Intelligent Homes with Energy Monitoring and Control using Smart Phones

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Abstract -

In this paper we present the details of a device we have developed which can automatically monitor the movements of people in a facility and control the lighting and air conditioning to minimize the wastage at the same time displaying the energy consumption details in any type of smart phone device. Not only it can display the status of the facility at a given time but also it can be operated manually to switch off some unwanted devices from anywhere in the world. It may be a device that a frequent traveler may like to have installed in his house since he can randomly on/off lighting in his house while he is away to mimic that there are people in the house. Some preliminary calculations shows that using this concept a typical house can save up to 30% of electricity whereby reducing the amount of carbon dioxide emitted to the environment. This percentage can be even more for a facility with many occupants with many unoccupied rooms.

We are living in a world full of electronic appliances, television monitors, and computers. When we get into our car we will see a multitude of displays to indicate the amount of petrol left in the tank, engine temperature, current petrol consumption rate and many more. Did you ever wonder why none of our ultra modern homes have any such displays even just to tell how much our energy consumption is? Did you ever wonder why we cannot tell how many air conditioners are on at a given time in the house and how many are running in rooms without any occupants? Using our invention which we called i-Home we provide an innovative solution to this problem. We have designed and developed a device which can provide a solution by using ultrasound distance measuring sensors (PING Sensors), motion (PIR) sensors, pressure sensors, temperature sensors. The i-Home will monitor the movements of people and control the lighting and air conditioning to minimize the wastage automatically. Also it has a unique feature where it can display the status of the home at a given time through the inbuilt LCD monitor or on any of the smart phone devices which has the facility to connect to the Internet. Moreover the devices can be operated remotely using any smart-phone.

Keywords – Intelligent Homes, Sensors, Energy Efficiency, Microcontrollers

I. INTRODUCTION

Recently, importance of environment monitoring has become an essential part of the society. Environment monitoring can aid us as an alerting mechanism to monitor events and to rectify when something is out of norm. It can also be used to predict pattern of events so one can have better plan ahead. Home is an environment that can be monitored for its energy consumption, security, health care and many more. Home is one that consumes energy to run most of appliances such as cooling, heating, lighting and more. There are many ways to reduce the energy consumption in a house. One of the best ways is to use sensor technologies and wireless communication which has potential to reduce the energy usage and increase awareness towards the energy saving by controlling and monitoring human activities and environment in a house. This led us to the idea of building a home with multiple sensors technologies.

The aim of our proposed device is to use multiple sensors for monitoring home activities and to control and act as a real time monitoring mechanism towards home activities. Here our main focus is to control and monitor towards energy efficiency.

In this product we have designed and developed three microcontrollers and in built LCD system that control and displays status of several sensors namely measuring distance (PING Sensors), motion (PIR) sensors, pressure sensors, and temperature sensors for monitoring the home activities.

II. THE I-HOME SYSTEM DESCRIPTION

This section describes structure of the i-home system with related hardware components and software flow charts.

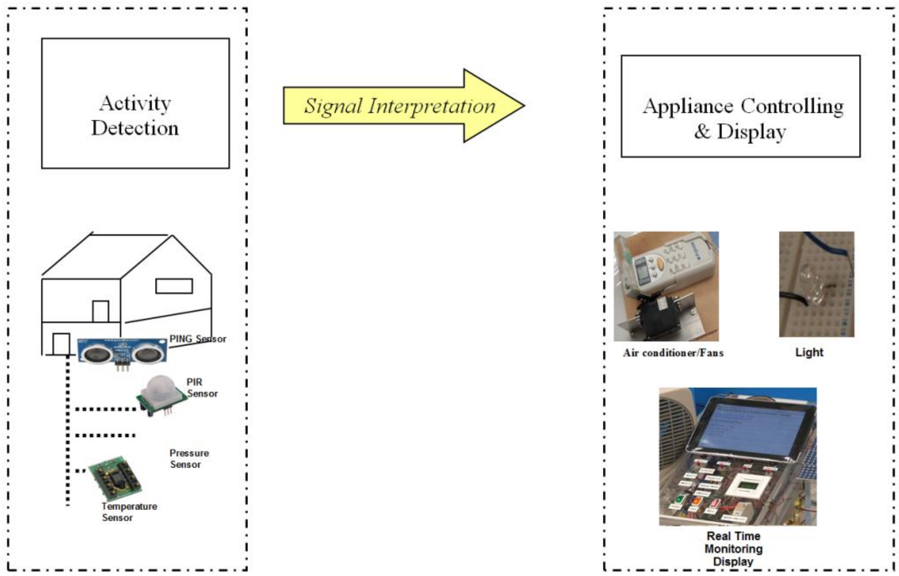

Figure 1 System Overview

The main hardware of the i-Home controller consists of two Slave processors, and 1 Master processor. The programming flow chart of the Master Processor and the Microcontroller Connection diagram are given in Figure 2 and Figure 3 respectively.

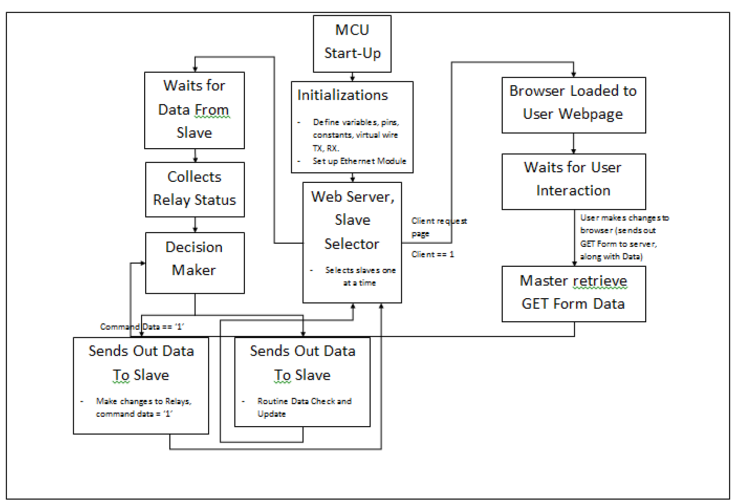

Figure 2 Programming Flow Chart of the Master Processor

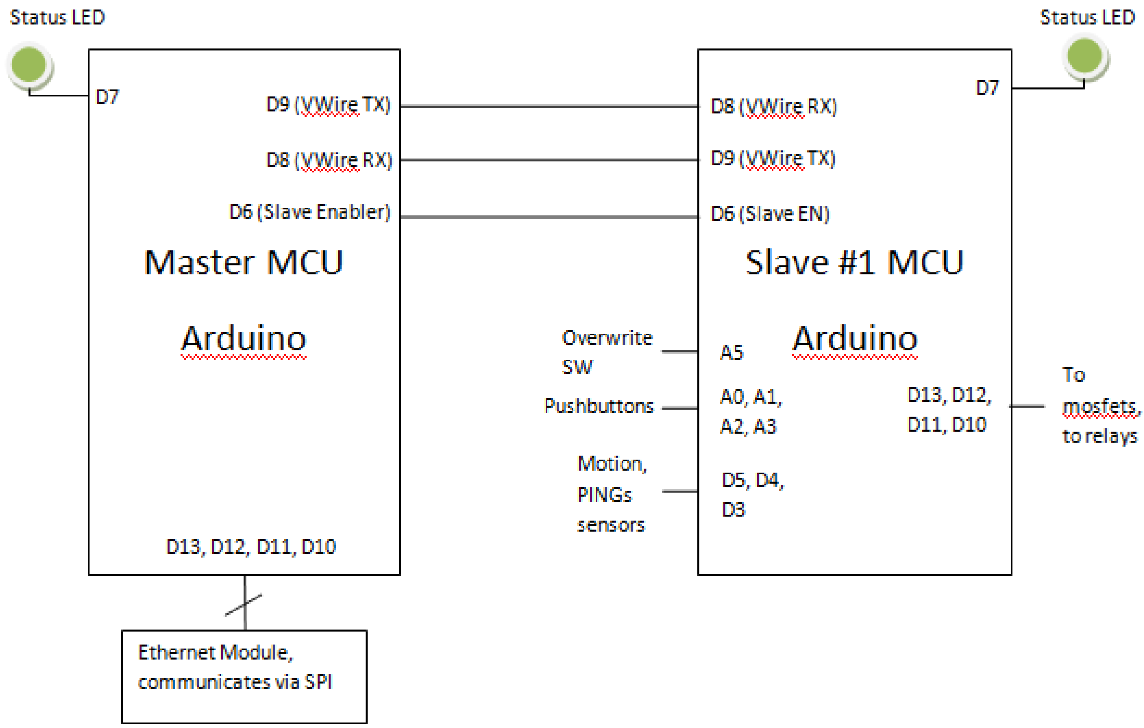

Figure 3 Microcontroller Connection Diagram

III. APPLICATION OF MULTIPLE SENSORS FOR ACTIVITY DETECTION

This section describes various sensors (external to the invented unit) that are used to support the system implementation. We have used Pressure sensors based Air-Conditioner/Fan Control, Motion Sensors (PIR) based Lighting Control and Distance measuring (PING) sensor based on Door control as well as LCD control panel.

A. Pressure Sensor Based Air-conditioner Control/Fan

Air conditioner is one of the appliances that contribute to high energy consumptions. In our house, we used Flexiforce sensors or pressure sensors in order to improve the energy efficiency as well as giving comfort where cool air can be directed towards the occupants in one detected area. Pressure sensors will be the best solution to detect exact location; for example while a person is sleeping or sitting in one place (Figure 4).

Figure 4 FlexiForce force Sensor

The Flexiforce sensors have a sensing area device which defined by the silver circle on top of the pressure-sensitive ink which extends to the connectors at the other end of the sensor, producing the conductive leads. The pressure sensitive ink is a polymeric binder of phenoxy polymer [1]. The sensing area of the sensor measures in a way that resistance is inversely proportional to applied force. When no force or pressure is applied to the sensor, the resistance is high while as the force is applied to the sensor, the resistance then decreases in value.

In our i-home prototype test bed, the pressure sensors placed under a carpet to detect the pressure exerted on it. Whenever the person stands or sits on the carpet, it will change the resistance of the sensor and the microcontroller can locate the position of the person in order to switch on the air conditioner and fans.

B, Temperature and Humidity Sensing

Maintaining temperatures in each room in the house may also help to control the energy usage. In our system, we have used Sensirion temperature and humidity sensor to monitor the changes in temperature and humidity (Figure 5).

Figure 5 Sensirion Temperature and Humidity Sensor

The Sensirion Temperature and Humidity sensor forms a single temperature and humidity measuring unit. Temperature sensors are silicon based temperature-sensing ICs that are designed to output digital representations of the temperatures. In principle, it works when two identical transistors are operated at a constant ratio of collector current densities; the difference in their base-emitter voltage is proportional only to absolute temperature. Thus the temperature sensors produce an analog voltage output where the voltage proportional to absolute temperature [2].

C. Motion Sensors (PIR) Based Lighting Control

Lighting system in a house is also one of the significant appliances that may need to be controlled by using sensors in order to reduce energy usage. We have used Passive Infrared (PIR) sensors (Figure 6 and

Figure 7) in the house. The PIR sensors are motion detector that senses emitted infrared radiation through a Fresnel lens and infrared-sensitive element.

Figure 6 Passive Infra-Red Sensors (PIR)

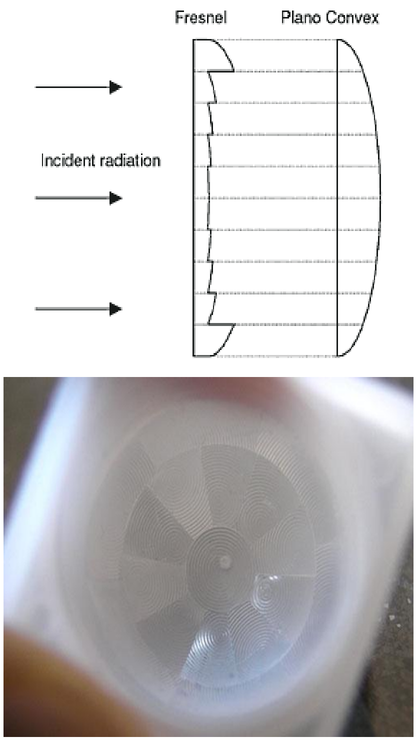

Figure 7 A Fresnel lens

Passive Infra-Red (PIR) Sensors have two sensing elements made of a pyroelectric sensor with a rectangular crystal in the center that can generate electric charge when exposed to infrared heat radiation energy. The two sensing elements are connected in a way that they cancel signals caused by vibration. When the sensor is idle, both sensing elements detect the same amount of Infrared. However when person passes in front of a sensor, they will activate the sensor element and produced output wave signal.

In our i-home prototype setup, we used PIR sensors to switch off lights when there are no movement in the room and switch on the lights when someone enters.

D. Distance Measuring Sensors (PING) Based Door Control

The Distance measuring (PING) sensors are able to detect the distance of an object in front of the sensor within a range of 3cm to 3.3m (Figure 8). The PING sensor transmitting a burst of ultrasound at 40 kHz called a ping (above human hearing range) and hits an object, then the burst echo returns back to the sensor. The sensor provides an output pulse based on the time of the reflected echo. Then using the speed of sound and the measuring time or echo pulse width, the distance- to –target can be determined [4]

Figure 8 PING Sensor

In our i-home prototype, we used the PING sensor to detect the presence of occupants as a person enters through a door or leave through the door of the house. The PING sensors can be used to transmit signals for the opening and closing of the doors (Figure 9).

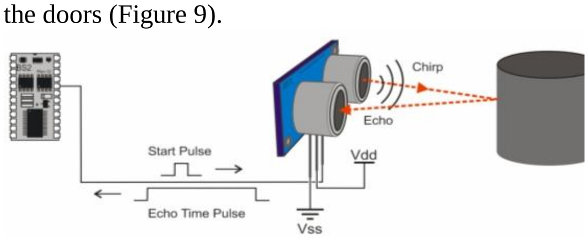

Figure 9 Shows the Echo time pulse detected by the PING sensor [4]

IV LCD Display and Smart Phone Interface

Monitoring is one of the stages that can be done to keep occupants aware and reduce the energy usage in a house and also for safety reason. In our self configurable eco home, we have an LCD for monitoring the status of the home. We have developed LCD interface that able to display changes in status of hardware and sensors, temperature of the rooms and also display amount of energy consumption. We don't need to run the interface on computer desktop but efficiently the monitoring can be viewed on the LCD screen, which is relatively low cost, small and marketable product. The LCD interface could track the energy usage in the house. The occupants will be able to know which lights, fans or air conditioners are on at a given time in every room. Hence the occupants inside the house will get a better monitor and more conscious of their energy usage. The LCD interface also shows the status of doors of the house. Thus based on the LCD monitoring, safety security of the house is known every time people coming in and leaving the house. Also using the inbuilt web server the information can be displayed in any external smart pone display such as the iPad shown Figure 10.

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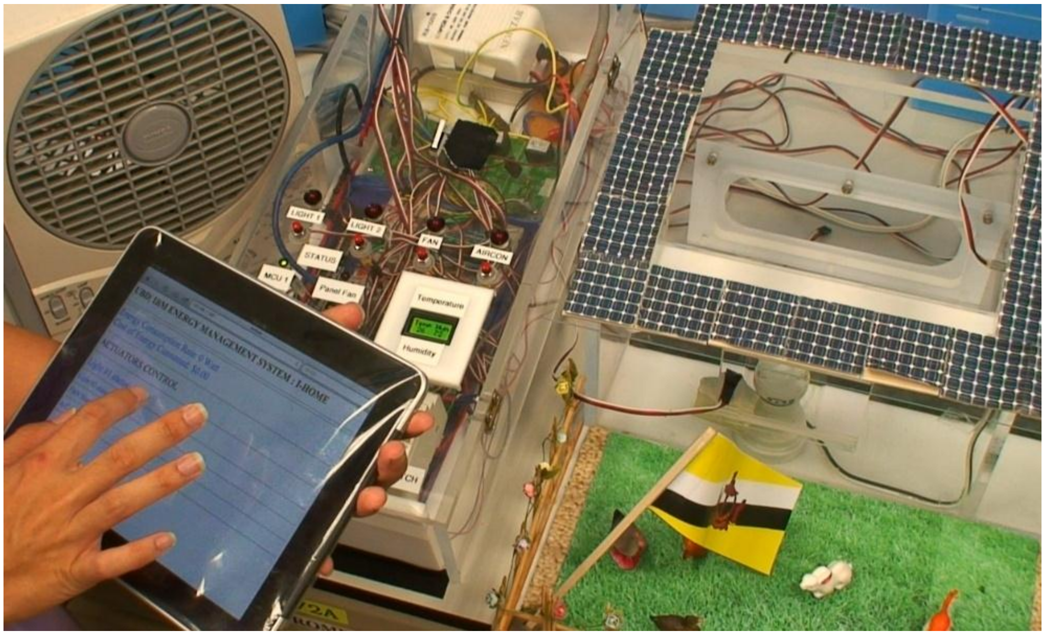

Figure 10 Smart Phone (i-Pad) used to manually control the lighting and air-conditioning

V Comparison of Normal and Automated i-Home Scenarios for Energy Efficiency.

After setting up various sensors we then calculated the energy consumption in a normal home and smart home. We have assumed the following two scenarios for the comparison of the energy consumption in a normal home and a smart home.

Table 1 Scenario in a Normal Home Environment

Time	**Scenarios in a Normal Home Environment with two persons**
7 am to 5pm	Lights at foyer/garden, Living room , Room 1 and Room 2 are switched off
5 pm to 6 am	Lights at foyer/garden are switched on (Night time)
5.30 pm to 9 pm	Lights in the Living room are switched on. AC system is also switched on. During this hours person A and B may move back and forth from living room and their rooms .Lights and the AC are not switched off.
9 pm to7 am	Person A and B are in their own rooms and lights in living rooms are switched off. The AC is also switched off.

Table 2 Scenario in an automated i-Home

Time	**Scenarios in a automated i-home with two persons**
7am to 5pm	Lights at foyer/garden, Living room, Room 1 and Room 2 are switched off.

5pm to 6am	Lights at foyer/garden are switched on when dusk is approaching and go off at Dawn time, (around 5.30 am) using photo sensors. • At 5.30 am, lights in rooms 1 and room 2 also switched off when approaching Dawn time. • If outside the room is bright then the light inside the room will automatically match bright to the outdoor lighting. These are controlled by photo sensors.
5.30pm to 9pm	Lights in the Living room are switched on within this hours when person A in the room. AC system is also switched on. • However, at 6.30 pm to 7.30 pm, person A leaves the living room and Lights are automatically switched off. Person B also not in his room (room2), thus no energy from lighting system is being used. These are controlled by motion sensors.
9pm onwards	Lights in the living room are switched off when person A and B are not in the room. AC system is also switched off. These are controlled by motion sensors.
10.30 pm	Person B went out of his room 1 for a while, lights in the room are automatically switched off. When Person B back to his room, then lights are on again. These are controlled by motion sensors.

After assuming the above two scenarios we have obtained the results shown in the Figure 11 below.

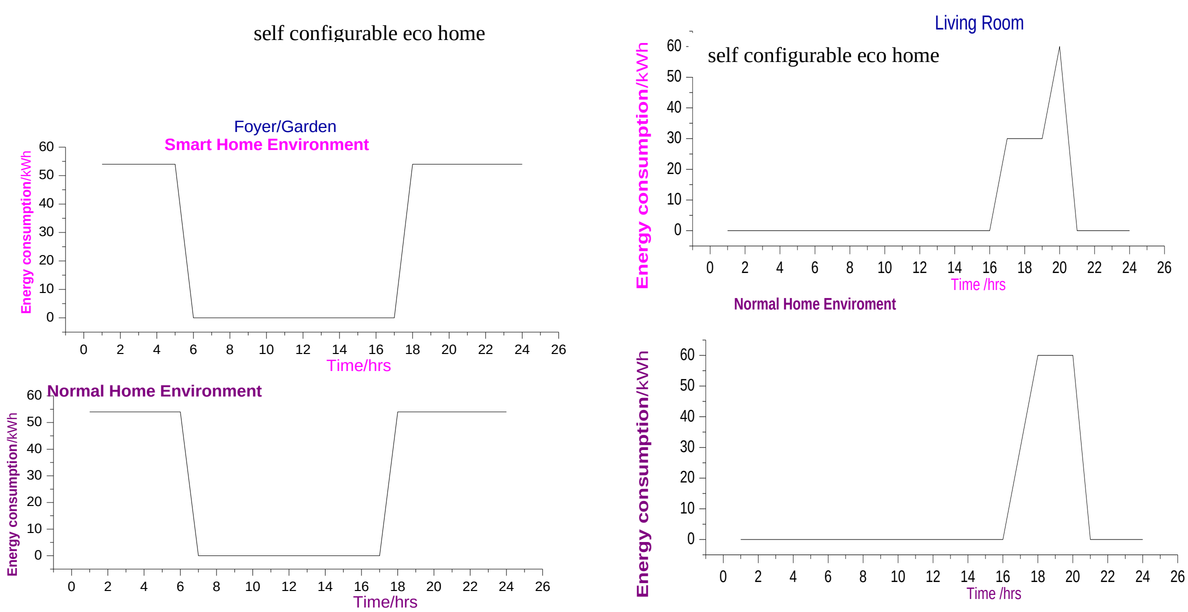

Figure 11 Energy utilization in a normal and an automated i-Home

Using this sample scenario we found out that the energy consumption of a normal home which was about 35 kWh can be reduced to about 22 kWh using our i-home technologies, that is about 30% savings. Final outlook of our product is shown in the Figures 4.1 and 4.2. The product that we designed and developed can monitor inputs from multiple sensors and control lighting, air-conditioning and other devices accordingly to reduce the energy consumption. It has an LCD interface to display the status of the devices and occupant's activities. Also it has remote connectivity option whereby any smart phone can be used to monitor and control the devices in the house. This product has a huge commercial potential since it can help reduce energy bills for average homes. It is highly marketable since the cost is very minimal. It will support economically since as a whole it will help any country to reduce the carbon foot print. Also it will enhance the quality of life, health, and support elder care and security for those in assisted living communities.

VI CONCLUSION

In this paper we described about our invention in which we have designed and developed a product that can control the environment of a home using the feedback of a multiple sensors. The product can monitor and control the air conditioning systems, lighting systems, fan arrangements etc. In our design we used an LCD Interface to display the activities locally. For remote operation any type of a smart phone which has the ability to connect to the Internet can be used. Hence it is relatively low cost and can be seen as a standalone marketable product which can reduce the energy consumption in typical homes. The LCD interface or the smart phone display is capable of showing real time data such as current energy consumption, rate of consumption, temperature of the home, the status of the air-conditioning units etc. to keep occupants aware of the energy consumption of the house. It has a unique feature where it can be operated manually to switch off the appliances that are not being used from anywhere in the world. Some preliminary calculations shows that using our i-Home concept a typical house can save up to 30% of electricity whereby reducing the amount of carbon dioxide emitted to the environment. Some past work and future directions of smart homes are reviewed in [6].

Figure 12 Final Prototype

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