The Smart Home for the Elderly: Perceptions, Technologies and Psychological Accessibilities : The Requirements Analysis for the Elderly in Thailand

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***Abstract*—Various studies of assistive technology, embedded into the house for helping elderly persons have been introduced. There are many terms used to call this assistive technology, such as smart home, intelligent home, and home networking. The current technologies for smart home system can be divided into two basic categories: passive-intervention devices and active-intervention devices. Passive-intervention devices monitor an elderly person's condition and safety without intervening in his or her care, such as detecting heart rate, respiration, and restlessness by using electrode-slipping device, inserted under mattress pads. Active-intervention devices play more active role in an elderly person care, such as all sensors equipped with alarms, reminder systems, and medication administration system. The smart home technologies enhance a quality of living and allow the elderly to live independently in their homes, while their adult children are working. A successful promotion of smart home technologies does not depend only on the intelligence itself, but it also requires needs, concerns, perceptions, and psychological accessibilities for elderly persons. This paper proposes the smart home model for the elderly in Thailand, based on the stakeholders' requirements, concerns, and perceptions. By given the selected technologies in passive-intervention devices and active-intervention devices, this paper shows the perceptions, psychological accessibility factors, needs, and concerns of specific smart home model for elderly care, using a questionnaire and survey. The interpreting of the results of statistical analysis relies on both qualitative and quantitative methods, therefore the smart home model for the elderly in Thailand can be designed and implemented, practically based on the stakeholders' perspectives.**

Keywords—ageing society; assistive technology; smart home; requirement analysis; passive-intervention devices; active-intervention devices; Thailand 4.0

I. Introduction

In 2015, there were 901 million people aged 60 or over, comprising 12 percent of the global population, the population aged 60 or above is growing at a rate of 3.26 percent per year [1]. The number of elderly persons is expected to accelerate to 1.4 billion by 2030 and 2.1 billion by 2050, and could rise to 3.2 billion in 2100 [1]. By 2040, Thailand, the number of people aged over 60 will be reached 32.1 percent [2]. In 2016, the CIA world fact book shows that the elderly dependency ratio in Thailand is 14.6 [3]. The elderly dependency ratio is the ratio of the elderly population (ages 65+) per 100 people of working age (ages 15- 64). Increases in the elderly dependency ratio put added pressure on governments to fund pensions and healthcare [3]. An ageing society has affected developed countries in many ways, such as laws, public policies, business activities, especially in welfare services and healthcare since the elderly persons are more vulnerable to illness. Problems such as a rise in expenditure of healthcare, quality of care e.g. increased burden on caregivers, insufficient and inefficient care are needed to be more concern in the future [4]. Because of the aging population, National Statistical Office (NSO) Thailand noted that there would be a dramatic shift when it came to the percentage of elderly people no longer working, therefore the government must focus on the budget of public policies of increasing the retirement age in the nearly future [5]. This gradual change is also concerned by Thai government, the prime minister recently put the transformation of ageing society into the Thailand 4.0 development plan to guarantee that the appropriate amount of budget will be invested into the ageing smart living system in the future (Thailand 4.0 is the national agenda that aims to shift the economy, society, environmental sustainability by building strength from within and connecting the country to the global community under the principle of "Sufficiency Philosophy" of the HM King Bhumibol Adulyadej). Therefore, the large amount of money from both private sectors and government will be invested into the elderly healthcare projects. The elderly assisted system or smart home technology is also considering as the partial of Thailand 4.0 driving [6].

This paper will show the brief introduction, the state-of-the-art of the necessary features of the smart home system, the proposed activities recognition system for the elderly daily life and the survey results of the users' requirements of the assisted technology for elderly in Thailand. The contribution of the paper will be as follow; the introduction, the characteristics of the smart home technology that would be suit for the most elderly in many countries (or we can say that this is the universal model of the assistive technology), the proposed practical activities recognition based on Activities of Daily

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Livings (ADLs) and the survey results of the stakeholders' requirements (the survey have been conducted to gather the requirements of the system from the caregivers, the elderly, their adult children and the doctors) of the smart home for the elderly in Thailand.

II. The Assistive Technology

In recent years, the concept of assistive technology has been developed to facilitate self-care and enhance the independence of the elderly living in their homes. Some examples of assistive technology include: devices which compensate services for cognitive, sensory, and physical disabilities; adoptions to the design, lighting, and furnishing of living environments; sensors and network systems that monitor daily activities to help the elderly maintain their health and safety while living independently; and various methods of social communication [4]. The popular term used to call this assistive technology is smart home technology. Smart home technology is "using basic and assistive devices to build an environment in which many features in the home are automated and where devices can communicate with each other" [7]. Smart home technology for the elderly can also be defined as "information-based technology that passively collects and shares elderly residents' information with the elderly themselves and family members in addition to primary care providers" [8]. There are two basic categories of assistive devices which can be used to monitor elderly residents; passive-intervention devices and active-intervention devices [9]. Passive-intervention devices monitor an elderly person's condition and safety without intervening in his or her care [4]. For example, an electrode-slipping device that can be inserted under mattress pads for detecting heart rate, respiration, and restlessness [10]; the motion detection device which provides the resident's location over time, this kind of device can be helpful for the elderly activities recognition, such as the number of bathroom visits, walking up and down stairs, and doing house work. The usefulness of motion detection device is the adoption in fall detection. Active-intervention devices play more active role in an elderly person care [4]. For example, the alert signal will be sent to the family members if the system detects that the elderly has fallen and are unable to get up [10]; reminder systems for elderly users, many of these systems perform the task if the elderly residents do not respond so to ensure their safety [7]; medication administration system, the system can remind the elderly to take medicine on time and keeps reordering when an inventory of pills is running low [4].

Although the use of smart home technologies has an array of potential benefits in improving quality of life for elderly persons, a successful promotion of smart home technologies would require an essential assessment of the needs, concerns, psychological accessibilities, and the perceptions. Some of the concerns that must be investigated before adapting smart home technology include: customizing systems to meet the needs of related stakeholders i.e. elderly persons, caregivers, and elderly families; making systems user friendly; and costs optimizing of modifying existing home to accommodate the assistive technology [7]. People's willingness to use the smart home technology is another barrier [4]. To determine stakeholders' readiness to use this technology, an individual's self-perception of need is one critical factor that should be considering [10]. One example of psychological accessibilities for elderly persons is a fear of lack of human responders since they must be remotely monitored all the time [7].

This paper aims to establish the smart home model for the elderly in Thailand, based on the stakeholders' requirements, concerns, and perceptions. Basically, smart homes are embedded with both semi- and full-automatic systems for various pre-programmed functions and tasks such as elderly assistance system and tools, shade and climate control, lighting control, multi-media control, and temperature control [11]. This cozy living environment is also referred to as ambient intelligence which is sensitive and adaptive to enhance home comfort for everyone [12]. Figure 1 shows the proposed smart home model to assist elderly persons.

The technologies illustrated in figure 1 are the necessary features of smart home for the elderly, which have been identified by [13], the success story of the selected technologies has been shown in Australia e.g. the accommodations and communities for the elderly in Toowoomba (the town in Queensland), an individual design for each smart home depends on health and financial situation of the user [12]. The seven selected smart home technologies are briefly described below:

1. Video monitoring: an activity monitoring system is used to monitor activities in daily life.

2. Fall detection: the exchange of signals between Bluetooth beacons attached in several places in the house and wearable devices can be used to detect falls.

3. Use of robotics: e.g. an intelligence cooking hob and oven; and robot vacuum cleaners.

4. Shade and climate control: fine-tuning control of shading related to home temperature, humidity, lighting, and ventilation.

5. Lighting control: the automatic lighting system allows any lights to be activated on and off when the elderly is in the room.

6. Smart watch: wearable device for medical monitoring, and fall detection.

7. Video door entry systems: the door entry system that allows the elderly to see who is visiting and the elderly can open the door remotely.

We conducted the survey research to seek the perceptions, psychological accessibility factors, needs, and concerns of seven selected smart home technologies (see figure 1) for an elderly care, using the questionnaires and survey. The self-administered questionnaires were designed and the survey was conducted on the stakeholders [14]. To guarantee the high response rate of the survey, the instruction and the purpose of inquiry were clearly explained; and the questionnaires were left to fill out and collected up later. The benefits of this survey method are the accuracy of sampling, the high response rate, and the low rate of interview bias [14]. A survey was carried out at a major local hospital near the university campus, elderly service centers and home-care services at home. The outcomes of the survey indicated the necessary requirements and the

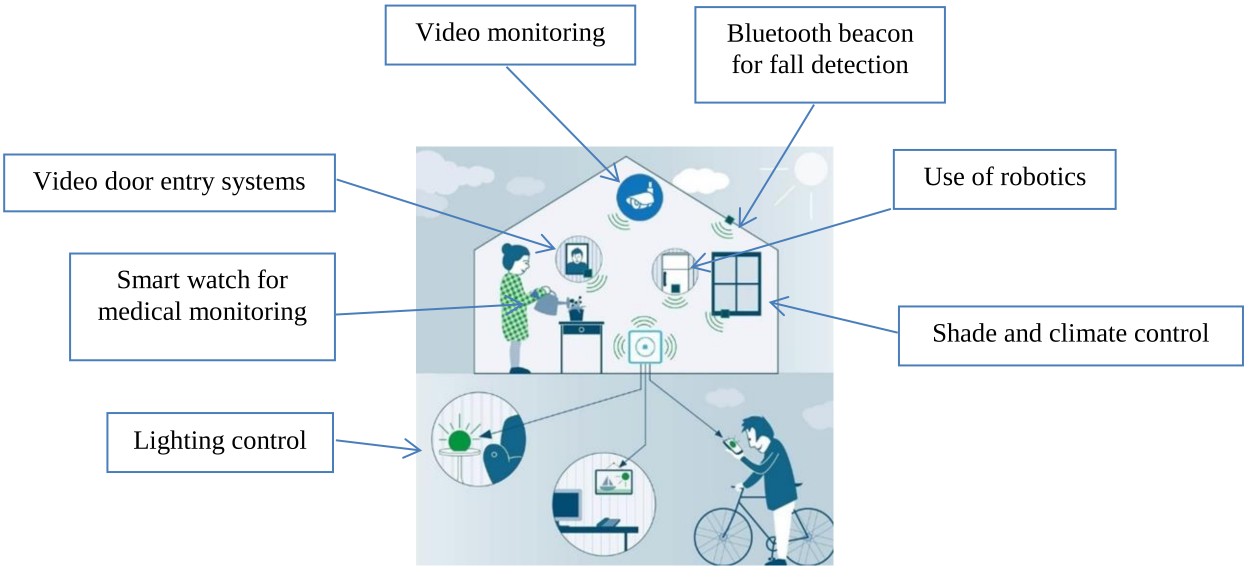

Figure 1. The proposed smart home model to assist elderly persons (Image adapted from http://relaxedcare.eu).

perceptions of the smart home for the elderly. Therefore, this information will be later used as the design principal of the assistive technology projects in Thailand. The results of the survey will be discussed later in section 4.

Once the smart home model has been established, this positioning paper also proposes a practical activity recognition and classification, based on Activities of Daily Livings (ADLs) of Thai elderly. ADLs are divided into 2 types of activities [15]; Basic ADLs (BADLs) and Instrumental ADLs (IADLs). BADLs are the basic self-care activities such as feeding, brushing teeth, dressing, walking, and sleeping. Whereas, IADLs are the activities with instruments such as washing dishes, ironing, watching TV, and sweeping. To recognize and classify these activities, the wearable devices such as the smart watch, the wrist band, the sensor tag and the chest strap will be used to send the signal to the Bluetooth beacons attached in the different places in the house. The features then will be extracted and interpreted using the designed algorithms. A practical activity recognition and classification is very useful for home-based care to help the elderly to remain at home safely if possible.

III. The Activities Recognition

Basically, BADLs/IADLs can be illustrated in table 1. Table 1 describes BADLs and IADLs that would be familiar with the daily activities of Thai elderly such as sitting on the floor for praying and meditation. Thai elderly are often go to the temple every Sunday for making a merit and they always sit on the floor for praying and meditation. For the dressing activity, we also include tying the slipper into this activity type since many of Thai elderly like tying the slipper in the daily life. They only tie the formal cut-shoe when they dress the formal suit for going out.

TABLE I. BADLs/IADLs.

Type	***Activities***	***Activity and independence description***
BADLs	Feeding	Feeds self without assistance (using spoon and fork)
	Brushing teeth	Brushes self-teeth without assistance, including the use of toothpaste
	Dressing	Gets clothes and dresses without any assistance except for tying shoes (tying the slipper is included in this activity)
	Walking	Walks from one place to another without assistance
	Walking upstairs	Walks up the stairs without assistance
	Walking downstairs	Walks down the stairs without assistance
	Sleeping/lie down/sitting on the floor	Sleeps or lies down on a bed and sits on the floor
IADLs	Washing dishes	Washes dishes, glasses
	Ironing	Irons shirt, trousers, shorts, etc.
	Sweeping	Sweeps floor using broom
	Watching TV	Sits on the sofa, chair and watches television

The block diagram of activities recognition for the elderly daily life activities is illustrated in figure 2 below.

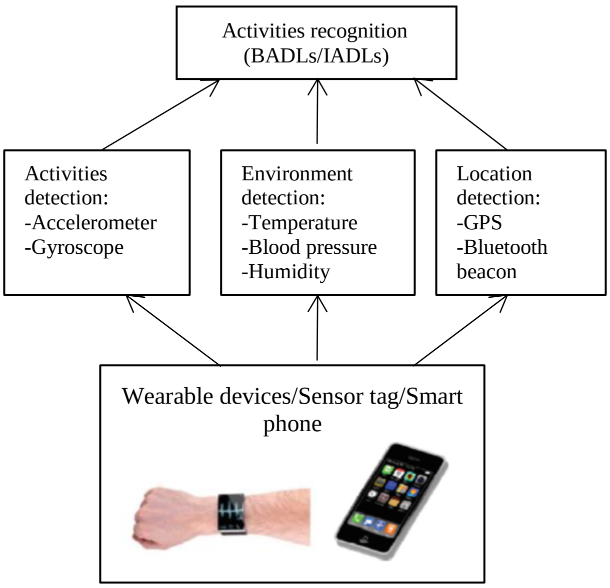

Figure 2. Signals transmission between wearable devices and Bluetooth beacon.

In figure 2, the wearable devices/sensor tag/smart phone will send the signal to the Bluetooth beacon (the beacons will be attached within the house). The health information such as blood pressure, temperature, heart-rate, movement and location will be transferred and recognized. Figure 3 shows activities recognition based on BADLs/IADLs.

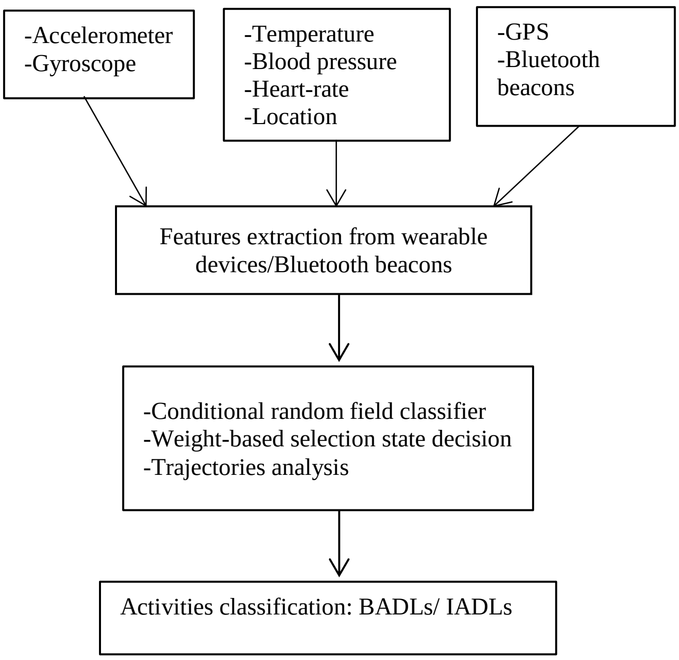

Figure 3. CRF/weight-based selection state decision/trajectories analysis for activities classification.

The features such as acceleration X-axis, acceleration Y-axis, acceleration Z-axis, acceleration magnitude, temperature and altitude features will be extracted into 2 major groups:

- Time-domain features: mean, maximum, minimum, standard deviation, variance, range, root-mean-square, correlation, difference and main axis.
- Frequency-domain features: spectral energy, spectral entropy and key coefficient.

The necessary features will be combined and the weight will be adjusted for CRF classifier. The results of activities will be classified into BADLs and IADLs. The challenge of the proposed method is how to integrate the useful information from multiple sensory devices (from seven selected smart home technologies), mentioned earlier for the activity recognition in daily life.

The Proposed Method:

The brand-new sensor tag from Texas Instruments Incorporated (TI) model CC2650STK has been selected for our proposed method. This sensor tag kit provides the data sources for activities recognition, the selected data sources are contactless IR temperature sensor, humidity sensor, gyroscope, accelerometer, magnetometer, barometric pressure sensor and on-chip temperature sensor. The necessary features for this proposed method are acceleration X-axis, acceleration Y-axis, acceleration Z-axis, acceleration magnitude, temperature and altitude features. The important features such as acceleration in X-Y-Z and acceleration magnitude will be used in fall detection. The wearable sensor tag from TI and the prototype model of the proposed method are shown in figure 4. Once the sensor tag has been sync to the application, the features from data sources will be transmitted to the application. The chart of accelerometer data source is shown in figure 5.

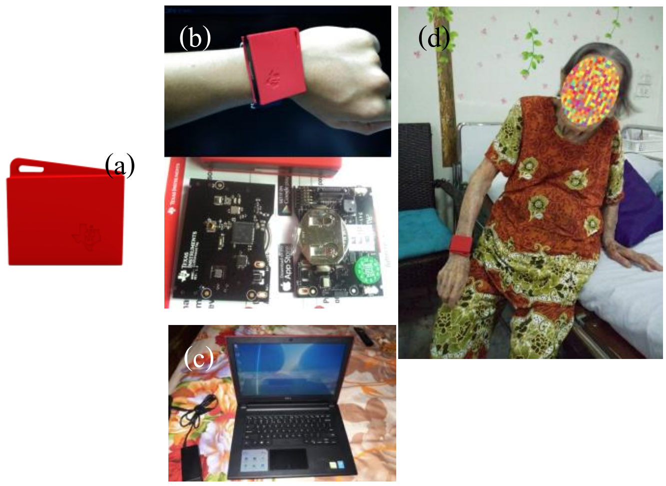

Figure 4. The prototype of the activities recognition system ((a) The sensor tag model CC2650STK, (b) The MCU of CC2650STK and its wearable model, (c) Laptop for data sources transmission, (d) The elderly in homecare center wears the device for the data collection).

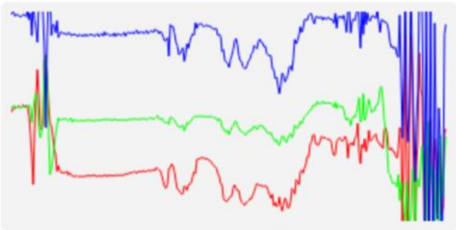

Figure 5. The application charts the accelerometer data source.

The proposed method consists of 2 parts:

1) The offline mode; The elderly will wear the wearable sensor tag device and they will do the daily life activities described in Table 1. The CC2650STK will transmit the multi-sensory signals (acceleration X-axis, acceleration Y-axis, acceleration Z-axis, acceleration magnitude, temperature and altitude features) to the linear prediction model [16]. This prediction model aims to minimize the error of the signal prediction, the model is widely used in many applications such as speech recoginition, spectrum analysis and signal restoration. The result of LP coding then will be training for the classification step.

2) The online mode; The unknown multi-sensory signals will be sent from the wearable device and transformed into the LP coding. In classification step, the unknown will be classified into BADLs/IADLs as mentioned in Table 1.

The linear prediction is the signal simulation in the time interval of n denoted by $f(n)$. By combining the linear weight of n previous signals, the linear prediction can be derived as

$$f^\wedge(x) = \sum_{i=1}^{n} c_n(i) f(x-i) \tag{1}$$

where n is the integer in the discrete time interval, $f^\wedge(x)$ is the prediction value of $f(x)$ and $c_n(i)$ is the coefficient value of the prediction. The error of prediction denoted by $e(x)$ is the different between the actual value of the signal $f(x)$ and the prediction value $f^\wedge(x)$, the error of prediction can be derived as

$$\begin{aligned} e(x) &= f(x) - f^\wedge(x) \\ &= f(x) - \sum_{i=1}^{n} c_n(i) f(x-i) \end{aligned} \tag{2}$$

Normally, the error of prediction is also the signal which will be used to improve the prediction value in the feedback loop. The feedback equation can be derived as

$$f(x) = \sum_{i=1}^{n} c_n(i)\, f(x-i) + e(x) \tag{3}$$

In practical use of equation 3, the matrix form of the signals is

$$f(x) = F(x-1)c(x) + \varepsilon(x) \tag{4}$$

where $F(x-1) = [f(x-1), f(x-2), \ldots, f(x-n)]$ and $c(x) = [c_1(x), c_2(x), \ldots, c_n(x)]^T$.

The block diagram of the proposed method is shown in figure 6.

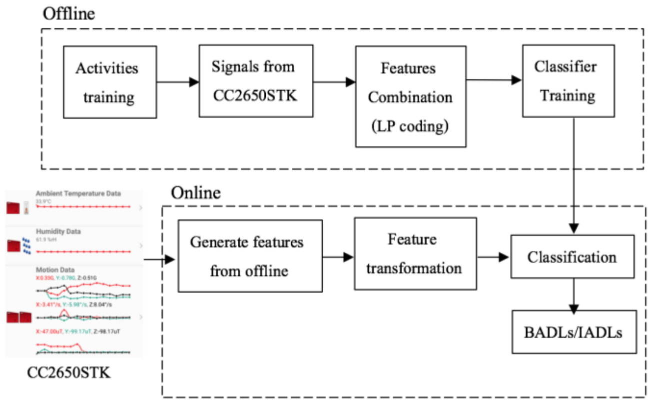

Figure 6. The proposed method.

The future experiment for fall detection in the video monitoring system (see figure 1), features extracted from video will be used for action recognition. The evolutions of consecutive frames can be modeled by trajectories [17]. The execution rate (velocity) of activities may often vary; therefore the trajectories analysis together with the features from the sensor tag can be combined to improve the accuracy of fall detection.

IV. The Survey Results

20 questionnaires had been done by the users in the hospital which are the doctors, nurses, the elderly and the adult children; the other 20 questionnaires had been collected at the private home users and the elderly service centers. The results of a survey we conducted revealed that the stakeholders were highly agreed about the necessity of the assistive technology/the embedded system/the smart home for the elderly (the average scores are 4.23). The survey also shown that the smart watch/the wearable devices is the first technology that the stakeholders will choose if they have limited budgets to buy the devices for the elderly to assist their independent living, whereas the second running up technology that the stakeholders will choose is the video monitoring system. The results of the survey are shown in table 2.

TABLE II. THE SURVEY RESLUTS.

5: Strongly agree 4: Agree 3: Agree or disagree 2: Disagree 1: Strongly disagree

Statements	***Min***	***Ave.***	***Max***
I have concern that the assistive technology is very important to help the elderly living alone in the house.	3	4.23	5
The assistive technology should be optimized in term of cost and flexibility to the existing home accommodation.	3	4.27	5
From the 7 selected technologies in figure 1, choose the best 3 technologies that fit for your need (in the case that your family have the limited budget).			
1. Smart watch	3	4.19	5
2. Video monitoring	3	4.11	5
3. Fall detection	2	4.00	5
The embedded devices should be installed in the house with the concerning of the elderly privacy (The elderly may feel the lack of privacy since they must be remotely monitored all the time).	3	4.00	5
Using basic devices such as smart phone with application is not enough for monitoring elderly.	1	3.46	5
The assistive devices should provide the interaction/communication capability.	3	4.12	5
The reliability of the assistive system/maintenance/on-site services from the service providers.	4	4.47	5

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