiving clear benefits with acceptable levels of risk [59]. Figure 7 illustrates various possible methods, each of which has a set of advantages and disadvantages; the most suitable technique contains a variety of possible ways, each of which has a bunch of advantages and disadvantages. The technique that is the most suitable for a particular homeowner will depend on the homeowner's preferences.

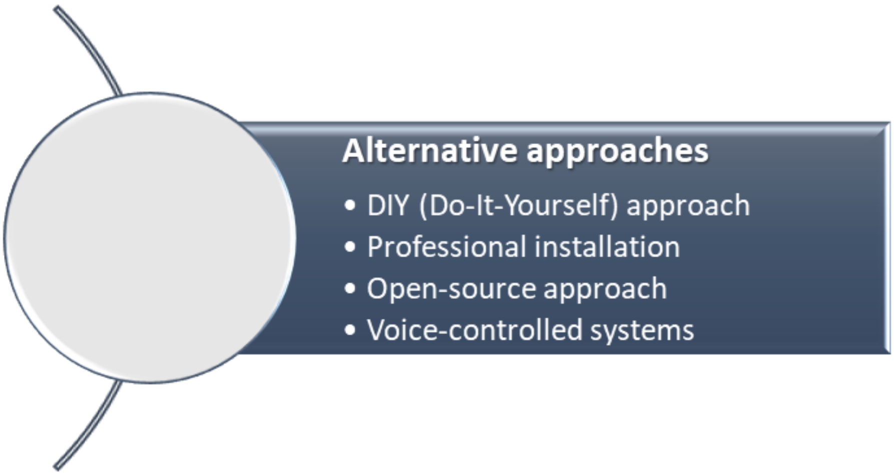

Figure 7. Alternative approaches within a smart home system.

4.4. Smart Homes and a Healthy Environment

The spatial variability of air temperature, lighting, and home space pollution in an intelligent home is mainly attributable to the architectural design in general and the furniture layout and home system design (e.g., luminaires and ventilation system) in particular; however, this variability was reduced in later experiments by optimizing home space layouts and building system designs [60]. It also requires air purifiers and sensors to detect and remove airborne pollutants. In addition, mold and other allergen growth can be hindered by using a programmable thermostat to control indoor humidity and temperature. With the use of sensors, cameras, and other equipment that will help to inform caregivers or family members if something goes wrong, a smart home may also be used for monitoring elderly individuals or people who have chronic illnesses. This can be performed by keeping an eye on them using the home. The technology used in smart homes has the potential to significantly improve the health and well-being of the people living in those homes by providing them with the resources and information that they require to lead healthier lives. Research by Cho, M.E. and Kim, M.J. (2022) suggests that smart homes can improve the health of their residents in six different ways: through physical activity, recreational pursuits, social interaction, professional and personal growth, and responsible use of resources [61]. In conclusion, AI simulation models are an essential component of the design of smart homes because they make it possible to maximize the building's energy efficiency, develop individualized living areas, enhance the building's safety and security, automate its operations, and supply real-time data analysis.

5. Case Study: Smart Home Living Spaces Analysis

5.1. The Temperature of Comfort in Different Living Spaces

The United Nations has categorized ten home features: entertainment, cooking, eating, relaxing, sleeping, studying, playing, washing up, transportation, storage, and external conditions. In the context of a case study of a living area in a smart home, technology might be used to manage the temperature for the various purposes of the space. For instance, a family could want to install an intelligent home system to enhance their home's energy efficiency, boost its security level, and make living easier. The innovative heating system for each subzone in one room depicted in Figure 8 could be one of the features that could be included in the intelligent home system. This would allow the family to control the temperature in their home using their smartphones or voice commands. Other defenses against potential attackers might be afforded by installing sophisticated security components inside the system, such as sensors for doors and windows, motion detectors, and surveillance cameras. Moreover, the family would receive notifications on their phones if any strange behaviors were spotted, and they would be able to monitor their home remotely even while they were not there. This indicates that the system for a smart home may include a smart thermostat, which would learn the routines and preferences of the family and then automatically change the temperature to provide maximum comfort while minimizing energy use. In the living spaces case study of a smart home, technology would demonstrate how an intelligent home system can improve the quality of life for a family by making their home more convenient, secure, and energy efficient. Furthermore, this would be done to show how a smart home system can improve a community's living standard. According to the authors' research, the following temperatures are ideal for various rooms in a home based on the activities of the people living there.

- Living room: A comfortable temperature between 21–22 °C in winter is recommended for these activities. Accordingly, it is divided into three subzones: A1, A2, and A3)
- Bedroom: This region's recommended comfort level is between 19 and 25 degrees Celsius. Accordingly, it is divided into three subzones: A1, A2, and A3.
- Kitchen: The ideal temperature ranges from 18 to 22 °C. It is divided into subzones, but only one is permanent A1. The others are only used for a short time.
- Bathroom: The optimal temperature range for this area is between 23 and 28 degrees Celsius. Accordingly, it is divided into two subzones: A1 and A2.

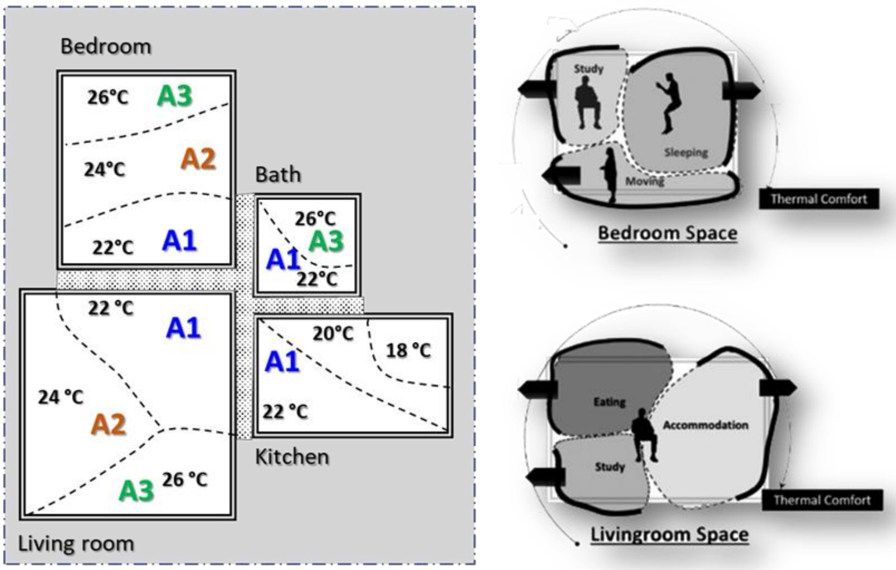

Figure 8. Rooms' temperature comfort according to human activities and home zones [62].

Modern smart homes are based on the mathematical model of the AI in smart home systems, together with the associated data transfer and processing processes, in the form of error-correcting coding and a systematic methodology [63]. Artificial intelligence (AI) can regulate thermal comfort in different room locations and in-home human activities by creating intelligent systems. However, these systems are typically controlled depending on the user's activities. As a result, thermal comfort varies significantly from person to person, from room to room, and even from one position in a room to another. For this reason, it is essential to improve the integrated design of the sensors in the designing process and to create a system of sensors, infrastructure for enabling system interoperability, learning and control algorithms, and actuators (e.g., HVAC system setpoints and ceiling fans) that work under a governing central intelligent system to regulate thermal comfort in occupied spaces.

Sepasgozar et al. (2020) argue that more work must be conducted to integrate AI and IoT and use geographical data in creative home building to achieve a synchronic purpose between the design of the smart home and artificial intelligence [64]. It was also determined that additional research is needed into developing limited integrated systems for energy efficiency and the elderly care sector. As a result, they posed novel, complex questions about how the Internet of Things (IoT) and already established systems may be enhanced and further expanded to meet additional energy-saving challenges, guiding future research toward fully intelligent systems. According to Song et al. (2016), Creating an efficient smart building within modern architecture must take into account environmental conditions, seasonal and annual climate changes, the orientation of the building on the cardinal points, and supply sources, including water, electricity, and heat, to create a perfect volume-spatial structure of the building [65].

5.2. Spaces Shapes in the Living Area

The technology may partition rooms according to user preferences using a BIM model fed by AI. Figure 9 shows one possible arrangement for modifying the ceiling's shape and location. One method for adjusting the ceiling form and height in an intelligent home to reflect human mood is to include sensors that can detect changes in the environment, such as temperature, humidity, and light levels, as well as sensors that can track the presence and movements of humans. An innovative home system may utilize this data to modify the ceiling height and shape to maximize comfort and relaxation within the home. If the room's temperature gets too high, for instance, the system can automatically raise the ceiling to improve the flow of air and the effectiveness of the air conditioner. Equally, if the illumination in the room is too low, the system may lower the ceiling and readjust the lights to make the room brighter and more energetic. The smart home system may also consider home input, such as voice commands or a mobile app, to tailor the ceiling's shape and height to the individual's tastes. This information may be utilized to make instantaneous changes to the ceiling's dimensions and profile, enhancing the space's acoustics and making it more conducive to a calm and restful atmosphere for the inhabitants. Intelligent home systems incorporating sensors and feedback mechanisms can modify the ceiling's shape and height on the fly to provide residents with a more pleasant and adaptable environment. The following are some additional factors to think about when implementing a smart home system that may alter the shape and size of the ceiling to reflect the occupants' moods: Do not be afraid to use modified supplies; the ceiling height and overall structure may be modified with more ease if the construction uses malleable materials. For instance, the shape of a ceiling might alter in response to environmental factors such as temperature and humidity. Use the power of machine learning algorithms; using machine learning algorithms to examine sensor data and feedback mechanisms can make the system more intelligent and responsive. The ceiling's shape and height may be modified based on what the algorithms have learned about the building's residents. Use information from user profiles; create individual user accounts for your household members to customize their experience better. People's preferences for things such as ceiling height, shape, illumination, and other environmental aspects may be saved in these profiles. The intelligent home system may automatically utilize these data to adjust based on individual preferences. It is essential to keep privacy in mind. Privacy issues must be considered when installing sensors that monitor the location and movement of building occupants. Make it that the sensors collect just the essential data and that they are stored and processed safely. Connect to other preexisting smart home infrastructure; integrating ceiling height and shape modification with other technologies such as lighting, temperature control, and sound systems may help create a more comprehensive and coherent design. This has the potential to provide a more streamlined and pleasurable environment for the residents. Considering these other considerations, you may design a cutting-edge home system that modifies the ceiling shape and height to suit human sensation and creates a unique and pleasant space for each resident.

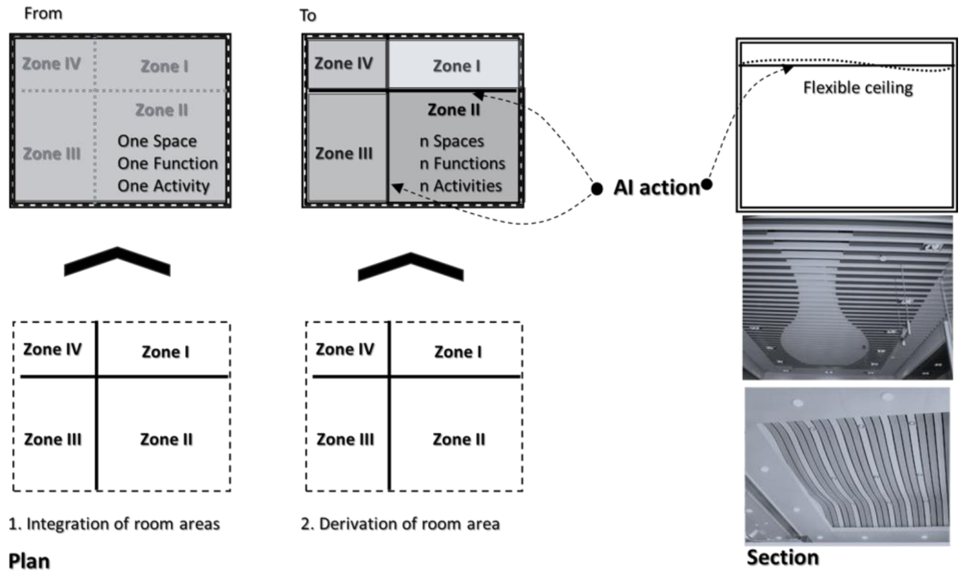

Figure 9. Rooms' temperature comfort according to human activities and home zones.

Consequently, the living area in smart homes should provide a multilevel computer control system for the optimal functioning of all residential spaces and conditions of smart homes. It is shown that all these tasks can be solved only with modern design CAD systems, which should be combined into a single project system to solve the creation of a complex smart home projects. To solve the tasks, it is necessary to create a training system for high-level specialists responsible for making strategic decisions, such as architects, urban planners, engineers, economists, power engineers, etc. Table 1 shows the summary of AI technologies, patterns, interactions, and energy efficiency in the design of smart buildings.

Table 1. Summary of AI Technologies, Patterns, Interactions, and Energy Efficiency in the design of Smart Buildings.

No	Topic	References
1.	AI Technologies in Intelligent Homes	
1.1	AI and Smart Home Interaction	[21–24]
1.2	Ubiquitous Computing	[25]
1.3	Environment—Smart Technologies	[26–32]
1.4	Environment—Smart Architecture	[32–37]
1.5	Expert System and Neural Network Communication	[38–41]
2.	AI patterns in Smart Home Design Features, Interactions, and Control	
2.1	Constant, Preemptive Safety Warnings and Security functions	[43–45]
2.2	Voice-Activated Control System	[46–49]
2.3	Options for Remote Observation and Video Surveillance	[50]
3.	Experience Integrating AI Technologies with the Human Environment	
3.1	Refusal of Cloud Technologies	[54–56]
3.2	A Smart hoME with New Standards	[57,58]
3.3	Smart Home System within Alternative Approaches	[59]
3.4	Smart Homes and a Healthy Environment	[60]
4.	Incorporating Considerations for Energy Efficiency into the Design of Buildings	
	Passive and Low-Energy Housing	[61]
	AI and the IoT Applications in Smart Homes	[62,63]
	Greenhouse Effect	[64]

6. Discussion

Artificial intelligence (AI) permeates many industries and inspires new solutions to long-standing issues. In recent years, it has also received increased consideration in the design of buildings and dwellings. Perifanis, N.-A., and Kitsios (2023) assert that smart homes have emphasized the performance benefits and success criteria of implementing AI [65]. According to Nikitas, A.; Michalakopoulou, K.; Njoya, E.T., and Karampatzakis (2020), artificial intelligence (AI) is a powerful idea still in its infancy. If used responsibly, they explain, it has the potential to provide a vehicle for positive change that could promote sustainable transitions to a more resource-efficient livability paradigm [66]. In addition, by harnessing AI's deep learning capabilities, we can give machines the tools they need to take on tasks that could fundamentally change how cities work in the future and usher in the era of the "smart city" [67]. Yet, they maintain that AI will always be only a tool in the hands of a designer and that it will never be able to replace the designer's sensitivity and intuition. While computers are not great at creating open, new ideas, architects who employ smart assistants are free to focus on the creative process. Yet, by automating routine jobs, we can put that time into creative endeavors.

Sentences from sensors and other embedded devices are fed into a smart home system's AI; according to Lynggaard, P. (2014), the character sequences that are either allowed or banned encode these broadcasts. Visuals are used in the permitted arrangements. However, prohibited accounts create holes in the visuals [68].

Due to the high redundancy of character sequences, accurate pattern detection is possible even when input sequences contain mistakes. The effectiveness of error correction in recovering lost data is enhanced. The information in a stochastic code can be deciphered by comparing the input data's code with the information portion of the code. Thus, input sequence mistakes and deletions are corrected, and an optimal picture encoding is also obtained, which minimizes the number of symbols in the image code, making image processing easier. Digital image authentication is a significant issue in the information age, since it is simple to alter any digital photograph, as stated by Begum, M. and Uddin, M.S. (2020). During the past few decades, verifying the legitimacy of digital pictures has been a pressing issue for academics [69]. It is possible to represent input data with a large number of smaller images, making a distinction between simple and complicated images. This improves efficiency in encoding detailed images—image processing using neural networks' functional transformations. A neural network can perform the role of a universal approximator of a nonlinear function whose inputs are a set of picture data [70]. The output of this function is the final image. Processing many input images in parallel neural networks is essential for high performance. This article presents a diagram of the smart home system, which consists of three main AI subsystems, one of which is responsible for processing single images. At the same time, the other is responsible for processing complex images using artificial intelligence technologies, which may include several devices. Artificial intelligence (AI) in the smart home is an intelligent assistant regulating various mechanical systems. Smart home innovations are crucial because of their profound impact on people's everyday lives. Essential responsibilities in researching and developing AI technologies for smart home systems include studying the principles of coding and picture construction and making decisions. Artificial intelligence (AI) technologies, which may involve several devices, are used to implement the processing of complex images. Ruili Zheng thought that improving the degree of intelligence in family life and the current way of life is likely to be a future development trend, especially given the exponential growth of information technology [71], where a diagram of the smart home system, which comprises these three primary AI subsystems, is provided in the design process.

Smart home innovations are crucial because of their profound impact on people's everyday lives. Essential responsibilities in researching and developing AI technologies for innovative home systems include studying the fundamentals of coding, picture formation, and decision-making. Artificial intelligence (AI) technologies, which may involve several devices, are used to implement the processing of complex images. A diagram of the smart home system, which comprises these three primary AI subsystems, is provided in the article. A study by Rock, L.Y., Tajudeen, F.P., and Chung, Y.W. (2022) found that home automation systems using AI models helped consumers save time, altered their lifestyles, and enhanced their sense of security, safety, environmental condition, enjoyment, convenience, and comfort [72].

Critical activities in advancing AI technologies in innovative home systems include the research of coding principles, picture construction, and decision making. .

The improvement of the smart home function requires serious attention to the implementation of the "Internet of things "IoT" in home design, where the term "Internet of Things" (IoT) refers to the interconnection of electronic devices that may exchange data wirelessly. Using this innovation, a gadget can help evaluate the scenario and form judgments without human input [73,74]. The relevant data from IoT devices are already present in the AI platform before they are integrated into a smart home system. Premade action algorithms are being put into use by the AI platform right now. With the help of AI, we can take raw data, transform it into actionable instructions, and then use it to create a behavior model that perfectly accommodates human requirements. This is because technology can now evaluate the outcomes of human interactions and foresee how things will progress (see Figure 10).

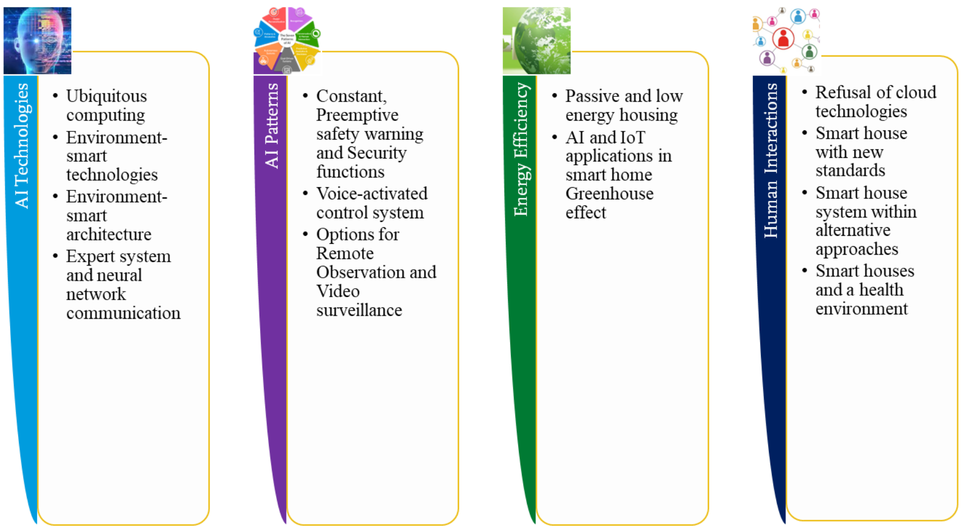

Figure 10. The framework of AI applications in the design of smart buildings**.**

7. Conclusions and Recommendations

AI models in smart home design can improve usability and convenience. In this case study, artificial intelligence (AI) technology in smart home systems enhances energy efficiency, user experience, and security. Smart homes will undoubtedly improve as AI technology advances and become more affordable. AI models can assist designers in creating smart homes that meet the needs of residents and improve their quality of life. When we talk about a "smart" home, we usually mean a place where people can feel safe, have a pleasant experience, and use their resources efficiently. While the term smart home may suggest otherwise today, intelligent room control was not initially included in the design process (from English, the word smart, in this case, is understood as designing and developing as convenient). Instead, priority profiles or manual control are used to manage the system. Because of advancements in artificial intelligence and increased functionality of equipment and systems, "intelligent" room management is now possible and more practicable than ever. This is how the system works. In other words, a "smart home" is a "thinking building" that can adapt to its surroundings and take appropriate action.

Architects and designers have to integrate the technical solutions within smart home components in a friendly manner, beginning with the design phase and based on the users' needs. This will allow the AEC sector to improve and design competent home functions during the design process. They have to ensure four factors:

- It should be possible to incorporate numerous tools, sensors, and processes into the house's technical and intelligent system during project design.
- While designing the home system, security should come first.
- The home system should be expandable and versatile to include future technological innovations.
- The user should be considered while designing the home systems. Therefore, they should be easy to use and intuitive.

Conclusions and practical recommendations for designing and developing buildings to improve creative home design are drawn from this analysis of how artificial intelligence models have been used, focusing on how the interoperability and compatibility of smart home devices can be improved.

Doing so will guarantee that the intelligent home performs at peak efficiency and delivers the best possible levels of comfort, security, and resource conservation for its owner. However, to create and construct smart homes, it is essential to emphasize individualization strongly. Therefore, AI models should learn from user behavior and adapt the settings of gadgets in a smart home to meet each user's needs and preferences. That way, the intelligent home can guarantee its inhabitants the most significant possible ease and comfort.

By integrating cutting-edge systems such as the Internet of Things and artificial intelligence, smart homes provide an environment where their inhabitants may feel safe, secure, and at ease. The term "Internet of Things," or "IoT," describes the practice of linking every object in our environment to the web. The integration of Internet-connected devices into the domestic sphere is also being explored to create novel value. Several smart home gadgets on the market today utilize all technologies. Activity detection, data processing, speech recognition, picture recognition, decision making, and prediction making are the six clusters of AI tasks we established for intelligent homes to facilitate ease of understanding. Smart home gadgets use artificial intelligence to learn to identify everyday human actions. Sensor data are analyzed to determine human activity, and an alert is sent if anything unexpected occurs.

This article helps readers understand cutting-edge home technology for boosting smart home features in modern building design by classifying the many types of smart homes already in use and the goals they seek to accomplish. It also highlights the conveniences homeowners may look forward to as a result of using this technology.

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