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Advances in Ubiquitous Computing: Integrating Location and Activity Sensing for Intelligent Services

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Abstract

Ubiquitous computing represents a paradigm shift by embedding computational intelligence into everyday environments, facilitating seamless, context-sensitive interactions. A notable accomplishment in this area is the combination of location and activity sensing technology, which allows for the creation of intelligent, flexible services that react to user context in real-time. Systems can identify patterns in space and behavior to provide real-time, personalized services by utilizing wearable technology, GPS, accelerometers, gyroscopes, and RFID. Effective healthcare, intelligent transportation, ambient assisted living, and context-aware retail settings are just a few fields in which applications are found. The technological foundations, system designs, and important enabling frameworks that facilitate this kind of integration are examined in this study. It also explores potential future approaches in edge computing, federated learning, and AI-driven context modeling while addressing critical issues like data privacy, energy efficiency, sensor fusion, and scalability. The combination of location and activity sensing revolutionizes ubiquitous computing and creates intelligent, proactive, and human-centered service ecosystems.

Keywords: Ubiquitous Computing, Location Sensing, Activity Recognition, Context-Aware Services, Sensor Fusion, Intelligent Systems, Edge Computing, Federated Learning, Smart Environments, Human-Centric Computing.

1 Introduction

The ongoing support from business and academia energies IoT technology's exceptional growth and results. Because of this, microtechnology, mobile networking, machine learning, and the Internet of

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Things are all evolving at an accelerating rate. The Gartner assessment provides the roadmap for the maturity of over 2000 technologies. Digital workspaces, intelligent machines, 3D printing, enterprise mobile security, and linked homes are among the 119 categories into which the technologies are divided. Machine-learning-based wearable and Internet of Things user interfaces are unlikely to see inflation. When the concept of the "Internet of Things (IoT)" emerged, recognizing additional sensing capabilities marked a vital shift from traditional computer networks (Mukhametov, 2020). Essential features for the design and deployment of ubiquitous IoT devices, including drones, satellites, wearable electronics, driverless cars, and Wi-Fi, are sensing and communications (S&C) (Park et al., 2019). Currently, in fixed IoT data processing pipelines, S&C operates independently through modules that often function like black boxes, leaving their internal mechanisms largely unknown. This modular architecture results in S&C processes running on two separate layers (communications and sensing) with limited collaboration, minimal hardware overlap, and rare integration (Han et al., 2010). The rapid rise of innovative IoT services like digital areas, autonomous systems, extended reality (XR), and flying cars underscores the pressing need for advanced sensing technologies (Roper & Bar, 2024). Analyzing received RF signal patterns and characteristics positions wireless sensing capability as a crucial component of the sensing solution. Nonetheless, the design of hardware, channel characteristics, and information processing for communication and radio sensing systems closely parallel each other due to the common use of high frequencies and extensive antenna arrays (Kumar, 2014). Consequently, sensing and communications systems can be co-designed, co-optimized, and co-deployed to enhance mutual support, utilizing the same hardware platform, shared spectrum, cooperative signal processing methods, and unified control systems (Giji Kiruba et al., 2023).

Key Contribution

Integrating the location with activity sensing will enable real-time contextual awareness.

- To enhance the intelligent service, which means the system adopts the proactivity to locate and improve the responsiveness and automation
- To emerge with the sensor data through smart cities and interpret it to take action through intelligent decision-making.

Various sections follow this paper. Section I describes the definition of ubiquitous computing and also explains the importance of integrating it with activity sensing. The next section clearly explains the advancements in various fields. Section II describes the various technologies used for this research. Section III describes the comparison table for ubiquitous computing with existing models. Section IV describes ubiquitous computing technology followed by the Internet of Things, Wearable Technology, and Smart home systems. Section V describes the integration of location and activity sensing followed by GPS, wearable sensors, and integration of multiple sources. Section VI explained intelligent services enabled by integration, personalized recommendations, health monitoring systems, and smart home automation. Section VII describes the various challenges and includes future directions. Section VIII covers the key findings and future trends of Ubiquitous computing.

2 Background Information

2.1 Ubiquitous Computing Vs Virtual Reality

Mark says that while UC "brings the computer into the world," VR "brings the world into the computer." He intended to say that complex models of an actual or imagined (part of the) world are typically the

foundation of virtual reality technology. In addition to numerous other static and dynamic descriptions of the modeled object, this model includes 3D (geometric) elements. Automobile digital mockups, for example, have advanced to the point where they can replicate crash testing using the vehicle's geometry and the obstruction, static and dynamic material properties, physics rules, etc. More and more world facts are fed into the computer as models get more complex. Ultimately, practically everything takes place in a virtual environment, and even people are modified to function as computer peripherals by wearing data gloves and wearing displays on their heads. Mark Weiser questioned the primary and secondary functions of humans and computers. He suggested adopting the UC vision to reverse these roles, putting humans at the center and eschewing computers' central function in favor of integrating them into the environment, particularly physical items. In this instance, he referred to UC as "embodied virtuality."

2.2 Ubiquitous Computing Vs Artificial Intelligence

Mark Weiser attacked the 1980s' excessively optimistic predictions for AI. AI research faced a devastating confidence crisis when he formulated his UC vision in the late 1980s and early 1990s. The term AI lacked a universally accepted and practical definition, leading to disappointments in its connection to human intelligence or the human brain. While the AI craze granted researchers significant funding, this support was short-lived. Mark Weiser suggested an alternative method for achieving a higher level of sophistication for computer-based solutions, which had been the overarching objective of AI. He thought that intent on specific aspects of "intelligent behavior" and transmitting each computer to a particular subset was a more reasonable aim. Linking the particular computers and compelling them to collaborate would enhance overall sophistication. Because of this logic, "brilliant" is regarded as humbler than "intelligent." In order to dedicate computers to a limited subset of "understanding the world around us," which is a crucial component of intelligent behavior, sensor technology is essential. By broadly deploying and linking sensor-based microcomputers, one might incorporate environmental data (location, temperature, illumination, movement, etc.) to create intelligent computer and computerized physical item behavior.

2.3 Ubiquitous Computing Vs User Agents

The word "user agent" is not as well known in everyday language as "virtual reality" or "artificial intelligence." UAs were viewed at the time as intelligent bridges connecting the user and the computer world, i.e., to improve human-computer interaction or make systems easier to use. User agents have frequently been likened to the stereotype of British butlers, who are subtle and unobtrusive, constantly available, and incredibly aware of their employers' preferences and customs. UAs were deployed as independent software components between users and applications, examining and learning from the user-software application by this analogy. Mark Weiser questioned five requirements that usually come from this comparison for user agents and suggested UA as a better option for the first three (Wang et al., 2022). For the last two, he thought the necessary base technology was not mature enough; UAs were supposed to advise their users based on their knowledge. Mark Weiser essentially questioned why they would not complete the task themselves, which is a commitment that UC ought to keep; although UC should be more radical and take over the interaction or do functions independently, Mark Weiser thought this was the only way to go if hundreds of computers surrounded people. One basic idea about UAs was that they would listen to what the user said. Natural language processing and speech recognition technologies were still in their infancy when Mark Weiser was working on them, so he thought they could not deliver satisfactory results in this area. Instead, he thought UAs should observe users to

discover what they want and wish (Bharath et al., 2024). The requisite (machine learning) technology was once again deemed too nascent to fulfill this potential (Mühlhäuser & Gurevych, 2010).

3 Comparison Table for Advances in Ubiquitous Computing in Existing Models:

Table 1: Comparison Table for Advanced Techniques in Ubiquitous Computing in Existing Models

Author Name	Technology/Methods	Focused Areas	Results
(Ghosh et al., 2020)	Edge Computing in Ubiquitous Sensing	Systems are energy-efficient	Reduce the latency and also improve the sensor data handling in real-time.
(Shoaib et al., 2021)	Deep Neural Networks and Smartphone Sensors.	It's mainly focused on activity areas	To achieve the classification accuracy used by CNN and LSTM models.
(Li et al., 2021)	Federated Learning and wearable sensor	Privacy among the context recognitions.	A decentralized training model protects user data and improves intelligent services.
(Wang et al., 2022)	IoT Sensors and AI Algorithms	Mainly focused on Health care areas	It's integrated with a location for activity sensing to improve the health monitoring system.
(Zhang et al., 2022)	GPS, Sensor Fusion, and AI	Mainly focused on Intelligent Transportation	Analyzing the real-time basis and optimizing urban mobility followed by traffic predictions are needed.
(Tan et al., 2024)	AI, Crows Sensing, and geographical analysis	Mainly focused on Smart cities	Sensing activity through urban planning and infrastructure optimizations.

From the above table 1, an author (Ghosh et al., 2020) describes the study as mainly moving through centralized concepts of cloud-based systems. It helps decentralize the edge architecture to improve energy efficiency, reduce location latency, and achieve sensing followed by immediate responses (Giji Kiruba et al., 2023). The author (Shoaib et al.,2021) describes the role of advanced AI algorithms used for complex sensors with data patterns (Banumathy et al., 2023). It also demonstrates that the deep learning model helps improve activity detection accurately in ubiquitous mobile environments (Shoaib et al., 2021). An author (Li et al., 2021) describes data privacy as an essential concern for this research, which should contribute to privacy in computing. It also ensures the location and activity without compromising user confidentiality. (Park et al., 2019). The author (Wang et al.,2022) describes about to validate the ubiquitous sensing for proactive healthcare solutions; It is enabled through adaptive based on patient movement in real-time. (Wang et al., 2022). (Zhang et al,2022), describes to underscore the location-based sensing that contributes to urban mobility optimizations. It also enables intelligent traffic control with efficient transportation services (Banumathy et al., 2023). The authors (Lee et al.,2025) mainly focused on research that should represent the evolution of AI interpretable followed by the human-centric, it's essential for the public adoption of complex locations, which contain sensitive applications like healthcare and governance (Tan et al., 2024).

4 Ubiquitous Computing Technologies

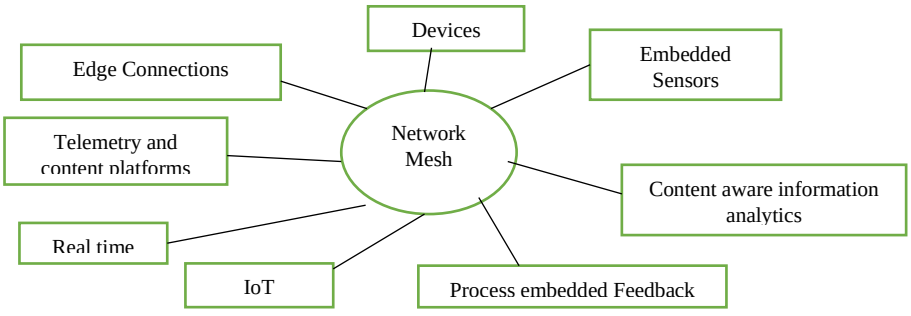

Figure 1: Components of Ubiquitous Computing System

The creation of ubiquitous computing systems necessitates the collaboration of four key components, as shown in Fig 1: sensors, cameras, and various smart devices that gather and process large volumes of data instantaneously. The Internet of Things facilitates information sharing amongst physical infrastructure components. Potential embedded devices (pads, boards, spaces, locations, and tabs) that are contextually aware. principles and technologies of information exchange (telemetry, content platforms, edge connections, and real-time feedback) that are sensitive to the context of information. These elements offer real-time change tracking and additional information about ongoing procedures. Because widespread computer systems are built on microelectronic systems, they may be the best way to digitize the infrastructure of smart cities. The agent (person, organization, management structures, or other information devices) has access to infinite facts about the status of the processes around him due to ubiquitous computing. Consequently, it raises the possibility of a fresh method of decision-making. The abbreviation DIKW stands for "data," "information," "knowledge," and "wisdom." For example, innovative garbage container technologies in smart cities can be considered an innovative waste disposal strategy. Companies like Big-Belly, Enevo, and Ecube Labs own the data technology development process. With a brilliant container that combines big data analysis and Internet of Things technology, you can estimate when the container will be filled and identify how occupied it is. Other issue areas of smart cities, such as energy system control and innovative health, are addressed through a comparable method of ubiquitous systems. The emergence of new digital technologies, especially advancements in cloud computing, the Internet of Things, and 5G technologies, will soon be linked to the introduction of ubiquitous computing. These technologies support the operation of extensive device-to-device communication systems, which form the foundation of smart city infrastructure, as well as optimization of decision-making time costs, adaptability to change, energy efficiency, and productivity. When building ubiquitous computer systems for smart cities, organizing the data from all the different devices can be hard. In smart cities, making decisions frequently necessitates simultaneously accounting for and analyzing several data sources. These days, most data are gathered in irregular formats, stored under various conditions, and frequently need to be processed by hand. The problem is implementing automated tools and establishing data collection, preparation, and processing methods. These obstacles can be surmounted by employing distributed machine-learning methodologies (Bran et al., 2021).

4.1 Internet of Things (IOT) Devices

With technology ubiquitous, the real world has evolved into an extensive computer environment. The integration of the physical environment with computational and decision-making capabilities was done through wireless and smart sensing devices to produce IoT method services. Applications, medical, business, multimedia, communication networks, and information access for both commercial and residential clients were all facilitated by this environment. User equipment was utilized to engage with fully independent customer access to resources. Adaptive communication technology connects customers to networks and services outside of their control. The user's device has a large number of programs. The bandwidth of the edge networks was optimized to accommodate ITF in this transmission manner, thereby enhancing the resource utilization of IoT-assisted detectors. The edge nodes processed numerous queries in a timely manner by utilizing the allocated bandwidth and copying cloud resources. The medical sensor data transfer system consumed a smaller amount of bandwidth since it could process fewer queries. Before, medical sensor data allocation was used to model the edge nodes so that the health monitor information centers wouldn't get too busy when they had many requests to handle. A way to manage service sharing and customer demands in terms of time. However, the service response time caused by improper request management undermined this strategy's efficacy. Flexible medical sensor data transmission methods can handle modest requests with less bandwidth use.

Computer network technology enables itself to exist in the background of the consumers' consciousness quietly. The ubiquitous computing model's main tenet is that computers should blend seamlessly into our daily surroundings and lifestyles. Because embedded processors in ubiquitous computing systems can sense and respond to their application environment independently, the computer is "invisible." On the other hand, widespread computing can work on any device, at any time, in any location, and with any data over networks. When clients walk from their cars to work, it can also transfer jobs between computers. It is part of connecting electrical components, including installing microprocessors for data transit. Devices for ubiquitous computing are constantly accessible and fully networked. Ubiquitous computing emphasizes learning by making computers easier to use and faster for everyday jobs. Several technologies, such as wireless communication and networking technologies, mobile devices, embedded systems, wearable computers, radio frequency identification (RFID) tags, middleware, and software bots, are included in the category of ubiquitous computing. This computing type is sometimes considered the natural progression from mobile computing. Functions like speech recognition, internet connectivity, and artificial intelligence (AI) are frequently incorporated. People can connect to information-processing devices more easily and conveniently when computers are integrated into everyday things, regardless of location or circumstances. This expression can also refer to a computing environment in which every instructor and student has a personal, internet-connected mobile computer that they can use both at home and at school. The foundation of ubiquitous computing is electronic downsizing, which makes it possible to incorporate computer technology into portable, lightweight devices and a host of other ubiquitous emergent scenarios. On the other hand, computers used to be large, bulky devices.

4.2 Wearable Technology

By enabling the seamless integration of computing into everyday life through devices such as smartwatches and fitness trackers, which capture data and offer services such as health monitoring and notifications, wearable technology is a critical enabler of ubiquitous computing. Examples of wearable technology in Ubiquitous computing, including health monitoring, fitness tracking, mobile payments, and remote patient monitoring, were also elucidated in this section. Health monitoring is a wearable gadget that tracks vital signs, activity levels, and sleep habits. It provides valuable information for both healthcare experts and individuals managing their health. Fitness trackers assist users with goal-setting, physical activity monitoring, and progress reporting. Alerts and Reminders: Smartwatches can send alerts and reminders and reply to messages without requiring users to check their phones. Mobile payments: Some smart tech supports mobile payments, which lets you buy things without touching anything. Remote Patient Monitoring: By enabling doctors to monitor patients' health problems remotely, wearable technology is employed in the medical field.

Figure 2 illustrates the structure of the framework. The main functions of the technology involve managing requests and overseeing storage. The cloud layer processes these requests even when resources are not immediately available. This function is activated through a personal device using either Bluetooth or Zigbee. There is a shortage of request controllers for most resources accessible to the detectors. Moreover, request processing and distribution occur quickly and without loss. A consistent flow is maintained in the pervasive ecosystem to minimize the chance of blocked requests. Storage management, including memory control and density assignment at the framework level, helps alleviate resource allocation backlogs and failures. The framework incorporates a recurrent learning technique to identify and reduce communication errors. To facilitate the uninterrupted distribution of requests, the framework oversees elements of the infrastructure layer, particularly memory allocation and request processing.

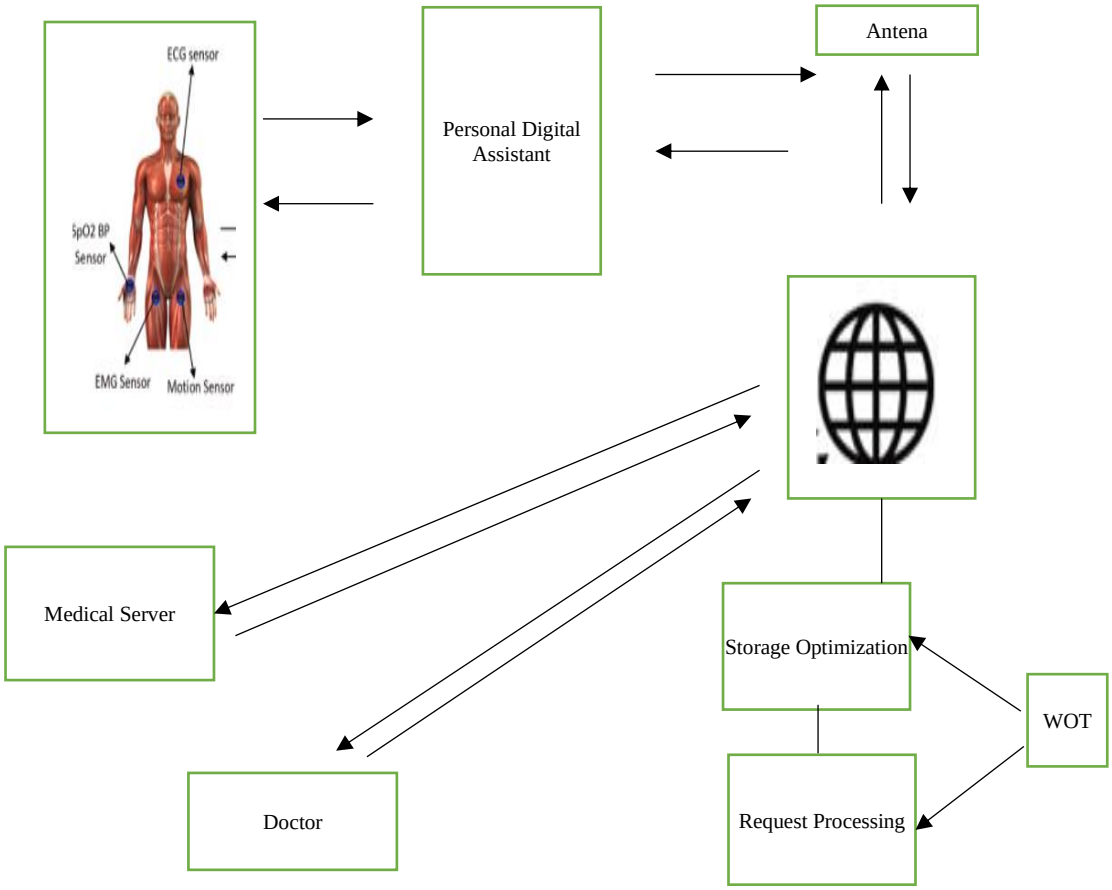

Figure 2: Ubiquitous Computing in Wearable Technology

4.3 Smart Home Systems

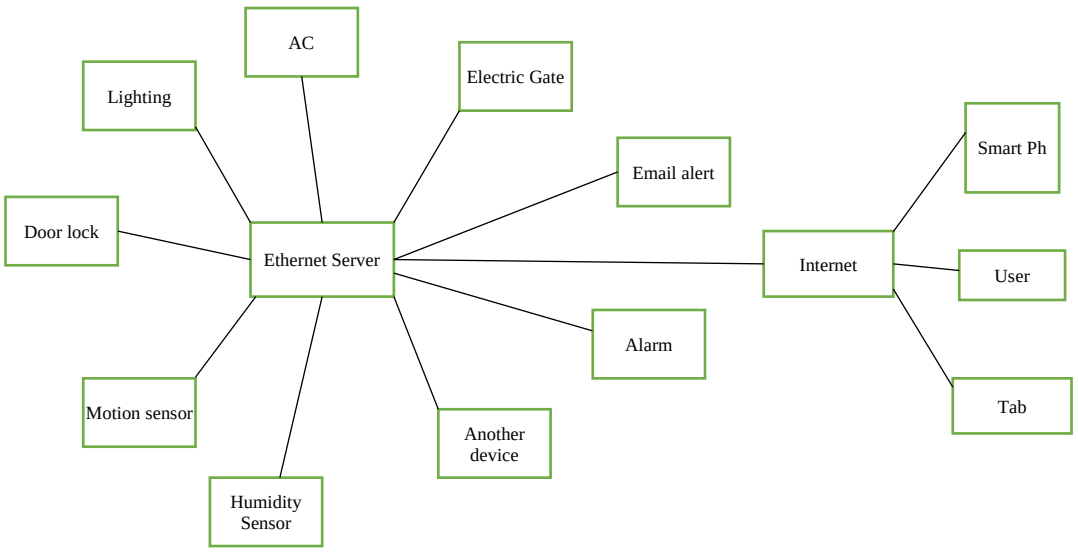

Figure 3: Ubiquitous Computing in Smart Home Systems

Figure 3 presents an overview of the proposed system design, which integrates an Arduino Ethernet-based microweb server with an Android application. The Arduino microcontroller is the primary

controller, operating the compact web server and executing essential functions. Direct connections exist between the core controller and various sensors, actuators, and relays. The smart home application enables remote control and home environment monitoring via an internet connection. Devices can connect through Wi-Fi or 3G/4G networks to access the internet. The design incorporates automatic control of the smart home environment, such as regulating room temperature, voice-activated feature switching, user authentication for system access, and energy management system control, which includes lighting, power outlets, and HVAC systems. Security and monitoring functionalities also feature intrusion and fire detection, (Jeong et al., 2019) augmented by email notifications and siren alerts.

5 Integration of Location and Activity Sensing

This technique is based on the Global Positioning technique (GPS), which uses satellite communication to obtain an object's coordinates and other important data. The monitoring process involves the establishment of speed and geographical restrictions, the acquisition of historical reports for the vehicle's movements, or the real-time surveillance of its location, in addition to getting SMS notifications when specific occurrences occur. Integrating the device with the car alarm and obtaining a map showing the vehicle's location if it is suspected of being stolen can also be utilized to prevent auto theft. Many new technologies and communication networks are needed for our system to track cars. Some examples are GPS, GPRS, the Internet (or "World Wide Web"), and GSM. Here are some broad categories into which our system's key services mainly fall: Maps An image representing the current position of a chosen car is provided to the mobile application as a static Google map. Google Maps is offered to display each user's vehicle's most recent position. Every report comes with a map that shows where every vehicle has been. Maps can also be used to draw borders, such as circles, around the area that the administrator user selects. The database stores information about how these circles are aligned. Warnings: When one of these four things happen, the user's cell phone receives an SMS notification. The first step is to Go too fast. The second stage is to go into or out of a geofence zone. The third one is Vehicle Stops and Moves. The final step is the car alarm sounding. Reports are offered to examine a vehicle's history over a chosen time frame. The suggested system may produce three different kinds of reports. A standard report is a regular report that gives standard GPS information, such as position (longitude and latitude), ground speed, and the precise moment the measurements were acquired. It is transmitted from the device at a user-specified interval. The user only needs to choose a time period to display the data that was entered into the database during that period. The speeding report eliminates the regular report by choosing a speeding number and only displaying data with speeds more significant than the specified threshold. The user can thus more easily filter out the times and places where her/his vehicle exceeded the speed limit (Chakravorty et al., 2002). Regular tracking reports are supplied at predetermined intervals. The system allows people to monitor their vehicles' positions, speeds, movements, and pauses. Setting geographical and speed limits, getting historical movement records, and tracking real-time are all part of the monitoring process, as well as getting SMS notifications when specific occurrences occur. Combining the gadget with the car alarm and getting a map showing the car's location in case it is suspected of being stolen are two ways this system can combat auto theft. Our system uses various new technologies and communication networks, such as GPS, GPRS, GSM, and the Internet, or the World Wide Web, to track automobiles. Every service offered by this system has undergone real-world testing. Future development could include enhancing the graphical user interface and adding additional features to the mobile application (Almomani et al., 2011).

According to the wearable sensor in active monitoring, sensors and cameras should be placed in the space rather than on the wearer. The wearable user would perform all detection and sensing on her body

in the purest form, negating the need for environmental infrastructure. The majority of the issues listed above can be resolved by wearable technology. Due to the wearable's constant mobility, personal items never need to be moved to a new location. Given that a wearable may be used for several years, a user's profile may naturally change over time. Additionally, since wearable computers never have to leave the person, they are naturally safer places for private info. Because a certain network address manages a room's resources, one might still deduce a person's location. Traffic analysis seriously threatens privacy, yet the TCP/IP protocols lack anonymous protections. One potential approach at the application level is to group numerous requests together using a crowdsourcing scheme. Like the Onion Routing scheme, Chaum Mixes exhibit promise at the network level. Of course, if an eavesdropper is at the end resource itself, the physicality of wearable applications may eliminate the need for traffic analysis. Lastly, privacy flaws can occasionally be found in the application itself. We aim to create a system that distributes personal information to those who need to know, not to provide complete privacy. Many portable systems exhibit functionality akin to well-lit environments and pervasive computing. For example, wearable technology has enabled nearby selection interfaces and tailored room controllers for individuals with disabilities. Additionally, wearable devices have been utilized to document users' conditions automatically over time, serving both health monitoring and video diary purposes. Lastly, many apps show information based on the user's situation, like tour guides and general notes. These systems use GPS (for outdoor use) or location markers (for indoor use) to determine where the wearable is. People wear active tags to let others know who they are, but location beacons are put in rooms to let others know where they are. Similar systems have identified a place or object using machine vision-recognized paper labels (Healey & Picard, 1998).

Table 2: Comparison for Various Features Provides by Ubicomputing Vs. Wearable Devices

Feature	Ubicomp	Wearable
Privacy		X
Personalization		X
Localized Information	X	
Localized Control	X	
Resource Management	X	

The issues with wearable computing, such as resource management, localized information, and localized control, are explained in Table 2. According to localized information, wearable computer systems struggle to preserve localized information, and bright spaces are not conducive to tailored information. For instance, all wearables must receive updated information about a single place if it becomes available. Furthermore, a wearable system's ability to sense information outside the user's immediate vicinity is frequently limited. Stereo, a large screen monitor, and an air conditioner are examples of localized control, which is utilized to regulate the different resources of the individual's body (Mohammed et al., 2024). Because of their low level, wearable gadgets create greater demands on wireless networks and CPUs; they also govern the devices that need to be found. Resource management: It is inappropriate for handling different persons' resources. In this case, it is linked to multiple wearable gadgets (Mann, 1997).

To integrate with multiple sources such as Networking, Sensor Technology, Distributed Computing, cloud computing, Internet of Things, Mobile computing, wearable devices, AI, ML, and AR. Networking, which means Ubiquitous computing, is heavily related to robust access and enables seamless communication through various devices for data exchange between the devices and systems. Sensor technology, which means the sensor helps collect more information about the environment followed by user interactions and enables context awareness of the application and services. Distributed computing allows data processing followed by multiple devices and locations, enabling scalability and

flexibility in ubiquitous computing systems. Cloud computing provides flexible sources related to intensive types of computation tasks and allows the ubiquitous computing system to be performed by complex types of intelligent processing. The Internet of Things, IoT connects to each object related through the Internet, which is the key component of ubiquitous computing. Integrate the wearable devices mentioned, such as fitness trackers and smartwatches. It plays an important role in personal health with the wellness applications in ubiquitous computing systems. AI and ML are used to analyze data from various sources related to predictions or decisions in real-time systems. It is also enhanced through intelligence in the ubiquitous computing system. AR covers digital information in the real world and provides interactive and immersive experiences.

6 Intelligent Services Enabled by Integration

Intelligent services that integrate various personalized recommendations enable ubiquitous computing, or pervasive computing. It is mainly focused on location and activity. This type of computing is integrated into everyday life; it is invisible and unobtrusive. Ubiquitous computing systems help collect more user location, environment, and activity information. It also allows for providing relevant information related to personalized services. To analyze this system's user data and context, it should offer various recommendations to various sources and provide optimal commuting routes. Here, we also explained the various real-time examples, such as location-based smart homes, wearable technology, and the context of aware shopping. Location-based services mean GPS uses various types of applications to provide directions for finding nearby businesses or tracking fitness activities in ubiquitous computing. Smart home devices automatically adjust preferences based on user preferences, such as lighting, temperature, and appliances. Wearable technology in smartwatches and fitness trackers monitors the various activity levels to prove personalized visions. Context-awareness of shopping means it automatically analyzes the waiting conditions (Lyytinen & Yoo, 2002).

One of the most promising technological solutions to address this violation of universal health parity is the pervasive implementation of health monitoring. Several sensors monitor these body vitals. The human body and these sensors will be involved as "Things" in an Internet of Things network. The transmission of these metrics to automated decision-making systems could be beneficial for clinicians in developing early predictions. Beginning with a significant departure from the current paradigm of sensitive disease diagnosis and treatment, this will transition to a proactive predictive health management approach. A patient's vital indicators, such as their temperature, heart rate, blood oxygen saturation, and others, must be continuously monitored in the modern healthcare system. Waiting in line and scheduling pathological examinations, which is how medical care typically operates, is neither appropriate nor an effective strategy to monitor health parameters during this epidemic continuously health parameters during this epidemic. Due to this, remote health surveillance has been regarded as an ideal experimental approach for the healthcare industry. It can be expanded to several applications using the Internet of Things (IoT), a promising technical approach. Combining communication and sensor technologies with an always-on and accessible service system, the Internet of Things (IoT) transforms commonplace objects into intelligent devices. Patients and instruments can collaborate like magic due to this cutting-edge technology. Patients and healthcare providers can now access healthcare services anytime and anywhere. The IoT architecture comprises three layers: application, network, and physical. The network layer is responsible for the acquisition and manipulation of data. You need much space to store sensor data with more accuracy and precision. Providing the vast quantity of sensor-collected data with rigorous training makes it possible to make more informed decisions. Furthermore, the network layer facilitates communication between various IoT devices. Additionally, the application layer makes

it easier for the results to be shared via a user interface. The information system, execution, productivity, speed, and accuracy of any real-time framework activity are, therefore, significantly increased by the emergence of the Internet of Things. Processing, sharing of information, real-time display, and experimentation have increased the productivity of the sensor network. Another way to describe a real-time, remote, and pervasive health observation system is that it continuously monitors the patient's physiological condition and the functioning of the life support equipment, regardless of time or accessibility restrictions, with the active involvement of health directors. This technology will deliver the precise augmentation that healthcare workers want, and the same insights can be shared online or through a network. As a result, a distinct strategy that is specially intended to monitor a patient's crucial situations has to be developed utilizing a standard design. Due to its many benefits, widespread health monitoring has surpassed traditional medical treatment as a valuable resource (Mohapatra et al., 2023).

Smart home automation is also enabled through ubiquitous computing integration, interconnected to various devices and sensors. It is also used to create various intelligent services, such as improving convenience and security within home environments. The intelligent services are collected from the various sensors, and smart homes provide various services related to automated tasks, Improved convenience, and improved purity. To adjust the lighting, temperature means the appliances are followed by occupancy, time of day, and user preferences. Here, we also explained computing in Smart homes, such as smart Thermostats, voice assistants, lighting, and security systems. Benefits of Smart home automation include increased conveniences, energy efficiency, enhanced security, and Accessibility. It also describes the various challenges in smart home automation, such as privacy concerns, interoperability issues, and cybersecurity threats. Privacy concern means ensuring security and the various smart home devices should collect privacy (Islam et al., 2014). To ensure that the different devices and systems are communicated through work. Cybersecurity threats mean protecting the smart home system from hacking and other cyber-attacks (Yar et al., 2021).

7 Challenges and Future Directions

This section describes the various challenges in ubiquitous computing, such as privacy concerns, security vulnerabilities, the digital divide, and accessibility and environmental impacts. It described the impact on privacy; security, medical, and production applications are anticipated to have beneficial privacy benefits, whereas other application settings are anticipated to have considerably negative privacy consequences. Any computer that adheres to data protection regulations must have a privacy-friendly design; context-dependent data protection filters, or "digital boxes," are not a good notion for the future. Only a system design that prioritizes privacy from the outset can limit the complexity of data protection issues. When it comes to the use and processing of data, it seems less crucial to make each step of the process transparent and logically understandable. A user's trust in a particular ubiquitous computing system that the service provider would securely manage personal data is an even more crucial component. Another risk is that a ubiquitous computer application could cause people to handle personal data carelessly. If a groundbreaking ubiquitous computing app comes out too soon, people might not pay as much attention to privacy protection during its most important development phase.

Data security concerns, in ubiquitous adding, a lot of smart items can talk to each other or to the user. Many of these interactions happen semi-automatically since they should be as subtle and situation-dependent as possible. The user will no longer know what the smart objects are doing. Here, the standard methods of control and correction in IT systems will not work. It's critical to safeguard system security in ubiquitous computing. This covers safety, privacy, and security. Preventing unauthorized individuals from accessing and altering private information is part of security. Communications must be kept private

and cannot be tampered with. Digital identity meetings need to be at least as reliable as face-to-face meetings. Security techniques and technologies are already well-established and proven. They must be modified to accommodate the unique characteristics of ubiquitous computing, particularly the decentralized nature of infrastructure, services, and objects and the often-constrained performance of cutting-edge object technology. Ubiquitous computing aims to precisely identify people, things, and communications (authenticity), and the demand for anonymity (to avoid data trails from the start) is inherently at odds. To a certain degree, digital pseudonym technology can help with this issue. Furthermore, each application must consider the conflicting anonymity and authenticity security objectives separately. Massive volumes of data will be gathered via ubiquitous computing, which can offer a thorough picture of a person's finances, activity, and health. The massive data sets and the imprompt networking of smart items will make it hard for users of ubiquitous computing to track the location, use, and potential combination of their data. Data security is crucial to maintaining privacy in ubiquitous computing (Qureshi, 2008). As several services will not completely develop unless accessible across borders, the networking of ubiquitous computing is not restricted to specific states. Standardized international laws ensuring privacy protection are necessary for this globalization. are wildly different (Zhu et al., 2024). The contrast between the comparatively open, self-regulatory mindset in the United States and the strict legal standards in Europe exemplifies these differences. A unified worldwide legal framework for data protection in ubiquitous computing will need to be established because of the long-term trend of smart device and service networking on a global scale. Ubiquitous computing is intangible, and because of its intricate networking, hostile interference, and system flaws might go unnoticed or be found much later (Khan et al., 2020).

Some pervasive computing applications, including healthcare, traffic management, or automated production lines, may risk significant property and endanger human lives. The dependability of ubiquitous computing is critical in applications where safety is paramount. For instance, a backup system or system redundancy must be used to ensure it. Advancement in sensor technology is connected with increased integration and intelligence. It also contains the sectors enabled through intelligent services and applications across various fields, such as healthcare, manufacturing, and environmental monitoring. Here, we also explain how smart sensors are defined in the advanced methods of potential impacts. Smart sensors and the rise of IOT have the basic data collection for incorporation with processing and communication through various capabilities. Integration means sensors are connected through IoT systems. It allows for the sharing of interconnections. Here, we also explained some examples of advanced technologies such as wearable devices, smart homes, smart cities, agriculture, and industrial applications (Javaid et al., 2021).

8 Conclusion

This section summarizes the main benefits of integrating location and activity sensing. It also mentions context-aware applications, personalized experiences, and optimized management and explains improved safety and security. Here, we also noted the context-aware application to understand the user needs and the adaptive system. Personalized experiences should discuss communication through location and activity data. Resource management helps to allocate the resources related to a smart city. Enhancing security and safety helps to improve the security system and should provide real-time monitoring of the location and activities. Future ubiquitous computing trends will help improve connectivity and seamless integration through day-to-day activities and intelligent automation.to explore new applications in ubiquitous computing, such as smart healthcare and adaptive learning environments with sustainable urban systems.

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