

Application And Analysis of Artificial Intelligence in Smart Homes

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Abstract. With the development of artificial intelligence (AI), the combination of AI and smart home has given users a better experience, and more and more people are willing to use smart home. In this paper, the main purpose is to lead readers to understand smart home and how to apply smart home technology (SHT). SHT needs to be supported by different systems. Different systems use monitoring, positioning and automatic controlling to give users better experiences. Although there are various articles which introduced the applications of smart home in the website, few studies have integrated the various systems into one introduction. From children to elderly people, SHT can help people within each age group improve their experiences. For example, monitoring children's security and elderly people's health. The goals for smart home systems are reducing the costs and improving the comfort. This paper hopes that in the future smart homes will become more and more intelligent, that is, from "responsive" to "active and predictive" services.

Keywords: Artificial intelligence, Smart home technology, Internet of things, Application or system of AI, Energy management.

1. Introduction

In recent years, the SHT and AI have developed rapidly. They help people gradually change from traditional life to intelligent life. The basic smart home is including sensors, wired and wireless networks, actuators, and intelligent systems [1]. For the intelligent systems, the AI must be used. The role of AI is receiving the requirements from human, trying to think like human and express the results to human. All operations performed by the AI are automated.

In today's society, various families have used the SHT into their homes. There are lots of brands of smart home now, such as Apple HomePod, Aqara Home, Google Home, etc. The SHT is convenient for people to control their home and make them more comfortable. Therefore, different systems will be introduced, and how can these systems be used in modern smart homes.

Firstly, the floor monitoring system with embedded triboelectric sensors is a new invention from SHT. It can catch enough sensory information from human's daily lives, and it does not have relevant privacy issues with cameras [2]. The researchers use highly reliable triboelectric coding mats and AI data analysis to create this system. And this system can be used for various smart home monitoring and interaction.

In the other hand, the house energy management systems (HEMS) also improve the level of lives for humans. Alden et al. state a new idea which can separate the Heating, Ventilation, and Air Conditioning (HVAC) dominant load component from the house load [3]. They also adopt the new model which bases on future weather data. In the process of testing, the SHINES dataset has been used. The results of testing are ideal because they are within the margin of error.

Furthermore, the smart home supported by Internet of Things (IoT) is limited and dispersed. Zaidan et al. search the information and make a survey from three different sides, smart home, IoT and applications [4]. IEEE Explore, ScienceDirect and Web of Science, which are three databases that used in the article search. Zaidan et al. put forward that AI technology can catch the possible changes based on applications of smart home powered by IoT.

The SHT must consume electricity to use, and the users want to reduce the cost of electricity and improve the level of comfort. Therefore, electricity fee and comfort level are conflicting each other.

In order to solve this problem, based on popular Strength Pareto Evolutionary Algorithm (SPEA2), the simulator investigation uses 11 smart home scheduling within more than 10 time slots [5]. Finally, a timetable has been generated, and users can change their requirements based on this timetable.

With the rapid growth of the world's elderly population in recent years, the requirements for families will continue to rise. Naseer et al. show a system which combines Generative Adversarial Network (GAN) and AI framework with IoT [6], and this system can transform to personalized elderly care in the smart home environment. Rely on this system, the elderly people can improve their independence and quality of life.

Base on the information mentioned above from the research articles, there are various systems or applications that can be used in SHT. Since 2016, the humans who have used the AI and smart home have increased rapidly. Therefore, the theme of this essay is the applications or systems of AI in smart home. The goals are helping readers understand some relevant knowledge about what are these smart home systems and how can people use them in daily lives. This is meaningful for both researchers and people who are interested in smart home.

2. Mainstream Technology Description

2.1. The Floor Monitoring System with Embedded Triboelectric Sensors

The floor mat is an important part of floor monitoring system. In Figure 1(b), a 4 * 4 floor mat is showed, and the same electrode pattern is used in the screen-printing process to create each floor mat. Also, a picture shows the components of the floor mat, which includes polyvinyl chloride (PVC) substrate, silver (Ag) sensing electrode and polyethylene terephthalate (PET) friction surface [2]. This floor mat is to determine the output ratio in relation to the reference electrode, a large-area patch electrode is utilized to record various gait steps and carry out rigorous position monitoring at the same time. This system has wide applications, it can be used in SHT, health care, security and IoT. Furthermore, this system can know the real-time location and identity of users via data analyzing. The advantages of this floor mat are low cost, large area, and interaction with various SHT. But this floor mat is difficult to make, and it may also be affected by the external environment such as rainy or snowy weather.

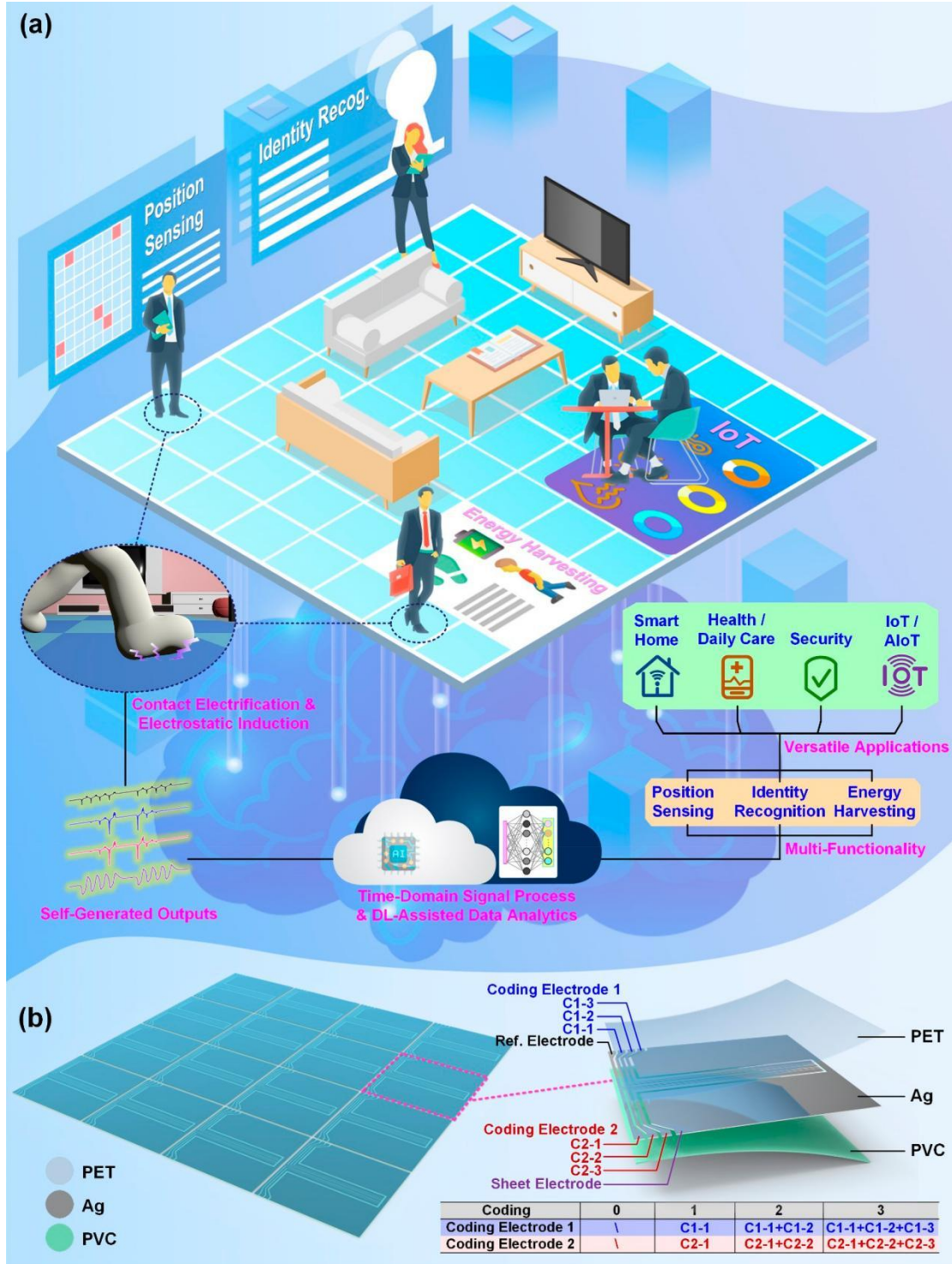


Fig.1 The floor monitoring system ((a): Smart floor monitoring system schematic diagram with DL-assisted data analysis and time-domain data processing. (b): A 4x4 floor mat array featuring an encoded electrogram design and magnified constituent layers.) [2]

2.2. The House Energy Management Systems (HEMS)

The HEMS adopts a new idea which includes the physical connection between weather and HVAC energy use and deep learning techniques. A novel long short-term memory (LSTM) encoder-decoder machine learning (ML) model is used in HEMS, and future weather data can be collected into this model. This model could replace weather forecasting. The HEMS integrates distributed energy resources (DER), such as solar photovoltaic (PV) and battery storage (BES) systems, in order to lessen the increasing carbon impact [3]. This research delves demand response (DR) plan and puts

PV, BES, HVAC system into modern HEMS of smart grid. The HEMS can monitor energy in real time and improve usage appropriately. It depends on weather; therefore, the limitation and problems will be showed in unusual weather. For example, the HEMS needs to use PV. The amount of sunlight exposure in a day affects the ability to obtain energy.

2.3. Smart Meter System Based on SPEA2 Algorithm

One of the earliest techniques to be thoroughly examined in comparison to other evolutionary-based algorithms was SPEA. And the SPEA2 is an improved version, it is different from its predecessor in that it uses an archive truncation method, a special density estimation approach, and an improved fitness distribution method [5]. In SPEA2, a strong and modern EMO algorithm is added. The main purpose of using SPEA2 are reducing the cost of electricity fee and improving user comfort. Finally, it can generate a timetable about smart home usage situation. Therefore, users could change their requirements or energy usage base on this timetable.

2.4. A System that Merges Generative Adversarial Network (GAN) with IoT-enabled Adaptive Artificial Intelligence (AI) Framework

The main purpose for designing this system is using GAN with IoT-enabled adaptive AI framework to manage the health care process of elders whose age are over 65. For example, this system can find early health risk cases, and it can reduce the response time if the patient is in emergency. GAN improves diagnostic model to keep everyone in balance (whether rich or poor). GAN also applies powerful predictive analysis to combine the data which is similar to modern data. Base on the GAN with AI framework in smart home, SHT can provide automatic recognition in various ways, such as mobility, medication and environment [6]. Therefore, the older people can be helped as soon as possible. The working process of this system includes reading, uploading, analyzing and reporting information. The user needs to wear a monitor like a watch to let the system read the health data such as blood pressure. Then these health data will upload to main IoTCloud. After analyzing by IoTCloud, a report will be sent to user and paramedics via message or email. It is better to help older people improve the quality of their lives. But not all diseases can be predicted in advance and written in IoTCloud. Therefore, not all diseases are completely dependent on this system.

2.5. A Natural Wood-based Triboelectric Self-powered Sensor (WTSS)

This part demonstrates the WTSS's working principle. The WTSS's sensing method relies on the interaction between electrostatic induction and contact electrification. Charge transfer takes place when the PTFE and wood film come into contact and separate; the wood surface produces a positive charge during contact, while the PTFE surface produces a negative charge. Electrons travel to the copper electrode via an external circuit during separation, until the two layers are fully separated. Electrons travel to the ground when the two layers make contact again, releasing the induced negative charge on the copper electrode. An AC signal is produced by the prolonged contact and separation of this triboelectric charge on the wood film surface [7]. The WTSS system can be used in many different applications of smart home in wood material such as smart door lock, smart floor and smart chair. Base on effective and simple processing procedure of natural wood, the WTSS system shows the features of sensitivity, flexibility, stability and thinness. But this system is easy to be influenced in rainy weather. For example, there are various electronic components inside wood, and wood is not waterproof, this may cause a short circuit of WTSS system.

3. Artificial Intelligence in Different Application Scenarios of Smart Home

3.1. Monitoring, Positioning and Automatic Controlling

Smart home monitoring and interactions are important for SHT which include position tracking, identity recognition and automatic controls. The SHT can locate user's position and apply some

automatic operations. Without the privacy concerns that come with cameras, floor monitoring systems can record a lot of motion and sensory data [2]. For example, a user uses floor mat for his SHT. Assume that the light is off in the bedroom, when the user goes to the bedroom, this action is identified by floor mat, and SHT controls the switch to turn on the light. After user leaves the bedroom, the light will be turned off automatically. Furthermore, the smart camera is also becoming popular in smart home now. Users install cameras inside or outside their home to monitor in real time. And this kind of cameras can identify people within the scope of surveillance. If a suspicious person is found, the system will send an email or message to user's account.

3.2. Energy Management

Now the use of energy is increasing all over the world especially electricity. For smart home, they need to consume electricity to keep working. Therefore, designing a useful energy management system is important for SHT. There is an inherent contradiction between consumer comfort and electricity costs. By employing the SPEA2 algorithm and appropriately allocating the use of electrical appliances, this problem can be resolved [5]. Smart homes need to minimize energy use while satisfying user comfort. For example, when users leave the home, the terminal of smart home turns off all of unnecessary energy use. In contrast, when users go back to home, they can turn on the smart home which they want before arriving via the application in their phones. IoT can analysis user's daily habit, including when and what kind of energy to use. For example, users need to use natural gas when cooking, they need to use water when washing the clothes or taking the shower. Base on this information, the main goal of SHT is to reduce the cost of energy and improve the comfort.

3.3. Health Care

With the growth of the world's population, the problem of aging population is becoming more and more serious. Health problems among the elderly are also of concern. SHT promotes elderly care including monitoring and reporting. It is the best way to improve quality of live and individual independence in a security environment. From small watch (mentioned in section 2.4) to big machine like X-ray or CT scanner, they are better to help people especially older people find their diseases as soon as possible. Base on database and IoT analyzing in medical area, the AI and machine learning is applied to remote diagnosis and telemedicine. In COVID-19 pandemic, the SHT can monitor user's health situation in real time and reduce the loneliness. Also, AI applications allow doctors and patients to no longer need face-to-face diagnosis to treat [8]. Although telemedicine is beneficial for elderly healthcare, the privacy and data security problems must be solved at first.

3.4. WTSS

One of the fundamental and essential components of the smart home system is the implementation of smart home appliance control, which can greatly enhance family intelligence. Smart home system combines WTSS, simple signal control circuit and some domestic appliances. When WTSS actions, the output signal will be produced. According to signal management and wireless signal transportation, domestic appliances can be controlled outside the home. This shows the effectiveness and simplicity of WTSS system. WTSS can not only be used in domestic appliances, but also can be used in personal computer software control such as music player. The AI can operate the button including play or pause, previous or next song, turn up or turn down the volume [7]. These features make it simple for WTSS to interface with IoT technology to enable remote control of computer software and to realize the intelligent and multifunctional operation of household appliances in smart home systems.

4. Discussion and Suggestion

4.1. Challenges

SHT is a combination of intelligence, automation and digitization. The AI, IoT and geographic information system (GIS) are necessary parts for smart home development. The utilization of geographical data in the construction of smart homes and the integration of AI and IoT are significantly lacking [9]. Also, in energy management and elderly healthcare area, there are large differences between modern and normal technology and SHT. The main purposes of users to use smart home are reducing the costs of electricity and energy. And users can improve the comfort. Therefore, the challenge problem is showed. Research directions towards completely intelligent systems can be guided by how to enhance and expand the Internet of Things and current systems to address additional energy-saving problems. Furthermore, the privacy and data security need to be valued. It's still difficult to link devices of various manufacturers and protocols seamlessly.

4.2. Future

AI may transform energy efficiency and home automation, advancing the smart home industry. In order to further expand the capabilities and advantages of AI-driven smart home systems, future research may integrate other smart home components and investigate real-time applications [10]. Furthermore, the future SHT does not limit at home, expanding to company, public facilities.

In addition, there are various sides that need to improve in the future. First, AI can provide from "responsive" to "proactive and predictive" services. The AI does not need to wait for instructions. AI can provide services forwardly base on the data collected in previous time; Secondly, personalized services can be powered by AI. AI can provide different services to different family members. For example, when children watch the TV, the cartoon will be played automatically; when father watches the TV, the football match will be played automatically. Finally, AI has abilities of autonomous decision-making and self-maintenance. AI is able to automatically identify equipment malfunctions and direct consumers toward repair or after-sales support. AI will handle security protection and software updates automatically, so consumers don't have to worry about it.

5. Conclusion

In this paper, Different systems use AI to drive the operation of smart home. From specific item like floor mat to Network, SHT helps people monitor, position and control automatically. SHT also provides support for energy management and healthcare. Although there are various AI tools today, such as ChatGPT, DeepSeek, AI can not solve all the problems which were produced by SHT. Base on the introduction above, AI will turn the smart home from a "network" of gadgets into a living, breathing thing that genuinely comprehends, looks after, and develops with its occupants. The home is now a warm, active partner that expands and improves human potential rather than a passive physical location. Our relationship with our living space is being drastically altered by smart homes, which offer previously unheard-of levels of comfort, security, and convenience. Reducing the cost and improving the comfort are important factors in all of the systems which mentioned in section 2 and section 3. Therefore, the smart home must connect home with the outside world such as public transportation and medical network. Instead of being an information island, AI can become an active "cell" of a smart city, seamlessly integrate with social services, and actively participate in the allocation of social energy. By taking this opportunity, this paper wishes that the applications or systems of artificial intelligence in smart home will develop better in the future.

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