APPLICATION OF ARTIFICIAL INTELLIGENCE IN SMART HOMES

Adrian Runceanu, *"Constantin Brâncuşi" University of Târgu Jiu, ROMANIA*
Mihaela-Ana Runceanu, *"Ecaterina Teodoroiu" High College, Târgu Jiu, ROMANIA*

ABSTRACT: The research investigates modern AI-based smart-home systems through their intelligent lighting systems and smart locks and AI sensors and adaptive thermostats and centralized control platforms. The Home Assistant ecosystem integration with TP-Link Tapo devices enables users to benefit from local system control and privacy protection and advanced automation features and optimized energy usage. The research shows how AI-based safety systems (which include fall detection and acoustic event classification and anomaly detection) improve home security through their artificial intelligence functionality. The research shows artificial intelligence technology enables basic smart homes to evolve into adaptive systems which predict user requirements and deliver customized experiences.

KEY WORDS: Smart Home, Artificial Intelligence, Home Assistant, Context-Aware Systems, AI Security, Ambient Intelligence, Smart Appliances.

1. INTRODUCTION

Smart homes now use AI technology to create adaptive spaces through predictive analytics and contextual information which goes beyond basic voice control systems. The first smart-home systems operated through basic rule-based automation which required direct user input to perform basic functions such as lighting control and temperature management and security system activation. The systems failed to understand user intentions and environmental changes and user context [1], [2]. The implementation of artificial intelligence (AI) and machine learning (ML) technology has brought about a complete transformation of smart home technology. Smart homes in the present day employ sophisticated sensing systems which unite computer vision modules with multimodal sensor fusion and probabilistic reasoning engines to understand intricate domestic environments. AI systems analyze user behavior to create personalized experiences through automated daily routine management. AI assistants now use predictive technology to start coffee preparation and adjust lighting and temperature settings before users make their specific requests [3], [4], [16].

Smart home technology experiences rapid development because AI architecture advancement enables fast development of new systems. The field has evolved from artificial neural networks (ANNs) to deep learning models and now uses state-of-the-art large language models (LLMs) including GPT-4 and Gemini and Claude and LLaMA. The new models provide better performance in natural language understanding and contextual understanding and multi-step problem-solving abilities. Users can experience more natural interactions through LLM integration with smart-home systems because these models understand complex user requests and create suitable suggestions and automatic assistance [5], [14], [17]. Smart home development now centers on predictive and proactive automation systems which go beyond basic reactive automation. Smart homes use Ambient Intelligence (AmI) principles through reinforcement learning and uncertainty modeling and adaptive decision systems to predict household needs before users make requests. The systems operate nonstop to reach

peak energy efficiency while controlling environmental conditions and delivering customized experiences for individual users and all members of their family [18], [19]. The growing use of edge computing together with distributed AI systems enhances smart-home systems by providing better autonomy and privacy protection and enhanced operational efficiency. Smart-home systems achieve better performance through local data processing because they eliminate cloud service dependencies which create delays during critical situations including intrusion detection and fall detection and environmental monitoring. Edge-AI models with anomaly detection functions work together to detect security threats which generate instant alerts that enhance home security systems [10], [20]. Research into multimodal AI and embodied intelligence and IoT-based IoT contextual sensing enables smart homes to evolve into fully connected systems. The current developments in smart home technology establish AI as the fundamental element which will create the next-generation intelligent living space through predictive analytics and user modeling and distributed cognition for enhanced comfort and safety and sustainability [21], [22], [23], [24], [25].

2. AI + Vision + Voice Integration

Google, Apple, Amazon and Home Assistant through their open-source platform have successfully merged AI-based multimodal functionality with voice and vision and environmental sensing capabilities into their smart-home platforms [14], [15]. The wide adoption of Amazon Alexa smart homes has been limited by privacy concerns and data collection practices and vendor lock-in restrictions which researchers have frequently documented [7], [10]. Apple protects privacy rights through its creative methods but its AI-based smart home system requires additional development to achieve complete functionality. The Apple company faces a technological disadvantage because their new Siri system with generative AI capabilities will not launch until mid-2026 [3], [6].

Google achieved a major breakthrough through its Gemini AI model integration with Google Assistant and Google Home platforms. The AI system improves platform operations through its ability to identify user intentions and perform contextual reasoning and multimodal processing [5], [12]. The new system capabilities include:

The system allows users to build intricate automated sequences which merge smart lighting capabilities with security functions and media playback and home climate control features. The system produces responses based on user activity data which it uses to understand the present situation. The system generates automated recommendations while running protective systems to stop potential problems from developing. Users can start multiple AI-based operations through voice commands which begin with "Google, I'm exhausted" to perform door locking and light shutdown and schedule generation and bedroom lighting control and background music activation. The system shows how AI-based home automation systems evolve from executing basic commands to creating personalized adaptive responses [14]. Research studies show that smart home technology development needs accessible systems which every user should be able to operate. The current AI-powered smart home technology demonstrates potential to decrease digital inequality because researchers develop affordable smart home systems which use standard connectivity protocols [6], [8].

Table 1. Key Subsystems and Functional Capabilities of a Modern AI-Enhanced Smart Home

Subsystem	Academic Description (Reformulated)
Smart Speakers and Voice Assistants	Modern smart homes depend on AI-powered voice assistants including Google Nest Audio and Amazon Echo and Apple HomePod which serve as main control centers. The natural language processing capabilities of these systems enable them to understand complex dialogues and maintain ongoing conversations and detect user intentions accurately for seamless device control [12].
Intelligent Lighting Systems	AI-powered lighting systems which include smart bulbs and adaptive switches enable users to control devices remotely while scheduling automatic operations and adjusting brightness and color temperature settings. The systems learn user behavior to create personalized lighting settings which follow circadian rhythms and energy efficiency goals and environmental conditions [14].
Smart Locks	The AI-powered pattern recognition system in smart locks works with anomaly detection to provide secure access management. The system operates independently to set locking schedules and behavioral rules while maintaining absolute safety protocols which enhance residential security.
Smart Thermostats	The Nest Learning Thermostat uses reinforcement-learning algorithms to perform automatic temperature and heating control. The system uses advanced algorithms to minimize energy usage while maintaining comfortable indoor temperatures and maintaining excellent indoor air quality [5], [11].
Cameras and Environmental Sensors	Modern smart homes use AI-enhanced computer vision systems to identify between human beings and pets and potential intruders. The system uses environmental sensors to identify between regular household sounds and security risks which produces better situational awareness [4], [7].
Smart Appliances	AI-controlled home appliances including washing machines and refrigerators and ovens provide users with detailed operational control and usage optimization and predictive maintenance capabilities. The devices operate through non-standard vibration methods and electrical signal patterns which enhance system reliability and minimize equipment failures.
Centralized Hubs	HomeKit from Apple and SmartThings from Samsung and Home Assistant serve as platforms which unite device management under single control systems. AI technology enables devices to work together while learning from each other and adapting to home environment changes.
Integrated AI Systems	AI engines such as Google Gemini and Amazon Alexa AI and open-source assistants enable smart homes to perform predictive automation and user behavior modeling and context-based reasoning and scene orchestration. The systems transform regular houses into smart ecosystems through learned data which produces better residential spaces.
Intelligent Safety and Security	AI-based safety systems operate continuously throughout 24 hours to detect dangerous situations in real-time. Modern security systems use advanced contextual analysis to identify people and objects and threats through their combination of facial recognition and object detection and behavioral analysis algorithms [20]. The system identifies between normal activities and critical situations through its AI-based analysis which proves essential for elderly care because it helps doctors detect medical issues early [20], [25].

Acoustic and Behavioral Analysis	Smart homes employ deep learning acoustic models to detect environmental sounds which enable the identification of dangerous situations through glass breakage detection during intrusions. The system learns household behavior patterns through anomaly detection frameworks which produces better detection accuracy and lower system power consumption [21], [25].
AI-Based Threat Correlation and Response	AI-Based Threat Correlation and Response Advanced security systems use multimodal data processing to execute coordinated security protocols when threats are detected. The system starts surveillance operations while it locks all doors and triggers alerts to both residents and law enforcement authorities. Edge-AI implementations decrease response times and protect user privacy through their ability to operate independently from cloud services [20], [21].
Overall System Intelligence	The entire system operates with intelligence because home protection systems advance through AI-based safety frameworks which combine computer vision with acoustic analytics and behavioral modeling and predictive reasoning systems. The development of distributed AI and cognitive IoT and multimodal sensing technologies will enable the creation of advanced smart homes which possess enhanced environmental understanding and improved protection for their residents [25].

Figure 1. Modern System for a Smart Home [13]

3. BENEFITS OF AI-POWERED SMART HOMES

3.1. Enhanced Convenience

Smart-home systems have become more user-friendly because AI technology enables voice assistants to understand complex commands that depend on context. The AI-powered interfaces let users do complicated household work by themselves while they stay busy with their daily activities. Research shows that systems which combine voice commands with gestures and environmental data enable users to access them regardless of their technical experience [2], [14], [26]. The smart home environment enables users to access features more easily through its adaptive system which provides better accessibility and simpler operation.

3.2. Energy Efficiency

Home automation systems that use artificial intelligence achieve their main advantage by optimizing energy usage. The system uses machine learning to optimize HVAC systems and lighting and high-power appliances through continuous analysis of user activities and environmental data and energy usage patterns. Smart thermostats that use ML algorithms decrease energy waste while

maintaining comfortable temperatures which leads to more sustainable and affordable household operations [5], [11], [27]. The systems use predictive models to optimize energy usage by analyzing user behavior and environmental data and current energy prices.

3.3. Improved Security

Smart homes achieve better security protection through AI-based perception and reasoning systems which they implement. The system achieves high accuracy in user and animal and intruder identification through its combination of facial recognition with object detection and behavioral analysis algorithms which minimizes false alarms and enhances situational awareness. The predictive-analytics engines in these systems detect security threats by analyzing motion patterns and time-based activities and typical household behavior to identify potential intrusions [4], [7], [21], [28].

3.4. Predictive Maintenance

The implementation of AI-based predictive maintenance technology for household appliances shows success in stopping equipment breakdowns and minimizing equipment shutdowns. The system uses vibration data and acoustic patterns and electrical usage to detect equipment failure warning indicators at their beginning stages. The system detects system failures before they become critical so users can perform scheduled maintenance which extends equipment lifespan and decreases maintenance expenses [9], [20], [29].

3.5. Personalization

Smart-home systems employ AI technology to generate personalized experiences which fulfill the requirements of every person living in the household. The AI system learns about user behavior patterns and personal choices to develop adaptive spaces which automatically change their settings through user interactions. The system uses context-aware learning and preference modeling to create customized scenes for different activities such as relaxation and work and sleep time which lead to better user satisfaction [12], [25], [30].

3.6. Health and Wellness Monitoring

Smart home technology now dedicates its research efforts to health monitoring as its primary focus. The system monitors user health information through AI algorithm processing of data collected from wearable devices and ambient sensors which identify irregular patterns. The system enables users to identify health issues at their onset through individualized suggestions which produce improved long-term wellness results for at-risk groups [9], [20], [31].

3.7. Entertainment and Content Recommendation

AI-based recommendation systems function as fundamental elements which improve home entertainment experiences. The system produces customized content recommendations through learned user behavior patterns and contextual data which it applies across multiple media platforms. The AI-based content delivery system provides users with better satisfaction because it generates customized media suggestions that fit their personal tastes [2], [26], [32].

3.8. Automation and Intelligent Scheduling

AI-based automation systems enable households to create customizable schedules for device operation which reduces operational expenses and improves energy management capabilities. The intelligent scheduling system uses user routines and occupancy data and real-time electricity prices to determine the best times for operating appliances including dishwashers and washing machines and electric vehicle chargers [11], [24], [33]. The system offers monetary advantages to users at the same time it provides environmental sustainability benefits.

3.9. Climate Control and Air-Quality Management

AI technology allows smart thermostats and purifiers and environmental sensors to function together for enhanced climate management and improved indoor air quality control. The system reaches its best indoor comfort level through its reasoning algorithms which analyze data from humidity levels and particulate matter and CO_2 concentrations and outdoor weather information. The AI system

operates temperature and airflow and filtration systems to establish a healthy environment with perfect comfort levels [6], [19], [34].

4. CONCLUSION

Smart homes in the present day operate through artificial intelligence which enables them to function independently by learning from human behavior and environmental conditions. The research demonstrates how smart homes use multiple interconnected systems to create responsive digital ecosystems through their intelligent lighting and smart locks and AI sensors and predictive thermostats and centralized control platforms. The research shows AI technology allows smart homes to develop into adaptive systems which use predictive functions to generate individualized user experiences. The systems use advanced AI models which include reinforcement-learning and multimodal deep-learning and large language models to understand natural language and perform predictions and task automation based on individual preferences. The Home Assistant platform demonstrates how open-source smart home systems can solve vendor-specific cloud system restrictions through its Tapo device integration. The system lets users operate their devices remotely through its user-friendly interface which provides full IoT functionality and advanced automation features. The integration of AI-driven analytics with behavior modeling through these connections allows developers to build advanced features which perform anomaly detection and energy optimization and personalized scene management and intelligent voice command systems. AI-based smart-home systems require security and safety functions to function as their fundamental operational components. The development from basic sensor systems to AI-powered contextual analysis through computer vision and acoustic intelligence and behavioral modeling leads to better threat detection accuracy and reliability. The system delivers its most significant benefits during emergency situations and elderly care and intrusion detection because it enables fast appropriate responses that produce better results. The research results show how AI-based smart homes change residential areas but scientists must create improved standards for system connection and AI privacy protection and ethical data handling and strong edge-computing systems. Smart homes will develop into complete user-oriented systems which provide enhanced comfort and safety and better energy management and personalized experiences through their ability to learn and adapt and manage complex domestic environments. The development of distributed AI and cognitive IoT and multimodal sensing technologies will enable the creation of intelligent living spaces which function as complete ecosystems.

REFERENCES

[1] M. A. SeekMeAI, "The evolution of OpenAI's ChatGPT from GPT-1 to GPT-4 and beyond," *Medium*, 2023.
[2] Saratix, "How artificial intelligence is transforming industries," *LinkedIn Articles*, 2022.
[3] S. Pandey, "ANI vs. AGI vs. ASI," *LinkedIn Articles*, 2023.
[4] A. Sharma et al., "Applications of AI and deep learning in advanced manufacturing processes and robotics," *ResearchGate*, 2023.
[5] T. Gadea et al., "Machine learning-driven optimization of communication systems," *Wiley Online Library*, 2021.
[6] J. Smith et al., "AI-enabled UAV systems for environmental monitoring," *MDPI Drones*, vol. 5, no. 4, 2021.
[7] L. Hernandez-Rivero et al., "Artificial intelligence for smart and sustainable cities," *ScienceDirect*, 2023.
[8] A. Kumar et al., "Recent advances in AI-enhanced decision-making systems," *ScienceDirect*, 2023.
[9] P. Duarte et al., "Predictive analytics for sustainable home ecosystems," *MDPI Journal of Marine Science and Engineering*, vol. 11, no. 1, 2023.

[10] C. Zhao et al., "Emerging threats in IoT-integrated systems," *ScienceDirect*, 2023.
[11] A. Bellini et al., "AI-augmented HVAC optimization," *ScienceDirect*, 2023.
[12] IEEE, "AI-powered human–machine interfaces for smart environments," *IEEE Xplore*, 2018.
[13] NICE S.p.A., *Micro Automation Range Brochure*, 2020.
[14] DevTechnosys, "AI in smart home automation: A complete guide," 2023.
[15] PiMyLifeUp, "How to use Home Assistant with Tapo devices," 2023.
[16] G. Cook and S. Das, *Smart Environments: Technology, Protocols, and Applications*. Wiley, 2020.
[17] A. Liu et al., "Deep learning-enabled context awareness for smart environments," *ACM Computing Surveys*, vol. 55, no. 7, 2023.
[18] J. Augusto et al., "Ambient Intelligence: Concepts and applications," *Springer Handbook of Ambient Intelligence*, 2021.
[19] S. de la Cruz et al., "Cognitive IoT architectures for smart environments," *Sensors*, vol. 22, no. 4, 2022.
[20] N. Y. Chong et al., "AI-based anomaly detection in smart homes for elderly care," *Sensors*, vol. 21, no. 12, 2021.
[21] X. Zhang et al., "AI-driven security and privacy frameworks for smart homes," *IEEE Access*, 2022.
[22] R. Want, B. Schilit, and S. Jenson, "Enabling the Internet of Things," *Computer*, vol. 48, no. 1, pp. 28–35, 2015.
[23] S. R. Pokhrel and J. Choi, "Toward enabling distributed intelligence: AI and edge computing in smart homes," *IEEE Communications Magazine*, 2021.
[24] P. Siano et al., "Demand response and smart homes: A review," *Renewable and Sustainable Energy Reviews*, vol. 118, 2020.
[25] M. A. Alaa et al., "AI-driven personalized services in smart living environments," *IEEE IoT Journal*, vol. 8, no. 12, 2021.
[26] S. Këpuska and M. Elharati, "Next-generation of virtual personal assistants," *IEEE Conf. on Intelligent Systems*, 2018.
[27] C. Jones et al., "Energy-efficient smart home systems using deep learning," *Energy and Buildings*, vol. 224, 2020.
[28] Y. Tian et al., "Video anomaly detection for smart security," *IEEE TPAMI*, 2021.
[29] M. Merenda et al., "Edge-based predictive maintenance in IoT environments," *IEEE IoT Journal*, 2022.
[30] A. Mahapatra et al., "Context-aware personalization frameworks for smart homes," *ACM ToIT*, 2022.
[31] L. Chen et al., "AI-assisted health monitoring in smart living spaces," *IEEE Access*, 2021.
[32] P. Covington et al., "Deep neural networks for content recommendation," *RecSys*, ACM, 2016.
[33] D. Papadaskalopoulos et al., "AI-based demand-response algorithms for residential energy," *Electric Power Systems Research*, 2021.
[34] R. Z. Homod, "AI-driven HVAC and air-quality optimization," *Buildings*, 2020.
[35] Grofu Florin, "Fast Data Acquisition System", Revista de Fiabilitate și Durabilitate Nr 1/2022 Editura "Academica Brâncuşi", Târgu Jiu, ISSN 1844 – 640X Pg. 49-54
[36] Grofu Florin, "Online monitoring system for electrical parameters", Annals of the „Constantin Brâncuşi" University from Tg. Jiu, No.4/2019, ISSN 1842-4856, pag 19-24.
[37] Florin Grofu, Constantin Cercel, "Experimental module for training with network analyzer", 12th International Multidisciplinary Scientific GeoConference & EXPO SGEM2012, Vol III- section Informatics, ISSN: 1314-2704, pg 111-117
[38] Gheorghe GÎLCĂ, Nicu George BÎZDOACĂ, Cătălin LUPU, "Classification algorithms of facial expressions by using the feedforward neural networks", National Scientific Conference with international participation "CONFERENG 2015", Tg-Jiu, November 13-14 2015, Nr. 4, pp. 80-85, ISSN 1842-4856, Annals of the „Constantin Brâncuşi" University from Tg. Jiu, Engineering Series
[39] Gîlcă Gheorghe, Lupulescu (Machidon) Alina-Elena, "Trajectory control for a mobile robot using a Pid algorithm", Annals of the „Constantin Brancusi" University of Targu Jiu, Engineering Series, No. 2/2024, pp 161-164
[40] Gheorghe GÎLCĂ, Nicu George BÎZDOACĂ, Cătălin LUPU, "Artificial Vision Algorithms based on Fractals for the Images Description", National Scientific Conference with international participation

"CONFERENG 2015", Tg-Jiu, November 13-14 2015, Nr. 4, pp. 86-90, ISSN 1842-4856, Annals of the „Constantin Brâncuşi" University from Tg. Jiu, Engineering Series

[41] Ilie Borcosi, Corina Ana Borcosi, "Customize SAAS applications through microservices", Annals of the „Constantin Brancusi" University of Targu Jiu, Engineering Series, No. 2/2022, pag. 86-90.

[42] Ilie Borcoși, Dragos Sandulescu, "The development of graphical application", Annals of the „Constantin Brancusi" University of Targu Jiu, Engineering Series, No. 1/2017, pp. 20-24, ISSN 1842-4856.

[43] Ilie Borcosi, Daniela-Lavinia Nebunu, Nicolae Antonie, "The modeling logic circuit using finite automata theory", International Conference on Industrial Electronics Technology & Automation (IETA 11) in International Joint Conferences on Computer, Information and Systems Sciences, and Engineering (CISSE11), December 3– 12, 2011

[44] Ionescu, M., Nicu-George BÎZDOACĂ, "The control of a biomimetic structure using the pid algorithm", National Scientific Conference with international participation "CONFERENG 2017", Tîrgu-Jiu, December 08-09, No. 4, Year 2017, pp. 113-118, ISSN 1842-4856, Annals of the „Constantin Brancusi" University of Targu Jiu, Engineering Series.

[45] Ionescu, M., Vilan, C., Dinca, A. "Control architecture the for a biomimetic structure study", 13th International Multidisciplinary Scientific Geoconference SGEM 2013, 16-22 June, 2013, Albena, Bulgaria, volume I, ISBN 978-954-91818-9-0, ISSN 1314-2704, pp.45-52, WOS:000349067200006

[46] Ionescu, M., Ilie Borcosi, "Monitoring ECG heart rate with AD8232 module", ISSN 1842-4856, Annals of the „Constantin Brancusi" University of Targu Jiu, Engineering Series, No.2/2023, pp 117-122