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Sensors and Robotic Environment for Care of the Elderly

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Abstract – This paper describes some development work of a system for elder care configured around sensors and robotic environment. A few sub-systems have been amalgamated to achieve the desired objective. The integrated system is able to support people who wish to live alone but, because of old age, ill health or disability, are at risk and are a cause of concern for their family and friends. The first part of the integrated system, named Selective Activity Monitoring (SAM) system, works on the principle of using sensor units (SU) to monitor various electrical appliances in a house. Rules, based on the daily activities of a person, are defined for the appliances to be monitored. The system can detect violation of the rules and generate an alarm. The rules are flexible and can be user-defined.

The second part of the system is a low-cost Physiological Parameters Monitoring (PPM) system, called Medicmate, which can be used to monitor physiological parameters of a human subject such as body temperature, blood oxygen level and heart rate. It can also detect a fall.

The third part of the system is a web-enabled, robot-based vision system. The robot, operating in a home environment, can be remote controlled by a computer over the internet. The camera, mounted on the robot, can be used to send a picture of the affected area.

Keywords – Sensors, robot, elder care, selective activity monitoring, physiological parameter, heart rate, accelerometer, impact senor, temperature sensor, wirelessly web enabled robot.

I. INTRODUCTION

As the world's population grows older, new challenges are arising to provide a safe, secure and sound living environment. According to the current estimates, in 2005 15.3% of the population in the developed regions of the world was aged 65 years and above. In the developing regions it was 5.5%. What is alarming is the rate at which these numbers are predicted to rise. As shown in Figure 1, the proportion of elderly will grow to 25.9% and 14.6% respectively for the developed and developing regions by 2050.

We are quite often saddened by news headlines such as "Elderly man lay dead for days in his home" and "Woman found starved in flat". These shocking news items force us to think that no one was looking after these people and imagine that they must have had an uncaring family. In such situations assistive robotics would be very useful [1]. At the same time, however, as a society we value our rights to live independently and to keep control of our own lives. Many elderly people dread the idea of being forced to live with their adult children, or in a rest home or other sheltered living arrangement.

Coupled with the problem of aging population, the cost of hospitalization is ever increasing, so is the cost of rehabilitation after a major illness or surgery. Hospitals are looking at sending people back as soon as possible to recoup at home. During this recovery period several physiological parameters need to be continuously measured. Hence telemedicine and remote monitoring of patients at home are gaining added importance and urgency [2-4]. In [2], the in-house movements of elderly people are monitored by placing infrared sensors in each room of their homes. While such a method may not be as blatantly intrusive as using cameras, still it encroaches into the privacy of the person. In [3] the new possibilities for home care and monitoring are discussed using wireless microsensors which are minimally-invasive. Patient monitoring using personal area networks of wireless intelligent sensors is reported in [4]. The development of care support system to monitor the overall health of welfare facility residents who need constant care has been reported in [5]. The reported system is designed with wireless sensors, wireless repeaters and a host computer. The sensors, however, must be in physical contact with the monitored subject to record respiration and physical posture.

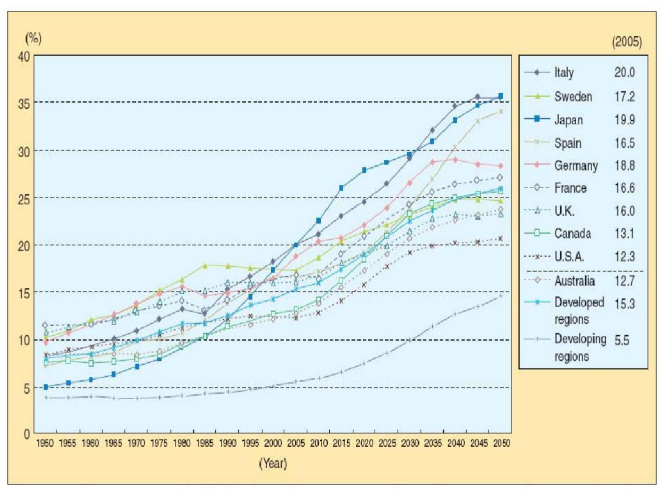

Figure 1. Elderly population growth (1950 to 2050)

Today, the progress in science and technology offers miniaturization, speed, intelligence, sophistication and new materials at lower cost. In this new landscape, micro-technologies, information technologies and telecommunications are the key factors in inventing devices to assist mankind. Patients are being monitored using a network of wireless sensors [6]. A system to monitor the overall health of welfare facility residents, who need constant care, has been reported in [7].

In this paper we have described some development works on elder care configured around sensors and robotic environment. A few sub-systems are combined together to achieve the desired objective. This works is a combination of three systems, selective activity monitoring, a low cost physiological parameters monitoring and wirelessly web enabled robot system. Based on their combined action it is possible to achieve a have sensors and robotic environment which can provides care to elder people.

II. SELECTIVE ACTIVITY MONITORING SYSTEM

The objective of this system is to monitor electrical appliances of special interest to extrapolate the physical state of the old people and send a warning message to the care-giver if required. Figure 2 shows the functional block diagram of the Selective Activity Monitoring (SAM) system [7]. The hardware components of the system are the Sensor Units, the Central Controller unit, a PC and a cellular modem.

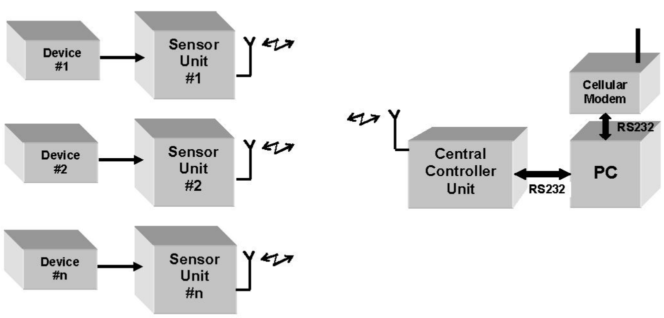

Figure 2. Functional block diagram of the system hardware

Not all electrical appliances at home are required to be monitored but each electrical appliance that needs to be monitored is connected to a sensor unit (SU). The SU detects when the appliance is turned on. It is possible to design the SU to detect a wide range of current, from small appliances such as a reading lamp to a room heater that draws a fairly large current. The SUs and the central controller unit (CCU) are equipped with RF (radio frequency) transceivers for two-way communication. The CCU polls the SUs at regular intervals and gathers the status of the appliances. The RF communication between the SUs and CCU is at 418MHz frequency. The maximum data transfer rate is 40 kbps. The CCU is connected to a personal computer (PC) using RS232 serial communication protocol. A supervisory program runs on the PC. Based on the rules that have been set for monitoring a home, the system generates an alarm when any appliance is not turned on in the designated time slot. A combination of rules may be set to trigger the alarm. On another RS232 serial communication port, a cellular modem is connected to the PC. When an alarm condition is met, the program can send a text message, using the short message service (SMS) facility of the cellular telephone network, to the mobile phone of a family member or a care giver who can then take appropriate action to contact the person and provide help if necessary.

The various components of the SU are shown in Figure 3. The five major hardware blocks in a SU are the power supply, RF transceiver module, micro-controller, current transformer circuitry and the LED display. The power for the RF transceiver, micro-controller and the current sensing circuitry are obtained from the AC mains.

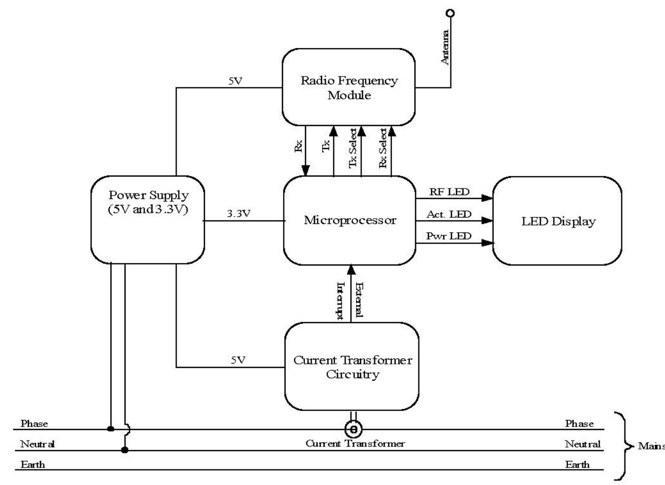

Figure 3. Core components of the Sensor Unit (SU)

The Radio Frequency module used is a Radiometrix BiM-418 transceiver capable of half-duplex operation at 418 MHz frequency. The TxSelect and RxSelect signals from the micro-controller configure the transmit or receive mode of the RF transceiver. The Rx and Tx are the receive and transmit data lines respectively. In our design, the data transfer rate is set to 38400 bauds. The microcontroller used is the SiLab C8051F020 mixed signal microcontroller. The microcontroller development board was used to build the prototype as it provided ready connection terminals for analog and digital I/O.

There are three Light Emitting Diodes (LED) – one to indicate that power to the SU is on, another to show that the RF communication with the SU is currently in progress and the third to indicate that the appliance connected to the SU is active, i.e. turned on.

The task of the load detection software is to continuously evaluate whether the load is active or not. A timer has been configured to generate an interrupt every 500ms. If 10 external interrupts occur within this period, the appliance is deemed to be active. The flow chart of the algorithm for load detection is shown in Figure 4.

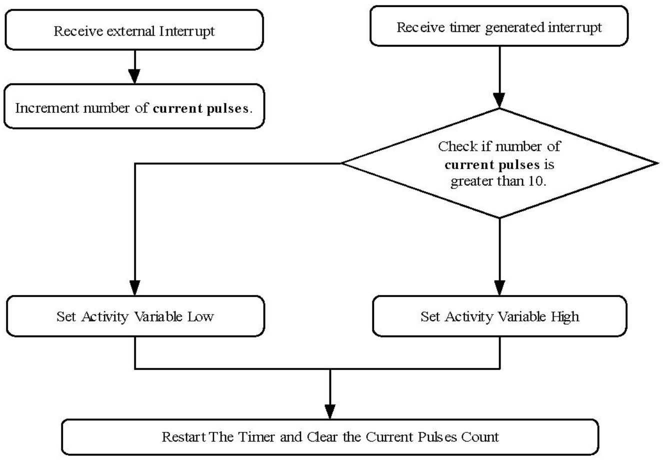

Figure 4. Algorithm for load detection

The various components of the CCU are shown in Figure 5. The four major hardware blocks in the CCU are the power supply, RF transceiver module, micro-controller and the LED display.

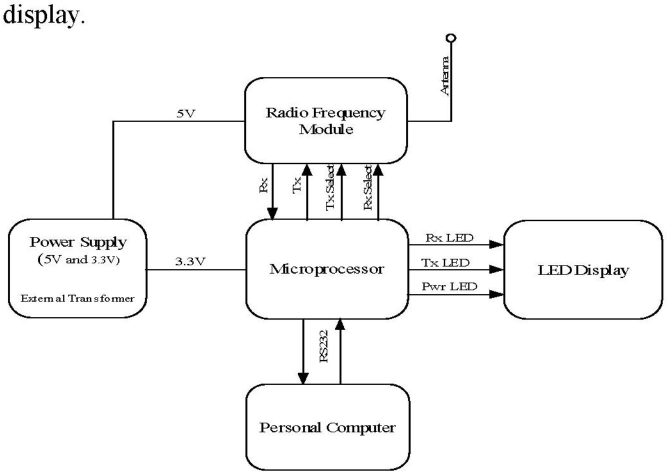

Figure 5. Core components of the Central Controller Unit (CCU)

Most of these components are similar to the SU. There are three LEDs – one to indicate that power to the CCU is on, another to show that the CCU is in transmit mode and the third to indicate that the CCU is in receive mode. The power supply unit generates 5V and 3.3V DC. The microcontroller is connected to the PC on the RS232 serial communication port which is set to operate at 115200 bauds.

The system was fabricated and tested with three sensor units and one central controller unit in an average size home. The complete system is shown in Figure 6. The sensor unit was successfully tested for various load currents, from 0.1A to 10A. The communication was very reliable. A Wavecom Wismo cellular modem was used for sending text messages to a mobile phone. Figure 7 shows the internals of the fabricated sensor unit.

Figure 6. Complete fabricated system

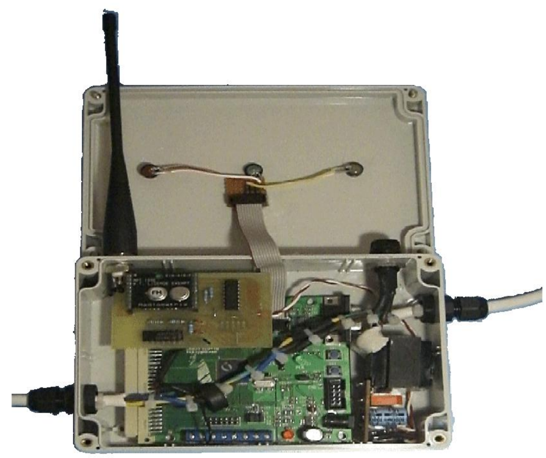

Figure 7. The Sensor Unit (SU)

III. PHYSIOLOGICAL PARAMETER MEASUREMENT SYSTEM USING MEDICMATE

While SAM monitors the activities of an elderly person on a continuous basis, sometimes it might happen that a person falls ill suddenly and it is essential to take quick action to prevent death. The Medicmate system has been designed to take several inputs from a human subject to measure physiological parameters such as temperature, blood oxygen level and heart rate. Figure 8 shows the functional block diagram of the proposed system hardware [8]. The inputs from the sensors are processed and the results transmitted to a receiver unit, which is connected to a computer placed in the home, using Radio Frequency (RF) wireless technology. The receiver unit decodes and analyses the data. If it is inferred that the person is medically distressed, an alarm is generated. The design is modular which makes it rather easy and straight forward to add extra sensors for measuring and monitoring other parameters.

The implemented system consists of three sensors: a temperature sensor, heart rate sensor, and an impact sensor. The signals from all the sensors are fed to the ADC (Analog-to-Digital) inputs of the micro-controller. The ADC inputs are time-multiplexed and sampled at different rates. The description of individual sensors follows.

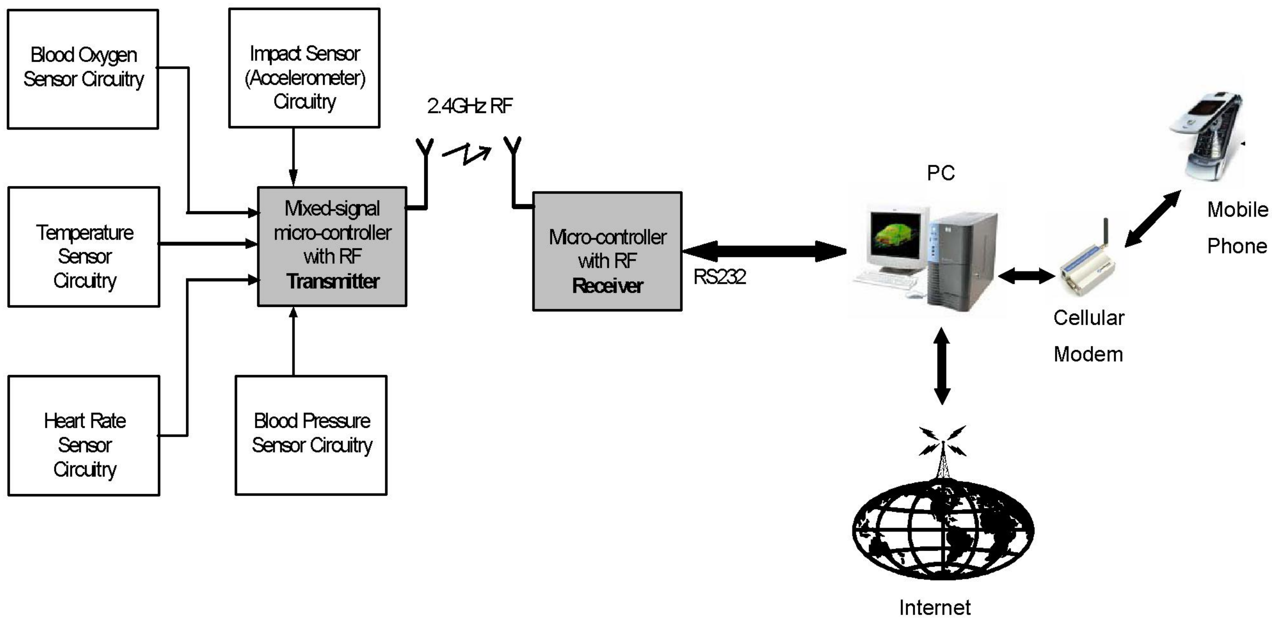

Figure 8. Functional block diagram of the proposed Medicmate

A. Temperature Sensor

The temperature measurement is done using a LM35 [9] precision integrated-circuit temperature sensor. It provides an accuracy of +/- 0.25°C within the desired temperature measurement range of 20-40°C. It has a very low current drain of 60 µA. This sensor is mounted within the wrist strap, positioned in such a way that it is in contact with the skin, allowing it to measure the external temperature of the skin. From the skin temperature, the body temperature is estimated. Because an exact measurement of body temperature is not required, this method is suitable. Rather, relative changes are monitored within set thresholds, which set off the alarm. This allows the device to detect changes in body temperature that could indicate the patient is undergoing any of the following conditions: trauma, injury, heart attack, stroke, heat exhaustion, and burns [10]. The temperature sensor is sampled once every 3 seconds.

B. Heart Rate Sensor

A custom heart rate sensor was designed to read the patient's beats per minute (bpm). The designed sensor is very small and inexpensive. The technique used to measure the heart rate is based on near-infrared (NIR) spectroscopy. NIR spectroscopy involves using light in the wavelength of 700-900nm to measure blood volume. At these wavelengths most tissues do not absorb light – other than hemoglobin (which is what we are interested in). This allowed for designing a non-invasive and low cost method of measuring the pulse. A silicon phototransistor and a GaAs infrared emitting diode were used in the sensor, moulded into a flat side-facing package. The amount of light that was detected by the phototransistor varied with the patients heart pulse, as the amount of absorbed IR light changed with the flow of blood, which is directly linked to the heart rate. This signal was then amplified, filtered, and sent to the microcontroller to be analyzed. The heart rate sensor was mounted in the finger glove as this position proved to give the best response.

C. Impact Sensor

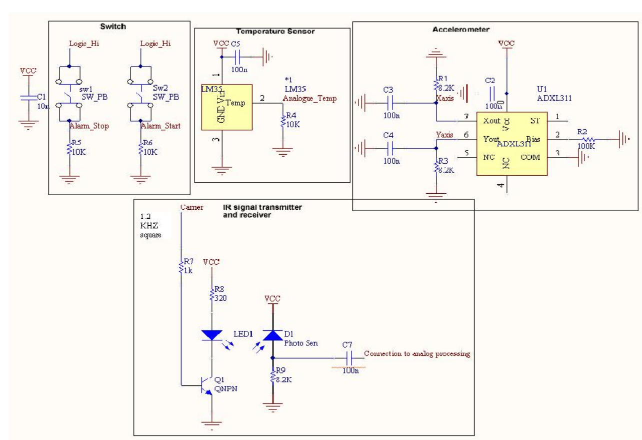

Figure 9. The electronic circuit of the sensor unit

An ADXL311 accelerometer was used as an impact sensor. It provides a 2-axis response, measuring accelerations up to +/- 2g. It was fitted into the wrist strap. The accelerometer provides an analog voltage, the amplitude of which is directly proportional to acceleration. This signal was scaled down to bring it within the acceptable input range of the micro-controller, and then analyzed. Software algorithms were used to detect sharp impacts, while allowing slower movements, such as walking, to be ignored. The purpose of this sensor was to detect sudden impacts that could indicate the patient had fallen over.

The Figure 9 shows the electronic circuit of all the three sensors.

D. Prototype and Experimental Results

The Nordic micro-controller development board was used to build and test the prototype design. The analog processing circuitry and the sensors were assembled on PCBs which were placed within the wrist strap. Figure 10 shows the prototype hardware. The prototype was powered off a 9V battery. The RF transmission has been tested to operate successfully at 10 meters range through obstacles such as concrete walls.

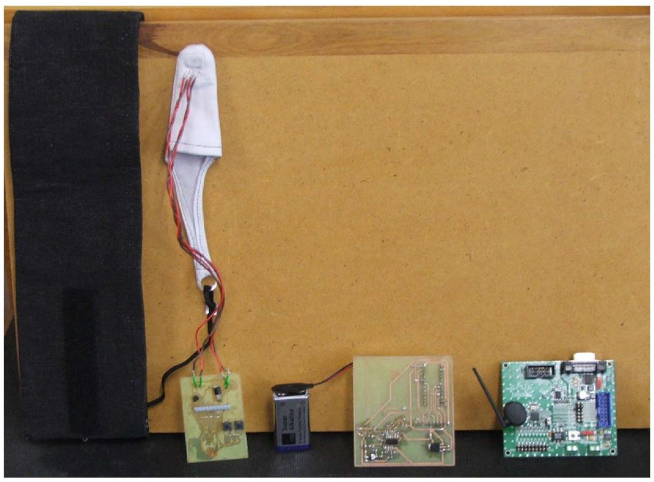

Figure 10. Device prototype and finger glove

IV. ROBOTIC ENVIRONMENT FOR CARE OF THE ELDERLY

The research, development and use of robots to human care has started a long time back. The block diagram representation of the evolution of the robotic research towards service robots is shown in Figure 11 [1]. A few service robots are already in market, one of them is a very popular one ASIMO from Honda as shown in Figure 12. In this research we try to use robot from a different perspective. It might happen that the care-giver gets a warning message from either of the above two systems. In that case it is possible to see some pictures of the inside of the house in which the elderly resides in the mobile phone.

A robot which is defined as Wirelessly Web Enabled Mechatron (WWEM) has been fabricated with a camera in-built into it. The robot can be controlled remotely from a computer over the internet by the care-giver and displays a video to him as feedback as to the robots actions and whereabouts. Embedding into the WWEM is a web server that holds the website for the user to access. The video is embedded into this website onboard and it communicates to the World Wide Web via a standardised wireless communication systems. With the communication system the robot can be used as a very flexible module for many applications due to its compact size and the ease to program it via a PC. The pictures of the fabricated robot are shown in Figures 13 and 14 respectively. The camera installed in the robot is shown in Figure 15 respectively. The fabrication has just been completed the experiment are now carried out.

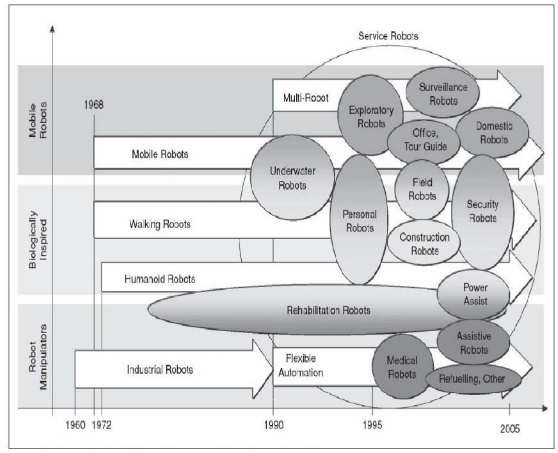

Figure 11. Time evolution of the robotics research towards service robots

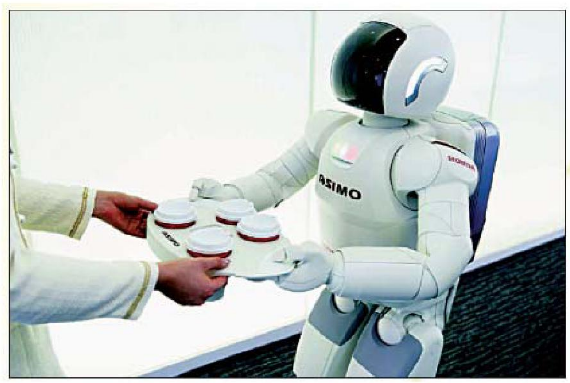

Figure 12. ASIMO Service robot from Honda

Figure 13. Fabricated robot for home monitoring

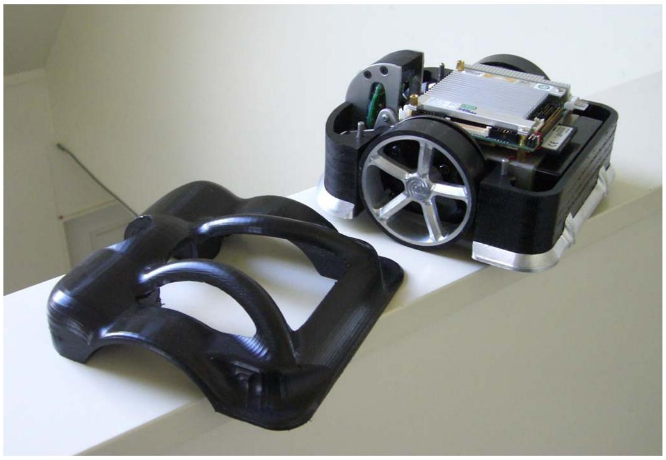

Figure 14. Detail view of the robot

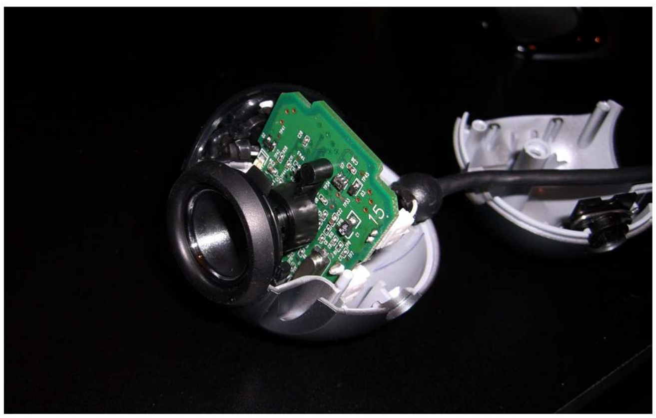

Figure 15. The camera and associated circuit of the robot for vision

V. CONCLUSIONS

In this research an arrangement to care elder people based on sensors and robotic environment has been reported. A few sub-systems have been amalgamated to achieve the desired objective. The system consists of three sub-systems namely: selective activity monitoring system to detect use of electrical appliances, medic mate to measure and detect physiological parameters and robot based vision system to get picture of the home under care via internet. Currently the systems operate well in stand-alone mode. There is a need to integrate them together to make it a complete system which is currently under investigation. The integrated system is able to support people who wish to live alone but, because of old age, ill health or disability, are at risk and are a cause of concern for their family and friends. The system works well in laboratory environment and is expected to be run on trial by the end of the current year.

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