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Abstract

Information technology advancement leads to an innovative paradigm called Ambient Intelligence (AmI). A digital environment is employed along with AmI to enable individuals to be aware to their behaviors, needs, emotions and gestures. Several applications of the AmI systems in healthcare environment attract several researchers. AmI is considered one of the recent technologies that support hospitals, patients, and specialists for personal healthcare with the aid of artificial intelligence techniques and wireless sensor networks. The improvement in the wearable devices, mobile devices, embedded software and wireless technologies open the doors to advanced applications in the AmI paradigm. The WSN and the BAN collect medical data to be used for the progress of the intelligent systems adapted inevitably. The current study outlines the AmI role in healthcare concerning with its relational and technological nature. Health monitoring and electronic patients? planning assistance applications are reported in the present work. Lastly, the challenges tackled in the AmI technology adaptation in the real world healthcare applications are highlighted.

Index terms— ambient intelligence, wearable devices, wireless sensor networks, wireless body area networks, wearable sensors, monitoring systems, computational int

1 I. Introduction

mbient intelligence is associated with the atmosphere at which emotional and rational intelligence is ubiquitous. In the AmI environment, individuals are bounded by embedded intelligent devices' networks to collect information nearby their physical places in order to provide services, and ubiquitous information. Intelligent devices are accessible whenever required through interactions and acting independently to allow high quality information to any user, at any time, on any device, and anywhere.

In healthcare environments, these devices are related to medical informatics, decision support, gathered electronic health records, knowledge reasoning and representation, and telemedicine. Patients' medical reports, radiological films, personal and medical information can be observed in remote places. Furthermore, remote robotics can be used in telemedicine and surgery. Nevertheless, these healthcare applications are used for specific clinical situations in certain services with explicit patient.

Distributed environment are used mainly with applications that are undeveloped to share actions and knowledge. Recently, AmI is related to the exponential evolution of Internet. For user-friendly applications, web browsers can support several features to allow users to use remote applications.

Recently, technology is moving towards Ambient Intelligence (AmI) environments to support inhabitants the daily life . In physical world environments, AmI allows the human to interact in an inconspicuous and intelligent way using computing devices with complete awareness of the people requirements and forecasting behaviors. AmI environments are essentially local including hospitals, offices, homes, transports, and control centers. Recently researchers are interested to comprise extra intelligence in the AmI environments for superior access to the indispensable knowledge and decision making that support individuals. Typically, AmI is related to several concepts, such as context awareness, embedded systems, and artificial intelligence to incorporate with other techniques including computer graphics, automation and communications. Several challenges faces the AmI requiring advanced techniques such as the artificial intelligence (AI), machine learning, computational intelligence, computer vision, and intelligent robotics that have been used in several applications [22][23][24][25][26][27][28][29][30][31].

AmI technologies have several features including transparent, adaptive, sensitive, intelligent and ubiquitous. Researchers reported different AmI definitions, namely i) AmI is an emergent multidisciplinary domain founded on ubiquitous computing that influences the protocols design, devices, systems, and communications [32], ii) AmI offers new interaction ways between people and technology to serve the environment and individuals' needs [33], and iii) AmI is a new research domain for non-intrusive, distributed, and intelligent software systems [34]. AmI is involved in several applications especially in the medical sector to improve the healthcare by developing for example an inclusive structured approach to electronic medical record (EMR) toward intelligent healthcare units [35]. Furthermore, it can be employed to augment smart hospital rooms that support both the medical staff and patients [36]. In order to achieve these features, wired/wireless sensor technologies are assimilated, tolerating the patient to interact and to control the19 Year 2017 ( ) H

hospital services. In addition, the clinical oriented interface can allow vital sign monitoring. Such wireless technologies include the use of Bluetooth, Zigbee, WiFi, and RF (radio frequency along with intelligent sensors. This AmI environment integrates several software and hardware technologies for manually or automatically controls electronic and electrical devices.

Smart environments and wireless technologies have an ultimate role to provide user-friendly tools to cope with the surrounding environment. Mahoney [37] established that smart environment can be considered ease the hospitals staff workload when supporting the AmI. These technologies endorse the clinical care quality with patient's independency, superior life quality and improving the health care quality. Several applications that support miscellaneous clinical requirements include condition unambiguous treatment and diagnosis, patient's remote monitoring and softcopy radiological film review. Moreover, assistive environments, such as RFID based smart hospitals, environmental sensors and monitoring cameras can be included to support healthcare. Such environments require integrated interconnect services in the automation systems, e-health systems and sensors through binding architecture [38].

The structure of the remaining sections is as follows. Section 2 introduces the wireless sensor networks role in the AmI systems. Section 3 reports several studies that have employed the artificial intelligence to develop advanced AmI systems. Conducting decision making, healthcare interactions and monitoring in AmI environments are addressed in section 4. The challenges face the AmI technology in healthcare are highlighted in section 5. Finally, the conclusion is considered in section 6.

2 II. Wireless Sensor Networks in AMI Systems

The Wireless Sensor Networks (WSN) is a compulsory technology for developing the AmI environment via providing the users by services based on their context. These networks offer flexible and dynamic structure for the acquired data transmission from the environment through sensors. The transmitted data is considered the base for developing the AmI services adjusted with the acquired information from the sensors system in charge of handling this information. The WSN allow information gathering about the environment and the user.

The foremost characteristic of the WSN is to transmit wirelessly the acquired data by sensors in diverse environments to other nodes for processing this data. Since the WSN consists of massive number of nodes, these nodes require special design characteristics, namely low power consumption, small size, low cost, and low complexity. Furthermore, network topology and protocol are considered during the WSN design to simplify the nodes functionality with less time consuming to reduce the power consumption. In the Wireless Body Area Networks (WBAN) for healthcare applications, the star topology is used mainly, where a central node coordinates the communication with outside the Body Area Networks (BAN) and the medical sensors [39]. Generally, the BAN has compact units responsible about transferring the vital signs from the patient's body and the physician or hospital. Several applications employed the BAN to monitor the patient's state, such as i) MobiHealth monitoring system for vital signs based on a BAN [40] and an m-health service stage using communication via Bluetooth between the central device and the intra-BAN, ii) WBAN VitaSens system including ECG, blood pressure, respiratory, and temperature sensors [41], and iii) Ubimon ubiquitous monitoring system for implantable and wearable sensors including accelerometer, ECG, humidity and temperature sensors [42].

Through the AmI paradigm, the way to offer the information to the society services and users is developed by including the Internet services. Services can be accessible by the user as well as by the system intelligence tolerate automatic delivery of the services. The user interaction with the services will be over interfaces. Consequently, in order to realize services based on this paradigm, the user context should be known requiring sensors in the patient's body and in the environment. Such facility can be acquired using AmI services to compromise the adopted service via the natural interfaces. Likewise, the interoperability and integration of these networks with Local, Personal, and other networks configurations become essential.

Hospitals and medical centers offer traditional healthcare services. For the scientific community, finding active methods to improve healthcare become challenging issue.

Post-surgery monitoring is considered one of the vital needs. Furthermore, patients need to contact their doctors easily. Nevertheless, traditional solutions for these aspects are inconvenient, costly, and inefficient for the patients for routine checks. Thus, E-health aims mainly to improve the health care quality, and to enhance the health care effectiveness. In order to direct the healthcare services from the hospital environment to the home, AmI environment become essential for personalized healthcare and for healthcare monitoring. AmI has been involved in several healthcare applications, such as computer-assisted surgery systems to remote surgical conduction with reduced risk [43], virtual reality systems to treat the anxiety disorders [44].

AmI allows a physical connection between the patient's daily practices and the e-health systems using wearable medical devices, smart environments software techniques. The context embraces the environment and the users' information, which contain different parameters, such as temperature, light, blood pressure, and heart rhythm. Different WSNs technologies, such as ZigBee; Bluetooth or Radio Frequency Identification (RFID), are employed to gather the AmI required information. Development of AmI systems requires also dynamic methods and mechanisms based on artificial intelligence (AI).

3 III. Artificial Intelligence in AMI Systems

Typically, AmI environment is profound to the living creatures' existence in it, ropes their activities and anticipates/remembers their actions [45]. Consequently, for health claims in AmI, data collected from vital-sign sensors plays a significant role. Several computational methods based AmI in vital sign sensors are developed. Sensor data analysis requires distributed/centralized models with the AmI systems [46]. Each sensor has committed processing abilities to perform local computation before transferring the data to other nodes in the WSN.

Numerous data mining and artificial intelligence (AI) techniques are used to analyze the sensors data in the AmI systems, including fuzzy logic rules, neural networks, machine learning and decision making. Such techniques assist AmI in healthcare monitoring. Several studies for developing AmI systems in healthcare have been carried out. Activity recognition system based on artificial neural network (ANN) has been conducted to regulate the falls occurrence using single sensor positioned on the individual's chest [47]. The results established that the ANN entails more tuning factors compare to the support vector machines (SVM).

A GerAmI system has been settled with the Alzheimer Santísima Trinidad Residence of Salamanca that used sensors to record the patients'/users' data, where the user wore an armlet holding a RFID chip for tracking individuals [48]. In the case of required assistance, a message containing the patient's name, the occurred problem and information about the paramount way to handle this situation is directed to the staff members PDA. In patients with Parkinson's disease, in order to predict clinical scores of data severity obtained from wearable sensors, a SVM has been implemented [49]. On a single environment, an AmI application has been outfitted with sensors and deliberated to improve the resident experience in the environment [50]. A Hierarchical Task Network (HTN) planner has been employed to produce actions sequences and eventuality plans to realize the aim goal of the AmI system [51]. The AmI system may react to a sensed health necessity by calling the medical professional and transferring health vitals through any communication device/tool such as email, or cell phone.

In smart health environments, a study has been carried out to proof the architecture concept for emotion regulation and detection of the patients through the an alysis of their facial expressions, behavior and vital signals [52]. Another study has been applied using the insulin dosing, glucose levels, sleep state, and physical activity data gathered from body-wearable sensors to detect type 1 diabetes [53]. An open research domain is directed toward the techniques used in order to acquire self-reported data and to integrate sensor-provided information from the sensor networks in the AmI system. Subsequently, a platform for collecting and integrating data from service providers and sensors into one cohesive format for further use in the experience sampling methods (ESM) has been implemented [54].

For cognitive-related pathologies, a game has been designed for the analysis and evaluation of the frontal brain activity via the videogame mechanics identification that include EEG brain activities associated to some cognitive skills [55]. Furthermore, another study, on the brain signals to recognize emotions, has been proposed using the neural network [47]. Several machine learning methods have been used to evaluate a predictive system performance that deals with the inhospital patients' mortality. These patients undergo overhaul of an abdominal aortic aneurysm.

4 IV. Decision Making, Healthcare Interactions and Monitoring in AMI

In order to conduct fully automated AmI applications, decision-making techniques are employed. Several studies have been carried out to implement decision making based AmI systems. Temporal reasoning has been used with a rule-based system in order to recognize hazardous states with decision making that resolve this situation and return the environment to a nonviolent status while communicating the place's residents [56]. Added, deleted, and modified fuzzy rules have been learned via observing the resident behavior in the iDorm application to adapt the environment according to the changing behavior.

Another AmI system based on decision making has been conducted to design a planning system supported by artificial intelligence to remind entities by their next daily activities as well as the incomplete tasks [57]. A hierarchical task network planner based AmI system has been proposed to produce plans of actions' sequences for responding to sensed health requirements by contacting medical professional and sending health vitals through email, cell phone, or fax [51]. Patients suffer from Alzheimer's disease and other disorders are also supported by developing an AmI system that help individuals to perform their regular errands through sensing their location/environment and offer decision making to forewarning caregivers in the critical situations [58]. In medicine, to in order to regulate optimal decisions sequences, Markov-based21 Year 2017 ( ) H

method has been used to describe the dynamic sequential decision making process [59].

Based on communication technologies and information, ambient systems can assist and enhance the life quality of individuals at home and anywhere. This promotes the services/infrastructures development toward autonomous life through the incorporation of the communication technologies and information through ambient intelligence in healthcare applications. In such domain, ubiquitous systems, wearable sensors and secure mobile can be engaged to improve the life health quality. Automated AmI systems require universe technologies to achieve the interaction between the patients and the physicians.

A theoretical framework has been proposed to support this interaction process [60]. In the AmI design, different measuring tools for the patient's rendezvous in technology progress and for testing the effectiveness of AmI prototypes have been used. Other interactive environment has been proposed for people rehabilitation with physical disabilities [61]. Due to the intuitive interaction of users, direct, and natural features of the AmI systems, it can be employed to recognize and predict the individuals' activities and can be involved with services and applications embedded in the surrounding environment. Based on inertial wearable sensors, a collective dataset for human gait has been gathered of further analysis [62]. A passive vision-based system to estimate the measurements of gait using light sensor along with 3D point-cloud has been proposed in order to explore the gait analysis of the wearable system that has 2 wireless sensors for acceleration fixed on the ankles [63].

AmI systems have been also supported the daily life healthcare through homecare assistance. A computational detection technique to quantify the changes in physical activity patterns using wearable sensor data has been proposed [64]. This technique can be applied to detect inadvertent changes in the individuals' patterns performance to validate the effect of any new healthy behavior on the individual's lifestyle. Another ambient system has been framed to promote social commitments and activities of the elderly individuals using in-home sensors by linking the information inferred with the social network [65]. This provides the old individuals with the chances to make new social networks. In the daily life environment, another AmI system application to support old people has been proposed to assess the fall risk assessment with preventing its occurrence using wearable sensors [66].

5 V. Wearable Sensors Devices in AMI Systems

AmI is an evolving restraint that passes intelligence to the individuals' daily life environments and creates sensitive environments to the human needs. Its main idea depends on enriching the surroundings with technology, namely interconnected devices to a network and sensors leading to a system that can take useful decisions to the users. Such decisions depend on the gathered real-time historical information and accumulated data. Based on the development in several technologies and areas, including networks, sensors, artificial intelligence, human computer interfaces and ubiquitous computing, AmI environment grows quickly.

AmI has several applications in the healthcare domain, including: I) Human fall detection by evaluating the wearable sensors data such as that obtained from the accelerometers. In this application, numerous algorithms and sensor's data transmission and localization are developed. In addition, an automated call to the person's relatives can be started with the fall situation detection. II) Human activity recognition that identifies the user's activities if he/she wears accelerometer(s). Such system requires machine learning procedures for analyzing the data received from the sensors. Numerous procedures for studying the sensor body locations in different positions, such as the ankles, chest, wrists, and thighs can be involved. III) Human stress detection, which detects the users' stress level using also machine learning procedures for data analysis data is considered one of the important AmI applications. IV) Automated human energy expenditure estimation can be carried out by analyzing the data from different wearable sensors, including the galvanic skin response, heart rate, and accelerometer. This system is also requires machine learning methods to estimate the energy expenditure.

From the preceding addressed applications of the AmI systems in the healthcare domain, it is obvious that the wearable sensors have the main impact in all systems. Wearable sensors have monitoring as well as diagnostic applications using their biochemical/ physiological capabilities. Physiological monitoring can be involved in diagnosis and enduring treatment of a massive number of patients, who suffer from cardiovascular, neurological, and pulmonary diseases including hypertension, seizures, asthma, and dysrthymias. Sensors are positioned and arranged in consistent with the clinical application under concern. For example, sensors for monitoring vital signs, such as the respiratory rate and the heart rate, can be arrayed when the monitored patients with chronic disease or congestive heart failure suffering clinical intrusion [67]. Sensors for capturing movement data can be used in monitoring applications effectively, such as in the homebased therapy interventions in stroked patients or to detect the elderly people mobility. Figure **??** demonstrated the monitoring system structure based on wearable sensors that attached to the users' body. In order to transmit the collected sensors data, wireless communication is trusted to convey the patient's data to any access point or mobile phone and communicate the information to an inaccessible center through the Internet. Detecting emergency situations using data processing systems are implemented to send an alarm message to the emergency service center for instantaneous assistance to the patients. Consequently, the wearable system consists of main parts, namely i) data sensing and collecting hardware sensor device, communication system of software/hardware to transmit the sensed data to a remote center, and finally the data analysis and processing technique based on machine learning in order to extract the significant and clinical information. Subsequently, development in the telecommunication, electronic circuits, sensors technology, microelectronics, and data processing and analysis methods is directly reflected to an improvement in the wearable systems for several healthcare applications.

The prominence of incorporating large scale wireless tele-communication tools, including the WiMAX, Wi-Fi Mesh, and 3G with tele-medicine attracts several researchers. Such technologies integration can be employed for endless people's monitoring who suffer from cognitive disorders, such as Parkinson's, and Alzheimer's. Furthermore, there is an important research studies that focused on the tiny wireless sensor devices development that integrated into wearable materials, fabrics or can be entrenched in the human body. Currently, the range of implantable and wearable biomedical devices increases due to the developments in the digital electronics, wireless communications, and micro-electro-mechanical systems (MEMS) technology. This provided multi-functional, low power and low-cost sensor nodes having small size and can interconnect through short distances. In addition, tiny sensor nodes will be applicable that have the advantage of the sensor networks depending on cooperative strength of a large nodes' number.

6 VI. Ambient Intelligence Challenges in Health Care

Ambient intelligence based on wireless communication and wearable devices has a significant role in several applications [68][69][70][71]. The ability to resolve to individuals requirements along with bridging the gap between devices, environment and individuals with widespread practice in changes management, innovation and knowledge sharing, lead to the presence of several challenges in the AmI environment. More challenges and limitations are raised in the healthcare area. Since AmI is considered a conception at which the environment ropes the individuals using embedded sensors and processors.

Wearable devices and handheld devices considered as interface between the system and user that allow the system to adapt based on the user's behavior. In order to realize higher quality health care environment including hospitals, homes, and medical centers, more effective healthcare systems based on the AmI technology become compulsory to handle inbed/wheel chair patients and many other critical cases. Massive progress in medicine and living circumstances increased the life expectations.

Intensifying healthcare cost and lack of healthcare experts poses a difficulty in today's society. Sensor equipment and communication equipment are engaged mainly to handle the challenges in the healthcare environment. In addition, artificial intelligent can produce a self-satisfying life style. In AmI systems, the detection the life threatening situations and rapid the time response in emergency cases. The information technology progress supports healthcare institutions including healthcare centers and hospitals to operate competently with saving cost.

Identifying the shortage in healthcare information management is considered one of the critical issues to develop AmI systems for based on advanced AI techniques. Furthermore, proposing active communication system to handle time-critical situations is considered one of the challenging problems in the Ami environment to improve healthcare delivery using distributed intelligence systems. Designing wearable electronic devices to assist chronic disease patients to know the correct medication, to give reminder, and to contact relatives in the critical situations as well as to suggest the appropriate diet in order to manage their heath conditions become one of the new research challenges.

Transcription problem of can be considered as a problematic of transforming one information form to an alternative or from one storing system to another. Thus, human resources must be allotted to copy the record from one format to an alternative, which is time consuming, error prone, costly and challenging for the real world AmI in healthcare. Another challenging aspect is the end user acceptance and usability of the complicated designed user interface. For potential assistance for the healthcare provision, AmI systems have been identified for all individuals' categories, however old peoples have limited experience to adopting technologies. Thus, in advance of organizing developed technologies, it is important to assess their acceptance. Moreover, the intensive care unit can be considered a complex system that includes massive health information and severe healthcare system components, including environments, patients, and tasks. Thus, in order to improve the patient outcomes and to enhance the health information technology, critical care delivery competence and the patients' safety, superior interaction in the intensive care units systems with the different healthcare information technology components become significant.

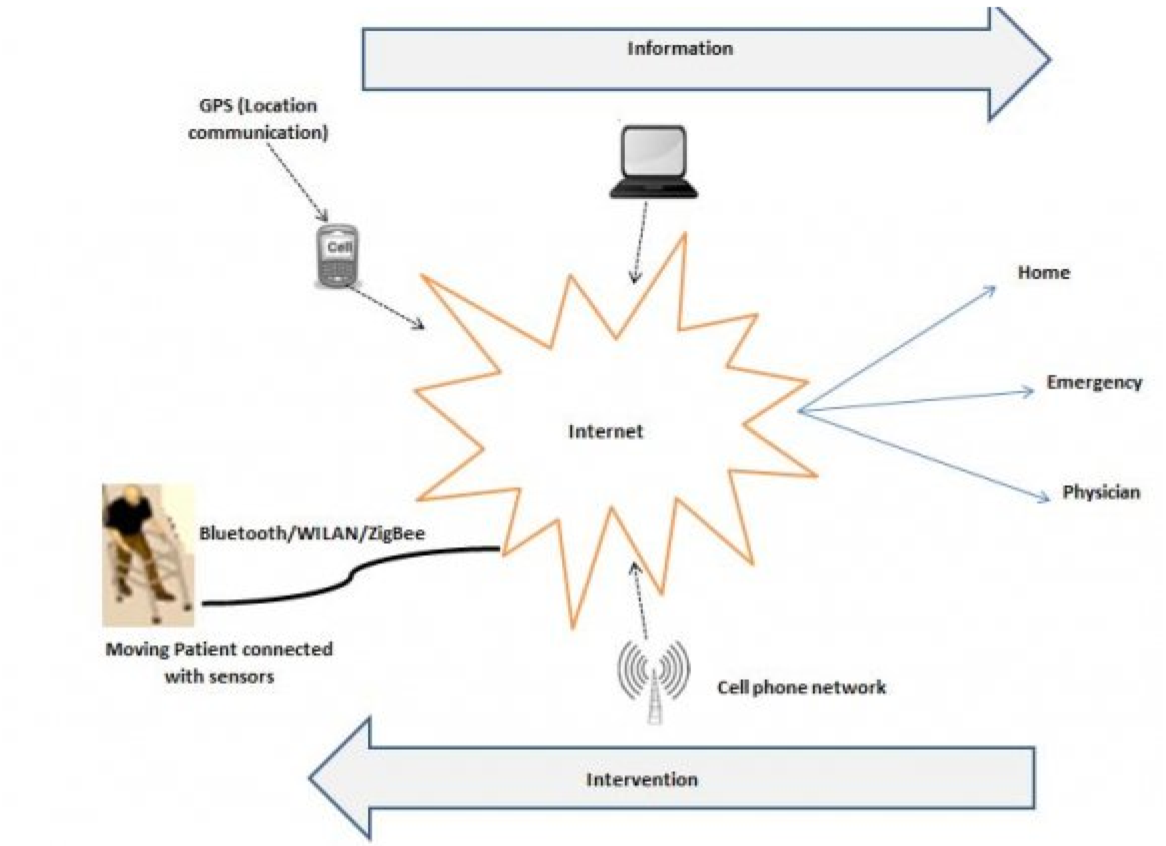
The AmI healthcare applications can be categorized into personal healthcare/wrist-worn monitoring devices, and institutional healthcare providers' aspects, including hospital environment sensor localization. In environmental intelligence, although in healthcare applications, research is going ahead, it does not grasped yet the maturity level due to the challenges in healthcare domain raised by the computer scientists as well as the difficulty to handle the critical situations at which errors are intolerable. Several research openings can be directed to explore the role of the AmI systems in several applications to support healthcare, including:

? Data analysis for health AmI environments Furthermore, one of the main hurdles to the sensing technology implementation, expressly for the wearable applications, is the sensors' size and the frontend electronics, which used to collect the movement and physiological data in the applications of long-term monitoring. Modern progresses in the microelectronics domain, allowed the engineering and researchers to improve minute circuits with front-end amplification, sensing ability, radio transmission, and microcontroller purposes. Improvements in the manufacture technology of the micro-electromechanical systems (MEMS), enables the miniaturized inertial sensors progress, which can be involved in the detection of the motor activities as well as other health cases monitoring systems. In addition, batch fabrication methods are challenging and have substantial reduction in the sensors' cost and size and cost. Moreover, microelectronics is recently depending on the integration of several components, including the radio communication circuits and the microprocessors, into a single unified circuit leading to the implementations of System-on-Chip [72].

7 VII.

8 Conclusions

The AmI technology is considered a new paradigm for upcoming applications in the information society proposing intelligent services based on the user context through interactive interfaces. Ambient intelligence has an emerging role in healthcare. The paper presented a snapshot of the AmI system related technologies as well as some empirical studies in healthcare. Robust foundation for the integrated AmI systems implementation is clearly reported based on the wearable sensors, information and communication technologies advancement to support healthcare. Several challenges are highlighted to inspire the researchers toward the AmI technology as a starting point for progress to provide effective AmI systems in healthcare. Such challenges include elder users' acceptance to this new technology, intelligence [1]



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