Smart Healthcare: Basic Health Check-up and Monitoring System for Elderly

Borwornlak Thaduangta[1], Pawit Choomjit[1], Sudhatai Mongkolveswith[1],
Umaporn Supasitthimethee[1] ,Suree Funilkul[1] and Tuul Triyason[1]
[1]Information Technology, School of Information Technology
King Mongkut's University of Technology Thonburi, Bangkok, Thailand
E-mail: 56130500113@st.sit.kmutt.ac.th, 56130500116@st.sit.kmutt.ac.th, 56130500098@st.sit.kmutt.ac.th,
umaporn@sit.kmutt.ac.th , suree@sit.kmutt.ac.th, tuul.tri@sit.kmutt.ac.th

***Abstract*—Thailand has become an ageing society. The consequences of the situation appear to be an issue for health organizations to prepare efficient, safe and equitable health care for an aging population. Throughout the past decades, technology has been frequently utilized because it has provided new methods to support the facilitate health care services. In this paper, we studied the health situation of the elderly and proposed the Smart Healthcare system. It consists of a bio-signal measuring prototype (blood pressure, heart rate and temperature) and a web application for both doctors and the elderly. It also includes an alert button. Evaluation was performed in two parts, which were qualitative interviewing and quantitative survey. We interviewed three doctors for confirmation regarding their opinion of the system (i.e. usefulness, visualizing data, and suggestions). Doctors replied that the system is useful for the elderly who are unaware of their own health information; consequently, they may unable to control their own health. For visualizing data, doctors normally view the measured data in number format. For displaying result to the elderly, it should be explained in simple statements that are easy to understand or described using color. Moreover, provision of an alert button is a valuable idea for saving lives. For the quantitative survey, we used the Technology Acceptance Model (TAM) as the core model to measure the acceptance by the elderly. Thirty 60-80-year-old elderly people participated in the survey. The result indicated that the elderly is perceived the usefulness of the system and were willing to use it unless they found it difficult to learn or understand because of possible negative attitudes toward new technologies.**

Keywords—elderly; e-health; smart healthcare; iot; ubiquitous;

I. INTRODUCTION

Thailand is becoming an aging society. The number of aging population (age above 60) seems to have dramatically increased in the past decade [1]. The increasing elderly population which is the group most likely to face health problems and need long-term care and appears to be an issue for the healthcare organizations to prepare for health care services [2]. For this reason, the idea of using the Internet of Things (IOT), e-health and ubiquitous health care has been frequently utilized to develop health care services for the elderly because it provides a new method for creating and improving health care services systems. Furthermore, these technologies support health information exchange between doctors and patients through network protocol or other communication technology, reduce costs, provide effective feedback to patients, speed up the transformation of healthcare between doctor and patient to improve health management. In addition, e-health is a suitable system for chronic disease monitoring (e.g. hypertension, diabetes, and hyperlipidemia), since the diseases mostly affect the elderly and they require a regular medical check-up schedule. Using the system can assist the elderly with health check-ups, so nurses or care givers can follow the elderly's health easily [3][4][5]. Moreover, due to their functional and physical limitations, the elderly may not be able to inform anyone when they feel sick and it may be difficult for some elderly people to get to the hospital [6]. Using IoT technologies can support self-management in healthcare or self-care at home. Doctors or care givers are able to monitor elderly health and the elderly are more aware of their own health information [7].

In this paper, we propose the Smart Healthcare prototype for basic health check-ups and health monitoring using biomedical sensors which can measure three vales: blood pressure, heart rate and temperature. These values are part of the vital signs and typically measured during a basic health check-up. Web applications for doctors and for the elderly are part of the system as well. When a doctor logs into the website, they are able to view all measured values of their elderly patient using a status color. Therefore, a doctor can observe an abnormal case rapidly and is able to post a comment or suggestion to elderly. The elderly's website was designed by considering their limitations. On the website, they are able to view their own measured values and doctor's comments also we have provided an alert button so when the elderly clicks it, doctors and care givers will receive an SMS. Finally, qualitative and quantitative evaluation methods are used in this study. We interviewed doctors, and the questions tended to focus on the usefulness of the system, the alert button including appropriate display of data. The elderly was asked to complete the survey based on the Technology Acceptance Model (TAM).

II. RELATED WORK

Our work applied sensor technology and the Arduino microcontroller board. The purpose of the system is to help the elderly with health management at home. In this section, we will describe research content that concerns the elderly's situation in Thailand and the use of technology to create a health monitoring system to facilitate taking care of the elderly, patients in hospital or even in their own home.

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A. Elderly Situation in Thailand

In 2016, the total population in Thailand was estimated at 65 million people. The age structure of Thai population is changing rapidly, the population above 60 has reached 17 million or 26% of the total population [8]. Moreover, the number of elderly who live alone is rising because the aging society influences family size. The elderly currently is living in households with only three persons on average. Moreover, the elderly is the group most likely to face health problems. It appears to be an issue with many communities' sections, with the government, healthcare organizations and family taking care of the elderly's health. The result of the health survey shows that 19% of elderly were home-bound because of their physical limitations. They cannot easily go outside. In addition, chronic diseases such as hypertension, diabetes and knee osteoarthritis are also an elderly health problem [1] [9]. The health survey of the elderly from the Health Intervention and Technology Assessment Program (HITAB) said that the elderly with hypertension or diabetes may not know their health information; thus, control of their own health is even more difficult [2]. For this reason, the elderly's health and their safety seems to be one of the biggest problems for every section of society. The idea of using technology for supporting health care service has become an initiative of new generation health care.

B. Internet of things for developing facilitate healthcare services.

The Internet of Things (IoT) is a system in which objects in the physical world could be connected to the Internet by sensors. The idea of using IoT has become a trend in healthcare services as it supports developing ubiquitous connectivity, there is low-cost, high-speed, universal network connectivity, available through wireless technology, and it makes almost everything connectable [10]. Applying the IoT to support health services may have started with the idea of using sensor technology instead of original health measurement devices to create a bio-medical data acquisition system. There are several studies that apply the IoT to create Smart Health monitoring or health care systems such as BITalino which is a bio-signal acquisition system prototype. The main purpose of the system was its capability of acquiring vital signs. The main hardware is Arduino. It is flexible and easy to use hardware that receives data from sensors and sends it to an android device via Bluetooth [11]. Because one major benefit of IoT, is that it is less time consuming, a hospital in Taiwan applied the IoT in order to resolve their nursing shortage. The system consists of wireless sensors connected to a tablet. Using the system can speed-up data collection, reduce human errors and increase efficiency of data collection [12]. Furthermore, there is a smart home project using sensors to capture in-home activity data in real-time including medical sensors (blood pressure, temperature and heart rate), meal preparation, hygiene observation and movement around the house. The tests were performed by using a pilot study, and Mrs. Elle who lived alone was one of their participants. One night, Mrs. Elle suffered a massive heart stroke and later died in hospital. When they viewed the data, they found that Elle's blood pressure had increased and decreased abnormally and her activities had changed drastically one week prior to the stroke. She barely used the bathroom or prepared a meal. The IoT empowers workforce, nurses, doctors or care givers to enable them to perform their tasks with less time, more effectiveness and the ability to monitor their patients anywhere. Importantly, using the technology allows care givers or family members to take care of the elderly even if they are not home. On the other hand, this project did not support emergency situation. The researchers informed that Mrs. Elle will be safe if the system is able to detect the stroke early. Moreover, they claimed that prevention of such incidents depends on collaborative action between the monitoring system and medical organizations [13].

C. Use of E-health to Support Elderly Health Monitoring

Currently, apart from using IoT, there is one technology involved in supporting health care services. The World Health Organization(WHO) defined the word "eHealth" as the use of information and communication technologies (ICT) for health, including treating patients, conducting research, educating the health workforce, tracking diseases and monitoring public health. The Design of a prototype of an e-health monitoring system, aims for a low-cost monitoring prototype which can be used to measure vital signs, store data on a server, analyze the data and when abnormal signs are detected it will notify care givers and doctors through a mobile device and registered email, the system benefits include monitoring health everywhere, low battery consumption, reliable and the system could be used by anyone [14]. As the e-health system can have a beneficial impact on health monitoring, it has motivated researchers around the world including Thailand. E-service for an Aging Society is research relevant to develop knowledge of technology to support a better quality of life for the elderly. The project developed the EasyCare prototype is a system offering improved efficiency in monitoring chronic disease and heart disease patients. The system was evaluated using a survey and the result has shown that patients taking better care of themselves at home. The Ministry of public health has informed that e-health is technology which connects people to a medical center, to provide efficient, equitable and safe healthcare services [15]. In addition, monitoring health and the measurement of vital signs are essential for determining a patient's health status and identifying early signs of illness. The vitals sign measurement in uncritical cases records the respiratory rate, blood pressure, heart rate and temperature [16]. Otherwise, critical care may be needed to measure vital signs closely, because of this need some researchers have attempted to also measure oxygen saturation, level of consciousness, urine output and assessment of pain [17] [18].

D. Web Design for Elderly

Sensory impairment in the elderly, includes visual impairment, cognitive impairment, and hearing loss. These condition have an impact on their daily life; hence, creating a website for the elderly should be consider a high priority. In this study we refer to the following principles of design:

- No Background music.
- Use 12- or 14-point type size, and make it easy for users to enlarge text.
- No flash contents or horizontal scrolling.
- Give instructions clearly and number each step.
- Use single mouse clicks.
- Use high-contrast color combinations, such as black type against a white background.
- Provide a navigation bar and contact information.
- Provide a way to prevent errors and allow users to edit any mistakes [19].

From related work, the benefits of this technology have enabled a new direction of health care services. It can empower the workforce, improve effectiveness of health care services for the elderly and help the elderly to take care of themselves better. In addition, the in-home monitoring technology, that includes several bio-medical measurement tools for the elderly and provides support when emergency situations occur.

III. SMART HEALTHCARE SYSTEM

The proposed Smart Healthcare System has two main parts, hardware and software. The hardware is the prototype which the elderly can use for measuring biomedical values: blood pressure, heart rate and temperature. The purpose of our work is to create a daily or scheduled health check-up so these three values were selected because of the results could be understood by everyone by reading the measured values and compared to standard health value criterion. Moreover, the other vital signs (e.g. oxygen saturation, urine output and level of consciousness) are essential for intensive care and critical cases. The results may require medical knowledge from a nurse or doctor for interpretation. When the elderly finish the measurements, the data will be sent to a MySQL online database. The software part is the web application for both doctor and the elderly.

A. *Hardware*

The main components of the prototype are an Arduino UNO R3 connected with Ethernet shield and e-health shield and two sensors (Blood pressure/Heart rate sensor and Temperature sensor) that are connected to e-health shield via a specific port for each sensor. One input pin on the Ethernet shield is also connected by a red LED light. Fig. 1 shows the final prototype.

Fig. 1. Smart Healthcare Prototype.

After the elderly connect all sensors to their body, the sensors will begin to measure and then if the Arduino is receiving data from each sensor, the LED light will light up to inform the elderly that the measurement step has been complete. To send data to the online database requires users to connect LAN with the Ethernet shield.

B. *Software*

Acquiring data from the Arduino was performed using Arduino 1.6.7 IDE, we wrote commands with C in order to control the Arduino and to establish the internet connection on the Ethernet shield for sending the data to the MySQL database. The main parts of the software are the web application for doctors and the web application for the elderly which was created using HTML5, PHP, jQuery and JavaScript.

1) Doctor Web Application, the main functions includes: displaying measured values of the elderly along with status color of each health records and comment section. The doctors are able to provide the elderly with suggestions or comments. In emergency situations a doctor will recieve notification via SMS when the elderly click the alert button during an emergency situation. In the first page after the doctor has logged in and choses the elderly patient, all measurement records of that person will be displayed with status colors. The color red indicates critical measured values, and the patient should go to hospital immediately if the red color appears. The color yellow indicates abnormal measured values, so the elderly should continuously monitor themselves to see if the value remains abmormal. The color green indicates normal values. The example of the doctor web page shows in Fig. 2.

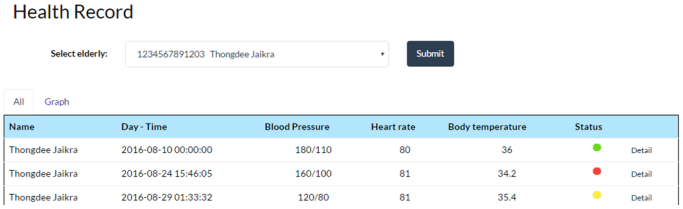

Fig. 2. The page shows all measured records along with status color.

This page, illustrates when the doctor clicks the graph tab, all health records will be displayed. In addition, a doctor can also click the button on the right column to see more details, such as the elderly's profile and comment section. The comment section is an area for the doctor to give advice to the elderly, it displays all comments, date and time as shown in Fig. 3.

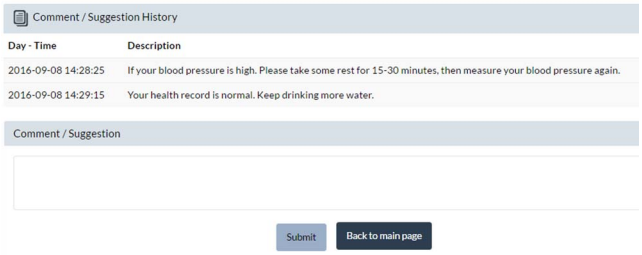

Fig. 3. The detail page which contains elderly profile and comments section.

2) Elderly Web Application, the web application for elderly includes an alert button for saving life. We have created a web page for the elderly according to the priciples of web design for the elderly as we mentioned in related work. The first page after login displays recently measured

records. We use three colors: red indicates critical measured values, so they should go to the hospital immediately. Yellow indicates abnormal measured values, the elderly should continuously monitor themselves to see if the measured value remains abmormal. Green indicates normal values. We use the colors for demonstrating the result to the elderly in a simple and clear way. In addition, Each record shows the doctor's comments. As shown in Fig. 4.

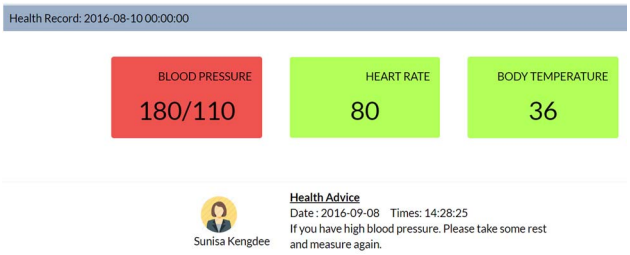

Fig. 4. Displaying the result for elderly.

The top right of the elderly homepage displays the text resize button which allows the elderly to increase or decrease text size. The alert button is available on this page as well. When the elderly clicks the alert button, the page will display message to inform the elderly that an alert SMS was sent to the doctor and care givers. They will receive the SMS, to help them provide prompt care for the elderly. The alert button (red button) and the notification bar appear on the page after the elderly clicks the button is shown in Fig. 5, and the SMS text message sent to doctors and care givers shown in Fig. 6.

Fig. 5. The alert button is at top right of the page.

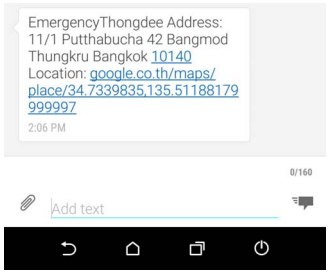

Fig. 6. The SMS text message.

IV. EVALUATION

Evaluation is performed in two parts, qualitative interviewing and quantitative survey based on the Technology Acceptance Model (TAM).

A. Qualitative Interviewing

There were three doctors participated in this interview. The first doctor was female General Practitioners and a Dermatologist. The second doctor were female director of Health Promotion Division: Department of Health, Bangkok Metropolitan Administration and the third doctor were male pediatrician. We described the system briefly to doctor and demonstrated the doctor's web application, and we then demonstrated the alert button on the elderly's website. Then we commenced the interview.

The first question was, "Measuring blood pressure, heart rate and temperature, are these three values adequate to basic health monitoring for the elderly?" According to the answers of the respondents, those three values are part of the vital signs which are used to measure everyone's basic body functions. Blood pressure is usually measured along with heart rate for a general health check-up. The body temperature is usually measured when a patient may have a fever. However, the doctors informed that blood pressure is the most important value, to measure for hypertension. The first and the second doctor said, "As you know hypertension is the chronic disease often found in elderly, we measure blood pressure for hypertension diagnosis". The first and the third doctors also added "the elderly may have white coat hypertension, which means their blood pressure is higher when measured at a medical center than at home because of nervousness; hence, monitoring blood pressure is mandatory for this group and we are recommend them to be measured at home". In addition, additional advice was provided by one doctor suggested frequently measuring blood pressure was required for the elderly who are unable to manage themselves when the blood pressure value was high. The second question was, "Using data for diagnosis, what is the most suitable display of measured data?" Typically, doctors diagnose by using reliable measured values in numbers or in plain text. Plotting a graph may be used to display long-term monitoring data. The final question was, "How do you provide health information to the elderly?" They replied "We explain the results according to what we perceived" As for our system displaying the results by using different colors, the doctors are agreed with the idea because the elderly may be unable to understand equally as well as other age groups. Furthermore, the doctors agreed the alert button was a good idea for life-saving support.

In conclusion, doctors informed us that in measuring the blood pressure of the elderly the result could indicate hypertension, which the most common chronic disease is found in the elderly group. Doctors typically suggest the elderly should measure it yearly or more often in the case of elderly who have uncontrollable blood pressure such as those with white coat hypertension. The heart rate should usually be measured along with the blood pressure of and temperature measured in case of fever or hyperthermia. The proper display of results should be provided in a reliable number format; however, in some cases for those who needed long time monitoring, the result could display in graph form to offer comparison of the results over time. To inform the elderly, of the results, using color would be an easy way for them to understand the information. In addition, the notification by SMS should be sent to inform their family members as well.

B. Questionaire based on Technology Acceptance Model(TAM)

We used a survey as a tool to evaluate user acceptance and it consisted of four aspects; Perceived Usefulness, Perceived Ease

of Use, [20] Attitude toward Usage and Behavioral Intention to Use which consists of 8, 11, 3 and 2 items respectively. [21] The survey was constructed with a 5-point scale (1-Strongly disagree, 2-Disagree, 3-Neutral 4-Agree 5-Strongly agree). The technology Acceptance Model is shown in Fig. 8. The other seven items were used to collect general information (e.g. gender, age and frequency of health surveillance).

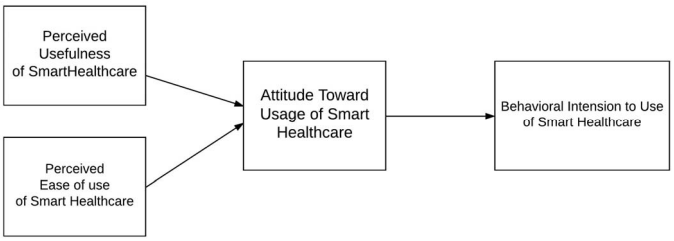

Fig. 8. Technology Acceptance Model (TAM) of Smart Healthcare.

The Cronbach's alpha coefficient for each section are displayed in Table I. The Cronbach's alpha is the coefficient of consistency, used for checking dimensionality of the questions. An Acceptable result should greater than 0.7.

TABLE I. CRONBACH'S ALPHA COEFFICIENT

Factor	Cronbach's alpha coefficient
Perceived Usefulness	0.847
Perceived Ease of Use	0.840
Attitude toward Usage	0.939
Behavioral Intention to Use	0.837

Analyzing the data was performed by using the Statistical Package for the Social Science (SPSS). In this study, our participants were thirty elderly people (aged 60 - 80), including both males and females. All were capable of taking care of themselves and all lived in Thailand. The description of participants is shown in Table II.

TABLE II. DESCRIPTION OF SAMPLE

Attribute	Value	N	Percent
Gender	Male	12	36.00
	Female	18	54.00
Age(years)	60	3	10.00
	61-65	11	36.67
	66-70	9	30.00
	71-75	4	13.33
	76-80	3	10.00
Frequency of health surveillance	Never	9	30.00
	Once a month	9	30.00
	Once a year	9	30.00
	etc.	3	10.00
Technology usage experience	Never	19	63.33
	Moderate	9	30.00
	Good	2	6.67
Health Status	Poor	1	3.33
	Average	23	76.67
	Excellent	6	20.00

The Smart Healthcare System is a new system for health monitoring. The aim of the survey was to collect the elderly's preliminary opinion toward the system. The descriptive statistics of sample are displayed in Table III. The results show that the elderly agree that the system is useful for a health check-up and they have a positive attitude toward the system. It could help them take better care of themselves. The mean values equal 3.46 and 3.44 respectively. However, even if they found the system beneficial, they may be unwilling to use it because using the system was not easy for them. The mean values of ease of use and behavioral intention to use are not strongly agree, its equal 2.79 and 3.10 respectively.

TABLE III. DESCRIPTIVE STATISTICS OF SAMPLE

Factor	$\bar{x}$	SD
Perceived Usefulness	3.46	0.565
Perceived Ease of Use	2.79	0.567
Attitude toward Usage	3.44	0.818
Behavioral Intention to Use	3.10	0.913

We also used correlation, a statistical measure that indicates the extent to which two or more variables fluctuate together. Pearson correlation (P.C.), is a measure of the linear dependence between two variables, the factors correlation's result is shown in Table IV.

TABLE IV. FACTORS RELATIONSHIP

Factors Relationship		P.C.	R^2	Sig.
Independent factor	***Dependent factor***			
Perceived Usefulness	Attitude Toward Usage	827.0	673.0	000.0
Perceived Ease of use	Attitude Toward Usage	606.0-	367.0	000.0
Attitude Toward Usage	Behavioral Intension to Use	715.0	512.0	000.0

The result shown in Table IV, indicates that the elderly perceived the usefulness of using Smart Healthcare positively (Sig. < 0.05 and the Pearson correlation was positive). Therefore, they found using the Smart Healthcare system cause beneficial. The elderly who have positive attitude toward the system and are willing to learn new technology and intend to use the system by themselves in the future (Sig. < 0.05 and the Pearson correlation was positive). On the other hand, as the relationship between ease of use and attitude toward usage is negative (Sig. < 0.05 and the Pearson correlation was negative), it indicates that if the elderly has difficulty in using the system, they may be unwilling to use the system even though it is useful for them.

Furthermore, the R-square (R^2), a statistical measure of how close the data are to the fitted regression line. Is displayed in Fig. 9 and include the TAM with the R-square values. The results shown that perceived of usefulness and attitude toward usage accounts for 68.4% (0.684), attitude toward usage and behavioral intention to use accounts for 51.2% (0.512), whereas

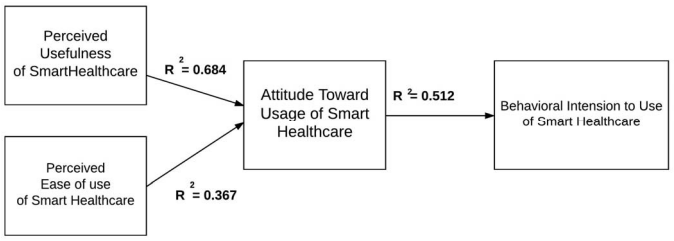

Fig. 9. The Value of Response Variable Variation (R^2).

CONCLUSION

In this paper, we researched doctor's attitudes toward using the Smart Healthcare system and the elderly's preliminary opinions toward the system. The mean values correlate with the TAM interpreted values. The results indicate that doctors and the Thai elderly aged 60-80-year-old realized the benefits of using the Smart Healthcare System. However; as the ease of use are negatively related to attitude toward usage, the elderly's attitude relies on ease of use. If using the system seemed difficult to them, and required learning to use the technology even if a user manual was included and the system was useful, they still demonstrated rejection to learn. This may be because of the exponential technology growth and their unfamiliarity with using computer, smart phones or technology. They have negative thoughts toward technology, and appear unable to adapt to this new technology and feel nervous while using it. These are the significant barriers for learning new technology. In order to help them, we have to provide a guidelines or an assistant. [18] Somehow, there are some elderly who are willing to learn using the technology or smart devices. Therefore, if the elderly is able to change their attitude, technology could provide them the quality, efficiently and safe health care services and ultimately offer them a better life.

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