

Artificial Intelligence in Smart Homes

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ABSTRACT

Artificial intelligence (AI) is a term used to describe a group of computerized systems that carry out jobs typically done by humans. AI in smart home refers to a residence equipped with devices and systems that use artificial intelligence (AI) to create automated and personalized environments by learning user habits to control devices like lights, thermostats, and security systems. This allows for a more intuitive experience, where the home can anticipate needs without explicit commands. AI smart homes provide homeowners with AI apps to automate homes. These smart-systems learn your habits and preferences, making your home more convenient, energy-efficient, and secure by automatically adjusting to your needs. The development of smart home technology has been given top priority in national energy strategies and strategic planning. This paper explores the essence of AI in smart homes.

KEYWORDS: *artificial intelligence, machine learning, AI, generative AI, smart homes, smart houses.*

INTRODUCTION

Technology is consistently improving our quality of life. The Internet of things, artificial intelligence, robots, and smart sensors will all feature in the homes of the future. Imagine a home that knows your preferences, adjusts the lighting automatically, and even manages your security. This is not a sci-fi fantasy; it is the reality of today's artificial intelligence house technology. A smart home is a system of devices and sensors interconnected to perform actions automatically and make life easy and convenient for the inhabitants. With benefits like energy efficiency, power bill reduction, automation convenience, and higher security, the number of smart homes is increasing. Devices like smart speakers, thermostats, robots, and ambient motion sensors are making our homes come alive and adjusting the settings according to our choices. The integration of AI in smart homes transforms living spaces into intuitive, efficient, and safer environments, revolutionizing daily life. The new systems are revolutionary in that they learn from your behavior, can predict your needs, and make decisions autonomously without always being told what to do. Figure 1 shows a typical smart home [1].

Artificial intelligence (AI) is a field of computer science that is concerned with creating advanced software that creates machines that think like humans. AI takes standard smart home technology to a whole new level. AI at home refers to the integration of machine learning and automation technologies to manage and control home environments without extensive human intervention. At its core, AI for smart homes involves the use of algorithms and sensors to learn from homeowners' behaviors and preferences to optimize tasks such as lighting, temperature control, and security. These home AI systems can analyze vast amounts of data from connected devices like thermostats, cameras, and kitchen appliances [2]. Smart houses are becoming increasingly commonplace, way to the improvements in synthetic intelligence.

WHAT IS ARTIFICIAL INTELLIGENCE?

The term “artificial intelligence” (AI) is an umbrella term John McCarthy, a computer scientist, coined in 1955 and defined as “the science and engineering of intelligent machines.” It refers to the ability of a computer system to perform human tasks (such as thinking and learning) that usually can only be

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accomplished using human intelligence [3]. Typically, AI systems demonstrate at least some of the following human behaviors: planning, learning, reasoning, problem solving, knowledge representation, perception, speech recognition, decision-making, language translation, motion, manipulation, intelligence, and creativity.

The 10 U.S. Code § 2358 define artificial intelligence as [4]:

1. “Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.
2. An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
3. An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
4. A set of techniques, including machine learning, that is designed to approximate a cognitive task.
5. An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision making, and acting.”

AI provides tools creating intelligent machines which can behave like humans, think like humans, and make decisions like humans. The main goals of artificial intelligence are [5]:

1. Replicate human intelligence
2. Solve knowledge-intensive tasks
3. Make an intelligent connection of perception and action
4. Build a machine which can perform tasks that requires human intelligence
5. Create some system which can exhibit intelligent behavior, learn new things by itself, demonstrate, explain, and can advise to its user.

AI is not a single technology but a range of computational models and algorithms. The concept of AI is an umbrella term that encompasses many different technologies. AI is not a single technology but a collection of techniques that enables computer systems to perform tasks that would otherwise require human intelligence. The major disciplines in AI include [6]:

- Expert systems
- Fuzzy logic
- Neural networks
- Machine learning (ML)
- Deep learning
- Natural Language Processors (NLP)
- Robots

These computer-based tools or technologies have been used to achieve AI’s goals. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. Figure 2 shows a typical expert system, while Figure 3 illustrates the AI tools. These tools are gaining momentum across every industry. Analytics can be considered a core AI capability.

ARTIFICIAL INTELLIGENCE IN SMART HOMES

The development of smart home technologies contributed to the transition of the home from traditional to a smart Internet-connected one. As the use of artificial intelligence (AI) grows more ubiquitous, the housing industry is looking to these new tools as an opportunity to improve housing access, reduce costs, and speed up housing production. AI can bring greater efficiencies to the construction industry as well, with technological innovations reducing construction costs. Homebuilders can leverage AI by employing drones, cameras, and mobile robots to analyze footage, monitor progress on construction sites, and confirm in real time that projects are aligned with design plans [7].

In recent years, AI in smart homes has transformed from a luxury concept to an essential part of modern living. A smart home is a residence equipped with technologies that include sensors, wired and wireless networks, actuators, and intelligent systems. It is a residence outfitted with cutting-edge technology that allows for the remote automation and management of various household systems and equipment. Smart homes integrate technologies such as IoT, AI, cloud computing, and sensors to achieve centralized management, interconnectivity, and remote control of home devices. Currently, smart homes are utilized more in energy management, intelligent interaction, and security with AI functions of voice recognition and image recognition [8]. Figure 4 shows a representation of AI in a smart home [9].

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN SMART HOMES

Examples of AI in smart homes include voice assistants like Alexa and Google Assistant, intelligent thermostats that learn your habits, AI-powered security cameras that differentiate between people

and pets, and smart appliances that suggest recipes or optimize cleaning cycles. Smart home technology has its applications in voice assistants, household smart devices, home safety and security, lighting, and entertainment. These applications enhance convenience, security, and energy efficiency by learning user behavior and automating tasks. Common applications include the following [9,10]:

- *Voice Assistants*: The evolution of virtual assistants demonstrates perhaps the most visible application of AI in smart homes. Voice assistants are becoming central to smart home ecosystems and have revolutionized how we engage with our clever houses. They leverage natural language processing to understand human voice commands and respond accordingly. These devices can be interlinked with the appliances and devices in the home through a common WiFi network. Devices like Amazon Alexa and Google Assistant use AI to understand and respond to voice commands for tasks such as playing music, controlling other smart devices, or getting weather updates. These AI-powered tools can perform tasks ranging from turning on appliances to creating grocery lists, all triggered by simple voice commands. Figure 5 shows some Ai-based voice assistants [11].
- *Smart Home Devices*: These include smart refrigerators, smart ovens, smart kitchens, smart speakers, smart security cameras, smart lighting systems, smart irrigation systems, smart beds and mattresses, smart locks, smart meters, robotic vacuum cleaners, and washing machines. Smart refrigerators can track inventory and suggest recipes, while washing machines can be programmed to run during off-peak hours. Today's smart kitchens are powered by AI that goes beyond timers and recipe apps. AI-enabled ovens can recognize dishes and auto-adjust time and temperature for perfect results. Devices like the Nest Thermostat use AI to learn the household's heating and cooling preferences to automatically adjust settings for optimal comfort and energy efficiency. Other appliances can coordinate their functions for greater efficiency. Some of these smart home devices are illustrated in Figure 6 [12].
- *Smart Lighting*: Smart homes have centrally controlled lighting systems controllable through voice, remote, and mobile applications. Smart lighting can be customized according to the usage pattern of every area of the home. Smart lighting systems can learn your schedule and preferences to automatically adjust brightness and color based on the time of day or the activity in the room.

Smart lighting systems use AI to learn your schedule and lighting preferences. They can automatically adjust the brightness and color based on the time of day or the activity you are engaged in.

- *Energy Management*: Perhaps the most impactful application of AI in smart homes is in energy management, where intelligent systems are dramatically reducing consumption while maintaining comfort and convenience. The heating and cooling systems in our houses take the major chunk of energy bills. AI-optimized climate control technology uses AI algorithms to learn the user behavior and fine-tune the settings. This way, the utilization of the heating and cooling is reduced. Smart thermostats and meters use AI to learn usage patterns, optimize heating and cooling, and suggest ways to save energy, which can lead to significant energy savings.

BENEFITS

The integration of AI and smart homes brings remarkable benefits, making daily life more convenient and efficient. AI-powered home automation systems create a highly personalized living environment. AI and generative AI benefit the sellers and the buyers in different ways. AI models in smart home design can improve usability, convenience, energy efficiency, user experience, and security. Other benefits include the following [10,12,13]:

- *Automation*: Automation is one of the best parts of AI smart homes. AI home automation contributes to a more convenient and personalized living experience. With AI continuously learning more about the residents' choices and preferences, it can automate how all the appliances work to make the lives of homeowners or residents easier. AI learns individual preferences for lighting, temperature, and entertainment to automatically adjust the home's ambiance when you enter a room. AI tools offer automation capabilities, streamlining various predevelopment tasks and potentially cutting down on both time and expenses. AI tools cannot completely replace human involvement in zoning and land-use efforts, at least in the near term.
- *Enhanced Security*: Another important aspect of using AI in smart homes is security. When it comes to protecting our homes, AI security solutions have dramatically raised the bar for what is possible. AI-powered security systems can distinguish between familiar faces and potential intruders in video feeds, reducing false alarms and proactively identifying threats. AI-

enabled cameras can identify the residents of a house, and built-in sensors can detect the presence of an individual. It can send real-time alerts in case of intrusions or when an unusual activity is detected. Smart security cameras and doorbells use AI to differentiate between regular movement, like a pet running through the room, and unusual activity that might indicate a security threat. Figure 7 shows AI-powered security of smart home [1].

- *Predictive maintenance:* AI can predict when home appliances like refrigerators, washing machines, or HVAC systems are likely to fail, allowing homeowners to address issues before they become major problems. AI can analyze information from smart home equipment to predict capability problems earlier than they become fundamental problems. AI can monitor the health of home appliances and systems to predict when maintenance is needed, sending alerts before a problem occurs. Smart homes' AI-driven predictive maintenance will transform home ownership.
- *Health Monitoring:* AI smart house has also extended into health monitoring. AI home systems can track environmental conditions like air quality and humidity, adjusting them to optimal levels for health and comfort. Some advanced setups even monitor the occupants' health, providing reminders for medication or alerts in case of emergencies like falls.
- *Voice Control:* Voice recognition technology is crucial to smart home systems because it allows people and devices to interact naturally and conveniently, which simplifies and improves home control. Users can control the lights, electric draperies, gates, and door locks in their home simply by using their voices. AI-powered voice assistants like Google Assistant and Apple Siri interpret natural language commands to control various devices, making daily tasks hands-free. With integration to voice assistants and smart speakers, residents could say, "Turn off the lights", and it is done. Natural language processing made commands feel intuitive.
- *Integration with Smart City:* Smart homes will connect to smart city systems, playing a bigger role in community-wide improvements. Through AI-powered systems, they can help balance the energy load on city grids by adjusting electricity usage during peak demand times.
- *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. Sensors include temperature, light, touch, proximity, video sensors, and sound sensors fitted on furniture.

- *Energy Conservation:* Appliances are lacking in energy conservation capabilities. Current forms of energy-saving technology have their drawbacks. Energy-conserving materials can be expensive. AI will improve the energy conservation of homes. Smart meters and thermostats are already widely available. These devices monitor temperature and energy usage in the home and are widely touted as energy and money-saving appliances.
- *Elderly and Disability Support:* AI can be used to improve accessibility and safety for those who need it, such as through voice-activated controls and automated assistance.

CHALLENGES

There are a number of obstacles that IoT applications in smart homes must overcome. When using several brands of devices, users find it challenging to create seamless connectivity and collaborative control due to the absence of unifying standards and protocols. There is still room for development in the intelligence of certain smart home appliances. One of the main challenges in the integration process is achieving interconnectivity and data exchange across various devices. Another significant challenge is the demand for compatibility and interoperability between diverse systems and devices. Other challenges include the following [14,15]:

- *Privacy and Data Security:* Data security and privacy protection are the most important issues in the construction of smart homes. In order to achieve the goal of smart homes, a large amount of personal information such as home addresses, device usage logs and even health information are collected when these devices are running. If the information is disclosed, customers' security and privacy will be seriously threatened. As home devices become more intelligent and connected, users' personal information and privacy are more vulnerable to intrusions and breaches, raising serious security and privacy issues in smart home systems. It is critical to make sure smart home technologies are secure. Systems require robust encryption, secure storage, and transparent data policies addressing legitimate privacy concerns.

- *High Costs:* Comprehensive smart home implementations require significant upfront expenses for devices, installation, and integration. Cost barriers particularly affect renters or budget-conscious households despite long-term energy savings and convenience benefits.
- *Incompatibility:* Device incompatibility issues seriously hinder the development and popularization of smart home systems. Several manufacturers develop smart home appliances, which causes compatibility issues and makes it difficult to incorporate other methods. It is difficult for smart home systems to be interconnected and work together due to the fact that different manufacturers adopt different data formats and communication protocols. Users feel extremely annoyed by this problem and it also hinders the development of an integrated smart home system. Industry standards and protocols are being developed to address these difficulties and ensure high compatibility and interoperability among smart home systems.
- *User Experience:* Although smart home systems can bring more comfort and convenience to customers, there are also a lot of usability problems on these systems. For example, network configuration, device pairing, and scene customization are common procedures in the whole configuring process of smart home systems. These processes are relatively complex and difficult for non-professional customers. To improve the learning experience of users, more user-friendly graphical user interface should be developed with drag and drop functions.
- *Waste:* Electronic trash or waste from smart home appliances has caused environmental problems due to the widespread use of smart home appliances.
- *Bias:* While there is always the potential for bias when using AI, it can be easier to detect and correct than unconscious bias exhibited by individual appraisers.
- *Cybersecurity:* Connected devices expand attack surfaces for malicious actors. Many consumers lack cybersecurity skills to properly secure networks, configure firewalls, or recognize compromised devices, leaving homes vulnerable to cyber-physical attacks.

FUTURE OF ARTIFICIAL INTELLIGENCE IN SMART HOMES

Smart homes powered by AI represent a major step forward from programmed automation to systems that can learn, predict and optimize residential operations

on their own. The evolution of AI in smart homes shows no signs of slowing. Several emerging trends promise to further transform our relationship with our living spaces. Biometric integration will make interactions with artificial intelligence in smart homes technology more natural and secure. Your home will be able to identify household members and react accordingly using advanced facial recognition, voice printing, and even gait analysis without need clear commands [9].

In recent years, the concept of the smart home has become increasingly widespread, and artificial intelligence (AI) has become an essential part of this technology. The future of AI in smart homes promises even more advanced integration and innovative applications that will further transform our living environments. Future smart homes will use AI to not just respond to our commands but to anticipate needs before they are expressed. As more devices become smart, AI will play a crucial role in ensuring these devices work together seamlessly.

CONCLUSION

Smart home innovations are crucial because of their profound impact on people's everyday lives. Smart home and artificial intelligence technologies are developing rapidly, and various smart home products have improved the quality of living for occupants. The integration of AI in smart homes has revolutionized the concept of living spaces, bringing about significant changes that impact efficiency, security, and convenience. The degree of automation in smart homes is significantly increased by this integration. Investing in AI smart home technology is no longer a luxury but a necessity for builders looking to future-proof their projects. As these technologies mature, we can expect AI in smart homes to fade into the background of our awareness while its benefits become more profound. More information on artificial intelligence in smart homes is available from the books in [16-21] and the following related journals:

- The AI Journal
- AI Magazine
- Journal of Intelligence
- Applied Artificial Intelligence

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Figure 1 A typical smart home [1].

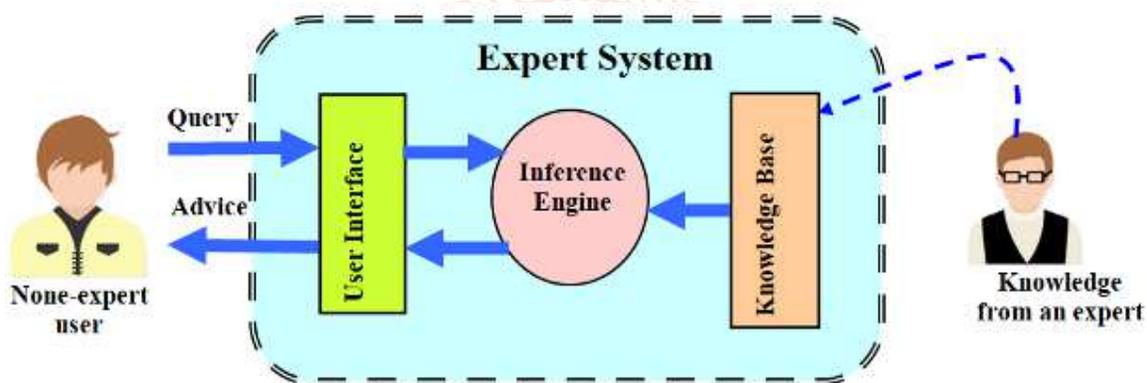


Figure 2 A typical expert system.

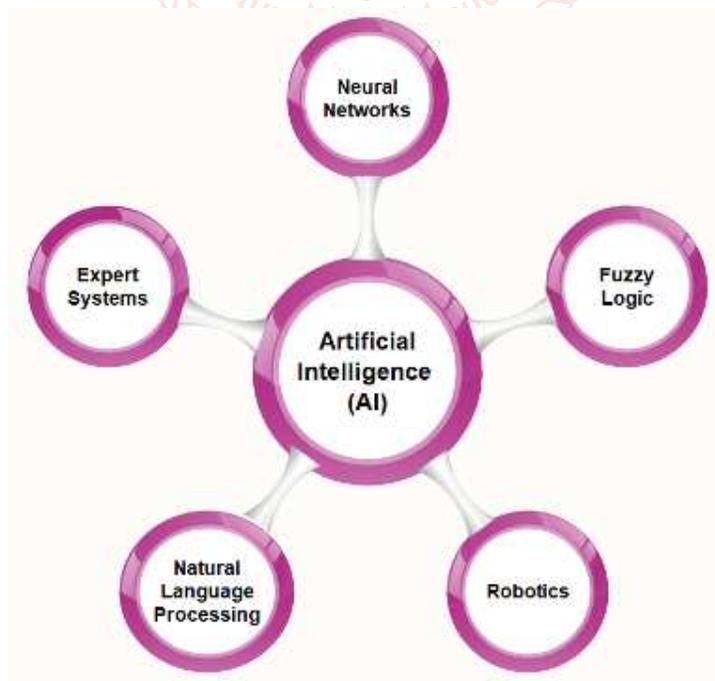


Figure 3 AI tools.



Figure 7 AI-powered security of smart home [1].

