Research Article

A Study on Smart Home Appliances Based on Artificial Intelligence System

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ARTICLE INFO	ABSTRACT
	Objective: The present study was based on the smart home appliances works based on the artificial intelligence system that are the recent evolution of emerging technologies in the deep learning and machine learning technologies. **Methods**: Smart home appliances are developed using the system of artificial intelligence. The home automation control, features, techniques used in the smart home appliances construction, its review and analysis are clearly examined. **Results**: The analysis of different types of smart home appliance and the comparative analysis of the usage and acceptance by the people in the current scenario are discussed. The performance and features of the smart home appliances and traditional appliances are compared. Thus, proving that the proposed study is human friendly and the features are highly supportive. **Conclusion**: The proposed study focuses on the different types of smart home appliances constructed based on the artificial intelligence system is highly affordable, convenient to use, easy operation and energy efficient. **Keywords:** Smart homes, Artificial Intelligence, Automation, Smart city

INTRODUCTION

The smart home appliances follow the working principle of automation. The system controls and operates the complete process of working with the help of electronic devices to reduce the involvement of human in the minimum level. The architecture of the automation system includes the basic fundamentals to use the electrical appliances in home and offices as well. It includes a greater number of benefits. Based on the requirement of smart home appliances are developed by the researchers and industrialists that include fans, lights, Air conditioner that works efficiently and acts as the affordable system of automation for controlling and monitoring the electrical appliances in smart home. The automated system is efficient and energy efficient as well. It helps in reducing the use of water and electricity with less wastage thus it is referred as the system of economical use. The evolution of smart home technologies in recent years has helped move homes from being conventional to being smart, internet-connected homes. A house that has technologies like wireless and wired networks, sensors, intelligent system and actuators are known as "Smart home" (Stojkoska & Trivodaliev, 2017; Guz, 2012).

The artificial intelligence and IoT are inter-related that offers numerous numbers of applications that can be used in the application of electronic devices operation control and management. By using the application of intelligence system things and people are connected by the network and other kind of services ideally by anyone, anyplace and at any-time. The significant application of the AI technologies is automation control system. The system controls the environment and energy consumption is monitored in the homes, offices, schools, museums and big buildings it uses various types of actuators and sensors for controlling the light, humidity and temperature. Though, the appliances are equipped with extremely sophisticated smart homes and automatic systems are able to monitor and handle household activities easily, increase the comfort of occupant and possible reducing energy consumption. Smart home technologies are used to collect and analyse the data from domestic environment. Additionally, it

improves the ability to operate different home systems. It also provides information to users (Firth et al., 2013; Moses et al., 2022). The AI technology has been used by smart home appliances. For clarity, AI capabilities is divided in smart homes into six major categories: activity recognition, data processing, speech and image recognition, decision-making, and prediction-making. Artificial intelligence (AI) can be used to recognise human behaviour in smart home products. It looks at sensor data for detecting human activity and raises the alarm when anything out of the ordinary happened inside the home (Guo et al., 2019; Porwal, 2024). The house simulator is developed and used it as a "expert system shell" to assist with the implementation and verification of the observe, learn, and adapt (OLA) algorithm for better energy management and conservation in smart homes (Qela & Mouftah, 2012; Min et al., 2024; Cho, 2024).

It was determined how artificial intelligence is applied in smart home products and the employment in our home in order to comprehend how it can be used for developing smart homes. Our research also revealed a gap between books and products. Smart homes consist of intelligent interactions that becomes more popular over the time. The inter-relation between the Literature, products, and the development of AI-enabled smart homes are all examples of the technology. The scope of the study is the application of artificial intelligence system in the home appliances for the building and development of smart homes with many productive features like efficiency in energy, minimum in wastage, less human intervention, enabling easy operation, control and management.

MATERIALS AND METHODS

The study design includes the various smart home appliances that works on the principle of AI technologies, the features and the automation control system in smart home are discussed.

1.1 Home Automation Control

The Smart home is referred as the "House Automation Control" that uses the recent technologies that helps in making the household activities more secure, economical, comfortable and convenience. The automation system of smart home that include major components such as;

User Interface:

Phone, computer and monitor of the desktop acts as the example of user interface. This interface is able to give commands to the controlling system.

Mode of transmission:

The mode of transmission includes wired connections such as wired connections like Ethernet and wireless connections like Bluetooth, infrared, GSM and radio waves.

Central controller:

The central controller is known as the hardware interface that has the ability for communicating with the user interface and able to perform the control and management of household devices.

Electronic appliances:

Electronic appliances like fan, lamp, lights, heater, television and air conditioners that are compatible by means of mode of transmission and are connected with the centralized control system.

1.2 Techniques used in smart home appliances

The smart home environment includes the collaboration of multi-disciplinary techniques that includes the specializations like electrical and electronic engineering, architecture and computer science. If the equipment is related to health sector, it includes the active participation of medicine, social sciences and occupational therapy. The concept of smart home can be achieved through the improvements in safety and life style based upon the information processing with intelligence system and using the characteristics of the smart homes more intelligently by using the single smaller component of AI.

The smart homes support the living with independence that offers the possibility of constructing and designing the intelligent monitoring system that are able to detect the situations and undesirable happening that includes any threats or hazards around the environment of smart home. It is more helpful in taking care of the elderly people

and the patients with health problems especially the people cannot be monitored by the health care professionals can be monitored well using the smart home management system.

The system can be highly helpful for the persons suffer from cognitive impairment, the system with installed pre-instructions, control and monitoring can give commands to them like cooking the food with menu and instructions to be followed, instructions for taking a shower and things to do before leaving the house such as taking the key, cap or umbrella, bag. Smart homes are constructed with embedded system for the enhanced functionality of the conventional home appliances and devices. The appliances developed with AI technologies that offers high level of support must be of commercial perspectives and it is deployed using simplest user interface.

1.3 Sensors

Sensors are the key element in the automated system of smart homes. It is the combination of hardware and software coupling that was installed in one or more places in the home. It can be able to provide information in detail that happens inside the house and in the neighbourhood. The movement sensors include the timer fitted inside the microwave and smoke alarm. Few enriched devices like taps that are fitted with sensors offers the instructions in detail for the users like the procedure to turn on the tap, the water flow and it can be stopped through the remote. Thus, most of the appliances inside the home can be operated with sensors.

The devices and appliances evolved using the sensors based on the AI technologies for the problem-solving strategies that include;

i.   The most flexible tool for monitoring the circumstances over the semi-autonomous devices that can offer the activities of the home globally inside the smart home
ii. It is a cohesive tool for gathering the information with global insight into the activities of the patients and elderly people inside the home.

Smart home provides the community of AI with the benchmarks of appliances over the traditional method using sensors for the effective, energy saving, stress free management of the devices.

1.4 Features of smart home appliances

In home networking, wireless technologies like Remote Control have grown in popularity recently. Additionally, the integration of wireless technology in automation systems offers a number of benefits that could not be attained with the use of a wired network alone.

1.4.1 Reduction in cost of installation

The cost of installation is reduced much since there is no requirement of cables.

1.4.2 Connectivity

The connectivity can be made easily with the control devices across the world using smart phones or tablets with installed applications for controlling the smart home.

1.4.3 Expandable

If the requirement is changed or newly introduced the extension of the network can be performed using the wireless network in specific.

1.4.4 Safety

Integrated smart home security system was created due to addition of new devices easily and the safety is ensured by the built-in security in the integrity of the smart home.

1.5 Various types of smart home appliances

The different types of smart home appliances are controlled by artificial intelligence system like household appliances, air conditioning, vehicles, refrigerator, laptops, desktops by using various modes of energy is displayed in Figure *1*.
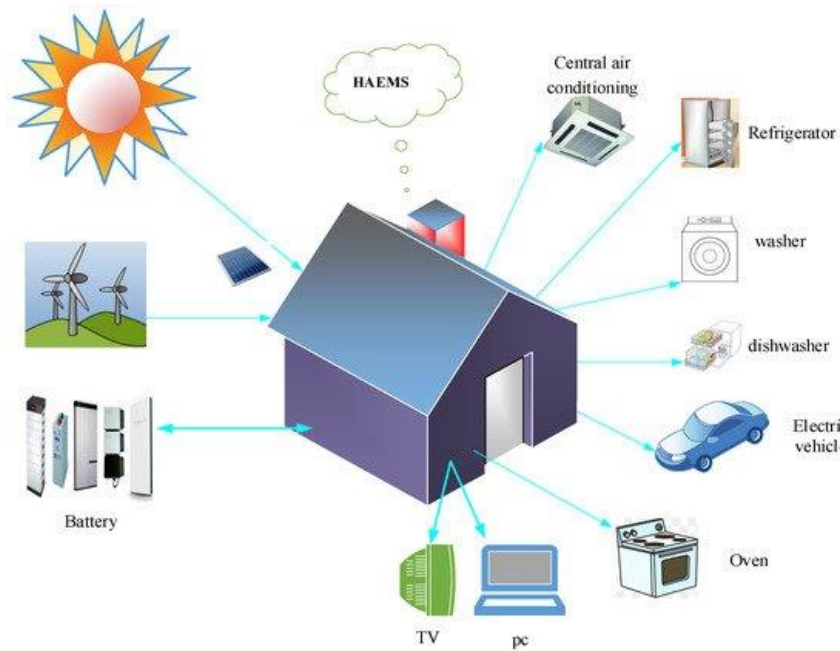
Figure 1 Different types of smart home appliances

1.5.1 Smart Kitchen appliances

A smart kitchen with AI capabilities consists of convenient smart gadgets with the potential to lower energy costs. These smart gadgets may now be remotely controlled and monitored via voice commands and smartphone apps, which adds another level of ease to daily life by saving time and effort. In its most basic form, an AI-enabled smart kitchen has smart appliances that can perform tasks automatically.

Everyone is aware of the difficulties in choosing a dish to prepare. It gets even more challenging when you look in the refrigerator for inspiration before giving up and placing an order for takeout. However, artificial intelligence is now present in smart refrigerators, helping you decide what to eat for dinner depending on what is currently in the refrigerator. This technology aims to reduce food waste.

The same level of AI and robotic assistance is given to cleaning as it is to cooking. Due to hectic schedules and shifting priorities, not everyone has the time to spend hours upon hours cleaning the kitchen and cooking in it.

1.5.2 Smart household appliances

In the load response programme, household appliances are categorised as responsive or non-responsive loads based on their capabilities. Responsive loads, such as water heaters and washing machines, occasionally transfer their use based on the provided tariff. Televisions and personal computers are examples of non-responsive gadgets because they are frequently utilised at the whim and without taking tariffs into account by the user. Even if the duration and amount of consumption of these devices cannot be controlled, a number of time periods can be suggested to the owners of these devices as operational times.

The main justification for this is because without the possibility of autonomous operation, the timing of people's activities will not be possible given the urgent requirement for them to control electrical equipment. Today, however, thanks to the development of intelligent washing machines, intelligent dishwashers, and self-driving vacuum cleaners, many tasks may be accomplished automatically without requiring human input. Second, the home appliance may now be accessed remotely and controlled by centralised software thanks to the internet of things   (Xin et al., 2017). This centralised management and control can be implemented using cloud services. Energy storage has been done in response to the costs and the time of usage in order to ensure the best performance of household loads with electric vehicles and devices. Nevertheless, the study was carried out without taking into account the sources of scattered output (Kermani et al., 2021; Rolla, 2023).

1.5.3 Smart lights and Fans

LED lighting systems have built-in controls and communication for smart lighting. You have more automation and freedom. The conventional fixed-wire connection is not a constraint on you. Humans can control the fixtures with a smart lighting system using any connected device. Humans may programme and control the lights using your computer, tablet, smartphone, and other devices. The smart lighting controls also make it simple to change the power supplied to a particular light fixture or connected lighting system as well as the colour temperature of the light.

1.5.4 Smart cooling appliances

The term "intelligent" refers to an air conditioning system that uses a variety of environmental and occupancy characteristics and extensive computing skills to give the resident with the best intertemporal comfort/cost trade-offs possible, subject to predicted retail energy prices. Retail energy prices may be influenced by wholesale energy prices, which is referred to as "smart-grid functionality." To illustrate the capabilities of the suggested A/C system controller, simulation studies are conducted (Thomas et al., 2012).

1.5.5 Smart heating appliances

The water temperature setting affects the performance of the water heater is operating. The water heater is disconnected when the water temperature exceeds the maximum temperature, turned on when the temperature drops below the minimum temperature, and left in its default state when the temperature falls between the defined range. Like water heaters, room heaters work on the principle of powering on and off by the controlled system according to the temperature maintained in the room and adjusted to the temperature of human's body temperature requirement.

1.5.6 Smart security system

People are protected from unforeseen health risks by a smart home security system. The same cameras and motion detectors that protect a property's outside can be used in smart homes to track the habits and activities of its residents. If a resident takes a sudden action and does not resume normal routines, the smart home can alert the family or emergency authorities. The elderly or those in poor health will particularly benefit from this aspect of a smart home. People are protected from unforeseen health risks by a smart home security system. The same cameras and motion detectors that protect a property's outside can be used in smart homes to track the habits and activities of its residents. The smart home can notify the family or emergency services if the resident makes an unexpected action and does not resume routine activities.

The elderly or those in poor health will particularly benefit from this aspect of a smart home. With the use of motion detectors, security codes, cameras constitute the smart home security system that determines the person is resident or intruder or a confirmed visitor. Artificial intelligence is alerted by the motion detectors software when something or someone needs to be examined.

Facial recognition software is used by the security system and the security code enables the inhabitants inside the house while restricting the others access based upon the pre-programmed data. Anytime a stranger is detected by a smart home security system, the owner can view a video of the visitor. Remote clearance and entry permission can be issued to greet guests. Unwanted guests can be ignored, but anyone trying to break in will result in a call to the police (Nicks, 2009).

1.5.7 Smart electronic devices

Appliances and surveillance in smart cities are the primary IoT applications for smart houses. The majority of researchers use vision sensors in IoT environments that solely target adult users for diverse purposes like the identification of deviant activities. Traditional wearable sensors, such heartbeat monitors, can make a baby feel uneasy if they are placed near any area of his body. Some babies also have sensor-phobia. To assess the behaviour of the infant, baby monitoring vision-based framework control charts, is accepted as the improvement tool. We build a control chart at predetermined intervals for frames of real time produced using the vision sensor connected. Motion of baby is depicted by the points on the chart of control; when these points surpass the upper control limit or drop below the lower control limit, the baby is exhibiting abnormal behaviour. When such conduct is observed, a signal is sent to the IoT's network of connected gadgets as a warning to babysitters in advanced medical facilities.

The newest and most popular technology on the market, the smart home automation system, makes life simpler and easier to manage. A home automation system built on the internet of things (IoT) is intended for elderly and disabled individuals. In addition to IoT technologies, this system architecture also makes use of cloud computing and artificial intelligence (AI) (Gladence et al., 2020).

1.6 Review Method for comparison

The three primary smart home product databases are smarthomedb.com, iotlist.co, and the Google search engine. The Google search engine has a massive amount of data, but it is not properly organised. Iotlist.co, a platform that displays a list of Internet of things (IoT) devices available for purchase, has a very tidy and appealing user interface, even though it is not only for smart home appliances that lacks the clearly defined categories. Many other website that concentrates on the gadgets of smart home and offers through the descriptions of the products. These factors led us to select as our data source for product reviews. Additionally, we came across a few cutting-edge situations when searching Google. The proposed smart home appliances are compared with the traditional methods according to their features.

1.7 Analysis of applications of smart home appliances

The qualitative induction technique was a step-by-step process. We identified five key roles of smart homes from the literature review: energy management, device management, smart decision-making system, intelligent interaction, security and healthcare. In order to create artificial neural networks, expert systems, smart decision-making systems, and intelligent structures were used, according to Tang. Using this information, we classified the AI features of smart home automation into six categories: speech recognition, data processing, activity recognition, judgement, picture recognition, and prediction. Data processing in this article comprises semantic analysis, data mining and rule-based technology.

The quantitative analysis of the quantity of individual group under books and the products was then performed. In final it is summarised the purpose of artificial intelligence in smart homes along with varied functions by studying the literature of selection and certain particular items.

A smart house is a ubiquitous computing application where ambient intelligence monitors the home environment to deliver context-aware services and enable remote home control. This document provides a summary of earlier research on smart homes and related technologies. There is a brief description of the components of smart homes and the way they are related to one another. It provides information on all the sensors, multimedia devices, communication protocols, and systems used in the realisation of smart homes (Alam et al., 2012).

RESULTS AND DISCUSSION

The smart home appliances referred to the home automation control that works on the principle of artificial intelligence system has specific features. The different types of smart home appliances are taken for the study shown in Figure *2* to analyse the features, characteristics, performance, cost of installation in the appliances like smart kitchen, household appliances, cooling and heating, lights and fans and other appliances is discussed in Table *1*.

Table 1 Smart home appliance usage per 1000 people

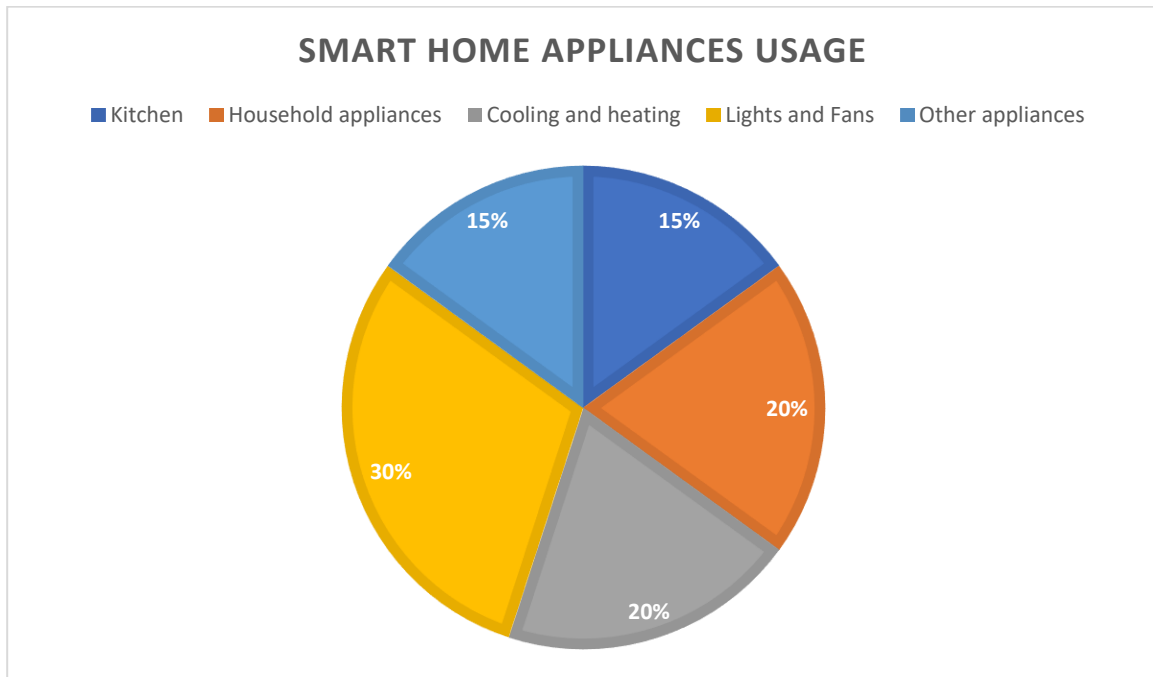|	Smart home appliance usage out of 1000 people	Percentage of usage
Smart Kitchen	150	15
Household appliances	200	20
Cooling and heating	200	20
Lights and fans	300	30
Other appliances	150	15

Figure 2 Smart home appliances recommended

The above pie chart shows that the various usage of smart home appliances by the people and recommended for use nowadays according to the acceptance and buying rate. The kitchen sales and usage are 15%, household appliances are 20%, cooling and heating appliances is 20%, lights and fans are 30% and other smart home appliances is 15% is proved from the various reviews based on data collection from google. The comparative analysis were tabulated in the Table 2.

Table 2 Comparative analysis of traditional appliances and smart home appliances

	Traditional appliances	Smart appliances
Energy efficiency	40%	80%
Security	30%	92%
Health care	40%	85%
Connectivity	30%	98%

Objective function controls and programs the intelligent appliance system. It is represented as;

$$\text{Objective function } Min = \frac{SP}{LF} \tag{1}$$

Where SP is cost of operation and LF is load factor. SP is defined from upper grid C_{EP}, profit grid C_{BS} and profit from program C_{DM}.

$$SP = C_{EP} - C_{BS} - C_{DM} \tag{2}$$

$$LF = \frac{Average\ of\ load}{Peak\ of\ load} \tag{3}$$

The modern smart devices are equipped with storage like batteries or plugged in hybrid electric vehicle.

$$P_{Batt,ch} \leq P_{ch,max}, \eta_{ch} u_{Batt}(h) \tag{4}$$

$$PBatt,dch(h) \leq (Pdch,max\eta dch)(1 - uBatt(h)) \tag{5}$$

Where, P_{dch} and P_{dh} are the maximum charge and discharge of the battery respectively.

$$Soc(h+1) = Soc(h) + \frac{PBatt,ch(h) - PBatt,ch(h)\Delta hsetp}{EBatt} \tag{6}$$

Where E_{Batt} is the battery capacity in kWh. A PHEV is generally the same as a battery, but there are a few additional restrictions. For example, a cut-off signal states that a PHEV battery can only be charged or drained at home, and Soc_{min} hourly states that a PHEV battery's minimum power level must also be met.
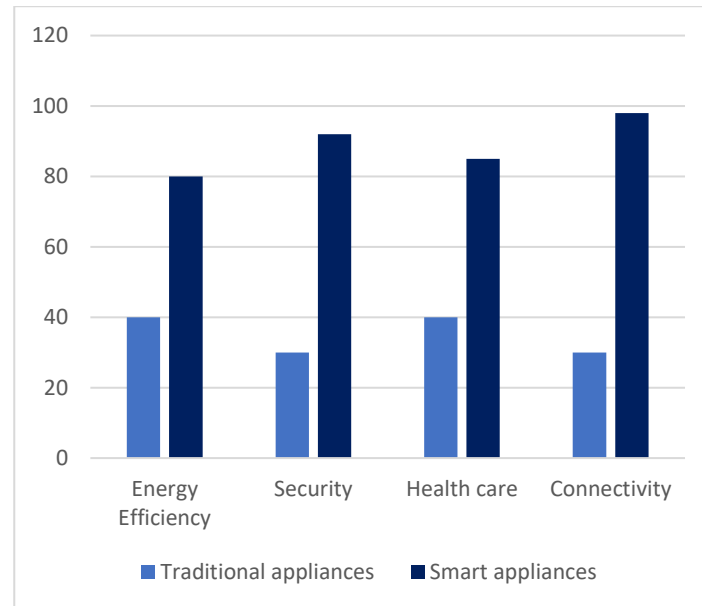

Figure 3 Comparative analysis of smart home and traditional appliances

The above Figure *3* displays the comparative analysis of the various features of the traditional appliances and smart home appliances in terms of efficiency, security, installation cost and connectivity. The smart home appliances show energy efficiency is comparatively 40% higher, security is 62% higher, health care is 45% higher and connectivity shows the highest results of 68% than the traditional method. Hence, the proposed smart home appliances give the better way of living in the smart way by reducing wastage and time.

These findings demonstrate that both diversity and quantity increased over time as more and more application sectors were explored. Since 2015, healthcare research has been declining annually while research on intelligent interaction has been rising. Research into energy management is growing as well is displayed in Figure *4*. It may be assumed that in the upcoming days, smart homes focus more on how people and the environment interact, as well as on how to make structures more individualised and sustainable (Guo et al., 2019).
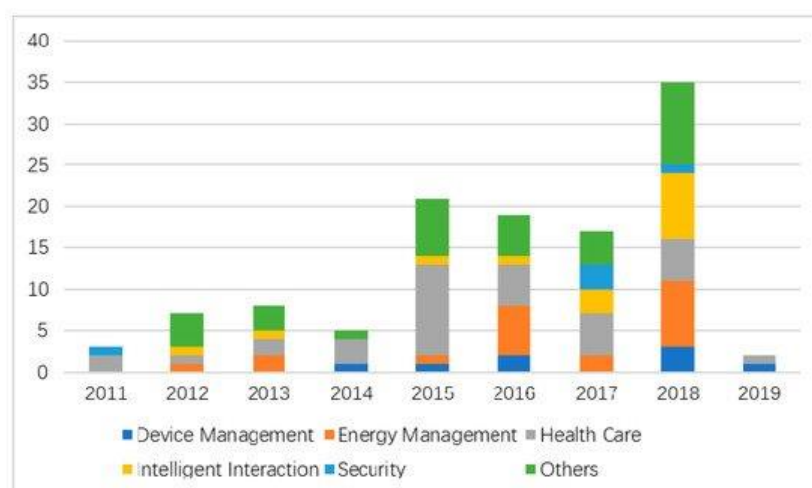

Figure 4 Applications fields of smart homes with AI (Guo, X et al., 2019)

The comparison between the proposed method and the previous researches the study has been revealed that the smart home appliances are in trend in recent years based on the artificial intelligence system accepted by the people.

CONCLUSION

The proposed study aimed to demonstrate the smart home benefits of AI. Numerous studies in the literature and a number of items were reviewed in order to accomplish this goal. Through the use of data processing, decision-making, activity recognition, prediction-making, voice recognition and image recognition, we discovered that AI technologies supports smart homes in the areas of energy management, device management, intelligent interaction, health care, security, personal robots and entertainment systems. In future, smart homes mainly aims on how people and the environment interact to create more individualised and sustainable structures.

The growing popularity of home automation is a result of its many advantages. Automation of residential features and appliances through local networking or remote control is referred to as "home automation". The basis for automation and real time decision making for the internet of things is provided by artificial intelligence (IoT). The study discusses several intelligent home automation technologies and systems from a variety of feature perspectives. The work focuses on the idea of home automation, in which monitoring and control tasks are made easier by smart devices put in residential structures.

When an appliance is connected to a central system and has the capability to be programmed, controlled remotely, or function on its own, depending on information from sensors detecting things like light levels, temperature or activity of the appliance monitoring is known as smart appliance and it is preferred as the part of smart home. Future work on integrating AI to smart houses will focus on creating standards that take into account both smart home technology and architectural design.

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Authors' contributions

The author contributed toward data analysis, drafting and revising the paper and agreed to be responsible for all the aspects of this work.

Declaration of Conflicts of Interests

The author declares that they have no conflict of interest.

Availability of data and materials

Not Applicable

Use of Artificial Intelligence

Not applicable

Declarations

The author declares that all works are original and this manuscript has not been published in any other journal.

REFERENCES

[1] Alam, M. R., Reaz, M. B. I., & Ali, M. A. M. (2012). A review of smart homes—Past, present, and future. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 42(6), 1190–1203.

[2] Cho, O. H. (2024). An evaluation of various machine learning approaches for detecting leaf diseases in agriculture. Legume Research. https://doi.org/10.18805/LRF-787.

[3] Firth, S., Fouchal, F., Kane, T., Dimitriou, V., & Hassan, T. (2013). Decision support systems for domestic retrofit provision using smart home data streams.

[4] Gladence, L. M., Anu, V. M., Rathna, R., & Brumancia, E. (2020). Recommender system for home automation using IoT and artificial intelligence. Journal of Ambient Intelligence and Humanized Computing, 1–9.

[5] Guo, X., Shen, Z., Zhang, Y., & Wu, T. (2019). Review on the application of artificial intelligence in smart homes. Smart Cities, 2(3), 402–420.

[6]   Guz, M. (2012). Models of holiday rest of the medical community of Łódź – recommendations for tour operators. Acta Innovations, 4, 113–158. https://www.actainnovations.com/index.php/pub/article/view/4_3

[7]   Kermani, M., Adelmanesh, B., Shirdare, E., Sima, C. A., Carnì, D. L., & Martirano, L. (2021). Intelligent energy management based on SCADA system in a real microgrid for smart building applications. Renewable Energy, 171, 1115–1127.

[8]   Min, P. K., Mito, K., & Kim, T. H. (2024). The evolving landscape of artificial intelligence applications in animal health. Indian Journal of Animal Research. https://doi.org/10.18805/IJAR.BF-1742.

[9]   Moses, M. B., Nithya, S. E., & Parameswari, M. (2022). Internet of things and geographical information system based monitoring and mapping of real-time water quality system. International Journal of Environmental Sciences, 8(1), 27–36. https://www.theaspd.com/resources/3.%20Water%20Quality%20Monitoring%20Paper.pdf

[10]   Nicks, V. (2009). AI enhances the smart home security system.

[11]   Porwal, S., Majid, M., Desai, S. C., Vaishnav, J., & Alam, S. (2024). Recent advances, challenges in applying artificial intelligence and deep learning in the manufacturing industry. Pacific Business Review (International), 16(7), 143–152.

[12]   Qela, B., & Mouftah, H. T. (2012). Observe, learn, and adapt (OLA)—An algorithm for energy management in smart homes using wireless sensors and artificial intelligence. IEEE Transactions on Smart Grid, 3(4), 2262–2272.

[13]   Rolla, K. J. (2023). Trends and futuristic applications of big data and electronic health record data in empowering constructive clinical decision support systems. Bio-Science Research Bulletin, 39(2), 78–91.

[14]   Stojkoska, B. L. R., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. Journal of Cleaner Production, 140, 1454–1464.

[15]   Thomas, A. G., Jahangiri, P., Wu, D., Cai, C., Zhao, H., Aliprantis, D. C., & Tesfatsion, L. (2012). Intelligent residential air-conditioning system with smart-grid functionality. IEEE Transactions on Smart Grid, 3(4), 2240–2251.

[16]   Xin, S., Guo, Q., Wang, J., Chen, C., Sun, H., & Zhang, B. (2017). Information masking theory for data protection in future cloud-based energy management. IEEE Transactions on Smart Grid, 9(6), 5664–5676.