# Enhancing Smart Home Design with AI Models

Subjects: Others

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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.

smart home design    AI technology    human environment    living space

## 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.

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.

## 2. 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 [7]. 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 [8]. 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 [9]. 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 [10].

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 [11].

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 [12].

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 [13]. 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.

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

## 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 [14]. 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 [15]. 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 [16]. 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.

## 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 [17]. For voice control of the light, the user needs the Internet, a voice assistant, and a connected smart home system; see **Figure 1**.
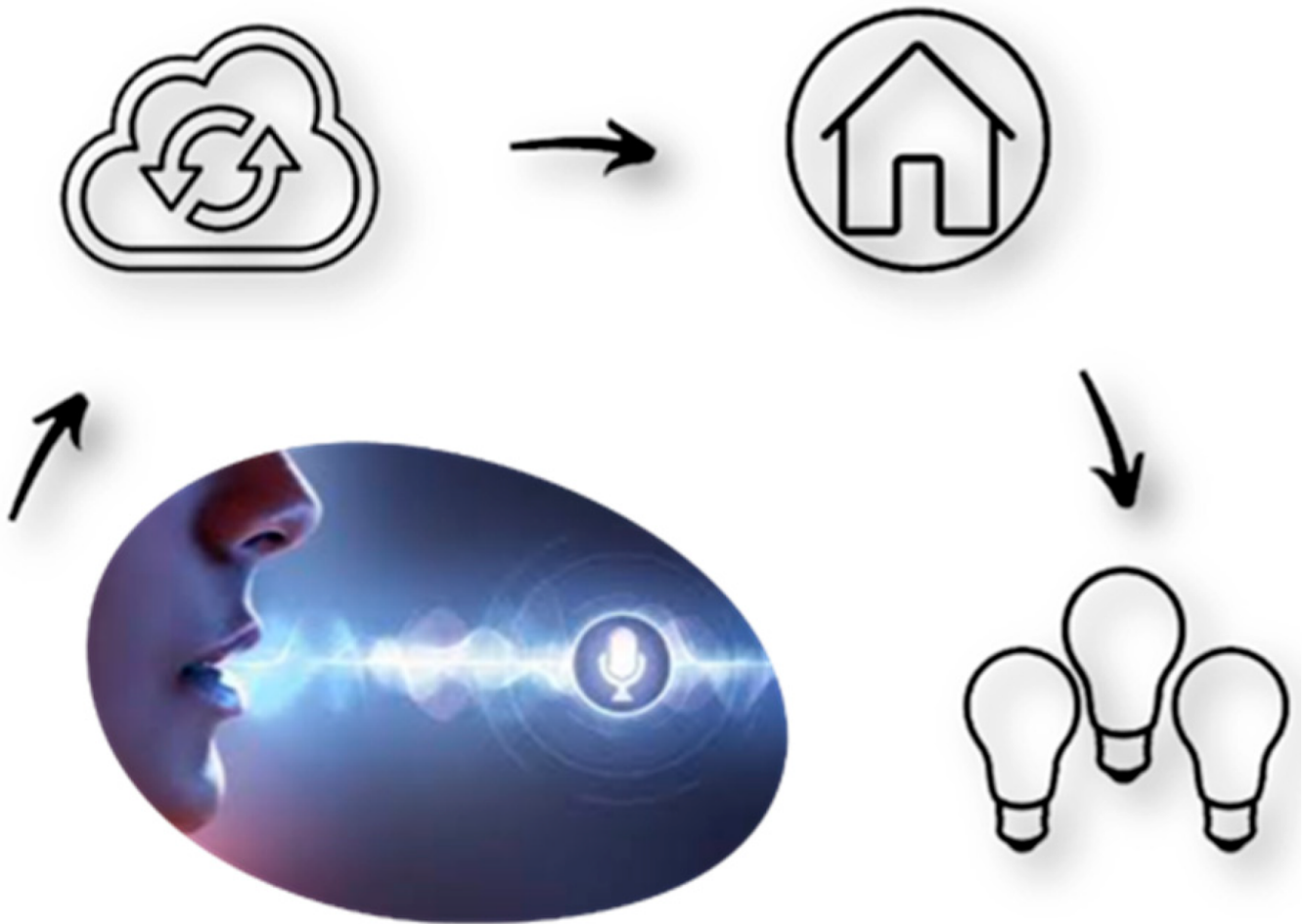


**Figure 1.** The voice control of the light in the smart home system.

## 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 [18]. 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 [19]. 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 [20]. 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 [21]. 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.

# References

1. Benjamin, K.S.; Mari, M.; Dylan, D.; Furszyfer, D.R. Knowledge, energy sustainability, and vulnerability in the demographics of smart home technology diffusion. Energy Policy 2021, 153, 112196.

2. Farzaneh, H.; MalehMirchegini, L.; Bejan, A.; Afolabi, T.; Mulumba, A.; Daka, P.P. Artificial Intelligence Evolution in Smart Buildings for Energy Efficiency. Appl. Sci. 2021, 11, 763.

3. Homod, R.Z.; Yaseen, Z.M.; Hussein, A.K.; Almusaed, A.; Alawi, O.A.; Falah, M.W.; Abdelrazek, A.H.; Ahmed, W.; Eltaweel, M. Deep clustering of cooperative multi-agent reinforcement learning to optimize multi chiller HVAC systems for smart buildings energy management. J. Build. Eng. 2023, 65, 105689.

4. De Fazio, R.; Mastronardi, V.M.; Petruzzi, M.; De Vittorio, M.; Visconti, P. Human–Machine Interaction through Advanced Haptic Sensors: A Piezoelectric Sensory Glove with Edge Machine Learning for Gesture and Object Recognition. Futur. Internet 2022, 15, 14.

5. Naomi, H.; Joakim, W.; Vinit, P.; Oliver, G. Artificial intelligence and innovation management: A review, framework, and research agenda. Technol. Forecast. Soc. Chang. 2021, 162, 120392.

6. Ghaffarianhoseini, A.; Ghaffarianhoseini, A.; Tookey, J.; Omrany, H.; Fleury, A.; Naismith, N.; Ghaffarianhoseini, M. The essence of smart homes: Application of intelligent technologies towards smarter urban future. In Artificial Intelligence: Concepts, Methodologies, Tools, and Applications; Information Resources Management Association, Ed.; IGI Global: Hershey, PA, USA, 2017; pp. 79–121.

7. Radha, R.K. Flexible smart home design: Case study to design future smart home prototypes. Ain Shams Eng. J. 2021, 13, 101513.

8. Elkholy, M.H.; Senjyu, T.; Lotfy, M.E.; Elgarhy, A.; Ali, N.S.; Gaafar, T.S. Design and Implementation of a Real-Time Smart Home Management System Considering Energy Saving. Sustainability 2022, 14, 13840.

9. Pritoni, M.; Meier, A.K.; Aragon, C.; Perry, D.; Peffer, T. Energy efficiency and the misuse of programmable thermostats: The effectiveness of crowdsourcing for understanding household behavior. Energy Res. Soc. Sci. 2015, 8, 190–197.

10. Xiao, G. Machine Learning in Smart Home Energy Monitoring System. IOP Conf. Ser. Earth Environ. Sci. 2021, 769, 42035.

11. Diraco, G.; Leone, A.; Siciliano, P. AI-Based Early Change Detection in Smart Living Environments. Sensors 2019, 19, 3549.

12. Alexakis, G.; Panagiotakis, S.; Fragkakis, A.; Markakis, E.; Vassilakis, K. Control of Smart Home Operations Using Natural Language Processing, Voice Recognition and IoT Technologies in a Multi-Tier Architecture. Designs 2019, 3, 32.

13. Chang, S.; Nam, K. Smart Home Adoption: The Impact of User Characteristics and Differences in Perception of Benefits. Buildings 2021, 11, 393.

14. Ge, R.; Shan, Z.; Kou, H. An intelligent surveillance system based on motion detection. In Proceedings of the 2011 4th IEEE International Conference on Broadband Network and Multimedia Technology, Shenzhen, China, 28–30 October 2011; pp. 306–309.

15. Almusaed, A.; Almssad, A.; Alasadi, A. Analytical interpretation of energy efficiency concepts in the housing design process from hot climate. J. Build. Eng. 2018, 21, 254–266.

16. Ahmad, M.B.; Abdullahi, A.S.M.A.A.; Muhammad, A.S.; Saleh, Y.B.; Usman, U.B.; Communication, T.S.O.D.I.A.W. The Various Types of sensors used in the Security Alarm system. Int. J. New Comput. Arch. Their Appl. 2019, 9, 50–59.

17. Vasquez, N.G.; Amorim, C.N.D.; Matusiak, B.; Kanno, J.; Sokol, N.; Martyniuk-Peczek, J.; Sibilio, S.; Scorpio, M.; Koga, Y. Lighting conditions in home office and occupant's perception: Exploring drivers of satisfaction. Energy Build. 2022, 261, 111977.

18. Avola, D.; Cannistraci, I.; Cascio, M.; Cinque, L.; Diko, A.; Fagioli, A.; Foresti, G.L.; Lanzino, R.; Mancini, M.; Mecca, A.; et al. A Novel GAN-Based Anomaly Detection and Localization Method for Aerial Video Surveillance at Low Altitude. Remote Sens. 2022, 14, 4110.

19. Guo, X.; Shen, Z.; Zhang, Y.; Wu, T. Review on the Application of Artificial Intelligence in Smart Homes. Smart Cities 2019, 2, 402–420.

20. Cioffi, R.; Travaglioni, M.; Piscitelli, G.; Petrillo, A.; De Felice, F. Artificial Intelligence and Machine Learning Applications in Smart Production: Progress, Trends, and Directions. Sustainability 2020, 12, 492.

21. Bogdan, R.; Tatu, A.; Crisan-Vida, M.; Popa, M.; Stoicu-Tivadar, L. A Practical Experience on the Amazon Alexa Integration in Smart Offices. Sensors 2021, 21, 734.