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REVIEW

Artificial intelligence in smart homes: innovative approaches and application opportunities

Inteligencia artificial en hogares inteligentes: enfoques innovadores y oportunidades de aplicación

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ABSTRACT

Artificial intelligence-supported smart home technologies are evolving rapidly, offering users enhanced living standards. This article analyzes the current state of AI-integrated smart homes, exploring both academic literature and product applications on the market. The primary goal is to understand the technological development trends and how theoretical research aligns with real-world products. The article explains how AI enhances automation, management, and human-robot interaction in smart homes. The results indicate a delay between literature advancements and market implementations, suggesting that AI-powered smart home systems will become more widespread in the near future.

Keywords: Smart Home Technologies; AI Integration; Automation Systems; Human-Robot Interaction.

RESUMEN

Las tecnologías para hogares inteligentes basadas en inteligencia artificial (IA) evolucionan rápidamente, ofreciendo a los usuarios una mejor calidad de vida. Este artículo analiza el estado actual de los hogares inteligentes con IA integrada, explorando tanto la literatura académica como las aplicaciones de productos en el mercado. El objetivo principal es comprender las tendencias de desarrollo tecnológico y cómo la investigación teórica se alinea con los productos del mundo real. El artículo explica cómo la IA mejora la automatización, la gestión y la interacción humano-robot en los hogares inteligentes. Los resultados indican un retraso entre los avances en la literatura y las implementaciones en el mercado, lo que sugiere que los sistemas para hogares inteligentes con IA se generalizarán en un futuro próximo.

Palabras clave: Tecnologías para Hogares Inteligentes; Integración de IA; Sistemas de Automatización; Interacción Humano-Robot.

INTRODUCTION

In recent years, the development of smart home technologies has transformed traditional homes into modern, technology-enhanced spaces. These technologies offer users numerous opportunities to automate daily tasks and improve energy efficiency. The application of artificial intelligence (AI) plays a significant role in enhancing the management of smart home systems, making them more efficient and user-friendly. Researchers have explored various aspects of these technologies, covering topics such as image processing and the development of modern health-assistance systems. Home automation systems, integrated with AI, provide

optimal solutions for security, energy management, and convenience. These approaches enable smarter and more efficient management of everyday household tasks.[1,2,3]

For instance, Huh and colleagues demonstrated the daily use of AI by developing shoe selection and storage technologies. Meanwhile, Qela and others strengthened the connection between AI and smart home technologies by creating simulation tools for energy management.[4]

AI technologies have become a core component of smart home products. These technologies are divided into six main functional categories for different purposes:

- Activity Recognition: Uses sensors to monitor human behavior and detect anomalies.
- Data Analysis: Collects data from various sources and transforms it into meaningful information.
- Voice and Image Recognition: Facilitates natural interaction through advanced technologies such as face and emotion recognition.
- Decision-Making: Makes effective decisions across a wide range of areas, from security systems to resource management.
- Prediction: Analyzes data from daily activities to predict future trends and needs.[5]

These functions play a crucial role in integrating technology into daily life. Current solutions for smart homes primarily target simple interaction levels and are used for home management. However, research on integrating AI with smart home technologies on a broader scale remains limited. Data from Google Trends indicates that the AI industry is growing rapidly, and there is a need for closer integration between AI and smart homes. This study aims to bridge the gap in this area by exploring both product trends and the role of AI in smart homes from the perspectives of architecture and human needs.[6,7]

METHOD

Theoretical Research Method

This study examines the application of artificial intelligence (AI) in smart homes by analyzing research published between 2011 and 2019. This period is considered a time when AI began to gain significant momentum. The research involved reviewing journal articles, conference papers, and other scientific literature.

The data was searched in Scopus using the following syntax:

(TITLE (smart home) AND TITLE-ABS-KEY (artificial intelligen)). The term “intelligen*” was used to include variations like “intelligent” and “intelligence”. Research materials were sourced from various academic publishers such as Springer, IEEE, Blackwell, MDPI AG, the Institute of Physics, and Elsevier B.V. However, significant repetition was found across databases, where the same research appeared under different databases using similar search terms. To manage this duplication and select relevant materials, a two-step selection process was applied. After the first step, 116 materials were selected. These were then analyzed using a qualitative inductive method. In the next phase, a second selection process was conducted to analyze AI technologies and the functions of smart homes. After this stage, 20 materials were selected for further examination. Additionally, searches were carried out based on ISO international standards and those not yet compiled.

Product Review Method

There are three main databases related to smart home products:

1. Google Search: This platform offers a large database of smart home products, but it is not well-organized. This can make it challenging for users to find suitable smart home products as the search results may not always be relevant or refined.
2. iotlist.co: This platform provides a list of IoT devices available on the market and is user-friendly in design. However, it does not focus solely on smart home products, and the categorization of products needs improvement. Expanding and refining the product categories would make it easier for users to navigate and find specific smart home solutions.
3. SmartHomeDB: This platform is specifically designed for smart home products, offering a more structured and organized database compared to the others. It provides users with easier access to relevant smart home product data. However, it lacks a comprehensive product comparison feature, which could hinder users who want to directly compare different products in the same category.

Each of these databases has certain advantages, such as accessibility, data organization, and user-friendliness, but they also present limitations that can complicate the process of finding and comparing smart home products. These limitations emphasize the need for a more refined platform that can combine the strengths of all databases while addressing their shortcomings.

Analysis of the Use of Artificial Intelligence in Smart Home

The qualitative inductive analysis method used in this study consists of several stages. In the literature review, we identified the main functions of smart homes: device management, energy management, healthcare

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services, intelligent interaction, and security. Tang explained the application of expert systems, artificial neural networks, and intelligent decision-making systems in smart buildings. Based on this analysis, we divided the functions of artificial intelligence in smart homes into six categories: activity recognition, data processing, decision-making, image recognition, prediction-making, and voice recognition.

This article focuses on technologies related to data processing, data mining, semantic analysis, and rule-based systems. In terms of product analysis, we identified six main functions of products using AI: energy management, entertainment systems, healthcare services, personal robots, intelligent interaction, and security. These functions were grouped into six categories: activity recognition, data processing, decision-making, image recognition, prediction-making, and voice recognition.

Finally, by conducting a quantitative analysis of each group in the literature and products, we summarized how artificial intelligence is applied in various functions within smart homes.

RESULTS AND DISCUSSION

Results of the Literature Review

First Selection Period

In this section, the publications related to the five main functions and six categories are presented in figure 1. A detailed discussion on various concepts is not part of the focus of this article; instead, the article aims to analyze the broad application of artificial intelligence in smart homes.

As shown in figure 1a, the management of smart home devices is supported by five artificial intelligence functions: data processing, decision-making, image recognition, prediction-making, and voice recognition. The number of publications in this field is not very high, and most are recent research studies, with the first studies in this area emerging after 2016.

Smart home energy management is supported by five AI functions: activity recognition, data processing, decision-making, image recognition, and prediction-making. Research in this area has been increasing since 2012. As shown in figure 1b, AI discussions have been broader in terms of data processing and prediction-making. Smart home healthcare is supported by all six AI functions: activity recognition, data processing, decision-making, image recognition, prediction-making, and voice recognition. This field has been studied extensively since 2011. As indicated in figure 1c, activity recognition AI is discussed more widely in this area. In terms of smart home intelligent interaction, four AI functions are utilized: data processing, image recognition, prediction-making, and voice recognition. Since 2012, many studies have been conducted in this area, though most of them are recent. As shown in figure 1d, activity recognition is more broadly discussed within this domain. For smart home security, two primary AI functions are used: data processing and image recognition. As shown in figure 1e, publications in this area are fewer compared to the other fields. The remaining studies mostly focus on the key challenges of applying AI technology in smart homes. According to the data presented in figure 1f, data processing and activity recognition are the most widely used functions across all smart home applications.[8,9,10,11,12,13]

The spread of AI applications in smart homes is illustrated in figure 2. These results indicate that over time, more application areas have been discussed, with both diversity and volume increasing. From 2015 onwards, research in the healthcare sector has decreased, while studies in smart interaction and energy management have grown. This trend suggests that in the future, smart homes will place more emphasis on the interaction between humans and their environment, as well as making buildings more sustainable. This shift highlights the growing importance of energy efficiency and enhancing user experience through AI-driven systems.[14,15,16,17]

Second Selection: Literature Selection

In the second selection phase, 20 publications were chosen for each application area of smart homes. In this phase, we discuss the results obtained in five application areas: device management, energy management, healthcare, smart interaction, and security.

First, in the area of smart home device management, as technology develops, the number of electrical devices in homes increases, and operational steps become more complex. In this case, AI could be very useful in helping users manage certain devices automatically. Some researchers have applied AI in smart home systems to monitor and control devices by automatically adjusting lighting and temperature conditions. Intelligent management in smart homes can be implemented by analyzing data obtained from sensor networks, learning users' previous behaviors, or applying logistic classification with the TensorFlow algorithm. Centralized control can make electronic decisions: monitoring, enhancing comfort, managing the environment, and delivering necessary information.

In the area of smart home energy management, building a sustainable society is becoming increasingly important. Many researchers are trying to reduce energy consumption and increase energy efficiency. Higher efficiency can be achieved by coordinating energy consumption in smart devices. AI helps to predict electricity demand by analyzing consumption patterns and understanding their relation to environmental factors. AI

supports home automation by analyzing users' energy consumption behavior and reducing energy costs. Activity recognition in AI helps link activities with existing home devices, and when wasteful energy use is detected, it can provide users with recommendations.

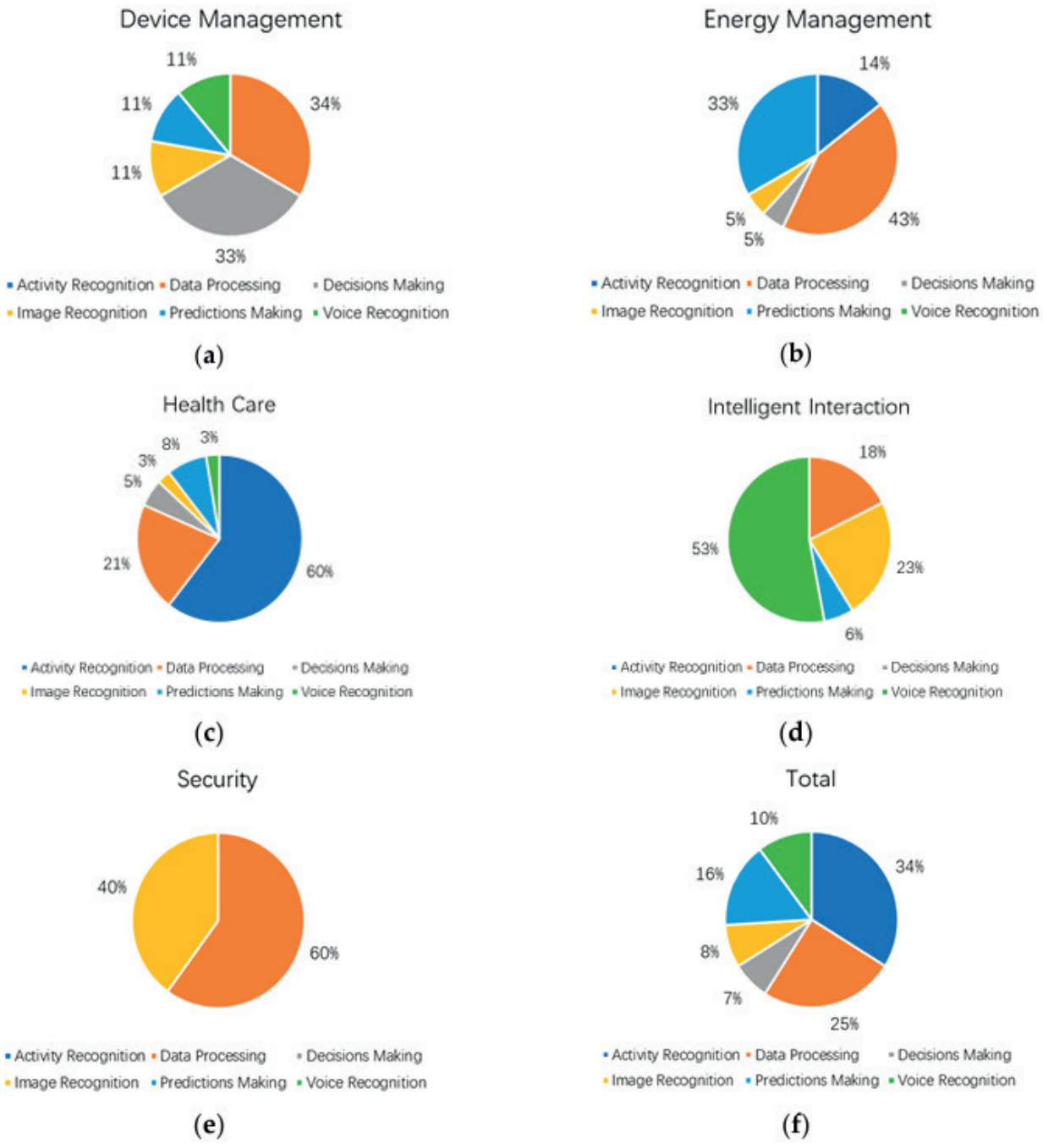

Figure 1. (a) AI functions in device management; (b) AI functions in energy management; (c) AI functions in healthcare services; (d) AI functions in intelligent interactions; (e) AI functions in security; (f) AI functions in all smart home functions

Third, in the area of smart home healthcare, with the gradual increase in life expectancy, home healthcare is becoming more important. By using sensor data, machine learning and AI methods can track individuals' behavioral patterns and lifestyle, detecting changes. AI systems, applying unsupervised clustering algorithms, recurrent neural networks, and genetic algorithms, continuously monitor elderly people and send alerts to caregivers in case of unusual activities. To support elderly people with cognitive impairments in performing daily life activities independently, intelligent agents must recognize their goals and the reasons for their next steps.[17,18]

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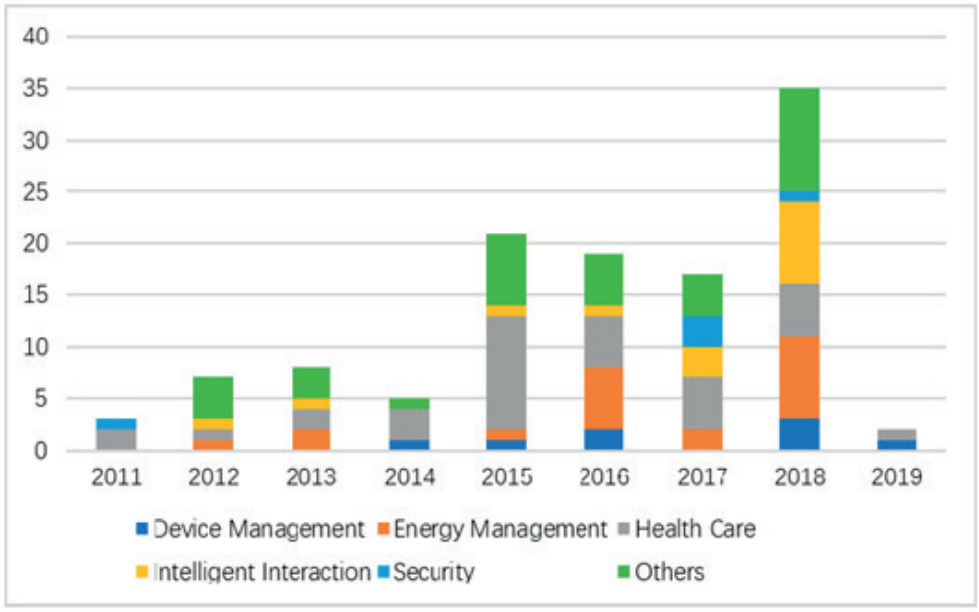

Figure 2. Application areas of artificial intelligence for smart homes

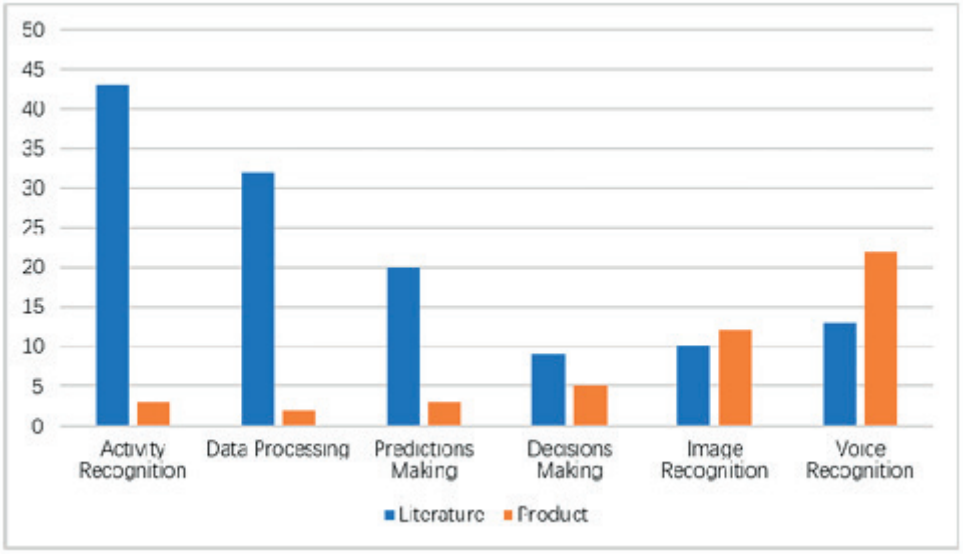

Figure 3. Comparison of artificial intelligence technology in smart homes between literature and products

In general, there are opportunities for further development of artificial intelligence in smart homes. Currently, AI functions like voice recognition and image recognition are increasingly used in energy management, smart interaction, and security fields. In the future, technologies such as activity recognition, data processing, and prediction are expected to be integrated into more products.[19,20]

This research may have some limitations. First, the subcategories of AI were not systematically selected. Second, the smart home product database we chose does not cover the latest products. Third, some relevant publications may not have been searched because the keywords used in the paper were not found in them.

CONCLUSIONS

The main goal of this research was to investigate how artificial intelligence functions within smart homes. To achieve this, numerous literature sources and different products were analyzed. It was found that AI technologies, particularly activity recognition, data processing, decision-making, image recognition, prediction, and voice recognition, are widely applied in areas such as device management, energy management, healthcare services, smart interaction, security, entertainment systems, and personal robots in smart homes.

There are some differences between the functions outlined in the research and the products available: products tend to use simpler methods, such as image and voice recognition, whereas the literature emphasizes more complex technologies, such as activity recognition and prediction. While image and voice recognition

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technologies are widely implemented in smart homes, the development of activity recognition, data processing, and prediction technologies continues.

Additionally, the study found an interesting result where smart interaction received more attention in both literature and products. In the future, smart homes will focus on better understanding the interaction between humans and the environment, making buildings more sustainable and personalized. One of the key future directions for the application of AI in smart homes is the development of relevant standards, taking into account architectural designs alongside these technologies.

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CONFLICT OF INTEREST

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