Context-Aware and User Adaptive Smart Home Ecosystems Using Wearable and Semantic Technologies During and Post COVID-19 Pandemic

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Abstract In recent years, technology-based health programs, including context-aware and user-adaptive smart home ecosystems, have shown tremendous potential to limit disparities in healthcare access and improve uptake in health programs, thereby improving health outcomes. In this chapter, we review the potential use and applications of context-aware and user-adaptive smart home ecosystems to support the diagnosis, monitoring and management of health conditions. Further, we also discuss the barriers and limitations of using wearable and smart home technologies, their facilitators, current gaps and future opportunities. The chapter provides evidence-based applications and a comprehensive understanding of the use of wearables and smart home ecosystems during and after COVID-19 pandemic for health care providers, researchers, students, and technology developers.

Keywords Context-aware · COVID · Ecosystems · Semantic · Smart home · Wearable

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1 Introduction

COVID-19 has evolved into a pandemic with almost 14 million cases and 600,000 deaths worldwide [1]. Unsurprisingly, during this pandemic, governments and public health authorities have implemented strict restrictions on movement to limit community transmission and have implemented strict efforts to control the pandemic such as hand washing, isolation, quarantining and social distancing [2]. Despite these efforts, the pandemic has had a significant impact on healthcare systems' capacity to continue to deliver essential health services, especially to vulnerable populations such as older adults, children, people living with chronic conditions, people living with disabilities and minorities [3].

In recent years, technology-based health programs have shown tremendous potential to limit healthcare access disparities and improve uptake in health programs, thereby improving health outcomes [4–10]. The success of technology-based programs has been attributed to their ability to overcome many health and social care challenges, as it generates new living spaces that combine the latest technologies with social environments to enhance the quality of life, independence, and health outcomes [11]. Indeed, the successes of these programs can provide a roadmap to people in desperate need to access healthcare services during the COVID pandemic, especially at the comfort of the individual's home, and hence been studied by several researchers in the past few months [12–17].

There is a rising need to bridge the home and healthcare setting gap, considering most individuals with chronic conditions and disabilities receive almost no care at home, where they spend most of their time [18, 19]. One such technology that could assist in providing care is Smart Home. The concept of Smart Home involves specifically designed living spaces to offer unobstructed support systems and interactive technologies to promote improved well-being, participation and independence that otherwise cannot be afforded [20]. However, the challenge involved in smart home technologies is ensuring it is safe and secure to disabilities, stress, falls, fear and/or social isolation [20]. Hence, these technologies have been integrated with numerous sensors to identify users' activity and provide a context-aware, user-adaptive and user-friendly function to support individuals without obstructing their normal activities [21–23]. An example of such a sensor is based on wearable technology.

Wearable technologies have recently gained considerable importance in both the application and research field as a means to monitor and track individuals and promote rehabilitation, surveillance and human–computer interaction [24]. Studies suggest that these low-cost technologies have a great potential to help monitor human activity and well-being in inherently noisy and complex environments to improve health outcomes and Activities of Daily Living (or ADLs), especially for older people or people with cognitive improvements [9, 25]. As a result, these technologies have long been considered solutions to support and promote independent living and healthy ageing [26], especially in smart home applications.

In this study, we defined a smart home ecosystem as 'a an information technology system using a combination of context-aware and user-adaptive techniques that acquire data from wearables to support the individual's healthcare needs both during and post-pandemic'. The smart home ecosystem involves user modelling and adaptation based on contextual awareness, including fuzzy personas and semantically linked models. This would enhance the individual's ability to improve health outcomes at home without obstructing independence and daily activities. Moreover, it would allow for efficient knowledge representation of the ecosystem using semantic technologies that medical professionals can utilise to make informed remote decisions regarding their health needs.

In this book chapter, we reviewed the potential use and applications of context-aware and user-adaptive smart home ecosystems to support the diagnosis, monitoring and management of health conditions. Further, we also discussed the barriers and limitations of wearable and smart home ecosystems, their facilitators, current gaps and future opportunities.

2 Smart Home Eco-Systems in Healthcare

A smart home ecosystem refers to a home environment equipped with information and communication technologies such as household devices, sensors and communication networks that can be remotely controlled, accessed and monitored to support the residents' needs [27]. This concept was initially designed to improve the users' level of comfort, security and energy efficiency. However, over the years, smart home ecosystems have been used to address a myriad of user needs such as comfort, convenience and user-friendliness [28] with the introduction of modernized sensors [29].

According to De Silva et al. [30] the smart home ecosystem can be divided into three categories based on their application. The first category looks at detecting and recognizing the actions of its resident to support their needs. The second category looks at storing and retrieving data captured within the smart home. Finally, the third category aims towards processing the data collected to forecast and alert residents regarding upcoming disasters or concerns. These categories can be further extended to reducing the overall energy consumption of the house by monitoring the activity of the resident and controlling and rescheduling the operating times to reduce energy supply and demand.

Several studies in the literature have implemented smart home ecosystems to create a sense of well-being and high quality of life for its users. For example, Arcelus et al. [31] developed an automated system of intelligent sensors that monitors the health and well-being of the elderly to provide them unobtrusive support with comfort and an independent lifestyle at an affordable cost. Chen, Pomalaza-Raez [32] implemented a low-cost wireless body sensor system to monitor the vital physiological signs of a person living at home, specifically human body movements measured through a waist-mounted triaxial accelerometer. Pham et al. [33] developed a cloud-based smart home environment that collected data from non-invasive sensors, including the residents' location and daily activities. They stored data in the cloud as textual information, which healthcare professionals could access in real-time. Jung [34] designed a smart home hybrid-aware model that collects data from environmental and biosensors and stores the data on a cloud-based server. The server analyses the data using machine learning algorithms to determine the activity of the elderly and monitor factors that may impact their health. Giovani Rubert et al. [35] and Freitas et al. [36] implemented a pervasive smart home system to monitor the vitals of a sick person using sensors, which was stored and analysed on the cloud to enhance medical services at home. Li [37] focused on limiting the obstacles faced by out-of-home medical visits such as time, effort and cost to travel by using the latest sensor technologies to collect vital patient data from the smart home environment. Data were transferred via the internet to healthcare systems, where medical practitioners can access them to provide real-time monitoring and intercept and respond quickly to medical emergencies. Similar methods were implemented in numerous other smart home technologies. These methods included capturing data from various sensors, storing and processing the data in a remote server and providing necessary feedback.

2.1 Benefits of Smart Home Eco-Systems in Healthcare

Smart home ecosystems have the potential to enhance home care for the elderly, people with chronic conditions and people with disabilities [38] due to their ability to maintain health and prevent loneliness amongst these individuals [39]. The power of smart home ecosystems to maintain health has been attributed to the advancement in intelligent systems [29] that enables monitoring, operational efficiency, management and consultancy [40]. For example, remote health monitoring allows for immediate health care and access to medical services within the smart home, or robotic devices assists individuals with disabilities achieve long and healthy lives [39].

The benefits of smart home ecosystems are evident in the clinical outcomes of the people living within these homes. Kelly [41] demonstrated the increased quality of life, reduced hospital readmissions, reduced length of stay in the nursing home and reduced length of stay in hospitals for individuals using smart home systems. In the study by Skubic et al. [42], residents who utilized sensors within a smart home ecosystem reported feeling safer. At the same time, their family members indicated that they were satisfied knowing that someone was watching over their loved ones. Further, Tomita et al. [43] reported better physical and cognitive status in older people using smart home systems, with 91% recommending its use to others.

2.2 Challenges in Smart Home Implementations

While the smart home ecosystem has numerous benefits in healthcare, designing a functional smart home is not without its challenges. Hence, additional research is needed to improve the overall performance and reliability of the system, thereby improving market penetration and acceptance.

The literature highlights three critical challenges associated with smart home systems. The first one is the need for *interoperability*. Smart home ecosystems rely on connection with numerous devices, sensors and communication networks. Interoperability is one of the critical aspects to ensure all components smoothly function together [44]. This is because most devices are built with different operating systems, hardware, programming systems, standards and communication protocols that may affect how data is exchanged. Therefore, there is a need for systems and devices to have similar protocols to ensure the proper execution of tasks [9, 45, 46].

The second challenge of smart home systems is associated with the *system infrastructure*. The smart home system relies on sensors, actuators and other devices to collect information, which is then processed and transferred to a remote server [47]. As the sensors, actuators and other devices collect large volumes of data [48], it would require proper infrastructure, including hardware, communication protocols and computations resources within a body area network and wireless area network that facilitates delay less and seamless connectivity [49]. In the users ‘ homes, AI-powered edge computing could be a key enabler here, providing data, analytics, and processing power where it is most required. In addition, the infrastructure would need to consider suitable evaluation metrics such as packet loss rate, handover delay, algorithm encryption complexity and throughput to optimize the performance of the smart home system [50]. However, the infrastructure for these systems should be carefully designed to limit integration issues and loss of data. For example, using edge computing to minimize data transfer volumes) while also focusing on low maintenance and energy costs to significantly benefit the resident [49].

Finally, the third challenge includes issues with the *security and privacy* of smart home systems. Researchers in the past have demonstrated several security threat issues, including traffic analysis, eavesdropping, node compromise, denial of service (DoS), physical attack, masquerade attack, sinkhole and wormhole attacks and so on [51]. Smart home systems consist of several devices shared over an internet network [52] to ensure a continuous flow of information. This allows the attacker to remotely control the home or access private health and financial information [44]. Several organizational leaders, in the past, have taken actions to limit the impact of security and privacy issues at three levels, i.e. to anticipate and prevent cyber-threats prior to their occurrence, continuously monitoring and neutralizing any threats to the system that are currently operational and restoring regular operations as soon as a threat is detected [53]. Hence, this approach can be considered to develop efficient security and privacy mechanisms within smart homes to ensure the safety of the residents while preventing privacy violations [44].

3 Wearable Health Sensor Technologies in Smart Home Ecosystems

Wearable sensors are devices that can be worn by residents [29] and are capable of real-time physiological health monitoring such as electrocardiogram, heart rate, electromyogram, body temperature, arterial oxygen saturation, respiration rate, electrodermal activity and blood pressure. Additionally, these devices consist of micro-electro-mechanical systems (or MEMS), which measure motion and activity through accelerometers, magnetic field sensors and gyroscopes [54]. These devices, along with remote monitoring systems, have the potential to increase access to healthcare [55], reduce medical costs, minimize exposure to hospital-acquired infections [56], create new opportunities for remotely monitoring clinically relevant factors and allow individuals to actively participate in their healthcare [57]. Thus, providing a massive benefit to vulnerable populations with health issues [58].

Several studies have discussed the potential of wearable sensors in health care. Khoshmanesh et al. [56] classified these sensors into three main categories: mountable, skin-like sensors, and textile-based sensors. These three categories use different sensing mechanisms such as resistive, optical, electrochemical, bioelectrical impedance, piezothermic, triboelectric, piezoelectric, piezoresistive and capacitive to acquire the target signals [56]. The target signal is processed within the wearable and transmitted to remote monitoring devices via a low-power radio signal. Data from these devices can be collected and analysed to support disease monitoring and treatment [59]. For example, Steele et al. [60] utilized a triaxial accelerometer worn around the non-dominant arm to measure the daily physical activity of COPD patients, intending to improve physical functioning. Varatharajan et al. [61] considered analysing the continuous foot movement using a wearable motion sensor positioned around the ankle to acquire gait signals that could be used for early detection of Alzheimer's disease. Dieffenderfer et al. [62] developed a wristband, chest patch and handheld spirometer to identify environmental parameters such as ambient ozone concentration, relative humidity and temperature towards supporting asthma management. Sood, Mahajan [63] proposed a system that utilizes real-time health, location, environmental, drug and meteorological sensors to diagnose the chikungunya virus amongst infected users and take preventive measures on time. Therefore, applying wearables in smart homes can significantly improve comfort, health care and disease prevention amongst its residents [63, 64].

3.1 Architecture

The generic architecture of a wearable device can be divided into four modules, i.e. body area network, data logger, data analysis and real-time monitoring (Fig. 1). The body area network (or BAN) can be used in different wearable devices irrespective of its architecture. It requires a network of sensors being placed on the human body from

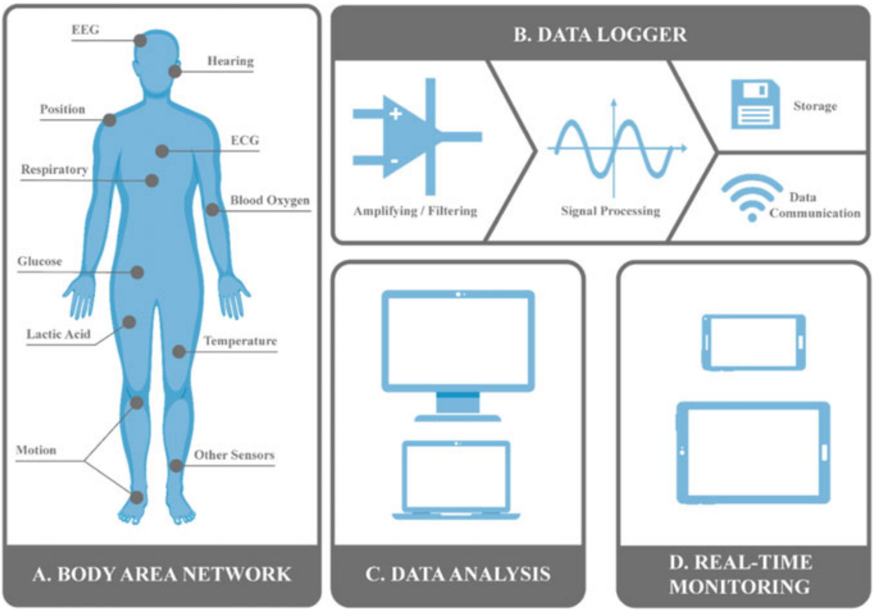

Fig. 1 Generic wearable device architecture [65]

which data is transmitted to a portable unit known as the sensing unit that processes the data extracted. This presents a clear advantage as it enables data centralisation into a single unit from different sensors to ensure remote processing. Moreover, it enhances the synchronization, control, programming and scheduling of the entire system based on the environmental and body conditions. Further, wireless communication is regarded as a key asset towards ensuring that the system is ubiquitous and mobile [65].

The data logger (or portable unit) is a user interface box that collects all the information from the sensors and other portable devices. Literature highlights two approaches to facilitate communication between the data logger and the sensors. The most simple and cheap technique is the use of wires. Some variations in this technique involve the wires woven into fabrics generally termed smart clothes to avoid loose wires and are considered favourable due to the ease of movement and increased comfort. Another approach is the use of biological channels, an innovative technique that utilizes the human body as a transmitter for electrostatic fields. The data collected through these approaches are received in the form of raw analogue data, which is amplified and converted into digital signals to be processed. The processing of data involves extracting individual features from the data to determine the subjects' health, detect disease, detect anomalies and determine support. The processed can be transmitted via a wireless network protocol or stored within an SD card [65]. Generally, the wearable relies on wireless communication standards such as Bluetooth low energy (BLE) with other devices to ensure data synchronization [66].

Wearable devices rely on several communication standards, as shown in Table 1. For example, Bluetooth is a low-power, short-range and low-cost radio frequency connectivity standard used for communication in fixed or portable devices. It operates on a 2.4 GHz spectrum with a frequency hopping technique across 79 different channels. This standard allows for up to 3 Mb/s data transmission rate over a 100 m distance. Specifically, this functions in wearable technologies using alternative protocols such as Bluetooth low energy (or BLE), an ultra-low powered technology to maximize the battery capacity, and Bluetooth 3.0 specification, which utilizes protocols similar to Wi-Fi physical (PHY) layers for increased data throughput. Another standard, arguably the most commonly used, is based on Body Area Network (or BAN), i.e. Zigbee. Zigbee is a low data-rate and low-cost standard that focus on the communication of devices with longer battery life. Zigbee operates at 868 MHz bands on a single channel, 915 MHz on 10 channels, and 2.4Ghz on 16 channels. The standard operates on a phased shift keying modulation at an offset of 250 Kb/s, with a maximum transmission range of 75 m [67]. Another popular standard adopted is Wi-Fi which allows for high data throughput of about 54–150 Mb/s between the ranges of 2.4–2.5 GHz for 35–120 m and 5.725–5.85 kHz for 70–250 m. The Wi-Fi standard focuses on providing a large bandwidth at low energy consumption, generally used when distance communication is required [65, 67]. One of the most recent standards is the IEEE 802.15.6, which focuses on a low-powered transmission with scalable rates, i.e. from 1 kb/s to over 100mb/s. This was developed for short-distance communication between 2 to 5 m and can allow up to 100 devices to connect simultaneously. This standard consists of three physical (PHY) layers distributed across a complex trans receiving hardware. The layers include ultrawideband, narrowband and human body channel [67].

Data transferred through the different wireless standards can be either stored or analysed in real-time to diagnose and predict health issues. For example, data collected from sleep sensors could be used to determine sleep issues such as sleep apnoea. A medical professional could use this data to improve the quality of care provided to the patient. In addition, the system could provide real-time monitoring and support to the patient to manage the physiological problem outside the medical environment as long as the patient has a stable internet connection [65].

4 Context-Aware and User Adaptive Smart Home Ecosystems

There is an increasing demand for healthcare technologies such as smart home ecosystems to dynamically adapt their behaviour in real-time based on user requirements, preferences, the underlying infrastructure and operational environments. Hence, several research approaches are currently being considered in developing

Table 1 Wireless technologies for wearable devices [67]

Wireless technology	Data Rate	Range	Frequency	Number of Notes	Other attributes
Bluetooth (802.15.1)	1–3 Mb/s	1–10 m	2.4–2.5 GHz	7 + 1	Small antenna, large bandwidth and crowded spectrum
BLE (802.15.1)	1 Mb/s	1–10 m	2.4–2.5 GHz	7 + 1	
ZigBee (802.15.4)	250 bb/s	10–100 m	2.4–2.5 GHz	Unlimited	
WLAN (802.11a/b/g/n)	54–150 Mb/s	35–120 m (a/b/g)	2.4–2.5 GHz	255	Small antenna, large bandwidth and severe attenuation
		70–250 m (n)	5.725–5.85 GHz		
ANT	1 Mb/s	10–30 m	2.4–2.5 GHz	N/A	
Passive RFID	868 kb/s	0–3 m	860–960 MHz	One read at a time	Large antenna, good propagation and limited bandwidth
Active RFID	10 s of Mb/s	0–100 m	433 MHz	1000 + reads at a time	Large antenna, crowded spectrum and limited bandwidth
UWB	52–480 Mb/s	3–10 m	4.2–4.8 GHz, 7.25–8.5 GHz, 3.1–10.6 GHz	127 + 1	Huge bandwidth, short-range, severe attenuation and high-rate for multimedia

systems that adapt based on individual contexts and/or requirements. The two primary approaches implemented are context-aware and self-adaptive systems [68].

A context-aware system can be defined as a software system that can understand the context of a particular system and shares its context with other systems or provide a response by itself [69]. Over the years, there have been several definitions for the context term. Most authors define the context based on location, time, identity, temperature, noise, desires, beliefs, intentions and commitments of the user [70]. For example, Brezillon [71] defined it as an interaction between humans, applications, and environments. While Brown [72] defines context as elements within a user environment that the computer knows about. Despite the numerous definitions, as highlighted by Dey [73], the most formal definition of context is "… *information that is characterized by a situation or entity, where an entity may include a person, place or object*".

Context can be classified based on instances involving different context dimensions. Prekop, Burnett [74] and Gustavsen [75] termed these dimensions as internal and external, where the internal dimensions are specified mainly by the user or captured through user interactions (i.e. user tasks, goals, processes, emotional states and work contexts), and external dimensions include context measured through hardware sensors (i.e. light, sound, movement, temperature, touch, air pressure etc.). Most context-aware systems use these dimensions to provide its user with relevant information or services [76].

Context-aware systems offer numerous different advantages that allow systems to act more autonomously to provide users with their needs and wants. In the past, context-aware systems have been implemented in healthcare to create dynamic environments to address specific research challenges using concepts such as data acquisition, interpretation, data modelling, reasoning and so on [77]. For example, Lee, Kwon [78] modelled individual contexts within a smart home environment using different ontologies including user domain, social context, home domain and function management to personalize healthcare services fully. Gómez et al. [79] proposed an Internet of Things (or IoT) monitoring system that senses the activities of older people with severe chronic conditions within their homes to enhance their quality of life. Park et al. [80] designed a context-aware simulation system that collected information from various virtual sensors and devices within the smart home domain to generate context-aware information. Neyja et al. [81] developed an IoT-based eHealth monitoring system that utilizes ECG signals to facilitate timely intervention and promote real-time monitoring of cardiovascular diseases.

Context-aware systems, in most cases, work with self-adaptive systems [82]. Self-adaptive systems have been increasingly used to manage problems related to contexts, which are subject to change over short periods and are poorly understood [83]. This is because self-adaptive systems have the potential to improve the systems by responding to issues in real-time to change context [84]; thereby improving the quality of service. Therefore, such a system enables the system to be technically and economically feasible that can provide autonomous changes to the tasks, loads, topology, and logical network characteristics [83].

Self-adaptive systems, in the past, has been conceptualized based on several different aspects, such as user requirements, environmental characteristics and system properties [85]. Salehie, Tahvildari [86] described several mechanisms adopted by self-adaptive systems to manage these aspects, including monitoring software entities and environment (i.e. context awareness), analyzing the changes, developing a plan to react to the changes and execute the plan to ensure the decisions take effect. For example, Alhafidh, Allen [87] developed a smart home system that adapts based on the stakeholders' lifestyle and anticipated activities to optimize the interface between the user and the household appliances. The system included.

i. numerous sensors to coordinate and control the smart home system to satisfy the users' behaviour,
ii. learn the behaviour of the different users and create a model to support their activity,
iii. determine the relationships between the user behaviour and heterogeneous smart nodes,
iv. manage resources to reduce wastage and maximize efficiency,
v. utilize cloud storage to store identified activities thereby enhancing long-term analysis of user behaviours,
vi. utilize agent-based systems to promote interoperability between components and sub-systems, and
vii. integrate security and privacy of user data within the system.

5 Issues in Implementation

In the past, several studies have been conducted in smart homes and context-aware systems. These studies have provided a roadmap regarding potential issues that may occur with its implementation to support the needs of the resident. These issues can be classified into four categories, which include: (i) interoperability, (ii) connectivity and (iii) context-aware architecture, (iv) security and privacy.

5.1 Interoperability

Smart homes rely on several smart nodes connected with sensors in a home area network to provide its resident with an intelligent living environment [88]. Most sensors (or devices), however, are built with different standards or communication protocols [44] that may affect their ability to ensure easy integration with a generic smart home system, which leads to the main issue of interoperability [89].

Several studies and solutions have been proposed in the past to limit issues related to interoperability. For example, Perumal et al. [90] proposed using a web-service and Simple Object Access Protocol (SOAP) framework that exchanges information and maintains operation between different smart home devices. Krishna, Verma [91] proposed the inclusion of a framework that considers several devices to communicate with one another to promote collaboration between smart devices and transfers this data to a centralized server where the smart home system can acquire, analyse, coordinate and monitor user activities. Furthermore, several leading companies are working towards achieving complete interoperability of devices that can ensure generic smart home systems development. An example of this change is evident in the Z-wave products, where Zigbee 3.0 considers interoperability with its previous versions [89].

5.2 Connectivity

Connectivity is one of the most important factors for the proper functioning of the smart home system [92]. Connectivity issues are common amongst various devices from different manufacturers and may exist because of the different standards and protocols [39]. According to Rehman et al. [93], the issues related to connectivity can be mitigated by including a unique identifier for all communication devices that allows for the development of an effective addressing policy. This would allow for the system to identify the device and ensure the quality of service. However, it may result in challenges with traffic characterization due to the inclusion of several different devices interconnected with the smart home device. To mitigate this issue, the authors discussed using a routing protocol that prevents packet loss and ensures energy efficiency, which creates an IoT system that is energy-efficient, scalable, and reliable.

5.3 Context-Aware Architecture

Context-aware computing systems utilizes heterogeneous data sources [94] to gather, process and store context data in real-time [69, 82], thereby providing services according to user needs, interaction with the environment and their localization [94]. The integration of such systems provides the user with an immersive experience that contributes to emotional, social and physical meaning throughout their daily actions and activities [94]. Hence, context-aware systems are considered a crucial part of ubiquitous or pervasive computing technologies [95]. However, when dealing with these devices, the system has to deal with different challenges. In a study by Bang, Rao [96], the authors described several issues with implementing context-aware systems. These issues include:

i. Obtaining accurate information: For the context-aware system to function efficiently, it needs to get precise information from the devices to derive future inferences. For health monitoring, information is personal and sensitive data such as vitals, schedules, contact lists, health status etc.

ii. Dealing with dynamic information: Context-aware systems function in a real-time environment that is expected to deal with dynamic information such as position, vitals, actions, emotional and physiological states, observable objects and orientations.
iii. Understand proper and relevant contexts: It is critical for context-aware systems to utilize data gathered through connected devices and hardware to provide information based on relevant contexts, addressing user requirements. Failure to support user requirements may affect system performance.
iv. Storing, Updating and Privacy of Context Information: The system would need to store data either locally or on the network. However, due to the generation of large amounts of data, there is a significant concern regarding the storage requirements and issues related to the security and privacy of user information.
v. Deciding Minimum Service that Context-Aware System should provide: The user needs are constantly changing. As a result, the system needs to consider these changes and provide contexts based on the user requirements.
vi. Handling Errors: Handling errors is critical for context-aware systems as inferences drawn must be accurate for the system to meet user requirements and ensure user security.

5.4 Security and Privacy

The smart home system is associated with connecting different devices via the internet and home shared networks [88]. In the past, researchers have highlighted several issues related to the security and privacy of smart home systems, which include aspects such as traffic analysis, eavesdropping, node compromise, denial of service (DoS), physical attack, masquerade attack, sinkhole and wormhole attacks and so on [51]. Hence, the smart home system should provide a security policy involving crypto-primitives to ensure authenticity (data does not consider malicious objects), integrity (data transmitted is identical to the data received) and confidentiality (data is inaccessible to unauthorized users) [89].

6 Conclusion

In this chapter, the concept of context-aware and user-adaptive smart home ecosystems using wearable technology is presented. Context-aware and user-adaptive systems can play a key role in developing smart home ecosystems by integrating numerous smart sensors such as wearables that can detect user activity based on different contexts. Therefore, including such a system can create a more responsive and active environment to meet user needs and requirements. As a result, several organizations worldwide are continuously looking at such practices to support monitoring and care.

The potential of context-aware and user-adaptive smart homes are threefold; (i) it can promote effective monitoring to its residents and provide improved feedback, (ii) adapt in real-time to meet the user requirements, (iii) provide at-home support to ensure changes in behaviour using wearable technologies and other devices. Moreover, in the future, with the growth and adoption of AI-powered edge computing and improved wearable hardware, it would be possible to promote better resource efficiency and thereby promote better health and behaviour outcomes.

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