# iHOME : An Ambient Intelligence Mobile CrowdSensing Smart Home System

**Lim Poon Koon, and Manmeet Mahinderjit Singh**
*University Sains Malaysia, Malaysia, limpoonkoon@gmail.com; manmeet@usm.my*

**ABSTRACT**
iHOME is a monitoring system that aims to help caregivers take care of their elderly. The main module of the HOPE system provides an intelligent ambient environment by employing prediction based on elderly's daily activity monitor. The goal of iHOME is for non-invasively monitor the elderly behavior pattern and to notify the caregiver upon abnormality detection such as fall detection in the their movement pattern. This enhances the safety of the elderly so that he/she could live independently. The technology behind this includes Arduino-based ambient sensors, tracking based sensors, Case-Based Reasoning prediction algorithm and Pebble wearable application.

**Keywords**: RFID, Arduino, fall detection, case-based reasoning prediction, smart homes, smartwatch

## I. INTRODUCTION

Apart from Malaysia, the world is also ageing rapidly, as we see, population ageing is a long term trend which began several decades ago. People aged 60 and older make up over 11 percent of the global population, and by 2050, that number will rise to about 22 percent. Globally, 40 percent of older persons aged 60 aged 60 years or over live independently, that is to say, alone or with their spouse only (United Nation, 2013). Current systems that introduce by industries provide many types of care services but issues in term of its operational and efficiency still exist.

When an elderly person still has the physical and mental capacity to live independently, but wants companionship with others who are their age, independent living could be a good option. On the other hand, they still need to add the luxury of services and amenities that independent living provides for maintain their independence. Therefore, industries have already targeted on this aspect and present numbers of a system to fulfill the elderly's requirement.

Besides that, in the evolution of embedded Internet or Internet of Thing (IoT), besides of the embedded sensors with other component, it also consumer centric mobile sensing and computing devices such as smartphone mobile devices. Mobile devices will auto consuming the sensor data contribute by the number of sensors whereas opportunistic sensing is more autonomous and user involvement is minimal (Ganti et.al, 2011). In this project, we are going to achieve Mobile Crowd Sensing by utilizing various ambient sensors and mobile devices. This work is an extension of the existing system known as AMISHA (Lim et.al, 2015).

The aim of this paper is to provide a non-invasive protection with real-time monitoring system for elderly. The focus is on emphasizing how the combination of multiple sensors improves the locate elderly without boundary. Besides that, by utilizing ambient sensors such as motion sensor and weight sensor and placing them correctly into the elderly's environment, the system is able to analyze the daily activity pattern of the elderly and it can inform the caregiver upon abnormality detection such as a missed event or fall. Using the same prediction feature, the system can also intelligently control the home appliances. The objectives of HOPE system-To provide a non-invasive monitoring of elderly behavior pattern and robust notification engine which react upon abnormality detection for enhancing safety and independent living. This paper is organized as follows. Section II reviews related study of existing works of research or industries' field. Section III describes the system implementation of system and introduce the predictive and the fall detection algorithm and hardware implementation of this project. Section IV contains discussion of the system. Finally, section VI contains the conclusion and draws some guideline for the future works.

## II. BACKGROUND STUDY OF PROTOTYPE

Based on the requirement of the project, study of related technologies has been done. The study can divide into two sections:

i. Smart Home, Ambient Intelligent and Prediction
ii. Fall detection Algorithm & Design

### A. Smart Home, Ambient Intelligent and Prediction

i) Smart Home
Researchers around the world have been focusing on the development of the smart home that could potentially assist the daily activities of people. As early as 2002, one of the idea and product discussed in (Das et.al, 2002), the MavHome is a smart home that

uses prediction algorithms to predict and thus automate those activities. In the paper, an example is given that the smart home is able to warm the heater prior to the waking up of user and ready the coffee maker once the user wakes up. This particular smart home uses four layers of agent architecture. The first layer is the physical layer which consists of the sensors, actuators, networks and agents. This is the layer of physical hardware within the house. The second layer is the communication layer where operations such as formatting and routing data done by software to different agents for different needs. The third layer is the information layer that gathers, stores and generates knowledge useful for decision making. Lastly, the decision layer selects actions to execute upon receiving information from other agents.

Besides its architecture, the specialty of MavHome is the three algorithms used for it to accomplish the prediction and automation. The first algorithm is LeZi-update. It is an approach to the location management problem which uses movement histories to learn likely future locations. The second one is SHIP (Smart Home Inhabitant Prediction). The algorithm uses sequence matching with inexact allowances and decay factors to determine the most likely next inhabitant interaction with the home. Instead of automating all the activities, MavHome uses Episode Discovery (ED) to determine which episodes (activities) in an inhabitant are significant and automates them.

ii) Ambient Intelligence

Ambient intelligence (Cook et.al, 2009) is an emerging discipline that brings intelligence to our everyday environments and makes those environments sensitive to us. Ambient intelligence (AmI) research builds upon advances in sensors and sensor networks, pervasive computing, and artificial intelligence. There are five major contributing technologies to AmI: sense, reason, act, secure and HCI. Since AmI is designed for real-world, physical environments, effective use of sensors is important. Some examples of sensors used are strained and pressure sensors on floors, sound sensor for security and speech recognition, image sensor for contextual understanding. To further categorize them, the wired sensors are often cheaper, more robust and use power sources while wireless sensors are more expensive, without wiring and relies on batteries. Another important aspect of AmI is reasoning, without proper model and algorithm to make reason of the collected sensor data, the data are useless. There are different activities to be recognized for different environments. For instance, lifestyle pattern recognition is more suitable in smart home while medicine intake pattern analyzing should be designed for hospital usage. Very often these pattern recognitions are highly related to spatial and temporal reasoning, very little can be done within an AmI system without an explicit or implicit reference to where and when the meaningful events occurred. For a system to make sensible decisions, it has to be aware of where the users are and have been during some period of time. Apart from the reasoning, HCI (Human-computer interaction) is another big field in AmI as many believe that it should be made easier to live with. While AmI offers great benefits to users by customizing their environments and unobtrusively meeting their needs, privacy and security challenges still exist. The current applications of AmI include smart homes, health monitoring and assistance, hospitals, transportation, emergency services, education, and workplaces.

iii) Human Movement Prediction

In the paper of Akhlaghinia et.al (2007), a few soft computing prediction techniques in ambient intelligence are discussed. One of the major technique is Case-Based Reasoning (CBR). As discussed in the paper, CBR relies on the analysis of data of the sensors to determine the best case to represent the daily activities undergone by the monitored person. The components of CBR consist of case representation, case retrieval, case reuse, case adaptation, case storage and the case base. Case representation will use the sensor data to generate a case based on it and the case retrieval will match the generated case using cases from the case base. User actions will influence the case adaptation process and case storage will store the adapted case. One example of this will be assuming a person goes to a lounge in a predictive building at 7pm and sets his or her favorite light intensity and temperature. In this case, the system will generate a new case in the database for the situation. When the same person goes to this location at the same time in the future, the favorite light intensity and temperature will be set automatically by the system as an existing case in the database matches this situation.

### B. Fall detection Algorithm & Design

Cao et.al (2012) designed an Android-based smartphone fall detection application is able to detect a fall event with high efficiency. In the work , the hardware used is a HTC G8. It is a smartphone that is equipped with MSM7225 ARM CPU and most important a tri-axis accelerometer that is used for the fall detection. For the software of this system, Android 2.2 Platform is used and the application written is based on Java and runs on the Dalvik virtual machine.

The equation used in the smartphone application is a threshold algorithm which is more classical in fall detection. However, the algorithm is made to be able to dynamically adjust its threshold value and time window according to user information such as the ratio of height and weight, sex and age. The algorithm is tested with real data of 400 falls and 1200 ADLs and hence the sensitivity of the algorithm is calculated to be 92.75%. The sensitivity of the adaptive algorithm is higher than the classical algorithm by 6%. The method is proven to be very useful and accurate. However, the smartphone needs to be attached to the waist of the user. It may not be the case in a home environment where users are not usually carrying their smartphones around in the home. Cheffena (2015) research present a system using Smartphone to detect fall. In the study, audio features such as spectrogram, Mel frequency Cepstral coefficients (MFCCs), linear predictive coding (LPC) and matching pursuit (MP) are considered. Besides, four different machine learning classifiers are considered for distinguishing between fall and no-fall events based on the extracted audio features. The classifiers are k-Nearest Neighbor Classifier (k-NN), Support Vector Machine (SVM), The Least Squares Method (LSM) and Artificial Neural Network (ANN). The classifiers are implemented in MATLAB environment.

A 10-fold cross validation is employed to carry out the experiment and analysis. 10 partitions of 26 sound events each are used with 1 of them being the test/validation data and 9 others being training data for the classifiers. The final result shows that best performance is achieved using spectrogram features with ANN classifier with sensitivity, specificity and accuracy all above 98%. The classifier also has an acceptable computational requirement for training and testing. However, there are some limitations with the system. For instance, the young volunteers are used in the experiment, the fall characteristics may not be totally similar to the actual falls by the elderly. Besides, the maximum distance of the subject to the smartphone is limited (around 5 meters) and the system may not work when the person is in a different room.

## III. HOME CARE AND POSITIONING SYSTEM FOR ELDERLY (HOPE) IMPLEMENTATION

This section will present the implementation of HOPE.

### A. Architecture of iHOME System

Figure 1 shows the overall system architecture design. Basically, the system divides into 4 parts which are users, indoor, outdoor and server.

i) User

The caregiver and admin can access the web application through the computer, whereas caregiver and elderly are accessing mobile applications through Windows Phone devices. Besides that, elderly required to wear a Pebble smart watch and attached RFID wearable tag with an unique ID. The fall detection algorithm is implemented in the Pebble smart watch.

ii) Indoor

The active RFID readers are located at indoor coverage, which responding to elderly's wearable for indoor tracking purpose. The Arduino-based ambient sensors include different kind of sensors and are placed at different locations for different purposes. For example, motion sensors placed at each location are used to determine the presence of elderly while weight sensors placed on the bed or sofa determine if the elderly is using the particular furniture. All of these ambient sensors transmit data to the Arduino-based parent node in which the node will propagate the data to the web server via Internet connection.Raspberry Pi is configured to simulate different home appliances. It allows real-time changes made to the home appliances' settings to be reflected immediately as the Pi constantly fetch the settings from the web server.

iii) iHOME Server

The web server will host a bunch of RESTful Web services that responding to web and mobile application.

The prediction service and notification service are also hosted in the server. A scheduler is used to run the prediction algorithm daily to update the adapted cases to the latest.

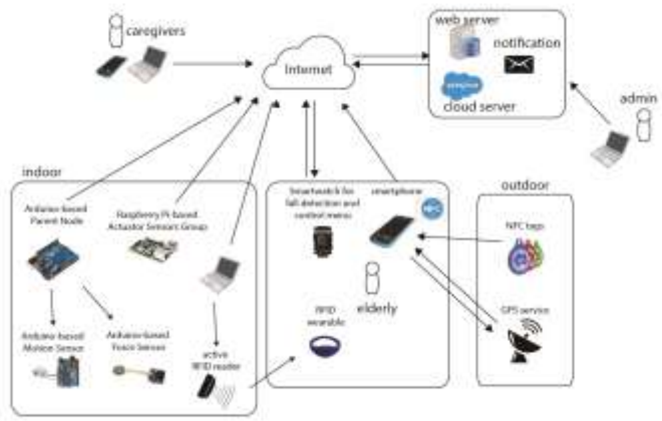



**Figure 1. Overall iHOME system architecture**

### B. Use Case of the system

Figure 3 shows that use case diagram of HOPE system. From the diagram, there are 4 actors of the system which are caregiver, elderly, admin and biometric cloud server. Each actor will describe detail as follows:

i) The caregiver is able to:

- Monitor indoor real-time position

- Send/receive notification
- Trace featured location of elderly visited
- Navigate to elderly current/latest position
- Set elderly's home location
- Receive help message
- Authenticate access mobile application
- Configure elderly's biodata
- Manage user (elderly)

*ii) Elderly is able to:*

- Wearable update preferences
- Control home appliances
- Being track position
- Navigate to the home
- Call for help to caregiver
- Authenticate access mobile application

*iii) The administrator can:*

- Do tasks as a caregiver
- Troubleshooting system
- Activate the wearable application
- Sensors pre-configuration & setup
- Setup automation for notification
- Monitor server condition

## C. Hardware implementation of the system

i) Arduino-based Ambient Sensors

Arduino boards are used along with different sensors and transceiver to develop the ambient sensors. The framework used in the development process is MySensors libraries. Figure 2-3 shows two different implementations. All the nodes communicate through the transceivers.

Parent Node:

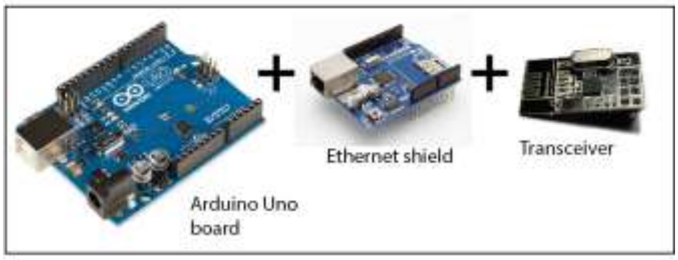



**Figure 2. Arduino-board (Parent Node)**

The parent node consists of an Arduino Uno board, an Ethernet Shield and a transceiver.

Child Node (Motion):

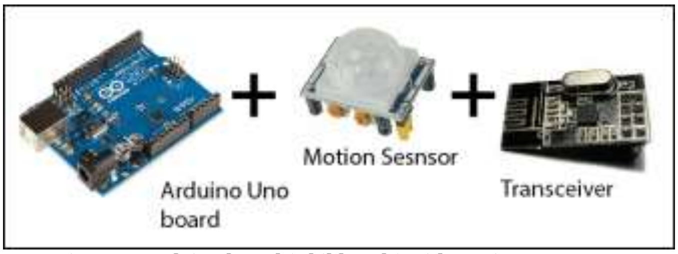



**Figure 3. Arduino-board (Child Node) with Motion Sensor**

The child node (motion) consists of an Arduino Uno board, a motion sensor and a transceiver.

ii) Raspberry Pi-based TV

Raspberry Pi board is used along with basic color LEDs (red, blue and green) and transistors to simulate the status of home appliances, TV, in this case.

iii) Active 2.4 G RFID reader

Active RFID reader is used to locate elderly at each zone of indoor coverage for position elderly by using wearable RFID tags.

## D. Algorithm implementation of the system

i) Fall Detection Algorithm

For prediction algorithm implementation, algorithm in Cheffena ( 2015) is used. The basic steps involved in the calculation are divided into two: pre-processing of BMI data and accelerometer data analysis. For the preprocessing step, Threshold max ($Th_{max}$) and Window trim ($T_{win}$) are calculated based on the age, sex and BMI of the elderly. These values are stored and are sent to Pebble smart watch. For the accelerometer data analysis, it is done on the smart watch. Firstly, the resultant acceleration $A_{sum}$ is obtained from the following equation:

$$A_{sum} = \sqrt{A_x^2 + A_y^2 + A_z^2}\ .$$

The resultant acceleration signal is partitioned using the $T_{win}$ and for each segment, $A_{max}$ and $A_{min}$ are captured. The fall is determined if $A_{max} > Th_{max}$ and $A_{min} < Th_{min}$ and $T_{min} < T_{max}$ and signal will be sent from Pebble to the web server immediately.

ii) Prediction Algorithm (Case-Based Reasoning, CBR)

For the prediction algorithm to work, CBR as discussed in Cao et.al (2012) is implemented. The algorithm has been modified to suit the processing need and data available in the system. The algorithm will go through several steps as listed at below to come out with the daily activities schedule (adapted case) of the elderly:

- Retrieve sensor data for latest three days and store them into three different lists

- For each list, partition the sensor data according to location and time and extract the sensors involved in each segment
- For each segment, look for, best suited case from the case base, determine the start time and the time of the case and search for actuator data to get the last settings of home appliances involved. Adapted case is generated for each segment
- Combine the adapted cases from all three days into one single schedule

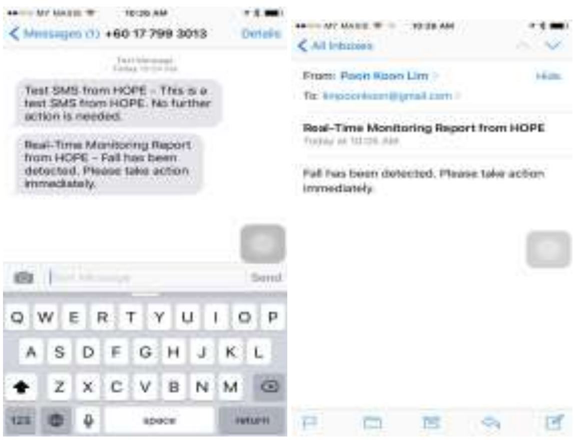
### E. Case study of HOPE Based on Various Scenarios

i) Scenario of elderly moving from one location to another

In this scenario, the elderly will move from bedroom to living room. He or she has just woken up from a nap and would like to watch TV in the living room. Upon reaching the living room, the motion sensor in the living room is triggered. The system will determine if the trigger is fresh (firstly triggered) and will automatically turn off appliances such as light and fan in the bedroom. At the same time, the light and fan in the living room will be turned on with the favorite settings analyzed by the prediction algorithm. When the elderly proceeds to sit on the sofa, the weight sensor on the sofa will be triggered, as set using the automation feature, the activity will switch on the TV along with his or her favorite channel. Figure 4-10 illustrates the notification samples, mobile and wearable user interface for home.

ii) Scenario of elderly abnormal behavior at indoor

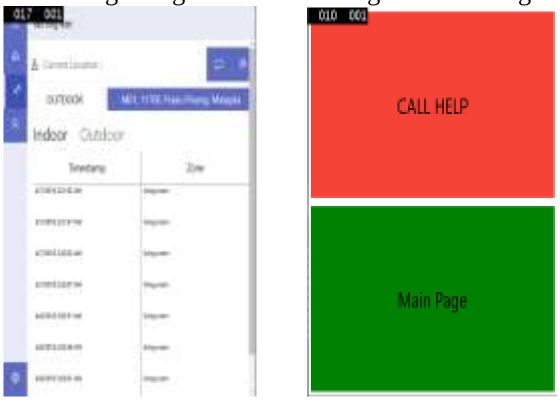
The abnormal behaviors of elderly include fuel or missed activity. If the Pebble smart watch detects if elderly has fallen down, signal will be sent to the web server. The web server will send notifications such as SMS or email to the caregiver as configured.




SMS Notifications Email Notification

**Figure 4 – 5. Sample notifications from HOPE**

Login Page Caregiver Main Page




Caregiver show Elderly detail Elderly First Page

Elderly Main Page

**Figure 6 – 7. User interface of iHOME mobile application**


Location Selection Page


Home Appliances Page


About Page

**Figure 8 – 10. User interface of iHOME wearable app**

## IV. SYSTEM DISCUSSION

The system will benefit to the caregiver and elderly by providing the better and caring home environment without caregiver putting full of attentions on elderly. It provides the non- invasive protection of elderly without limiting his/her freedom. In control of the indoor environment by elderly, provide elderly comfort condition. By detecting abnormal behavior of the elderly can enhance the safety of elderly and prevent elderly falls in a dangerous situation. Besides that, the fall detection of smartwatch can acknowledge by caregiver immediately and allow the caregiver react in time.

However, system provided the monitoring and tracking platform for elderly for the caregiver, but the limitation of this system still exists:

### A. Mobile Phone

For outdoor coverage, GPS and network access are required to track elderly position and exchange data to cloud server. But there are some places is not coverage of internet and GPS. Therefore, an assumption made is that the mobile phone is always connected to network, no matter is mobile data service or public Wi-Fi. Besides that, the alternative of outdoor tracking service, NFC tags that contain geolocation data assuming deployed around the home region or the city by assuming the smart city concept achieved. Mobile devices using the GPS and mobile service data is high consume battery life of the device which will limit elderly movement at outdoor. Therefore, the system cannot ensure that elderly be tracking and monitoring in 24/7.

### B. Ambient Sensors

Despite the ability of ambient sensors to detect the environment, they cannot differentiate if there is more than one person at the location. For example, motion sensor in the living room can only detect the presence of people, but they cannot determine the exact person in the room.

### C. Pebble Smart Watch

To make sure the fall detection work, the watch app needs to be activated 24/7. This limits the ability of the elderly to use other watch apps as he or she will need to switch the running app back to the HOPE watch app in order to let the fall detection works correctly. Besides, the Pebble smart watch relies on mobile device to send data to the web server. Hence the overall cost of implementation has increased, but since there are high possibilities that elderly will have at least a smartphone with them, the impact is reduced.

## V. CONCLUSION & FUTURE WORK

As a conclusion, this system is able help elderly live independently by monitoring and tacking elderly real-time. This project definitely can provide the bigger convenient to caregiver and elderly as well. As part of the future plan, there are a couple of ways to improve this system:

- Replace smartwatch that consist fitness, medical check sensors to monitor the heartbeat of elderly as a medical alert device
- Include a specialized GUI to let caregiver create custom automations to suit each adapted case from the prediction algorithm according to his or her preferences
- Create a wearable device that has all the functionalities needed for the system because it is more convenient to bring a single device around in the house especially wearable

## REFERENCES


Akhlaghinia.M.J, Lotfi.A, Langensiepen.C, “Soft Computing Techniques in Ambient Intelligence Environments,” IEEE, 2007.

Cao.Y, Yang.Y, Liu.W, “E-FallD: A Fall Detection System Using Android-Based Smartphone,” 9th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD 2012), 2012.

Cheffena.M, “Fall Detection using Smartphone Audio Features,” 2015.

Cook D.J, Augusto J.C, Jakkula V.R, “Ambient intelligence: Technologies, applications, and opportunities,” 2009.

Chaudhary.S, Nath.R, “A Multimodal Biometric Recognition System Based on Fusion of Palmprint, Fingerprint and Face”, 2009 International Conference on Advances in Recent Technologies in Communication and Computing.

Das S.K, Cook D.J, Bhattacharya.A, Edwin O. Heierman III, Tze-Yun Lin, “The Role of Predicition Algorithms in the MavHome Smart Home Architecture,” IEEE Wireless Communications, December 2002.

Ganti R.K, Ye.F and Lei.H , "Mobile crowdsensing: current state and future challenges," in IEEE Communications Magazine, vol. 49, no. 11, pp. 32-39, November 2011.

Lim.J; Mahinderjit Singh.M; Ahamad Malim.N ; Ambient Intelligence Smart Home Automation (AMISHA) System , i4CT Kota Kinabalu ( to be published)

United Nations Department of Economic and Social Affairs | Population Division, “World Population Ageing 2013”, 2013.