COSC 7388: Advance Distributed Computing

Mobile Computing In Health Care

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Abstract—**Mobile computing with its undeniable unique power has become a very promising and attractive research area nowsaday. Mobile devices has been used in many fields of our daily life as an education tool, a gaming device, a work assistant and especially a device for health care. The main intention of our survey is to bring to the notice of the reader how significant the role of Mobile computing in the area of Health care. We have broadly classified the application of mobile computing in health care into four main categories: daily fitness, health condition monitoring, doctor and patient interaction and clinic assistance. In each of these above categories, the role of Mobile computing would be presented with concrete example applications. Also, we present the challenges for applying mobile computing in health care.**

Keywords: Mobile computing, health care.

I. INTRODUCTION

Mobile computing [1] is a form of human-computer interaction by which a computer is expected to be transported during normal usage. Mobile computing has three aspects: mobile communication, mobile hardware, and mobile software. The first aspect addresses communication issues in ad-hoc and infrastructure networks as well as communication properties, protocols, data formats and concrete technologies. The second aspect is on the hardware, e.g., mobile devices or device components. The third aspect deals with the characteristics and requirements of mobile applications.

Mobile computing has evolved in leaps and bounds in the last few years, it all started with Laptops which powered computing technology to be mobile, followed by personal digital assistant (PDA). At the beginning a PDA is a mobile device that functioned as a personal information manager but some advancement in technology helped in making the PDAs have the ability to connect to the Internet, by including a web browser and also have audio capabilities, enabling them to be used as mobile phones or portable media players. Other technological advancements like touch screen technology have lead to the increase in popularity of PDAs and also laid the foundations for Smart Phones. A smart phone is a mobile phone that offers more advanced computing ability and connectivity and may be thought of as handheld computers integrated with a mobile telephone. A smartphone allows the user to run and multitask applications that are native to the underlying hardware. Smart phones run complete operating system software providing a platform for application developers. Thus, they combine the functions of a camera phone and a personal digital assistant(PDA). The trend is moving to smaller, more powerful, more affordable device.

These recent advances in mobile computing and the extreme popularity of mobile devices nowadays have made mobile computing a very promising and attractive research area. The conferences, Wireless Health [2], Mobile Health [3], which aim to accelerate the development and adoption of mobile computing for healthcare does stress upon the fact that the research community has realized a huge potential in applying mobile computing in health care.

In this survey, we would like to bring to the attention of the reader the current state of the art and also the challenges for health care using mobile computing. In our research, we could broadly classify them into four categories:

Mobile computing for daily fitness: mobile devices have become a major persuasion platform. They are ubiquitous and well suited to persuade users to maintain fitness, this has been done in several daily fitness applications for mobile devices.

Mobile computing for health condition monitoring: most mobile devices nowadays have blue tooth capability embedded which can be used to gather information from various medical sensors to provide the users with health information like cardiac parameter monitoring, diabetes and obesity.

Mobile computing for doctor and patient interaction: applications that use mobile devices to collect data on patient's current health status and send it to the doctor to keep the doctor updated with patient's status which will help in better routine or emergency treatment.

Mobile computing for clinic assistance: used for retrieving patients information such as physicians' orders and test results at anywhere or anytime, enables clinician to provide point-of care by reducing time-consuming and redundant paperwork, therefore, ultimately, improve the quality of care.

II. MOBILE COMPUTING FOR DAILY FITNESS

Mobile phones' advancement and proliferation have been staggering; most people now carry a mobile phone, always switched on. More than 70 percent of teens own a phone by the time they are 17; this number will only continue to grow. The mobile phone plays an important role in adolescents' lives, providing an always-connected link to their social network and identity. Various devices support exercise both indoors (for example, stationary bikes and treadmills) and outdoors (for example, heart rate monitors and step counters). They provide limited motivational support; they tend to interest only users who are already motivated to exercise. Mobile phones will likely become a major persuasion platform as they are ubiquitous and well suited to persuade users to exercise regularly. If the individuals are adequately motivated, mobile phone might be the perfect instrument for delivering persuasive messages, to change their behavior. The global retail market for mobile-phone-based games was US$5.4 billion in 2008 and should rise to $10 billion in 2013, according to Juniper Research. Hence mobile phone games empower us with a great platform for delivering persuasive messages. Combining motivation and exercise, fitness games can act as persuasive tools. They can trigger decision-making and also guide users through a process.

One health games research genre focuses on virtual-pet care. For Virtual pets are perfect companions for kids: failing to care for them doesn't have real-world consequences. **Fish'n'Steps** maps the number of steps (both indoors and outdoors through a wearable pedometer) a user takes to the growth and emotional state of a virtual fish in a tank. The fish's appearance changes depending on whether the user's total steps exceed predefined targets. The fish will be happy if its user has reached his or her daily goal or sad if the user hasn't. Problem is that the game runs on a stationary kiosk, so users can't monitor their progress continuously which leads to loss of interest after couple of weeks. **NEAT-o-Race** captures the amount of energy a user spends (using an accelerometer to measure user motion) and maps it to the speed of an avatar in a virtual race. Two user evaluations showed that players were engaged by the games and exercised more. Both Fish'n'Steps and NEAT-o-Race try to estimate how much a user exercises, but they can't distinguish among different kinds of exercise such as walking, cardio fitness, or strength training. **UbiFit Garden** infers such information from 3D accelerometer and barometer data. It maps different exercise types onto different kinds of flowers that populate a virtual garden on a mobile phone. **Fitness Adventure** relies on an interactive story to motivate people to walk outdoors. The game exploits a GPS device that tracks the user's movement in a town. None of these games detect users' heart rate and thus can't monitor exertion. **StepGreen** aims at caring for a virtual polar bear led to more environmentally conscious behaviors.

Three other mobile games have captured our interest and will be presented more in details below to illustrate the potential these applications have in store to influence the behaviors of the user. We start with the application **It's Time to eat** [9] followed by **Monsters and Gold** [10] and finally, **Brain Training** [13].

At the start of Its Time to Eat, players adopt a worm, dinosaur, dog, hippo, penguin, potato head, robot, stapler, or tree. Players are allowed to pick and name their pet to provide a sense of control as well as a sense of attachment.

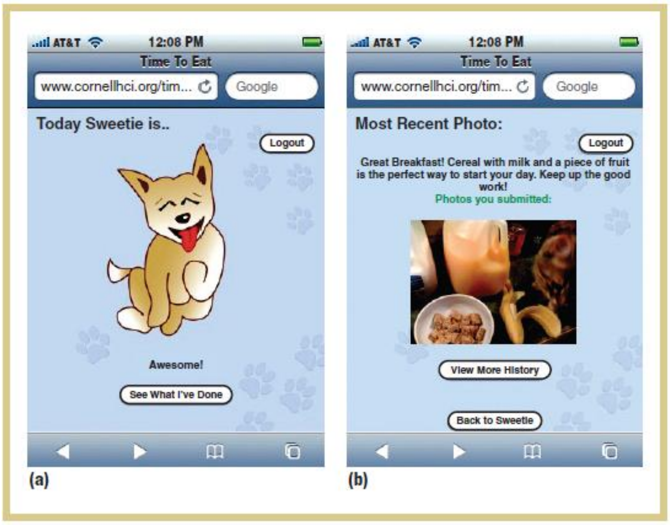

Figure 1. The Time to Eat's user interface: (a) the home screen, depicting the pet's current emotional state and (b) the feedback screen with the corresponding food photo. The pet's emotional state reflects the quality of meals the player has recentlyeaten and submitted. Navigating to the feedback screen lets players see recentphotos and their corresponding feedback and hopefully make a connection between their actions and the pet's current state

As the game begins, pets send users healthy-eating reminders via e-mail, such as "Good morning! Remember to eat breakfast today" or "A healthy breakfast is important". The messages and the times they are sent are configurable. All the e-mails sent to the players were written as if from the pets themselves. The user is prompted to take a picture of the meal and submit it. Score is awarded on two factors, whether the user ate anything at all and the healthiness of the food in the photo. The pet's appearance changes on the basis of that score. Each score from −2 to 2 has a corresponding state for each pet; negative scores produce a sad pet, whereas positive scores produce a happy one.

Findings from the study: 53 kids composed of 7 and 8th graders, who played Time to Eat ate a healthy breakfast more frequently than those who didn't. Children playing the game ate a healthy breakfast 52 percent of the time; kids who didn't play it ate a healthy breakfast approximately only 20 percent of the time. It was also found that kids needed to receive both negative and positive feedback from their pet, suggesting that emotional and social realism is the key to their experience and the game's motivational abilities. Interestingly there were no significant gender effects.

The games can be made more attractive for children by incorporating features similar to other games, such as reaching different levels based on how the pet is doing, increase the pet's interaction capabilities. Further, machine vision and image recognition tools could automatically rate photos and change the pet's status.

Time to Eat can also act as a powerful data collection tool and might reveal interesting pattern about eating habits and problem areas. There is a scope for encouraging children to complete home-work assignments or become more socially responsible by improving energy conservation and recycling habits.

The second game that we chose to elaborate in this survey is **Monster & Gold**, a context-aware, user-adaptive fitness game for mobile phones. Monster & Gold trains and motivates users to jog outdoors at the correct intensity.

To determine the user's heart rate, Monster & Gold processes pulse data, provided by a Bluetooth pulse oximeter clipped on the user's ear. It determines the user's position and speed through the mobile phone's internal GPS. While users jog outdoors, the game displays a one-way virtual trail that moves as if they were jogging on it. The distance run in the virtual trail is proportional to the distance run in the real world. The game resembles a GPS navigation system, but instead of real-world points of interest (POIs) such as churches and restaurants, users find virtual monsters, gold, potions, and shields, which last a few seconds, then disappear.

The goal is to score gold points (GPs) without losing health points (HPs). To collect GPs, users must maintain or increase their speed to pick up gold on the virtual trail before the gold disappears. To preserve HPs, users must slow down until monsters vanish, because hitting a monster decreases HPs. Users can recover HPs by picking up potions, and they can repel monsters if they've picked up shields. The game alternates between two tasks:

- Proceed-on-trail task (PROC), in which users should just keep jogging, and
- Reach-or-avoid task (ROAV), in which they should speed up or slow down to reach or avoid a particular POI.

Figure 2. Monster & Gold's GUI during (a) a PROC, in which users should just jogging; (b) a monster ROAV, in which users slow down to avoid the monster; and (c) a gold ROAV, in which users should maintain their speed or speed up to obtain the treasure chest

By considering the user's mean heart rate (MeanHR) during the PROC, the user's age to estimate her HRMax, and the exercise phase (warm up, main, or cool down) to determine the heart rate's optimal intensity range (OptRange), the game identifies one of three situations: MeanHR in OptRange, MeanHR above OptRange, and MeanHR below OptRange. The closer MeanHR is to the mean of OptRange (OptHR), the more gold. So, users jogging closer to the optimal intensity can score more points. A MeanHR above OptRange isn't healthy, so the game chooses a monster for the ROAV to encourage users to slow down. The higher the MeanHR, the larger the monster. So, the HP damage users suffer if they don't slow down is proportional to the risk for their heart. Although a MeanHR below OptRange isn't harmful, users aren't gaining cardiovascular benefits. So, the system gives users a chance to get tiny gold, whose distance and duration are such that they must increase their speed to reach it before it disappears.

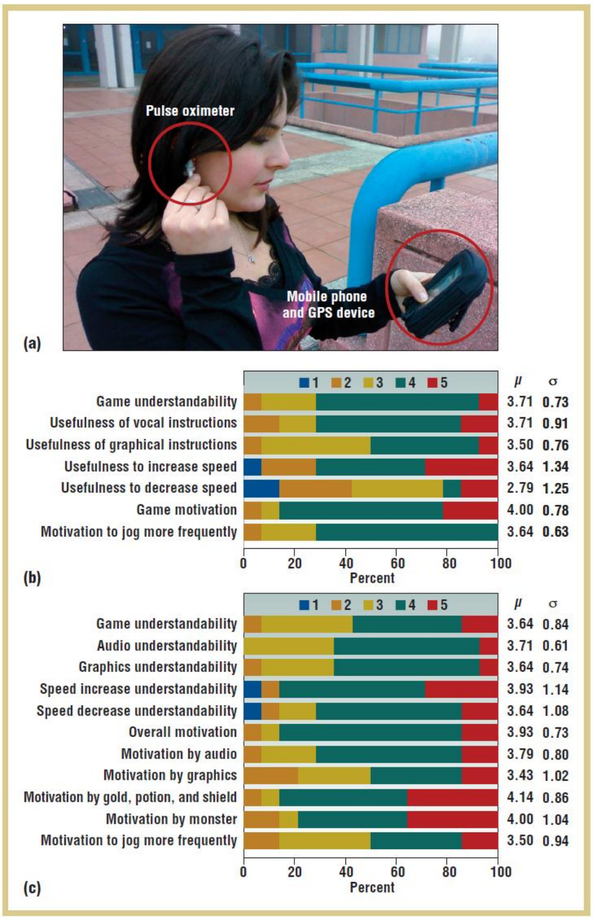

Figure 3. Monster & Gold user evaluation: (a) a user wearing the devices, (b) the first evaluation results, and (c) the second evaluation results.

The first evaluation's ratings show that users generally agreed with all statements except usefulness to decrease speed. The second evaluation's ratings show that we effectively improved this aspect and also confirm positive results about the game's understandability and motivational effect. Evaluations indicate that the improved version motivates and trains users in jogging for cardiovascular exercise. Improvements are made to the game by enhancing user-adaptive features like weight and training goals and also consider user performance details such as calories burned per session and long-term variations in the ratio of jogging speed to heart rate. Such an approach should provide each user with a tailored, fun training plan.

When we talk about daily fitness, it doesn't have to be physical fitness alone, even mental fitness is equally important. Hence we have extended our survey in this area to **Brain fitness**. With proper mental exercise one can achieve a better memory, greater focus, better multi-tasking abilities or a generally sharper mind. Traditionally this is done through Yoga which is not accessible to every individual and would demand heavy self motivation. Brain games have been scientifically demonstrated to enhance various cognitive functions through the magic of neuroplasticity. Everyone can benefit from doing mental exercises irrespective of the age.

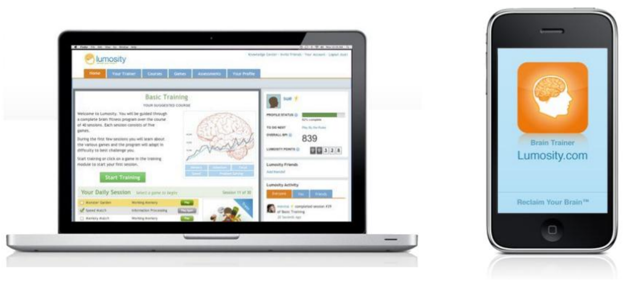

Figure 4. Brain Training Application by Lumosity

One of the most popular **Brain Training** application which is used by over 4 million users is Lumosity Brain Trainer. It includes 10 brain games designed to enhance your cognitive abilities, including memory, processing speed, attention, flexibility, and problem solving. Playing brain games a few minutes every day will help you achieve the best results.

In their survey, the authors have reported the following benefits for users from playing Brain Training:

- Memory performance: equivalent to improving by 12 percentile points on average.

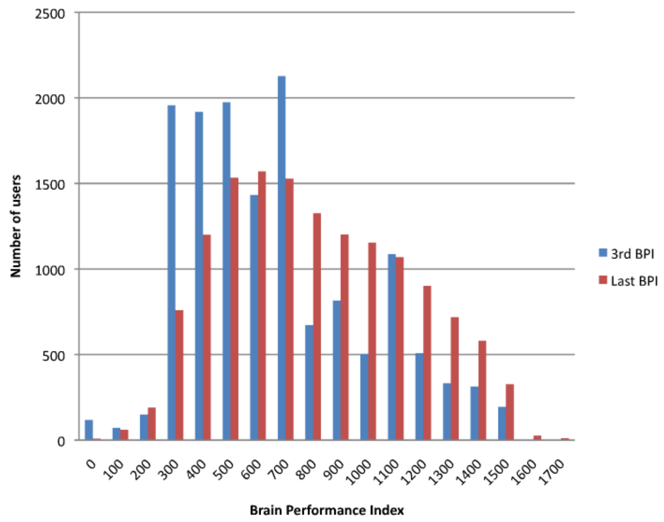

Figure 5. Memory performance improves with training

- Response inhibition performance: equivalent to improving by 24 percentile points on average.

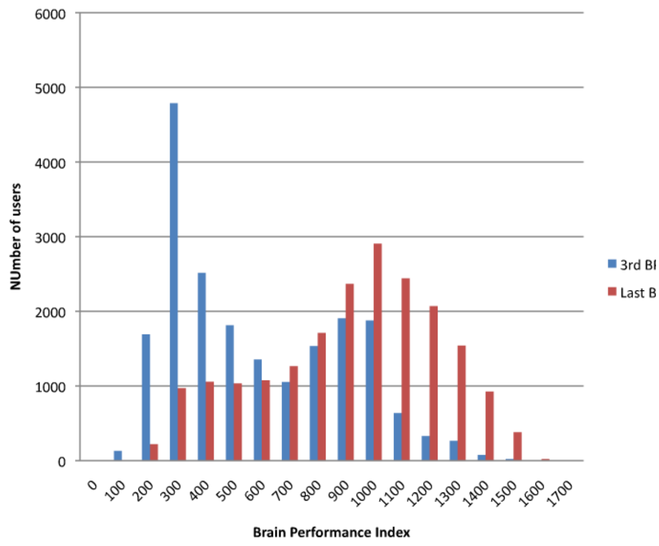

Figure 6. Response inhibition performance improves with training

- Processing speed performance: equivalent to improving by 28 percentile points on average.

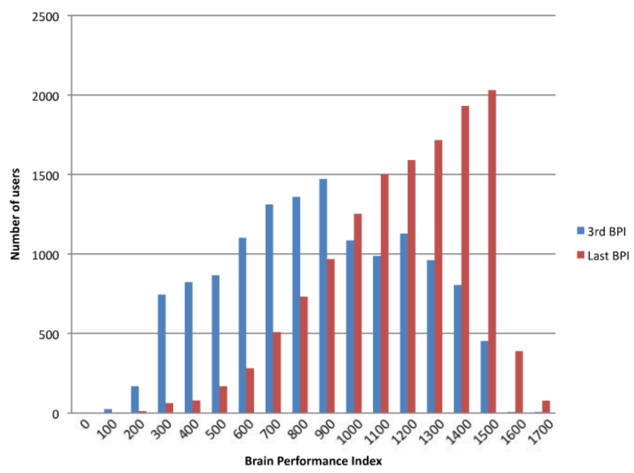

Figure 7. Processing speed performance improves with training

In the next section, we will present some remarkable mobile applications that have been being used for the purpose of monitoring user's health condition.

III. MOBILE COMPUTING FOR HEALTH CONDITION MONITORING

Constant monitoring can improve the patient's quality of life for various health conditions such as diabetes and obesity. This can be achieved by empowering and educating individual patients with proactive mobile computing tools and technologies such as mobile phones, Bluetooth and WAP. Integrating these tools provides a transparent way of monitoring, analyzing and modeling their metabolic performance and allows patients to become more responsible for the management of their health conditions. This, in time, could help reduce the workload on health service providers.

The motivation behind this kind of work lies in the pandemic of chronic conditions in the developed world. Today, there are over 171 million people with diabetes and over a billion people

Over-weight of which, over 300 million are clinically obese and Hypertension is rapidly increasing. Alternative mechanisms for delivery of care, and by which the quality of care can be improved for patients with chronic conditions. Patients need to become more responsible for the management of their conditions and require tools to empower and to educate them to achieve this. Mobile computing can be used to deliver an e-Health solution. These solutions allow individual patients to benefit from a longer and higher quality of life, and allow healthcare professionals to become more effective and efficient in their care of patients.

Bluetooth technology is used for wireless data transmission between mobile phones and specialized sensors. In this part of the survey we are going to present two applications, one designed for patients with Diabetes and other designed for patients suffering from hypertension.

The first application is "A Vision for the Use of Proactive Mobile Computing Tools to Empower people with Chronic Conditions" [11]. The approach used here is to gather some of the inputs form the sensors in the system and the second approach is to gathering the inputs is through manual entry by the patient. These inputs include individual's daily diet composition, activity listing and medication

The novel contribution offered in this project lies firstly in the collection, analysis and modeling of personal data acquired by wireless/wired sensors and/or by user entry. The second contribution lies in researching proactive computer software systems to utilize these data to assist in the delivery of the e-health strategy.

The project aims to harness the power of mobile technology to give the user continual access, on the move, to near real time information regarding their health condition:

- Data from sensors (blood glucose, accelerometers, muscle excitation etc) is acquired by Smart phone applications using wireless and/or wired links via data loggers, e.g. Intel Mote devices.
- Data is entered manually by the patient and can include a past record, and future plan, of the patient's diet, activity details and medication taken, such as insulin doses, types and times of doses.
- Health service systems then receive the acquired and entered data, on which analysis, processing and modeling is then performed. The results can help monitor and predict the future state of the patient's health.
- Using this information and the data acquired from sensors this scenario is modeled and advice is sent to the patient if they would require adjusting their medication or diet to undertake the desired activity, and maintain control of their condition.

Work was still in progress on this application because of which no experimental results have been discussed. But what is more important here is to understand the vision of this project and role it is playing in bringing Mobile Computing closer to the user for the user's health condition monitoring.

Next, we explore an application that uses Mobile computing to monitor certain Cardiac parameters [12] like the blood pressure to help users suffering from Hypertension.

Hypertension can be effectively prevented and controlled only if it is constantly monitored, along with the support of the health education and professional medical care. In the present work, an autonomic mobile monitoring computing system with alert mechanism in hypertension monitoring is proposed and implemented.

The aim of this application is to improve decision-making and reduce the numbers of medical errors. The autonomic mobile computing system is compound mainly of three parts:

Figure 8. The block diagram of the automatic computing system proposed.

- A cuff that includes a sensor and the circuitry necessary to measure the blood pressure (BP) and the wireless transmission of the information by means of Bluetooth.
- A mobile device that controls the operation of the cuff and receives the generated information of blood pressure
- A server connected to the Internet that stores the data of the measurements of blood pressure of each user of the system.

The control of the cuff is by means of an application developed for the mobile device. Using the approach of autonomic computation, the server and the mobile device can interchange information without the intervention of the user. The cuff and the mobile device can communicate when they are restricted to a distance. This is a disadvantage of the system, but on the other hand, it is a more economic proposal for the data communication of blood pressure.

The trend to use more computing devices may provide an opportunity for increased their potential and to provide the desired benefits and would be a critical part of health care information system.

The autonomic computing system was proven by nine hypertensive patients, 4 men and 5 women for a period of a month. The blood pressure values obtained with the system cuff were compared with the readings obtained with commercial equipment. Figure 9 shows the comparison for a session with the 9 patients for systolic and diastolic pressure. The readings obtained with both the equipments are found to be quite similar.

The results of the survey showing the comparison of the two approaches Manual and Automated have been tabulated in the figure 10. The Users were asked to rate both the approaches on the basis of handling, functions, interface and autonomy on scale of 10. According to the results, the aspects of handling and interface are better evaluated under the automated approach. The survey showed that the perception of users is favorable to the developed system under the automated approach.

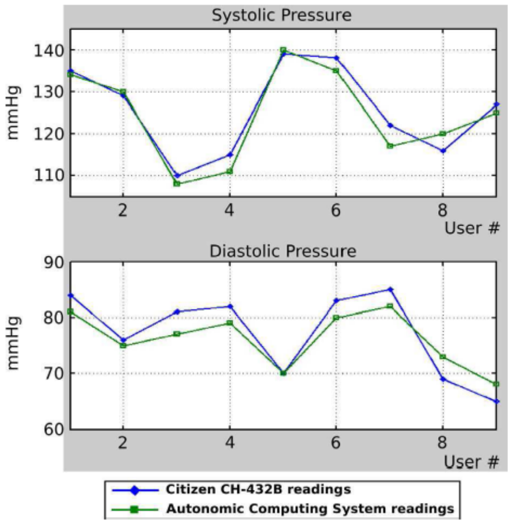

Figure 9. Comparison between the systolic and diastolic pressure readings of proposed Automatic Computing System and a commercial digital blood pressure monitor

Evaluated Aspect	Manual Mode	AC and AUI Mode
handling	2	8
functions	5	8
interface	3	9
autonomy	4	7

Figure 10. System evaluation under two operation modes

IV. Mobile Computing for Doctor and Patient Interaction

Applications in this section make use of mobile devices to collect data on patient's current health status and upload it to keep the doctor updated with patient's status which will help in better routine or emergency treatment.

We present two representative researches in this category:

- AndWellness: an open mobile system for activity and experience sampling [5].
- Telemedicine in wound healing [6].

AndWellness is a personal data collection system which uses mobile phones to collect and analyze data from both active, triggered user experience samples and passive logging of onboard environmental sensors. This system can be used to better understand a user's health related habits and observations.

The paper points out that researchers/doctors nowadays have begin to realized the need to monitor patients in situ (by activity and experience sampling) versus asking a participant to recall an event in the past, the reason for this is because "Recall bias" can badly affect the accuracy of the studies.

However, experience sampling studies have their own set of problems (participant's timely adherence, quality of responses) and researchers have been using a number of methods to alleviate these problems.

The authors claim that AndWellness incorporates all these usefulness of previous methods in it as well as some advanced features like contextual triggers to avoid bothering participants at inopportune times, smart branching survey to avoid asking redundant or useless questions, and sampling onboard sensors such as GPS to collect continuous data without interrupting the participant. This focus on adherence and quality of responses from non-technical participants sets AndWellness apart from other open source and commercial data collection systems.

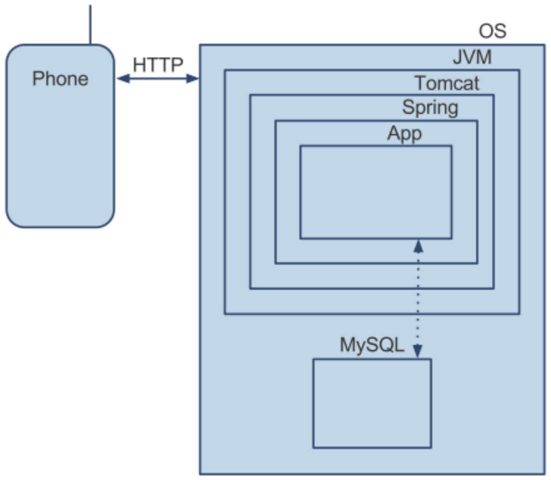

Figure 11. AndWellness Client-Server Architecture

The architecture of the system includes an application that runs on Android based mobile phones, server software that manages deployments and acts as a central repository for data, and a dashboard front end for both participants and researchers to visualize incoming data in real-time. The system has been designed to meet a number of requirements on usability (unobtrusive, easy to learn and use, minimized amount of interaction and interference with users), power (optimized to balance battery drain with accuracy), privacy (end-to-end encryption, randomized user names, authentication mechanism, etc.) and transparency (near real time data upload, dashboard to view feedback).

AndWellness server is implemented in Java 1.6, Spring frame work, using a REST style architecture which provides component replaceability, flexibility. AndWellness mobile application is implemented using the standard Android development framework provides configurable triggers for daily surveys and secure and reliable data transmission. The visualization part has been implemented with a mechanism that pre-aggregates collected data, which allows it to handle potentially large amounts of data.

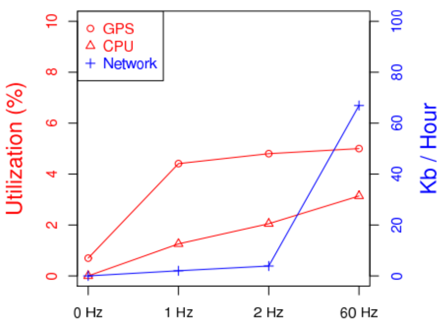

Figure 12. Resource ultilization of AndWellness mobile application collecting inferences at 0 Hz, 1 Hz, 2 Hz and 60 Hz

The authors finally present an evaluation on the performance of the system through some experiments on CPU, GPS, network bandwidth and battery usage with different activity inference frequencies. The experiments show that the inference is quick and efficient, the network bandwidth usage is acceptable but the entire battery life is drained unfortunately fast. There are some preliminary feedbacks that the reminders and response feedback is engaging but the the vibration pattern and ringtones used for the notifications were too annoying.

Overall, AndWellness incorporates a lot of advanced features that is definitely useful for the purpose of activity and experience sampling which is used in patient treatment and human behavior research. If the authors can fix the problem with fast battery life drainage in future research, the system could be of wide use.

While the above research describes using mobile devices for collecting text and sensors' data, this paper presents using mobile devices as an images transfering media for more immediate or emergent treatment.

The paper first explains a concept called telemedicine, which is defined as the practise of medicine from a distance. In the past, telemedicine simply referred to medical consultations taking place over the phone. However, the subsequent growth of the Internet (cheaper, faster and more secure transfer of data) has provided a unique opportunity for rapid, global clinical communication.

Nowadays, telemedicine in simple terms involves the transfer of medical information from one computer to another. This often involves still images but may include video, X-rays or other patient data. This transfer of information can enable faster interaction between clinicians and act as a communication tool between clinicians as seen in general surgical video conferencing outpatient clinics.

Figure 13. Telemedicine Desktop System

Patients who benefit most from telemedicine are those who find reaching clinicians difficult whether due to difficulty in travelling or distances. Wound healing is a branch of clinical practice that is visually based and, in many cases, managed in a community-setting. These patients are thus distanced from specialists and the wounds may make travel difficult. It is therefore likely that transmission of individual wound information to the General Practitioner (GP) surgery or a specialist centre would be of value to the GP or district nurses treating difficult and recalcitrant wounds in the community. As such, wound healing makes an ideal area for the development of telemedicine.

A clinic revolved around images of patient's wounds would enable the clinician to review more wounds during a single clinic without travel involved by either party. It would prevent uncomfortable and difficult travel arrangements for patients whilst enabling their wounds to be reviewed regularly by an expert in the field. 'Virtual clinics' where a number of community patients can be reviewed by a single consultant without a face-to-face consultation could therefore save considerable time and transport costs.

Telemedicine can also be used as a teaching tool with which to increase community knowledge base as well as providing support network to allied professionals in the community, e.g. district nurses. With patient knowledge and expectations increasing, this would enable an increased level of specialist care to be available where it is needed.

The paper then presents the architecture of telemedicine which involves a collection of technologies including computers, communication networks and specialised medical equipment. The most common feature of a telemedicine system is the ability to transmit high-quality digital medical images across a communication line. A telemedicine system requires remote connections, usually through Integrated Services Digital Network (ISDN) or ASDN lines which have bandwidths large enough to handle the amounts of data being transferred. Still images, video and/or audio data are provided using a digital recorder.

Overall, telemedicine like all of medicine is an ever changing and evolving discipline, and information on its costs and benefits are becoming of increasing interest to decision makers in health care. Thus, wound management projects which use telemedicine have shown potential for their role in evaluating remote patients. These projects show promise for potential improvement in the quality of wound care, enhancing availability, reducing costs and generating valuable outcome data.

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V. Mobile Computing for Clinic Assitance

This section focus on the of mobile devices in the clinic environment for aiding clinicians, such as retrieving patients information like physicians' orders and test results at anywhere or anytime, enabling clinician to provide point-of care by reducing time-consuming and redundant paperwork or reducing number of mistreatment caused by faulty information, therefore, ultimately, improve the quality of care.

Two representative researches are presented in this section:

A. Wireless interactive system for patient healthcare monitoring using mobile computing devices

The authors first reasoned that Smart-phones and Personal Digital Assistants (PDAs) are fast becoming powerful platforms for users to interact with a variety of systems for e-health and e-work situations. The use of Mobile Computing Devices (MCDs) and other wireless networking technologies

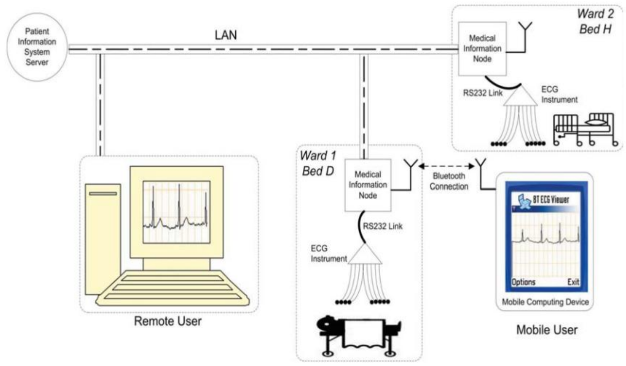

Figure 14. Structure of Medical Information System Network (MINS)

in e-health environments for patient record, resource or time management has the potential to improve overall patient care by reducing the occurrence of mistreatment incidents caused by faulty information.

The paper presents a Medical Information System Network (MISN) [7] that offers location based services such as instrument monitoring or recording and patient record entry using mobile phones. The MISN allows a medical instrument's output to be viewed and controlled by authorized mobile computing devices. The MISN consists of Medical Information Nodes (MINs) connected to a LAN. The MIN is an embedded system platform that uses a Bluetooth link to communicate with mobile computing devices (MCD). The MIN can also be accessed and controlled via a web interface.

There are two interactive interface mechanisms for the medical information system: an MCD based interface and a web based interface. The MCD based interface consisted of an electrocardiogram (ECG) viewer program that allows a user to interact with the medical information system using their MCD.

There are two methods for displaying real-time waveforms either using a conventional image formats such as

JPEG or a custom data format. The disadvantage of using image formats is the high data rate required to transfer the image files representing the ECG waveform, particularly in real-time. The advantage of using standard image formats is that support for displaying images is widespread and extra information such as blood pressure or heart rate can also be conveyed in the image file. The advantage of using a custom data format is to represent an ECG waveform is that a high data rate is not required in order to transfer the ECG Lead waveform data stream. A disadvantage is that a custom program is required to view the ECG waveform. A custom ECG viewer program was written in order to allow the real-time display of the ECG waveform.

The client program was written using the Symbian Nokia S60 Software development kit. The Symbian Nokia S60 Bluetooth API allows the Bluetooth serial port profile to be accessed via a standard socket interface. The Symbian Nokia S60 basic drawing API allowed real-time display of the selected ECG Lead waveform.

Connection between the user's MCD and medical information node is facilitated via Bluetooth. One of the advantages of using Bluetooth is that its short range ensures that the MIN only to be accessed when the user is within a particular location. This allowed the MIN to provide location specific access to medical instruments depending on where the user is.

The authors also analyzed the Bluetooth Serial Port and Dialup profiles for streaming the real-time ECG waveform data and found that Bluetooth Serial Profile was ideal to use because it allowed a higher data rate and required less complexity of setting up a connection between the MIN and the MCD. The ECG instrument Patient lead waveforms can be viewed using the MIN's webpage interface. The MIN ECG lead display webpage uses a CGI script to generate a dynamic Scalable Vector Graphics (a XML based mark-up language which allows an accurate image to be drawn from a raw data stream which in this case is an ECG waveform) image of the received ECG lead data stream from the ECG instrument.

The Suzaku embedded system platform was used to implement the Medical Information Node. The MIN's consists of a 32bit processor and communicates to the Bluetooth Serial Profile Module and ECG instrument via a serial interface. The Suzaku platform runs the uClinux Operating System and also has an Ethernet MAC controller to allow the MIN to be connected to a LAN.

Although the MISN was successfully tested, further work is required to increase the capability of the MISN by expanding the MINs to interface to other medical instruments. Wireless LAN connectivity will also be investigated for use with MIN platform.

B. MobileNurse: hand-held information system for point of nursing care

For better manage, analyze and communicate information during patient care, mobile systems can facilitate quick entry and retrieval of notes, rapid ordering and reporting of findings, and timely access to current patient records. The ability to use a single small communicator such as PDA to transmit different types of information within the hospital would be ideal for medical professionals circulating in a ward frequently during their duties. PDAs can also assist the nurses for receiving orders and displaying relevant laboratory data at the point of nursing care.

MobileNurse [8], a prototype mobile nursing information system (NIS) using PDA, is designed to communicate with hospital information system (HIS) via mobile support system (MSS) which interchanges and stores clinical data. MobileNurse consists of four components. The first is the medical order checking module. It enables nurses to retrieve patient information, such as physicians' orders or test results, anywhere and anytime. The second component is the nursing recording module. Nurses can record the results of their practices at the bedside. As a nurse executes the autosynchronization module of MSS and PDA, the existing

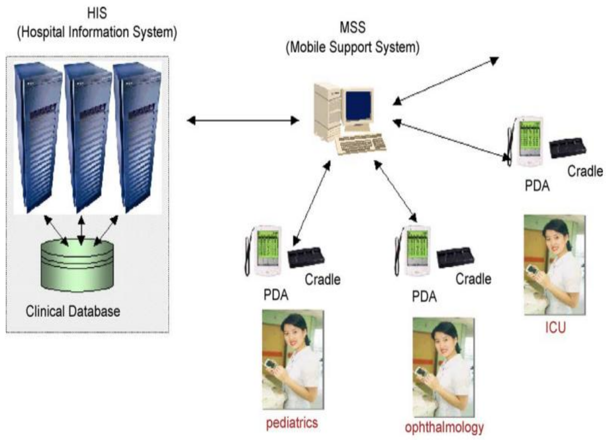

Figure 15. Overall architecture of Mobile Nurse

data of both systems can be interchanged and updated. The third component is the nursing unit care planning module, which retrieves the nursing care plans for all patients, such as patients' discharge, consultation, and transfer. The last component is the patient information management module with which nurses record the patients' demographic information during their interview of nursing assessment. Conventionally, nurses interview patients at their bedsides to gather and record the necessary information, usually on paper. With MobileNurse, instead of using paper, nurses can simply enter the information into PDA according to the format provided. With the help of MSS, users can not only proactively retrieve clinical data such as lab results and patient's demographic information, but also generate reports in various formats. Also, graphs are automatically generated based on the temperature and pulse provided to PDA. The patient information updated by MobileNurse clients is sent to HIS via MSS. This new information is shared by medical staffs who use the same MSS and HIS.

With the use of PDA in the clinical environment, nurses can spend more time on caring for patients by reducing time-consuming and redundant paperwork. MobileNurse provides 'point-of-care' nursing with up-to-date information, thereby improving the quality of nursing care.

From a clinical trial, the authors realized that the ease-of-use aspect of the system is the most important factor for success among the other technical issues. The clinical experiment also confirmed some positive facets of the point-of-care system: the ability to reduce duplicated works, and the improvement of care quality through the sharing of patient information all around the care units. To be accepted into real practice, however, the PDA-based point-of-care system should have an effortless user interface and be able to replace all paper based nursing records with PDA application.

Figure 16. Clinical trial

VI. Challenges for Mobile Computing in Health Care

A mobile device that is used for computing in health care would typically have to be:

- Always on
- Always connected
- And always recording

These three characteristics incoporates a set of challenges for computing on mobile devices [4]:

First, the device has to be not only mobile but also wearable or carryable. If the device is hard for user to carry, there are chances that the device will get dropped and then break or lost, which will cause a lot of problem especially when the device is not cheap to produce. Moreover, there will be problems of participant compliance when the device is not wearable or comfortable to carry, such as, participants forget to wear device, leaving it in car, purse or backpack; participants clothes do not have pockets or participants do not like wearing it when play sports; participants do not like to carry bulky or chunky items. There are some suggested methods to solve these problems, such as, making the device as small or even as stylish as possible, something like a wrist watch is desirable; moreover, the device should try to provide other functionalities (shows time, calendar, outter temperature) to users apart from its main health care related functionality to encourage the users to carry it; finally, some forms of reminders from the researcher to the participant to carry the device would also help.

Secondly, because the mobile device will always have to be powered on, there will be challenge in battery life, the device would be impractical if it can only operate for few hours a day and what would happen if the user forget to recharge it. Moreover, since the device has to be on all the time, there will certainly be problems when users forget to turn it on or accidentally shut it off. There are certain solutions that would help overcome these problems: first, the device should be rechargeable; secondly, the doctor should consider whether the device will be feasible for the participant to shut off, the power button can be modified to prevent accidental turn-offs or the device cannot be turned off by the user but would be automatically shut off when no data collection will be carried out (i.e, night time); finally, some kinds of reminders to tell the user to recharge their devices in the night time would also be helpful.

Thirdly, since the device will have to be connected for data transfer, the research will have to face the problem of connection lost or gaps in collected data. Wireless connection also consumes a lot of power and the cost for wireless connection service nowadays is not negligible. To overcome these problems, the device or application should be designed to accommodate lost connection and data gaps, for example, determining acceptable gap length, planning on longer observation periods to collect required number of valid days, monitoring data daily and contacting participants when problems are noticed. The device should be designed to be capable of operating in store and upload mode whenever possible to save battery and overcome connection lost. Moreover, bulk data transfer can also reduce of total amount of data that needs to be sent over the network, thus, potentially reduces cost.

Finally, since the mobile device will record and transfer participants' information, researchers would have to deal with the problems of privacy (what information to record and transfer so that the participant will not feel uncomfortable), security (communication channel is not secured, unauthorized access to collected data) and how can the collected data be shared or published. To overcome these problems, there has been some suggested solutions, such as, devices only collect really necessary data or even let the participants to view collected data and choose which to upload; use Wireless Carriers' networks because they are secure; use IT best secured practices (firewall, encryption technique, access authorization).

VII. CONCLUSIONS

It can be observed that as the Mobile devices are getting smaller and more powerful; their popularity has also been increasing. Especially, because of the huge potential for computation offered by these mobile devices at a very affordable price, Mobile Computing application can be seen in any aspect of our daily lives.

The various games and applications presented in four categories in this survey highlight the current impact of Mobile computing in the field of Health care. All the experiments and evaluations done for each of the games and applications point out to the fact that users have easily and quickly adopted themselves and users actually find it more convenient, accurate, interesting and helpful when Mobile computing is integrated into health care.

Associated with all these advantages, however, are a set of challenges for mobile computing that researchers would have to seriously consider when designing mobile devices and applications to make them practically usable.

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