International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 2, Mar-Apr-2026, ISSN (Online): 2395-566X

Intelligent Sensing in Smart Homes: A Holistic Review of IoT Architectures, AI-Driven Analytics, and Human-Centric Applications

[1] Daniel Karikari Frempong, [2] Mutala Nakpan Jentina, [3] Hannah Owusu Ansah, [4] Gabriel Oduro Asirifi

[1,3] School of Optoelectronic Engineering, Hubei University of Automotive Technology, Shiyan 442002, China
[2] School of Materials Science and Engineering, Hubei University of Automotive Technology, Shiyan 442002, China
[4] School of Automotive Engineering, Hubei University of Automotive Technology, Shiyan 442002, China

Abstract – The pivotal role of intelligent sensors in building and running smart homes is discussed in this literature review. First, we present a brief overview of smart homes and intelligent sensors, emphasizing the critical importance of this sophisticated technology used to transform ordinary homes into intelligent AI-controlled houses. The review then delves into the principles of several types of intelligent sensors, including energy, health and wellbeing, environmental, security, and appliance sensors. Besides playing a critical role in gathering data for personalized home automation services, this section touches upon their remarkable contribution to sustainable living, energy-saving, and human wellbeing. The review next examines key technologies and standards that enable seamless communication between devices, such as Matter, Wi-Fi, and Zigbee. This section also sheds light on how artificial intelligence and machine learning could change the paradigm of processing information collected by these intelligent sensors, leading to advanced predictive analysis and decision-making. Finally, we propose ways to address some challenges that impede the widespread application of intelligent sensors, such as interoperability, security, privacy concerns, and affordability. We also present promising avenues for future research on intelligent sensors for smart living, such as increased autonomy, advanced sensor miniaturization, and human-centric design.

Keywords – Energy Efficiency, Intelligent Sensors, Artificial Intelligence (AI), Internet of things (IoT), Smart Homes.

I. INTRODUCTION

A smart home is currently conceived as an advanced and tightly integrated residential environment comprising a network of interdependent devices that can function independently, monitor remotely, and undertake automated processes [1, 2]. Such systems are meant to create unprecedented standards of comfort, security, and energy efficiency by improving key processes, especially those associated with lighting, heating and air conditioning systems (HVAC), security systems, and multimedia systems [3, 4]. Creating a truly proactive experience of living due to the integration of ICTs is the main objective of the smart home concept [5]. In this complex network, the intelligent sensor is used as the eyes and ears of the entire system [6], constituting the basic hardware infrastructure for gathering data in real time and designed to detect and quantify different types of events and physical phenomena, ranging from simple changes in temperature and humidity levels to complex motion detection, varying levels of illumination, sound frequency, and presence of VOCs/pollutants [7, 8].

The intrinsic ability to perform computations locally for high-quality processing and intelligent decision making characterizes smart or intelligent sensors from the classic ones [9, 10]. These sensors decrease any delays and bandwidth issues resulting from constant cloud interactions by performing computation locally, which is commonly called edge intelligence [11, 12]. Through such local computing, intelligent control and automation of the living space become feasible, whereby raw environmental information becomes meaningful through conversion to digital data [13]. Smart sensors are now no longer just limited to their application areas in the modern setting; they include the use of motion sensors for adaptive security, thermodynamic sensors to manage climate and ensure occupant wellbeing, and specific air quality sensors for real-time health monitoring [14, 15].

The emergence of smart homes has shifted from fixed, programmatic automation systems to self-learning, highly adaptable ones due to the quick evolution of the IoT, availability of the 5G connection, and developments in the field of AI and machine learning (ML) [11]. To make these sophisticated systems able to learn, there is the necessity for constant supply of behavioral and environmental information that can be utilized by sophisticated algorithms for anticipatory behavior modification [8]. As an illustration, AI-embedded thermostats take into account multi-modal information from temperature and occupancy sensors, which significantly lowers the costs associated with energy consumption [16]. Likewise, for the purpose of minimizing unnecessary alarm triggering and maximizing threat identification efficiency, advanced intelligent surveillance systems utilizing intelligent camera technology can now conduct accurate object classification, distinguishing between human residents, household pets, and motor vehicles. These forecasting and adaptability qualities that define the next generation of home automation are made possible by continuous data flow [10].

Furthermore, the emphasis in sensor development is placed on holistic well-being owing to the implementation of "Indoor Environmental Quality" (IEQ) as a crucial metric in smart buildings standards [17]. Currently, intelligent sensors monitor the intricate relationships between thermal, optical, and auditory comfort as well as occupancy. The use of non-intrusive, passive sensors enables constant gait assessment, fall identification, and cognitive impairment prediction without violating the user respect and daily routines, which is particularly significant for health management and geriatric applications [18, 19]. This innovation allows a preventive health management system beyond the clinical setting through the combination of physiological information with behavioral features [19, 20].

However, despite all these advances, there remains significant social and technological resistance to the proliferation of intelligent sensing technology. Issues of compatibility among different devices supplied by various vendors, power-hungry nature of high-resolution sensing nodes, and serious concerns regarding security and privacy issues remain to be very problematic barriers [21]. High-grade encryption capabilities and decentralized approaches aimed at preserving privacy through federated learning and blockchain integration become necessary due to the sheer volume of highly sensitive data that needs to be collected within the realm of the private sector [22, 23].

To ensure comprehensive coverage on the topic of intelligent sensor applications within the smart home, the review considers various classifications of sensors, such as occupancy, utility meters, security, health-oriented, and environmental ones, and provides detailed information on their functionalities in today's smart automation systems. In addition, the use of machine learning and artificial intelligence technologies in personalizing smart home user experience and conducting predictive analysis is considered. Finally, future advancements in sensor technology, which include the development of Matter interconnection protocol and energy harvesting smart sensors, are explored.

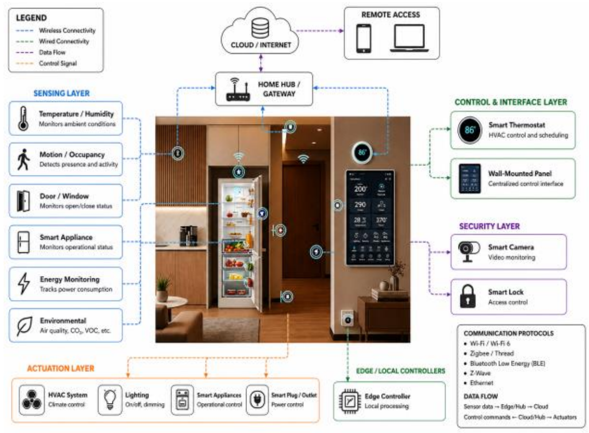

Fig. 1. Smart Home Ecosystem: Sensor Integration (Highlights the core concept of sensors within a connected home)

II. INTELLIGENT SENSORS IN SMART HOMES

An extensive mesh of intelligent sensors acting as the principal means of interfacing between the digital control logic and the tangible environment inside the smart residence constitutes the basis for the architecture of a contemporary smart house [24]. Unlike the traditional sensors, the intelligent sensors incorporate computing resources, which facilitate self-triggering, self-extraction of salient features, and self-filtering of data at a local level. The current section provides an exhaustive analysis of the multiple sensor classifications currently employed within the smart house architecture, based on the nature of their functionality and physical principles of transduction.

A. Environmental and Atmospheric Sensing

Among the most prevalent components of a smart home system is the environmental sensor, which is designed to monitor the ambient environment to maintain the balance between energy savings and comfort [25]. It should be noted that the dielectric constant of a thin film polymer changes directly depending on the moisture level in the thermostatically controlled environments with the use of capacitive humidity sensors and highly accurate thermistors [26]. Recently, they were incorporated into multiple sensing arrays that can simultaneously measure "Apparent Temperature," a composite indicator of both heat and humidity [27].

The IAQ monitoring process is now recognized as an important area of application relating to health concerns that extend beyond simple thermodynamics. The MO_x approach is used in Intelligent Gas Sensors (IGS), whereby the electrical resistance is changed through the process of adsorption of the VOCs (volatile organic compounds) on the heating film, commonly tin dioxide [28]. The NDIR continues to be regarded as the best choice for the detection of CO_2, applying the Beer-Lambert's law to determine the level of concentration through the unique wavelength of absorption of CO_2 molecules at 4.26um [28]. Furthermore, laser optical particle counters using Mie scattering technique for the measurement of particulate matter ($PM_{2.5}$ and PM_{10}) are employed in high-pollution scenarios [29].

B. Human-Centric Sensing: Occupancy, Motion, and Health

The basis for "proactive" automation technology is occupancy sensing and Human Activity Recognition (HAR). In view of its affordability and ability to sense the motion of heat-emitting objects within a divided FOV, passive infrared (PIR) sensors remain king of the hill [30]. But emerging solutions are employing Millimeter-Wave (mmWave) radar to bypass PIR's shortcomings, especially its inability to distinguish a stationary occupant. FMCW waveforms are sent out by mmWave devices working in the 60–77 GHz band in order to detect subtle movements such as chest wall vibrations caused by breathing, which allows highly accurate occupancy sensing even if the individual is resting or lying down [31, 32].

The adoption of technology geared towards "Ageing in Place" is exemplified by the integration of health and well-being sensors. Wearable devices equipped with photoplethysmography (PPG), which monitors the alterations in the absorption of light within the microvasculature network in the skin to detect blood oxygen saturation and heart rate, collaborate with hub devices within a smart home environment to alter environmental conditions, such as increasing light intensity when detecting signs of depression due to low physical activity levels or decreasing room temperature when there is a fever [33]. In contrast, floor mats or sensor-based beds analyze sleep architecture and gait stability, giving warning about neurodegenerative diseases while smart mirrors with CMOS sensors employ rPPG algorithms that allow for extracting vital information from face coloring [34].

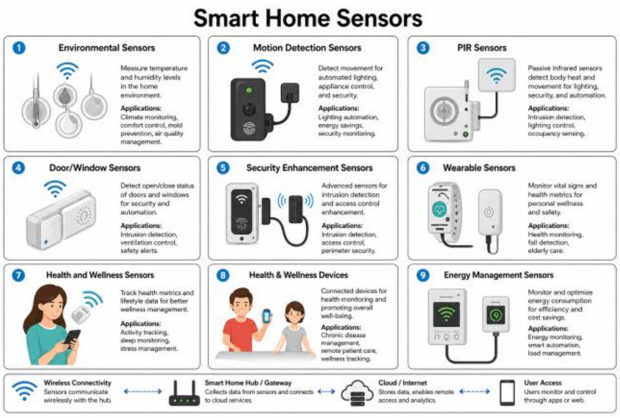

Fig. 2. Diverse Sensor Types and Applications in Smart Homes

C. Security, Surveillance, and Machine Vision

The security element in a smart house is one of the most advanced elements that have evolved from simple magnetic reed switch technologies utilized in touch-based door/window sensors to highly advanced technologies such as artificial intelligence computer vision [35]. Today, acoustic sensors (microphones), which can identify specific "danger signatures" through edge sound recognition based on their unique sonic qualities, such as broken glass or falling bodies, may be integrated with existing motion detection sensors [36].

One of the most significant technologies in contemporary surveillance technology is Intelligent Vision Sensors (IVS). The convolutional neural networks are utilized locally to process high-resolution video footage collected from IVS in order to carry out object classification and facial recognition [37]. Since the sensitive biometric information is processed locally and not uploaded to the cloud, local processing or Edge AI becomes vital for protecting users' privacy [38]. By detecting "blobs" or silhouettes, rather than high-resolution identities, the most sophisticated systems can also utilize the Light Detection and Ranging (LiDAR) technology to ensure security. Using pulsed laser beams, LiDAR generates accurate three-dimensional images of one's home surroundings without the need for traditional cameras.

D. Resource Management and Infrastructure Sensing

Residential Sustainability Key Drivers. Key factors responsible for the sustainability of the residence include energy management sensors. Smart power meters and smart plugs use current transformers (CT) or shunt resistors for assessing electricity usage [39]. Sensors could detect "energy vampires" and help optimize energy consumption through segmentation of total electricity usage patterns into single appliances in combination with NILM algorithms [40]. Voltage and current sensors monitor the PV generation output of the system in the presence of renewable energy sources and enable the automated scheduling of electricity-intensive tasks, including washing dishes or electric vehicle charging, during peak hours of solar generation [41].

Moreover, ultrasonic leak detectors and intelligent flow meters are employed for infrastructure monitoring purposes. The difference between normal and burst pipe operation is made through analysis of frequency vibrations and water flow rates within the piping network. This enables them to automatically shut down the main valve to prevent extensive damage to the property [42].

E. Technological Principles and Transduction Mechanisms

The MEMS (micro-electro-mechanical systems) technology has been able to develop the underlying physical principles that dictate the operational efficiency of such devices. Most accelerometers and pressure sensors use either the piezoelectric or piezoresistive modes of sensing, in which the generation of electrical charges or changes in resistances occurs due to mechanical pressure [43]. Capacitance sensing works by using any variation in the gap between electrodes and the dielectric properties of the media to alter the amount of charge stored [44]. The electrochemical mode of transduction involves the chemical reactions occurring at the electrodes generating an electrical charge relative to the gas content [45, 46]. RF and mmWave Sensing: This is the state-of-the-art in-home sensing, providing a non-line-of-sight advantage over optical sensors by tracking movement and respiration through walls and furniture using the Doppler effect and Time-of-Flight (ToF) calculations [45]. The seamless incorporation of "invisible" sensing into the walls, furniture, and appliances of the smart home is made possible by the combination of these transduction principles and the ongoing hardware miniaturization.

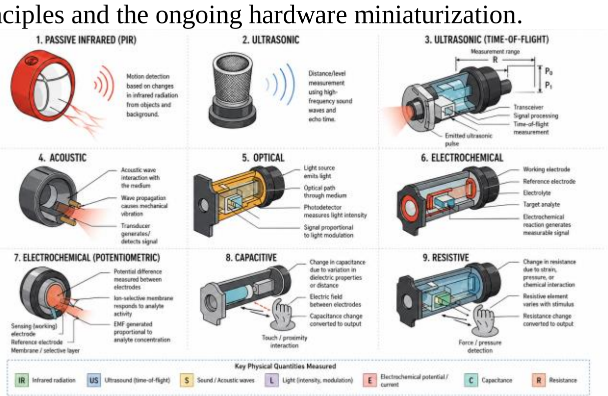

Fig. 3. Schematic Representation of Intelligent Sensor Technologies and Their Underlying Transduction Mechanisms

III. Applications and Use Cases

The targeted use of smart sensors that enable adaptive anticipation is the engine behind the conversion of conventional living buildings into 'Ambient Intelligence' (AmI) environments [47] Such systems not only aim to enhance comfort, safety, and efficiency, but they also seek to establish cooperation between human behavior and the environment.

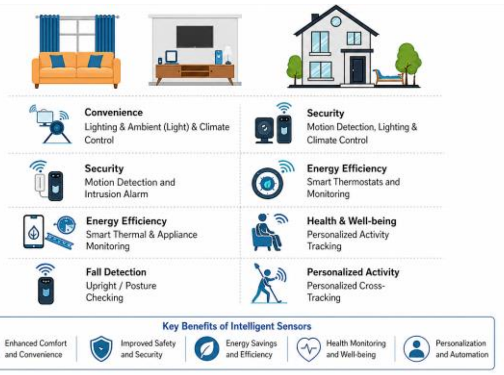

Fig. 4. Schematic Overview of Intelligent Sensor Applications in Smart Homes: Functionality and User-Centric Benefits

A. Convenience and Occupant Comfort

The creation of an "Adaptive Home" that would respond to the needs of humans by means of non-intrusive surveillance systems is the primary objective of comfort driven by sensor technologies [48]. To achieve "Circadian Lighting," that changes the temperature and intensity of light according to the biological clock of the occupants, advanced lighting systems are now equipped with highly sensitive photodiodes along with information on occupancy levels [49]. Moreover, multi-zone thermal control has replaced traditional setpoints in controlling temperatures. Smart thermostats leverage Reinforcement Learning (RL) to create optimal microclimates in the occupied zones while saving energy in unoccupied zones by analyzing data from temperature, humidity, and air flow sensors [50].

The ability to use NLP to command advanced entertainment and utilitarian systems via acoustic sensor arrays is now available, making hands-free interaction more. The techniques of beamforming and "far-field" microphone systems allow current voice-controlled systems to filter user commands from ambient sound to facilitate media configuration, appliance controls, and even window controls [51].

B. Security, Safety, and Proactive Protection

In modern smart home security systems, the reliance on reactive alarm detection techniques has been replaced with a more proactive method of threat assessment [52]. Leveraging the use of Deep Residual Networks (ResNet), IVS sensors can identify genuine intrusions from normal activities, such as pet movement or swaying plants, thereby eliminating false alarms by as much as 90 percent. Authorized homeowners can gain entry effortlessly with the help of facial recognition algorithms that are processed at the edge nodes for the sake of user privacy while capturing unauthenticated access attempts in real-time [53].

Life-safety sensors provide an indispensable layer of protection against environmental dangers beyond intrusion. Prior to being triggered by standard smoke alarms, slow-burning fires or leakages can be identified due to the higher sensitivity levels of electrochemical sensors based on graphene in detecting CO and VOCs [54]. Fall detection has been made contactless for vulnerable groups, including the elderly. Upon sensing a fall, automatic emergency contacts can be made and smart locks unlocked for rescuers. Detection of falls occurs through mmWave radar and 3D LiDAR sensors by scanning the skeletal motion patterns.

C. Energy Efficiency and Sustainability

Sustainability within the smart house system comes through the detailed tracking of water and energy consumption. Current sensing devices installed at the main panel can distinguish between the "harmonic signatures" of each appliance to deliver an accurate load analysis for Non-Intrusive Load Monitoring (NILM), which represents a great step forward towards transparent energy consumption. Using the collected information, HEMS can perform demand-side management and schedule the operation of energy-consuming processes such as laundry and EV charging during periods of high renewable energy generation or lower utility rates.

Integration of sensors has had another advantage when used for water management. The monitoring of pressure and acoustics in the pipes allows the identification of "micro-leaks," comparable to a single drop, with the help of smart flow meters equipped with ultrasonic transducers. In landscape design, smart irrigation systems using real-time measurements of evapotranspiration and soil moisture help avoid overwatering, thus decreasing household water consumption by 40% [55].

D. Health Monitoring and Well-being

Hospital-at-Home care is more frequently offered through the smart home [56]. Multi-level sensors are employed for continuous monitoring of the wellbeing. Although smart mirrors employ computer vision for the non-invasive evaluation of a skin condition and lung function, PPG biosensors are deployed for monitoring the cardiovascular system. High-precision sleep monitors capable of sleep phase (REM vs. Deep Sleep) tracking and detection of apnoea attacks without heavy medical devices, based on passive RF sensing or mattress integration, are available.

In addition to that, atmospheric detection plays a key role in ensuring good respiratory health. Once the pollutants exceed the health benchmarks, the automatic ventilation process begins through the HVAC system as indicated by the IAQ detectors which detect $PM_{2.5}$, CO_2, and formaldehyde concentration. For asthmatic patients or those with chronic obstructive pulmonary disease (COPD), this is particularly important [57].

E. Predictive Analytics and System Intelligence

Moreover, monitoring of the air is required to maintain good health of the respiratory organs. If the number of pollutants exceeds the acceptable concentration set by health guidelines, the automatic ventilation will be provided through the HVAC system controlled by IAQ monitors determining the content of $PM_{2.5}$, CO_2, and formaldehyde [15]. It is particularly valuable in cases when patients have asthma or COPD. The latest development towards Edge AI ensures that such complex calculations are done on site, thereby minimizing the delay and enhancing safety. Moreover, by training through anonymous information communicated throughout a series of interconnected residences, the "Federated Learning" model makes it possible for the smart home to enhance its accuracy without compromising personal privacy [58]. Finally, the concept of "Self-Healing Home," in which the use of predictive maintenance sensors to detect early signs of equipment breakdown, including the vibrations of a motor in a refrigerator, and arranging for maintenance before total failure can be achieved.

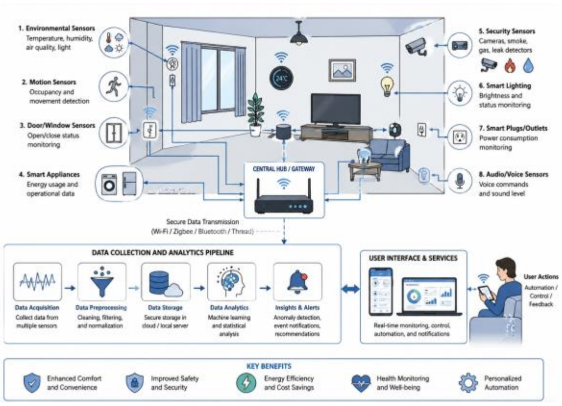

Fig 5. Schematic Illustration of Data Acquisition, Transmission, and Analytics Pipeline in Smart Home Sensor Networks

IV. Key Technologies and Protocols

The sophisticated interplay of communications protocols along with multi-layered computing platforms makes it possible for smart homes to transition from rudimentary automation to full-blown sentient systems [59, 60]. Homogenous connectivity schemes have been superseded by heterogenous connectivity frameworks due to the increased availability of intelligent devices, which demands low latency, high reliability, and efficient data transfer [61, 62].

A. Connectivity Protocols and Interoperability

Connectivity is the nervous system of the smart home, which comprises various connectivity standards dedicated to different sensors. Due to the bandwidth of Wi-Fi (actually IEEE 802.11ax/6), it remains the basis for data-intensive use cases such as 4K video surveillance and real-time machine vision [63]. BLE 5.4 has become the de facto connectivity standard for wearables and transient health monitoring equipment, yet, due to its power-hungry nature, Wi-Fi is not suitable for battery-powered sensors. Zigbee 3.0 and Z-Wave (Long Range) come up with self-healing network architecture that allows for delivering messages in large residential areas while maintaining micro-ampere current for sleeping nodes [64].

The ratification of the Thread protocol and the Matter standard (version 1.3) is the greatest breakthrough of late times in this sphere [65]. By supporting direct communication between devices belonging to different ecosystems (Apple, Google, and Amazon), but without any cloud translation required, the IP-based application layer called Matter eliminates silos created by manufacturers [66]. Unlike traditional hubs, Thread creates a reliable and more secure low-power, IPv6 addressable mesh transport for Matter [67]. It takes less than 100 milliseconds for a motion sensor made by one manufacturer to trigger a response by the lights made by another due to this synergy [68].

B. Computational Paradigms: The Edge-Cloud Continuum

A hierarchical architecture has emerged for analyzing large telemetry streams captured by sensors, where an effort is made to reach a balance between computational resources and data privacy. In time-critical use cases such as anomaly detection in security systems or fall detection for the elderly, edge computing has gained critical importance [69]. In cases where TinyML algorithms are deployed in-house on the sensor node or gateway, no sensitive biometric and audio information is ever transferred to the cloud, thus mitigating concerns about privacy.

At the same time, the cloud infrastructure remains crucial for lengthy, intensive analytics activities. For processing multiyear information sets, complex neural nets, like LSTM for predicting trends in home energy consumption, require scalable GPU capabilities provided by the cloud environment [70]. Moreover, the use of the cloud makes it easier to take into account external factors in the home's decision-making process, including fluctuations in utility prices and forecasts of meteorological phenomena [71]. To achieve higher prediction accuracy, the modern AI approach to home management uses a mixed strategy, wherein local edge nodes are responsible for real-time reactions while the cloud provides the global level of intelligence [72].

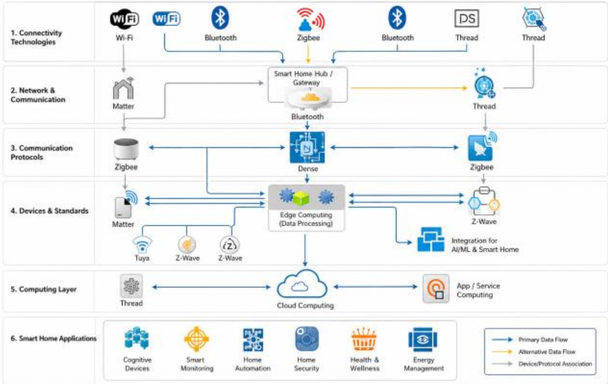

Fig. 6. Integrated Framework of Smart Home Technologies: From Communication Protocols to Intelligent Applications.

V. Challenges and Limitations

Despite all the advantages that intelligent sensors have for smart houses, a number of significant hurdles stand in the way of the implementation of these devices. First, although some communication standards have emerged (e.g., Matter), interoperability and compatibility still pose a significant problem because of the existence of multiple communication standards. Since the collection of any private data raises the issue of its potential leakage, security and privacy become a priority in terms of sensors. An additional limitation that discourages people from installing intelligent sensors is their price and accessibility. Inaccuracies caused by false readings can be a result of poor accuracy and reliability and impact the efficiency of sensor usage. Wireless sensors are constantly faced with the challenge of power consumption since they need regular charging or replacement of batteries. Finally, usability and acceptability require attention; thus, an ergonomic design is vital.

VII. Conclusion

Undeniably, intelligent sensors lie at the core of designing and operating smart homes, transforming regular homes into highly integrated homes that operate using artificial intelligence. This review has shown how numerous the uses of intelligent sensors are, from providing convenience to enhancing safety, saving on energy costs, and promoting health benefits through data collection and AI/ML algorithms. The use of these sensors leads to enhanced security and climate management systems, as well as personalized health care and predictive maintenance systems, with edge computing and cloud computing working hand-in-hand alongside protocols such as Matter and Thread to achieve seamless automation. However, despite the vast number of uses for these sensors, there are certain fields within this sector that need more exploration.

References

[1] E. Ok, "A Detailed Review of the Progress in Home Automation Systems," *Cham, Switzerland: Springer*, 2025.

[2] A. Al Tareq, M. R. Mostofa, M. J. Rana, and M. S. Rahman, "A comprehensive review of intelligent home automation systems using embedded devices and IoT," *Control Syst. Optim. Lett*, vol. 2, pp. 198-203, 2024.

[3] N. Samancioglu, K. Väänänen, and R. Castaño-Rosa, "Aligning smart home technology attributes with users' preferences: a literature review," *Intelligent Buildings International*, vol. 16, no. 3, pp. 129-143, 2024.

[4] N. Ogasawara, "Three decades of collaboration in rheumatology: a comprehensive co-authorship network analysis (1994–2023)," *Reumatologia*, vol. 63, no. 2, p. 68, 2025.

[5] M. Caldera, A. Hussain, S. Romano, and V. Re, "Energy-consumption pattern-detecting technique for household appliances for smart home platform," *Energies*, vol. 16, no. 2, p. 824, 2023.

[6] I. V. Sita and B. David, "Development and implementation of a comprehensive smart home automation system using home assistant and IoT devices," in *2024 4th International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME)*, 2024: IEEE, pp. 1-7.

[7] A. Eltaleb *et al.*, "Smart home sensor systems: Advancements and applications," *Int. J. Electr. Eng. and Sustain.*, pp. 120-228, 2023.

[8] S. Mekruksavanich and A. Jitpattanakul, "Efficient and explainable human activity recognition using deep residual network with squeeze-and-excitation mechanism," *Applied System Innovation*, vol. 8, no. 3, p. 57, 2025.

[9] P. Ranjan, R. S. Rao, K. Kumar, and P. Sharma, *Wireless communication: Advancements and challenges*. CRC Press, 2022.

[10] M. J. Reis and C. Serôdio, "Edge AI for real-time anomaly detection in smart homes," *Future Internet*, vol. 17, no. 4, p. 179, 2025.

[11] S. Choudhary, "Predictive Analytics in Marketing: Exploring How AI Can Predict Future Customer Behavior and Trends," 2025.

[12] J. D. Billanes, Z. G. Ma, and B. N. Jørgensen, "Data-driven technologies for energy optimization in smart buildings: A scoping review," *Energies*, vol. 18, no. 2, p. 290, 2025.

[13] Y. Lu, L. Zhou, A. Zhang, S. Zha, X. Zhuo, and S. Ge, "Application of deep learning and intelligent sensing analysis in smart home," *Sensors*, vol. 24, no. 3, p. 953, 2024.

[14] Y. Park and J. Han, "Smart home advancements for health care and beyond: systematic review of two decades of user-centric innovation," *Journal of Medical Internet Research*, vol. 27, p. e62793, 2025.

[15] T. Rahaman, "Smart environmental monitoring systems for air and water quality management," *American Journal of Advanced Technology and Engineering Solutions*, vol. 1, no. 01, pp. 1-19, 2025.

[16] G. Karuna *et al.*, "Smart energy management: real-time prediction and optimization for IoT-enabled smart homes," *Cogent Engineering*, vol. 11, no. 1, 2024.

[17] A. Alongi, L. Pacileo, M. M. N. Shahrabani, P. Spūdys, R. Scoccia, and L. Mazzarella, "Smart sensors for Indoor Environmental Quality in residential smart buildings: a review," *International Journal of Sustainable Energy*, vol. 44, no. 1, p. 2578592, 2025.

[18] S. Trinh, D. Skoll, and L. A. Saxon, "Health care 2025: how consumer-facing devices change health management and delivery," *Journal of Medical Internet Research*, vol. 27, p. e60766, 2025.

[19] C. Forchuk, J. Serrato, D. Lizotte, R. Mann, G. Taylor, and S. Husni, "Developing a smart home technology innovation for people with physical and mental health problems: considerations and recommendations," *JMIR mHealth and uHealth*, vol. 10, no. 4, p. e25116, 2022.

[20] M. Sloane *et al.*, "Materiality and risk in the age of pervasive AI sensors," *Nature Machine Intelligence*, vol. 7, no. 3, pp. 334-345, 2025.

[21] H. Sebestyen, D. E. Popescu, and R. D. Zmaranda, "A literature review on security in the Internet of Things: Identifying and analysing critical categories," *Computers*, vol. 14, no. 2, p. 61, 2025.

[22] A. Bhardwaj and S. Goundar, "ATP the New-Age Threat Vector and Cyberattack Trends," *The Techno-Legal Dynamics of Cyber Crimes in Industry 5.0*, pp. 55-78, 2025.

[23] R. Kaur, T. Rodrigues, N. Kadir, and R. Kashef, "A Survey on Privacy Preservation Techniques in IoT Systems," *Sensors (Basel, Switzerland)*, vol. 25, no. 22, p. 6967, 2025.

[24] M. Sharma, A. Tomar, and A. Hazra, "Edge computing for industry 5.0: Fundamental, applications, and research challenges," *IEEE Internet of Things Journal*, vol. 11, no. 11, pp. 19070-19093, 2024.

[25] S. Ahmed, A. Pasha, T. Kumer, M. Akhtaruzzaman, and M. Hossain, "Advancements in Air Quality Monitoring Systems: A Comprehensive Review of Emerging Technologies for Enhancing Environmental Health," *Indoor Air*, vol. 2026, no. 1, p. 3080684, 2026.

[26] J. Qian, R. Tan, M. Feng, W. Shen, D. Lv, and W. Song, "Humidity sensing using polymers: A critical review of current technologies and emerging trends," *Chemosensors*, vol. 12, no. 11, p. 230, 2024.

[27] M. V. Kumar, K. S. Raju, K. Rajakumar, and S. Saravanakumar, *A Study on Next-Generation Materials and Devices*. CRC Press, 2025.

[28] J. Wang *et al.*, "Chemiresistive Gas Sensors: Materials, Mechanisms, and Applications on the Road to Intelligence and Multifunctionality," *Small*, vol. 22, no. 13, p. e12547, 2026.

[29] F. S. Islam, "A comprehensive analysis of air pollution in Dhaka City, Bangladesh, and the application of artificial intelligence and machine learning for enhanced management and forecasting," *International Journal of Applied and Natural Sciences*, vol. 3, no. 1, pp. 131-167, 2025.

[30] A. Shokrollahi, J. A. Persson, R. Malekian, A. Sarkheyli-Hägele, and F. Karlsson, "Passive infrared sensor-based occupancy monitoring in smart buildings: A review of methodologies and machine learning approaches," *Sensors*, vol. 24, no. 5, p. 1533, 2024.

[31] G. Diraco, A. Leone, and P. Siciliano, "A radar-based smart sensor for unobtrusive elderly monitoring in ambient assisted living applications," *Biosensors*, vol. 7, no. 4, p. 55, 2017.

[32] G. García-Gutiérrez, E. Aparicio-Esteve, J. Ureña, J. M. Villadangos-Carrizo, A. Jiménez-Martín, and J. J. García-Domínguez, "A Practical Case of Monitoring Older Adults Using mmWave Radar and UWB," *Sensors*, vol. 26, no. 2, p. 681, 2026.

[33] I. Dhamanti, I. M. Nia, K. Nagappan, and B. P. Srikaanth, "Smart home healthcare for chronic disease management: a scoping review," *Digital Health*, vol. 9, p. 20552076231218144, 2023.

[34] M. Recmanik *et al.*, "A review of patient bed sensors for monitoring of vital signs," *Sensors*, vol. 24, no. 15, p. 4767, 2024.

[35] M. S. R. Jahid, "AI-Powered Smart Home Automation: Enhancing Security, Energy Efficiency, And User Experience In Modern Housing," *American Journal of Interdisciplinary Studies*, vol. 6, no. 02, pp. 76-114, 2025.

[36] D. Guna-Tilaka, W. Sawangphol, T. Charoenritthitham, T. Kanjanapoo, T. Burasotikul, and K. Pongprasit, "An acoustic sensing system for noise monitoring and source identification using transfer learning," *Expert Systems with Applications*, p. 130014, 2025.

[37] S. Patel and S. Neethirajan, "CowPain Check: AI-Based Facial Expression Analysis for Dairy Cow Welfare," *Journal of Animal Science and Technology*, 2025.

[38] A. Santra *et al.*, "Machine learning-powered radio frequency sensing: A review," *IEEE Sensors Journal*, 2025.

[39] J. A. Martinez-Velasco, A. Serrano-Fontova, R. Bosch-Tous, and P. Casals-Torrens, "Survey on Methods for Detection, Classification and Location of Faults in Power Systems Using Artificial Intelligence," *arXiv preprint arXiv:2507.10011*, 2025.

[40] L. Fabri, "Understanding the Interworking of Humans and AI to Design Purposeful Smart Services," 2024.

[41] Y. Rezaee Danesh, "Harnessing Beneficial Microbes and Sensor Technologies for Sustainable Smart Agriculture," *Sensors*, vol. 25, no. 21, p. 6631, 2025.

[42] A. L. Young, "Sensor-Driven Flood Risk Monitoring in Levee-Protected Floodplains and Urban Storm Sewer Networks," Cornell University, 2025.

[43] T. Chetia and B. Chetia, "Piezoelectric MEMS Sensors and its Applications," *Microelectronics: Simulations, Modeling and Applications*, pp. 393-423, 2026.

[44] S. Bian, M. Liu, B. Zhou, P. Lukowicz, and M. Magno, "Body-area capacitive or electric field sensing for human activity recognition and human-computer interaction: A comprehensive survey," *Proceedings of*

the ACM on interactive, mobile, wearable and ubiquitous technologies, vol. 8, no. 1, pp. 1-49, 2024.

[45] A. Bansal, "Pushing the Accuracy and Range Limits of Wireless Localization Systems," Carnegie Mellon University, 2024.

[46] M. Pandi, "Quantum Microwave Illumination Protocols Enhancing Low-Power Radar Detection in Noisy Wireless Environments," 2026.

[47] A. Kumar, G. Sharma, A. Sharma, P. Chopra, and P. Rattan, "Advances in Networks Intelligence and Computing," *Intelligence and Computing,* 2024.

[48] N. A. Aziz, T. R. Razak, S. Nordin, H. Jarimi, Y. Su, and S. Riffat, "AI-Based Modeling of Indoor Air Quality and Thermal Comfort: A Systematic Review of Human-Centric and Adaptive Approaches," *Journal of Climate Change,* vol. 11, no. 4, pp. 29-29, 2025.

[49] S. Devasthali, M. Sharma, A. Sharma, and G. Gupta, "Technology Use Across Age Cohorts in Older Adults: Review and Future Directions," *Communications of the Association for Information Systems,* vol. 57, no. 1, p. 39, 2025.

[50] M. R. A. Berkani *et al.*, "Advances in federated learning: Applications and challenges in smart building environments and beyond," *Computers,* vol. 14, no. 4, p. 124, 2025.

[51] X. Liu *et al.*, "Understanding in-situ programming for smart home automation," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies,* vol. 7, no. 2, pp. 1-31, 2023.

[52] Y. Liu *et al.*, "A survey of embodied ai in healthcare: Techniques, applications, and opportunities," *arXiv preprint arXiv:2501.07468,* 2025.

[53] Y. Belal, S. Ben Mokhtar, H. Haddadi, J. Wang, and A. Mashhadi, "Survey of federated learning models for spatial-temporal mobility applications," *ACM Transactions on Spatial Algorithms and Systems,* vol. 10, no. 3, pp. 1-39, 2024.

[54] L. F. Ribas Monteiro, Y. R. Rodrigues, and A. Zambroni de Souza, "Cybersecurity in cyber–physical power systems," *Energies,* vol. 16, no. 12, p. 4556, 2023.

[55] Z. Turskis and V. Šniokienė, "IoT-driven transformation of circular economy efficiency: an overview," *Mathematical and Computational Applications,* vol. 29, no. 4, p. 49, 2024.

[56] T. Manavi, H. Zafar, and F. Sharif, "An era of digital healthcare—a comprehensive review of sensor technologies and telehealth advancements in chronic heart failure management," *Sensors,* vol. 24, no. 8, p. 2546, 2024.

[57] B. Kadirvelu, T. Bellido Bel, A. Freccero, M. Di Simplico, D. Nicholls, and A. A. Faisal, "Digital Phenotyping for Adolescent Mental Health: Feasibility Study Using Machine Learning to Predict Mental Health Risk From Active and Passive Smartphone Data," *Journal of Medical Internet Research,* vol. 28, p. e72501, 2026.

[58] C. S. Whitaker and D. K. Monroe, "A COMPREHENSIVE FRAMEWORK FOR SECURE AND PRIVATE SMART HOME INFRASTRUCTURE USING DECENTRALIZED EDGE AI," *European Journal of Emerging Real-Time IoT and Edge Infrastructures,* vol. 1, no. 01, pp. 12-21, 2024.

[59] T. Wang, D. Li, B. Zhang, X. Liu, and W. Shang, "Resilient topology reconfiguration for industrial *internet of things: A feature-driven approach against* heterogeneous attacks," *Entropy,* vol. 27, no. 5, p. 503, 2025.

[60] M. Büyük, E. Avşar, and M. Inci, "Overview of smart home concepts through energy management systems, numerical research, and future perspective," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* vol. 47, no. 2, p. 2024924, 2025.

[61] S. Mishra, N. Gupta, and P. Goktas, *AI and ML Techniques in IoT-based Communication: A Path to Sustainable Development Goals*. John Wiley & Sons, 2025.

[62] A. M. Etman, M. S. Abdalzaher, A. A. Emran, A. Yahya, and M. Shaaban, "A survey on machine learning techniques in smart grids based on wireless sensor networks," *IEEE Access,* vol. 13, pp. 2604-2627, 2024.

[63] A. I. Adamu, P. K. Donta, D. M. Ali, S. Sarang, G. M. Stojanović, and S. S. Sarnin, "A systematic literature review of advanced machine learning techniques in wireless body area networks: Application, challenges, and future directions," *IEEE Access,* vol. 13, pp. 194729-194778, 2025.

[64] A. Gheibi-Fetrat *et al.*, "A comprehensive review and classification of micro-scale and macro-scale interconnection network simulators for research and education in network-based computing systems," *The Journal of Supercomputing,* vol. 81, no. 16, p. 1553, 2025.

[65] A. Pradeep and S. K. Reddy, "Advancements in Matter Standard 1.4. 2 for Seamless and Secure Smart Home Interoperability: A Comprehensive Study," *Journal of Internet of Things and Information Technology ISSN: 3107-4502 (Online),* vol. 8, no. 2, 2025.

[66] Z. Shen *et al.*, "A survey of next-generation computing technologies in space-air-ground integrated networks," *ACM Computing Surveys,* vol. 56, no. 1, pp. 1-40, 2023.

[67] M. Nickel and D. Göhringer, "A survey on architectures, hardware acceleration and challenges for in-network computing," *ACM Transactions on Reconfigurable Technology and Systems,* vol. 18, no. 1, pp. 1-34, 2024.

[68] Y. Khomenko and S. Babichev, "Modular IoT Architecture for Monitoring and Control of Office Environments Based on Home Assistant," *IoT,* vol. 6, no. 4, p. 69, 2025.

[69] G. Huang, X. Chen, and C. Liao, "AI-driven wearable bioelectronics in digital healthcare," *Biosensors,* vol. 15, no. 7, p. 410, 2025.

[70] X. Wang, Q. Li, and W. Jia, "Cognitive edge computing: A comprehensive survey on optimizing large models and AI agents for pervasive deployment," *arXiv preprint arXiv:2501.03265,* 2025.

[71] E. J. Sacoto-Cabrera, A. Perez-Torres, L. Tello-Oquendo, and M. Cerrada, "IoT, AI, and Digital Twins in Smart Cities: A Systematic Review for a Thematic

Mapping and Research Agenda," *Smart Cities*, vol. 8, no. 5, p. 175, 2025.

[72] N. Sugunaraj *et al.*, "Distributed energy resource management system (DERMS) cybersecurity scenarios, trends, and potential technologies: a review," *IEEE Communications Surveys & Tutorials*, vol. 28, pp. 224-277, 2025.