Ambient Intelligence in Health Care: Current Technology and Challenges

Leo Liu
Advanced Topics in Human Computer Interaction
liliu067@aucklanduni.ac.nz

ABSTRACT
In this literature review, we will focus on the use of ambient intelligence in an institutional healthcare environment and its enabling technology. The application of ambient intelligence can be divided into two fronts: in institutional healthcare providers such as hospitals and geriatric care facility, and in preventative medicine such as personal health monitoring device. Six papers are chosen to convey a broad range of perspective on the healthcare environment. The themes of the papers reviewed range from implementation and testing of AmI technology to the overview and discussion on the current status of AmI technology in health care.

INTRODUCTION
Ambient intelligence is a concept in which environment supports the people inhibiting them. In this concept processors and sensors are embedded into everyday objects. Cloth, handheld devices, furniture will act as interface between the user and system. The system will be able to adapt, anticipate user’s behavior. The idea is to apply this technology to health care environment (i.e. hospitals, geriatric facilities). In order to achieve higher quality, more efficient and affordable health care.

Vast advancement in medicine and living condition has contributed to the increase in life expectancy of today’s society. Life expectancy around the world has risen dramatically, by 11 years for men and 12 years for women over the last four decades. While life expectancy rises, we are not necessarily enjoying the longer length of life. Some of us will remain in sick bed or wheel chair for the remaining years. Rising healthcare cost and shortage of healthcare professional also pose a problem for today’s society. The cost of supporting aged person is greater than that of supporting a child by according to one calculation, round 3 to 5 times [1]. At the same time, great leaps in information technology, sensor technology and communication technology has been realized. These technology can help to deal with the challenges we face in today’s medical and healthcare environment. Artificial intelligent can help to create a more self-sustaining life style. Sensor and communication technology allows us to detect life threatening condition and shorten the response time of emergency personnel. These technology can be embedded into everyday object without intruding our way of life. The advancement in information technology and communication allows healthcare institutions such as hospital or geriatric care facility to operate more efficiently thus saving cost.

In the following sections we will summaries six healthcare related papers, all focusing on improving the management of healthcare institutions. Each paper approach the problem in different prospective. In the paper Individualization, Globalization and Health [2], the author focuses on identifying weaknesses in information management of health care in regional basis. As well as briefly mentioning the emergence of the personal health enabling devices that focuses on prevention rather than treatment. In the paper “Ambient Intelligence-the Next Step for Artificial Intelligence” [3], the author describes how artificial intelligence can be applied to the field of ambient intelligence. In the paper “In the paper “Context-Aware Mobile Communication in Hospitals” [4], the author presents an effective communication system for use in time-critical environment. In the paper “GerAmi: Improving healthcare delivery in geriatric residences” [5], the author introduces a multiagent, distributed intelligence system for reducing task time of nursing staff. In the paper “An internet of things-based personal device for diabetes therapy management in ambient assisted living (AAL)” [6], the author presents a personal electronic device to assist diabetes patient in choosing the correct dosage for insulin injection as well as suggest the suitable diet to manage their blood glucose level. In the discussion we will review the technologies mentioned in this report and present the challenges faced by today’s healthcare technology.

INDIVIDUALIZATION, GLOBALIZATION AND HEALTH
This paper gives an overview of current status of health informatics technologies applied in hospital and personalized care. The author divides the information technology management in hospitals into two categories: transinstitutional health information system (tHIS) and institutional health information system (iHIS). Transinstitutional health information system describes the processing of information, data and knowledge in health care in more than one health care institution whereas iHIS focuses on an autonomous health care institution. The author identifies the existing problems in iHIS: problem of cost, user acceptance, transcription (transfer of patient’s record from one form to another), maintaining referential integrity (assignment of data to a patient). Problems in tHIS space are
also identified: problem of logistic, terminology, stability and tailored information management.

The example given in the paper describes a medical center comprises of more than 30 medical departments with information system support of 40 servers, 1200 clients, 800 printers and a computer network. In addition to computer supported part, there are paper based patient record exist for legal reasons of which 70% of documents in paper are based on patient records generated from computer documents or forms. The large amount of servers storing information that contains duplicates can correspond to the rise in cost. As newer technology is introduced they are conflicts with the old standard and practice. This creates problem in user acceptance. As pointed out in the paper, much of the paper based records originates from digital record. This creates huge transcription overhead and inefficient staff time usage. Furthermore, as time went on, it becomes impossible to tell the origin of the document.

In the next half of the paper, the author introduces the idea of health-enabling technologies. A ubiquitous health care system that focuses on early detection, prevention and alleviating chronic diseases. These technology relies on ambient intelligence [7] to adapt to user behavior, sensor systems for accurate measurement. Various breakthrough technologies are mentioned [8]: wearable tech, micro sensors embedded into textile, sensors measuring ECG or EMG. Combining these technology with HIS, the author believes we can achieve a cooperative, shared care and a new view on medicine.

**AMBIENT INTELLIGENCE – THE NEXT STEP FOR ARTIFICIAL INTELLIGENCE**

The author starts off by citing a report from the European Commission’s Information Society Technologies Advisory Group (ISTAG). There, AmI is described as the amalgamation of components such as smart material, actuator made of electromechanical system and sensor, I/O device, ubiquitous communications. [9]. These technologies are described as operational technologies. To connect and make sense of the various components requires the use of Artificial Intelligence. The report states artificial intelligence can be used for media management, handling, human interaction, computational intelligence, context awareness and emotional computing. The author of the paper – “Ambient Intelligence – the Next Step for Artificial Intelligence” [3] takes this idea further and argues that AI is not only an enabling technology for AmI but AmI is the next step for the advancement of AI.

The author first describes various AI techniques used in AmI applications. The first is in use of sensors, which can be used to interpret spoken language i.e. obtain electric signal from a microphone or natural language input. Natural Language Processing requires use of statistical and knowledge-based approach. Another type of sensor is the use of vision which computationally can be image processing, image acquisition, object recognition, scene analysis and image flow analysis problem. All of which can benefit from the use of AI. Having these sensor technologies is not enough to interact with human intelligently. In order for user to perceive the system as intelligent, it must be able to aware of the contexts. Contexts includes the environment, human emotion, human pattern. For example, the user might not want to watch a TV show or football game if the guest visiting is in a bad mood. In order to achieve these requirement, the system must look deeper than the data received simply from a sensor reading.

Other aspect of AmI is the planning and decision making capability. A popular research area for this is the multiagent system. Multiagent system allows machine to solve complex real world problem using communication, conflict resolution, negotiation, argumentation and emotion. It is especially useful for modeling social systems where optimal solution can be obtained. An example is the scheduling of shifts and delegation of tasks in hospital as seen in [4]. Another example given in the article is the intelligent driving system in cars where router planning needs to consider traffic, weather, cost, time and accident reports on road. The author argue that these planning will require optimization technique which is an area that emphasis AI.

In the end, the author points out that artificial intelligent can benefit from AmI by providing the stimulating challenges for the community. These challenges includes hospitals, geriatric residence, homes, which will the focus of this literature review.

**CONTEXT-AWARE MOBILE COMMUNICATION IN HOSPITALS**

In this paper, the author presents a context-aware mobile system to facilitate communication and processing data in a hospital environment. The contexts includes location, time, task, role reliance, artifact location and state. In context-aware communication, a set of predefined circumstances must be fulfilled before the message is delivered. For example, a message to the doctor for next shift would only be delivered when the said doctor enters the ward. In order to develop the system, the author conducted workplace study at a hospital of high demand using interviews and participant observation. The system is implemented using PDA connected the instant messaging server through wireless access points. The instant messaging server acts as proxies to hospital IS proxy agent, context-aware agent. The agents are developed with Salsa (Simple Agent Library for Seamless Applications). An application that interface with user and implements ambient intelligent logic (reasoning, context perception and action). To accurately estimate the location of user, as location in an important context in a hospital environment, the author implements a neural network, trained to map the signal strength at each floor. The result of the usability evaluation from 28 hospital staff members showed positive response for most of the features.
GERAMI: IMPROVING HEALTHCARE DELIVERY IN GERIATRIC RESIDENCES

Similar to the previous paper, this paper focuses on hospital management, particularly in the task planning of personnel. The author presents GerAmi: an intelligent multiagent system and architecture to optimize work, schedules and provide immediate information about patient and care facility. The system is implemented using PDA for the nurses, controllable alarms, wireless access point and centralized server. The location tracking of individual is implemented using RFID tags on the wrist band and RFID reader in doorways and corridors. The intelligence aspect of the system is designed using case-based planning (CBP) mechanism that has learning and adaptation capability. The author implements these functions using common BDI (belief, desire, intention [10]) reasoning model. The system also accounts for sudden interruption. For example, the GerAmi will reject the initial plan and seeks an alternative when a patient crises has occurred.

The system prototype is implemented in a care facility for Alzheimer patients over the course of 5 months. The usability study focuses on the nursing staff and found a substantial reduction in task time. Especially the indirect-action tasks, i.e. filling out reports, monitoring patients and periodic visits. The author argue that this will result in nurses spending more time in direct-action tasks, i.e. caring for patient.

AN INTERNET OF THINGS-BASED PERSONAL DEVICE FOR DIABETES THERAPY MANAGEMENT IN AMBIENT ASSISTED LIVING (AAL)

In this article, the author demonstrated an implementation of AmI for diabetes therapy management from home. The paper addresses the difficulty of diabetes patient having to monitor their blood sugar level and the dosage of insulin injection [6]. The insulin dosage depends on the psychological stress, physical activity, drugs, intravenous fluids and eating habit. As it currently stands, the protocol is to have the patient follow the dosage provided on the infusion protocol board provided by the physician. Problem is that they require patients to guess their own diet and glycemic index, leading to dosage error. For that reason, the author developed a system to assist the patient in calculating the insulin therapy dosage.

The implementation of the ambient assisted living environment consists of a RFID card to store patient health record, a glucometer to measure the blood sugar level and a handheld electronic personal device for the patient to interface with the system. The handheld device received information from the glucometer and presented to the doctors and nurses to be analyzed. The implementation utilizes the 6LoWPAN wireless sensor network technology which allows individual device to be connected to the internet and the global information system. 6LoWPAN is built on top of the low power wireless technology IEEE 802.15.4. While incorporating the capability of full internet protocol suite – TCP/IP. This allows for individual devices to link up with existing World Wide Web network.

The human computer interaction aspect of the system is comprised of two parts: the application interface used by the physician and the nurses, the web portal and glycemic index database presented on the patient’s handheld device. Physician and nurses can consult the patient profile and the insulin dosage board to recommend an accurate insulin dosage to the patient. The patient will be given the proper dosage of insulin to take as well as a list of healthy food product to consume according to the requirements from their insulin therapy.

The important aspect of this solution is that measurements and interaction with the patient can be done at home. The author does outline few weaknesses to the system. The interface requires some understanding of insulin therapy which can be daunting to the newer patient. The insulin regimen is given not only to patients of diabetes but also given to patients before, and after surgery. If the system was implemented for them the blood glucose level would need to be set to different value. The author concludes that the main enabling technology for this system is the communication technology, namely 6LoWPAN. From the author’s point of view 6LoWPAN allows defining of solutions closer to the patient, physician and nurses and allows easier integration.

AMON: A WEARABLE MULTIPARAMETER MEDICAL MONITORING AND ALERT SYSTEM

In this paper, the author present a wearable health monitoring device that, as described, can be unobtrusively embedded into user’s outfit. It allows patient to carry on his/her daily life while allowing health care professional to monitor their condition. The main target of this alert system is high-risk cardiac/respiratory patients [11]. The advanced care and alert portable telemedical monitor device (AMON) has several features that are distinct from other designs.

1. Multiple sensors embedded into one device: blood pressure, oxygen saturation (SpO2), electrocardio graph (ECG), body temperature.
2. Activity monitor using two-axis acceleration sensor
3. Online Analysis and emergency detection
4. Flexible communication channel design including GSM or TCP/IP

The AMON system is comprised of two main components: wrist-worn unit and a stationary unit at the telemedicine center (TMC). The wrist-worn device contains various sensors and the author deploys specific algorithms to process the sensory data. If at any time the processed measurement is out of range, the device will trigger an alarm to the TMC. The medical personnel at the TMC will recheck the data and depending on the situation, the TMC can immediately organize per hospital care and transportation.
One issue point out by the author is that single sensor measure by itself is not conducive of the patient’s condition. The measure must be taken into the context and environment in which the patient is in. For example, a sudden spike in blood pressure should not trigger a warning if user is exercising. If the user is stationary, then it will be a cause for concern. By using the acceleration sensor, the device can estimate the user’s current activity. Of course, as the authors admit, this assumes the user’s activity is walking at high speed.

Throughout the article, various weaknesses can be found. The sensor measures are, in some cases, inaccurate due to the high level of noise. The complex interface of the TMC requires extensive training for the healthcare professionals. The weight and noise generated from the wrist-worn device poses some discomfort for the patients. Overall, AMON presents the first implementation of health enabling technology that incorporates sensor technology, wearable technology and wireless technology. And as the author remark, it is the first time such device has been tested in a real world environment.

**DISCUSSION**

Over the past few decades with the advancement of information system technology, sensor technology and communication technology, vast improvement has been made in the field of ambient intelligence, smart home and smart devices. The expectation was that the same improvement will be made in the field of healthcare in either institutional healthcare environment or preventative medicine such as home healthcare. Yet scouring much of the academic scenes, we see very little advancement in the adoption of such technology in healthcare industry. Much of the papers reviewed are dated 5 to 10 years before this report is written. Most of which are prototypes. Very little has been written about the effect of deployment of AmI in the real world environment.

Much of the problems to this has been addressed in the paper “Industrialization, Globalization and Health”. That is problem of user acceptance and problem of transcription. Technologies presented in this paper such as personal monitoring device, wrist-worn monitoring device and hospital environment localization sensor are perfectly functional. Ultimately, no matter how intelligent the system, the information received by these devices need to processes by some healthcare professional (the physician or the support staff). But as it currently stands, doctors and nurses are already overloaded and barely able to get their work done already. A recent report shows that more than a third of doctors personally admitted missing test result of patient because they are already stretched in their workplace. [12] Problem of transcription can be seen as a problem of translating one form of information to another or from one storage system to another. When a new technology is introduced without a truly integration of the old technology. Human resource must be allocated to transcribe the record from one form to another [13]. These processes are time consuming, costly and error prone.

Last but not the least, the issue of usability and end user acceptance also present challenges for the real world adoption of AmI in healthcare. Technical issues such as device being too heavy, noisy and intrusive to daily life [11]. Or user interface designed too complicated and requires training for newer users [6].

**CONCLUSION**

In this literature review, we present an overview of the application of ambient intelligence in healthcare environment. The first two papers [2] [3] describes the need for ambient intelligence in hospitals, personal care and the importance of artificial intelligence. Two implementation of ambient intelligence application are presented. One designed to manage the tasks in fast paced intensive care facility and another designed for scheduling shifts in elderly care facility [4] [5]. Two application of AmI are presented in the last two papers reviewed. Here we focus on the preventive care: AMON (a wrist-worn health monitoring device) and electronic personal assistance for insulin dosage, and diet planning. Lastly, we discuss the challenges faced in the adaptation of AmI technologies in the real world environment.

**REFERENCES**


