Ambient Intelligence in a Smart Home for Energy Efficiency and Eldercare

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Abstract. In this paper we present our research results related to smart monitoring, control and communication with the main objective of energy efficiency and eldercare in mind. One of the main objectives of this research work is to use multitude of different sensors to monitor activities in a smart home and use the results to control the home environment to meet the objectives of energy efficiency and eldercare. Here we present the application of the smart monitoring to a prototype system.

Keywords: Ambient Intelligence, Energy Efficiency, Eldercare, Smart Homes, Sensor Integration, Environment Monitoring.

1 Introduction

It is observed that people in many countries including Brunei, America, Japan, Singapore and New Zealand are now living longer and living well for longer periods of time. This has created a relatively new and growing area of health care and provider services, known as elder care. Elder care encompasses a wide variety of issues, including choosing a safe environment for the elderly person to live happily and safely and other related areas. In addition, what if elderly couples choose to live on their own or if elderly persons are living alone? For effective elder care, the traditional healthcare services need re-thinking. Instead of focusing on providing services to cure illnesses, it would be more effective to provide constant healthcare monitoring and raise an alert if something amiss is suspected. This not only lowers the cost of the healthcare as early treatment is less costly and very likely the elderly patient is still able to visit the nearby clinic or hospital, but also the quality of life of the elderly would be better as nobody likes to be sick or bedridden. Without proper care, the will to live could be impacted. Constant monitoring is also needed in order to detect cases that require urgent attention which otherwise could be life threatening, such as in cases of serious household accidents including fall, burn etc.

In our research project we will also look at the use of different modalities such as video and audio sensors for home monitoring for eldercare and energy efficiency. In this project, we used multi-modal sensing to model and analyze humans and their

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behaviour patterns with the aim of understanding better the well being of humans through constant monitoring and also help reduce their energy bills by central monitoring and control to make the society healthy and energy efficient.

Mainly we developed technologies for energy efficient homes and also homes that can support elderly people, disabled people using smart technologies. Alternatively these techniques can serve as a mode of protecting homes/factories and their contents from theft. Moreover this can be a remote monitoring and automatic alerting facility for a control centre operated by a single person. In this project stationary audio/video sensors, mobile sensors, floor sensors, and other sensing devices are installed in a model home/office and connected to a stationary and a mobile processing unit. The processing units will then determine the activities, usage of energy and other events by integrating the multitude of sensing devices to a main control center and subsequently it will act accordingly to reduce the energy usage and alert the authorities if any abnormalities are detected.

2 Energy Efficient Smart Home Technologies

There are a growing number of new research proposals and findings in related to new and alternative energy technologies. However there are many easy and cheap ways to reduce energy use at our homes by efficient energy management. Most of which simply require a change in behaviour. However we did not see much effort in this direction of research where by one can reduce the energy usage by monitoring and automatic control to make a home energy efficient. In the paper 1 we have proposed such a system to reduce the energy usage of a typical home using WIFI technology enabled smart switches. This is a prototype system intended to change the energy usage pattern of people. In this project we are looking ahead to enhance this technology by adding various different types of sensors to enhance the monitoring and control of the environment.

Energy plays an important role in many of our homes. We use it for many purposes including keeping cool during the day and providing light to our homes in the night, refrigerating and cooking our food and boiling our water. Apart from reducing the energy usage it may also require to find out ways of increasing the renewable energy input to the home. In the paper 2 the authors propose the use of solar cells as renewable energy source.

There are some other approaches in which researchers have devised artificial intelligence based techniques to build energy efficient systems 3. This paper presents and overview of commonly used methodologies based on the artificial intelligence approach with a special emphasis on neural networks, fuzzy logic, and genetic algorithms. A description of selected applications to building energy systems of AI approaches is also outlined. In particular, methods using the artificial intelligence approach for the following applications are discussed: Prediction energy use for one building or a set of buildings (served by one utility), Modelling of building envelope heat transfer, Controlling central plants in buildings, and Fault detection and diagnostics for building energy systems.

In Australia there are many organizations that promote the energy efficient homes. Sustainable Energy Development Office is one such organization 4. They provide methodology and required skills for the new home builders and people who intend to renovate their existing homes so that the finished home is energy efficient. In recent days there is a growing demand for intelligent homes and there are a number of professional service providers for such homes 5. They have commercial level light controllers, curtain controllers and other type of sensors and controllers.

In Singapore there is a model smart home known as STAR home 6. There they conduct research in relation to intelligent homes and among the themes they investigate entertainment, health care, security and power efficiency has been given high priority. In Japan they often call smart home a Ubiquitous home 7. In many smart home installations it was quite interesting to see the integration of multitude of sensors to harmonize the activities in a home with the help of modern technology. In the Unites States some companies even mass produce smart homes 8. It is a fine example of how fast the smart or intelligent homes are going to invade the communities who can afford the new technologies.

However these commercial level devices/systems developed in developed countries are not particularly applicable for countries like Brunei as it is required to understand the climate and the living patterns of Brunei people and their culture. Hence in our paper we first tried to acquire some of these commercially available sensors and install them in a prototype system in Brunei and monitor the patterns.

3 Experiment Setup

The preliminary data collection for this project has been performed at a model room in the Institute of Infocom Research, Singapore. However, in order to get realistic results it is necessary to acquire further data and analyze them for different scenarios and different sensor inputs suitable for Brunei climate and culture. The authors have demonstrated the use of smart home technologies to reduce energy consumption in an average house in their research work partly presented in the papers [1]&[2].

In this research we design, implement and monitor with the aim of future energy efficient and eldercare enabled home. The following two figures show the execution scenario in pictorial form.

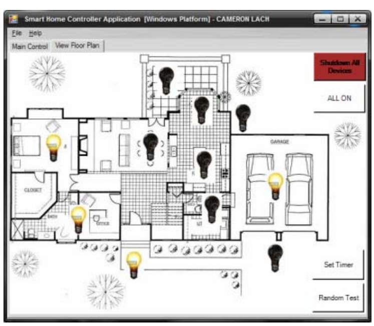

Fig. 1. Smart Home Control System for Energy Efficiency – Device Map (as of [2])

Fig. 2. Smart Home Control System for Energy Efficiency – GUI (as of [2])

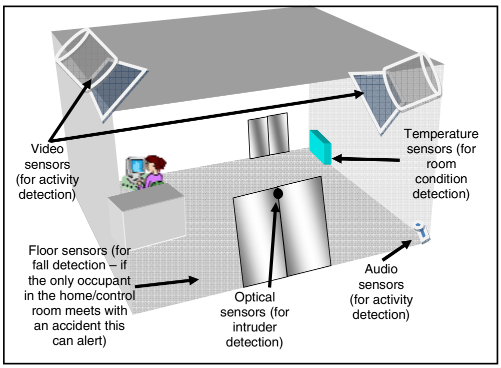

Fig. 3. Smart Home with various sensors

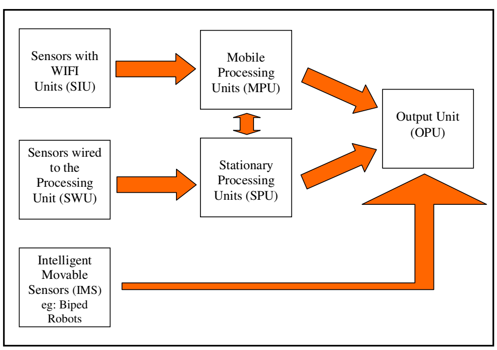

Fig. 4. Example Scenario of the Operation

The first task of this project is to install a single SWU (Sensor wired to the Processing Unit) connected to a SPU (Stationary Processing Unit). For the SWU a high resolution video camera will be used. For the SPU a high end desktop computer with a capture card is used. Then the video data will be acquired and stored in the hard disk of the desktop for offline processing. The video data captured contained various different human activities, such as walking, crying, shouting, talking on the phone, falling etc. Subsequently the video data are analysed and activities are extracted using image and video processing algorithms. Subsequently the offline processing will be upgraded to real-time processing when the processing algorithms are fully optimized.

Then a testing with a single SIU (Sensors with WIFI Units) and a MPU (Mobile Processing Unit) will be carried out. For the SIU we will initially use a WIFI capable mobile phone with a built in camera. Subsequently the data are analysed and activities are extracted.

In the next phase of the project other kinds of sensors such as audio sensors, optical sensor etc. are tested. The detected activities will then be sent to an OPU (Output Unit) for alerting the necessary personnel if there is amiss inside the house or inside the control room. Once all the necessary components are investigated the sensors and processing units will be installed in a real model house for real time testing with real occupants.

4 Video Sensor Based Event Recognition

We used a state-based approach to recognize events and actions. The state diagram in Fig. 5 shows the transitions between states defined for a tracked human in the image sequence.

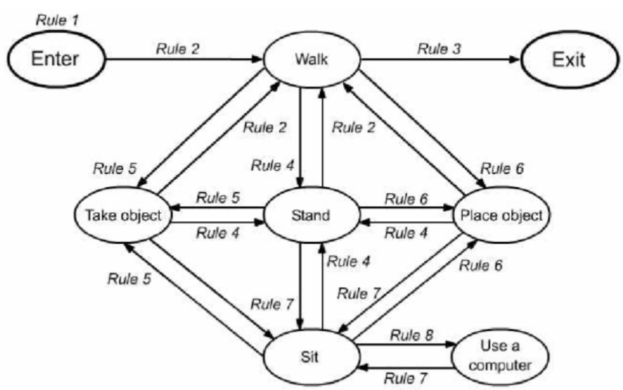

Fig. 5. State Transitions for Video Sensor Based Activity Detection

5 Audio Sensor Based Event Detection

Video sensor based event detection approach has some short falls like it fails to cover the entire room and also event non-detection due to occlusion. Hence in this section we

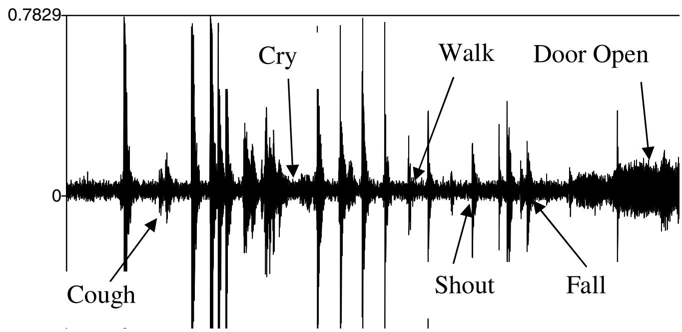

Fig. 6. A sample long audio file used for audio based event detection and segmentation

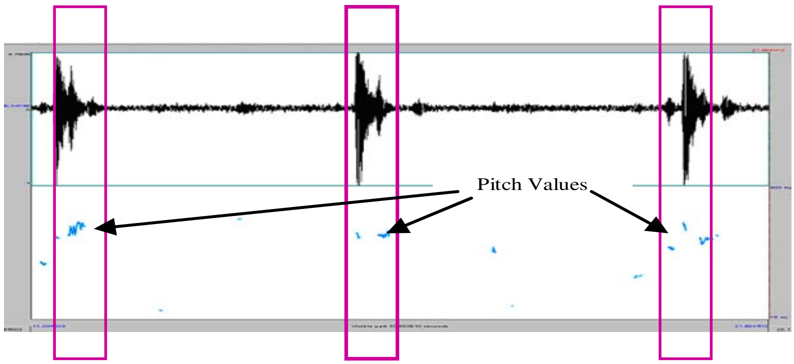

Fig. 7. Pitch values detected at coughing events

consider audio sensor based actions. Here we adopted a combined pitch and intensity based audio event detection to classify cough, walk, cry, door open, fall, and shout audio events into their respective group. Example audio file are shown in the Fig. 6-7.

6 Results

Forty image sequences containing different actions and events were used to evaluate the accuracy of action and event recognition. Table 1 shows the accuracy of recognition of events in our proposed system.

Then we used audio data for event detection. The separation of cough, cry and shout (vocal track generated sounds) from walk, door-open and fall was done using pitch contour detection. This is due to the fact that vocal track generated audio signals consists of its inherent formant frequency component. Then cough, cry and shout were further separated using the intensity contours. Cry had a constant intensity profile, while cough and shout had some abruptly increased intensity values. However cough and shout were easily separated by using the energy of the audio pulses. Walk has its inherent property of gradual increase of the intensity profile till the steps are

Table 1. Video based event detection

Video events (no of events in the video clips tested)	Classified correctly	Classified incorrectly	Not classified	Average Detection Accuracy %
Enter (20)	17	3	0	85.0
Walk (35)	31	4	0	88.5
Exit (20)	19	1	0	95.0
Stand (15)	13	0	2	86.7
Sit (15)	14	0	1	93.3
Use PC (12)	9	3	0	75.0
Take object (5)	5	0	0	100.0
Place object (5)	5	0	0	100.0
Unusual event (9)	8	0	1	88.9
Overall average accuracy				**90.3**

Table 2. Audio based event detection

Audio Events (no of events in the audio clips tested)	Classified correctly	Classified incorrectly	Not classified	Average Detection Accuracy %
Cough(16)	15	1	0	93.8
Walk (25)	24	1	0	96.0
Cry (12)	12	0	0	100.0
Door open (19) (Enter or Exit)	16	2	1	84.2
Fall (14)	12	2	0	85.7
Shout (10)	9	0	1	90.0
Overall average accuracy				**91.6**

getting close to the microphone and then gradual decrease when walks past the microphone. The following table (Table 2) shows the results of the audio monitoring sensors we have obtained.

7 Conclusions

In this paper we have presented our research results related to smart monitoring, control and communication with the main objective of energy efficiency and eldercare in mind. Our video based analysis has given us a comprehensive set of results to understand the human actions in an enclosed room or in a home environment with the possible detection of Entering, Walking, Exiting, Standing, Sitting, Using a PC, Taking an Object, Placing an Object and any other unusual event including falling. These activities can be used to control the room lighting, air-conditioning etc. to reduce the total energy usage of the house.

Then the introduction of the audio event detection increased the possible types of actions that can be detected like cough, cry and fall which may be hard to detect just by video only. These short duration and scattered events may occur outside the coverage area of the video camera system in the house and hence may go undetected if only a video based system was employed. These audio based sensors are vital in homes aimed at automated eldercare to reduce the privacy problems that may occur due to video based sensors.

Currently we are working in the prototype implementation of other sensors such as ultrasound and temperature sensors to increase the knowhow of the ambient intelligence to provide the features of a smart room facility constructed in one of our research facilities to obtain real life data and their analysis.

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