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50. Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
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R M Parkin, M R Jackson, S J Chun

Domestic Health Monitoring for the Aged and Infirm

ABSTRACT

The proportion of UK population aged over 65 has increased rapidly in the last decade and it is forecast that by 2031 this sector will be over 23%. In general much of this has to do falling birthrates and healthier lifestyles resulting in increased longevity. The proportion of people over the age of 85 has seen a six-fold increase in the last 50 years.

This population ageing will generate an increasing need for hospital visits and medication. An increased provision of care homes for the elderly is also predicted. This will (in many instances) lead to perceptions of a lower quality of life as many people would rather stay in their own homes. The aging population is likely to result in more single person households and this will create an unacceptable demand for homecare support visitors.

This paper describes a system for health monitoring in the home with the aim of supporting aged and infirm people to stay in their own homes for longer whilst providing them, and their relatives, peace of mind that they are being continuously monitored for signs of abnormality. If the system observes erratic or abnormal behaviour it will instigate a series of events using a telephone dialler.

- Primary level – inform the local health support team that there may be a problem – response is a telephone call to check for lucidity, etc.
- Secondary level – local medical support can “dial in” to records of monitored parameters and assess level of support needed in short and medium term.
- Tertiary Level - emergency level – summoning of ambulance.

A prototype system has been designed, constructed and tested. It is capable of monitoring external body temperature and humidity, heart function (Electrocardiogram), heart rate and body attitude (fall sensor). The prototype is worn on the body with a “sensor belt” and localized microcontroller which communicates with a PC base station via Bluetooth®. The base station has a telephone dialler system to summon assistance and can also act as a web server to permit remote healthcare professionals to access patient monitoring history.

The system has proved effective in limited trials with some loss of service due to difficulties with the sensor belt keeping ECG electrodes in place under everyday activities (eg bending down, reaching up to shelving). It is also reported that the sensor belt was uncomfortable when worn for long periods. These matters may be overcome by the design of a more comfortable sensor harness. The cost is sufficiently low for wide ranging application including personal purchase, especially where there is already a household PC available.

INTRODUCTION

The total population of the UK rose by 17 per cent from 50.2 million on census day 1951 to 58.8 million on census day 2001 [1]. The rate of growth over this period is comparable with a number of European countries (Austria 17 per cent; Belgium 19 per cent; Germany 20 per cent) though it is slightly more modest than the EU average (23 per cent). It is also more modest than the growth in some other countries around the world (USA 80 per cent; Australia 133 per cent). The 2001 census showed that for the first time there are more people over 60 than there are children.

As well as increasing in size, the UK population is now also older overall than it was in 1951. While the proportion of the population aged under 16 has decreased to 20 per cent from 24 per cent on census day 1951, the proportion of the population aged 60 and over has increased to 21 per cent from 16 per cent on census day 1951. Thus, for the first time ever there are more people aged over 60 than there are children. This ageing of the population reflects longer life expectancy due to improvements in living standards and health care. It also reflects the fact that there have not been any events with a corresponding effect on life expectancy like that of the first and second world wars.

The ageing of the UK population is particularly evident when the number of people aged 85 and over is considered. On census day 1951, there were 0.2 million people aged 85 and over (0.4 per cent of the total population) in the UK. By census day 2001, this had grown to just over 1.1 million (1.9 per cent of the total population).

Older people place an increased burden on health care services. This takes the form of increased visits to GP surgeries, home visits, hospitalization and even long term residential care. Support from relatives in the extended family has largely disappeared due to social changes and many people dislike having to move away from their home environment and thus put off calling in healthcare professionals until a crisis makes this inevitable.

The leading cause of death in the over 65's (in the US) has been shown to be heart disease, responsible for 36% of deaths [2]. It is widely recognized that many people die from a first heart attack and were "unaware" that they had a heart problem and most cardiac specialists advise that an earlier recognition of abnormal heart behaviour (followed by appropriate treatment) is likely to extend lives.

It was thus postulated that a wearable system that permitted non-intrusive, daily monitoring of elderly or infirm people in the home would derive significant health benefits. It would provide peace of mind for relatives and encourage people to take more interest in their health and extend the period that they could remain in their own homes before having to undergo hospitalization or a move to a residential care home.

CONCEPTUAL DESIGN

The health monitoring system is comprised of 5 main subsystems sensory devices, micro-controller, wireless communication module, monitoring base station and internet communication. These are linked together as shown in Figure 1.

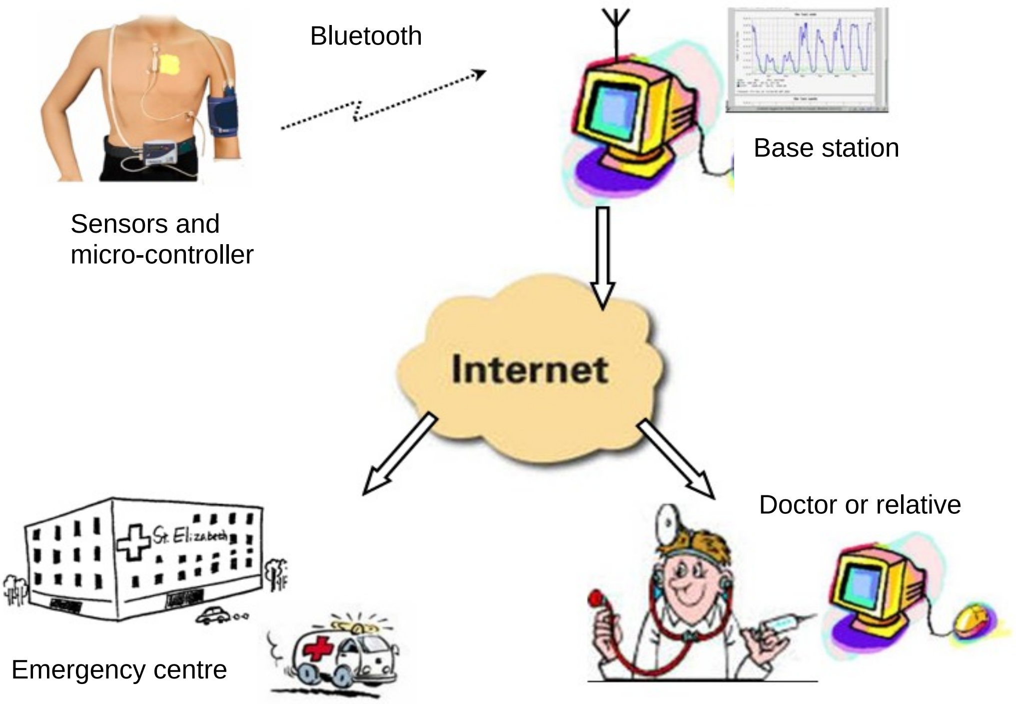


Figure 1 Remote Monitoring Concept

The system can include a base station with a telephone dialer, which can call a relative to inform of concerns or, on some periodic basis, to give assurances that all is well. In the event of a potential problem it can call a local health centre to ask them to telephone the monitored person or request a visit. In such a case it may be that a telephone conversation with the person will suffice to ensure that there is no problem, otherwise the local health centre can access the base station server to get historical traces of monitored parameters to aid a decision. In the event of an emergency (eg a fall followed by no motion, heart problem) system can directly call for an ambulance. Of course some of these messages could be sent via email or SMS text to a mobile phone.

HARDWARE DESIGN

When considering sensing for domestic health monitoring, there are many potentially useful parameters (eg respiration, blood glucose, body temperature) which are difficult or intrusive to measure. The concept in this work is to use non-intrusive monitoring and this precludes certain parameters (eg blood glucose). The following sensors have been used:

Body Temperature – using a Maxim/Dallas DS18S20 one wire bus system [3]. This permits direct reading of temperature in 0.5 °C increments. A useful feature of the devices is that each has a unique identity code and this can be linked to a named person. More resolution may be obtained with a DS2438. The normal (internal, core) body temperature for a human is 36.5 °C and the normal measurement methods are "in mouth" or "in ear" thermometers. These are too intrusive and thus we use skin temperature on the chest which is normally about 32 °C.

Body Humidity – certain problems can cause sweating (humidity increase). Many sensors require a correction factor for operating at other than 25 °C, but this is catered for as we have a measure of temperature. The Honeywell HIH-3610 is a good quality sensor with an analogue output, V_{out}, ratiometric to supply voltage, V_{rail}, [4]

$$sensorRH = \frac{V_{out}}{V_{rail}} - \frac{0.16}{0.0062} \qquad \text{typical at 25 °C}$$

$$trueRH = \frac{sensorRH}{1.0546 - 0.00216T} \qquad \text{where T is in °C}$$

Heart Rate – can be obtained by measuring the electrical potential between 2 electrodes placed in the upper body triangle. The output is only circa 1 mV and so an instrumentation amplifier, Texas Instruments INA128P [5], is required. The design uses a dry type ECG electrode from Polar [6]. To avoid noise problems it is necessary to use a low pass filter. The obtained trace gives an cardiogram of heart activity, from which may be obtained both information on heart function (shape of curve) and heart rate (period) – as seen in Figure 2.

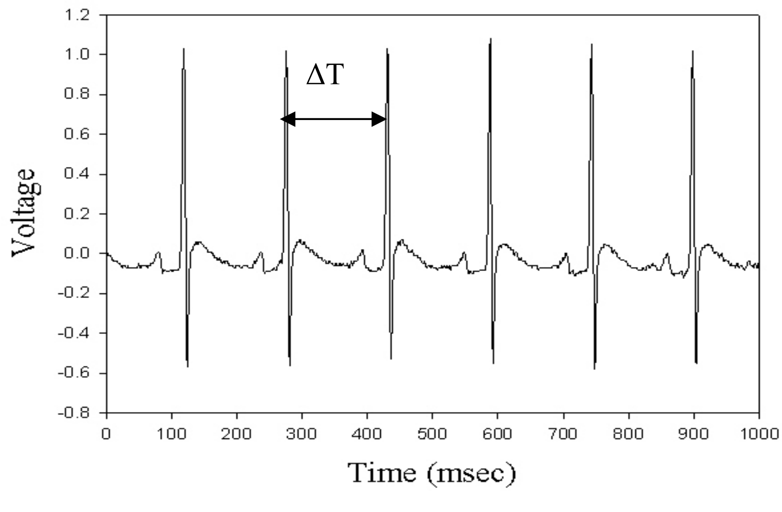


Figure 2 ECG Trace with Heart Rate

Attitude Sensing – useful information on the body "attitude" can be obtained via an accelerometer. Modern MEMS based accelerometers can measure not only dynamic acceleration (vibration or shock), but static acceleration (gravity). The latter allows for measurement of body attitude or tilt. This can be done in two planes at once, conventionally "pitch" and "roll". One can thus tell of the wearer is lying on their front, back, right side or left side. A fall will produce rapid changes and shock impacts rather than the smoother transitions expected from deliberate lying down etc. As the construction is that of a silicon "slab" suspended on ligaments, the transition from 0°to +/- 90° is sinusoidal with best case resolution of circa 0.3°. The device used was an ADXL202 [7] having a PWM output.

$$\theta_p = \sin^{-1}\frac{g_p}{g}$$ where g_p is the output reading of "pitch"

One problem with people monitoring systems is that they may remove the system for various activities (eg bathing). It is clearly undesirable for the lack of motion or lack of heart rate signal to trigger an "emergency situation". For this reason the system is equipped with a "wear detection switch"; a resistive sensor which has two electrodes in contact with the skin when worn normally.

Micro-controller – the sensors are connected directly to a micro-controller which performs the functions of measurement, whether by one-wire bus, PWM or analogue (on board Analogue to Digital Converter). The device used for the prototype was a GP Controller Board from iensys ltd [8], based on a PIC18F458 from Microchip [9]. This board has a one wire bus driver and 8 analogue inputs. It also has an RS232 communications port. Communications between the micro-controller and the base station were arranged via Initium Bluetooth devices [10].

SOFTWARE DESIGN

The original software concept was to use the base station to provide the protocols for connecting the Bluetooth communication system to the wearable monitoring system. The base station than carries out all timing procedures and polls the wearable device on a regular basis to gain access to the data stream. The base station gets the data from the micro-controller and then adds it to the history file, analyses trends, makes decisions and initiates an "event" (eg calling the local health centre) if required. The software for the base station is written in National Instruments LabView®. The fact that Bluetooth devices have a unique identity code means that one base station could monitor several people (useful for care homes).

The micro-controller controls all the sensors and converts sensor readings from analogue to digital values as required (via the on-board ADC). Some information is provided directly in digital form and so the software contains routines for pulse width measurement and for driving the "One Wire Bus" used on the temperature sensor.

PROTOTYPE

The test prototype utilized a readily available General Purpose Controller Board (as detailed above). All the sensor systems were built into a modified version of the Polar dry ECG harness [6]. The system was wearable with the GP board being fitted to a belt loop and being powered by a PP9 9V battery. The battery was sufficient to power the system for about one day, but would not be suited for practical usage as a battery life of one to several weeks would be a more realistic target. The system is shown in Figure 3, along with the positioning of the sensor belt on the chest of a volunteer.

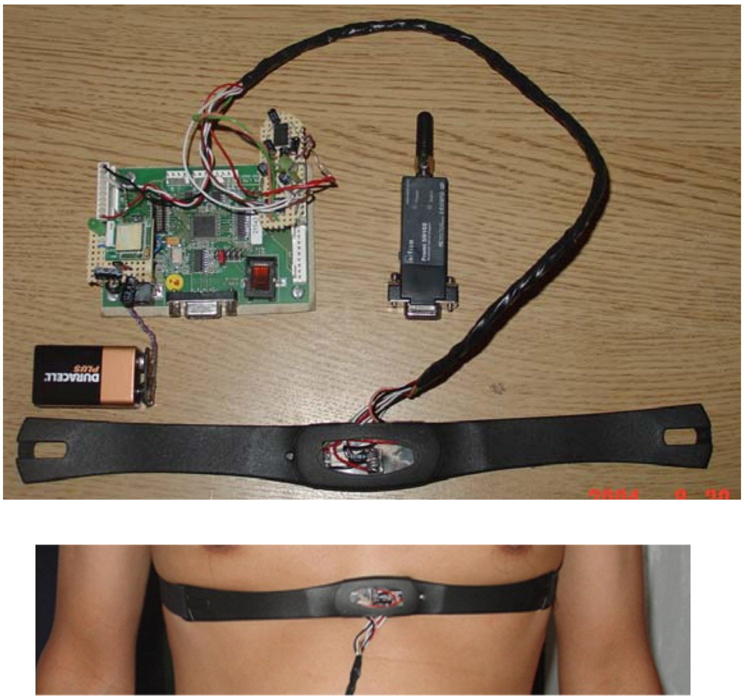
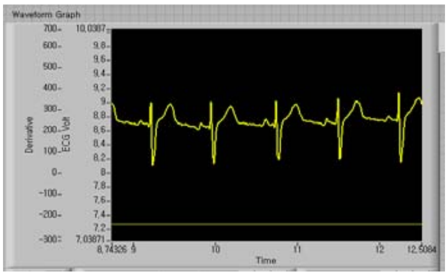
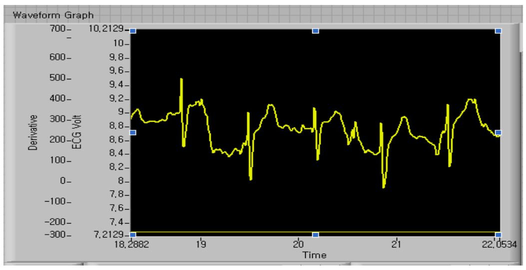


Figure 3 Monitoring System and Volunteer with Sensors on Chest

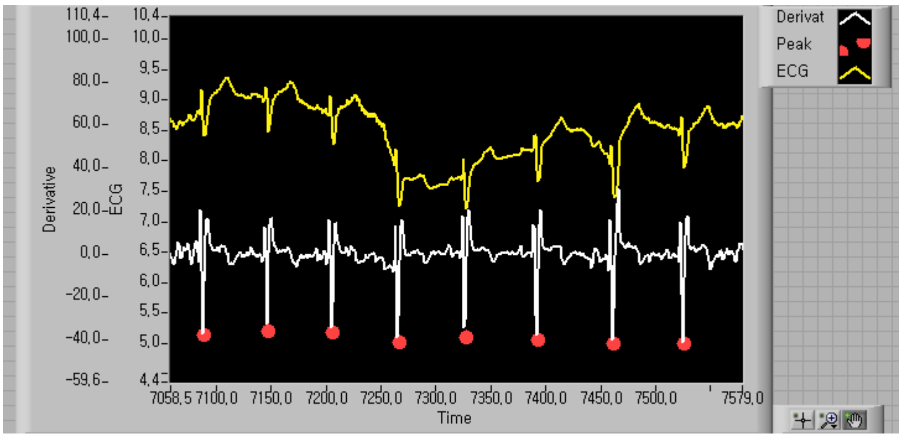
EVALUATION



(a) ECG in stable body condition



(b) ECG with body moving



(c) Anchored ECG waveform

Figure 4 ECG Waveforms

Early tests displayed a problem with the ECG measurements. When the body was at rest, the waveforms were very stable (Figure 4(a)), but when moving around there were "vertical shifts" in the output (Figure 4(b)). This made the calculations for heart rate very difficult to stabilize. The solution was obtained by taking the derivative of the signal as this then suppressed the dc shift levels and left the signal very stable. Figure 4(c) shows the unstable upper trace and the conditioned (lower) trace which was then used for heart rate calculations.

A typical base station PC output is shown in Figure 5. The system works well and is informative. Wearers have found the sensor belt difficult. If too tight, with a "curvy" body shape, the sensors have a tendency to float clear of the skin; the "in wear" sensor reports this and the results are not compromised. The down side of this is that no monitoring then takes place until the sensors are again settled.

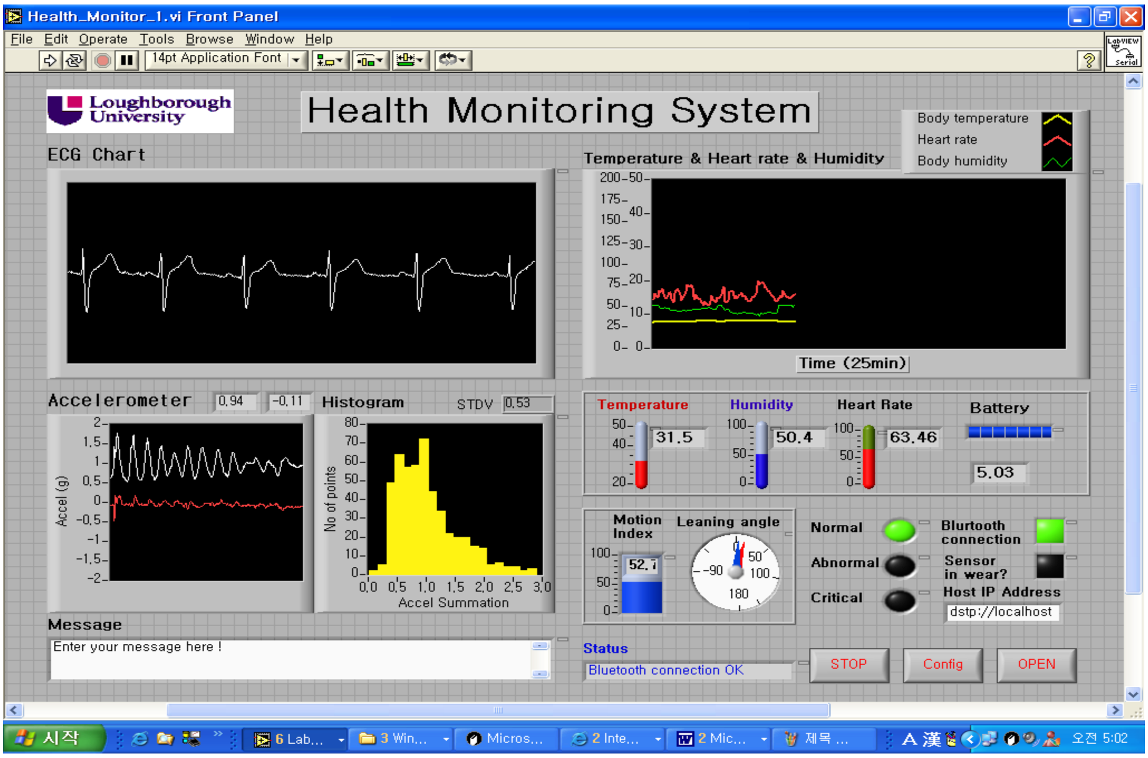


Figure 5 Base Station Screen

The Bluetooth wireless communication system has proved very robust over a range from 30 to 100m, depending upon the devices used (eg type 2 or type 1 respectively). Battery life is limiting at the moment, but some of that is down to the GP board. A more readily wearable system would use one of the "nano-watt" series of PIC devices [9]. This would go into a periodic sleep mode consuming literally nano-watts. Upon demand (or at timed intervals) it would then wake-up, turn on the sensors, take measurements, transmit the results and then go into hibernation again. It is the base station that takes decisions regarding events and actions. It would be possible for the server version to allow the persons healthcare professional to set or modify rules that would trigger events such as "inform local health centre" or "call an ambulance". The base station is mains fed and permanently powered, so there need be no loss in monitoring activity.

The problems experienced would easily be rectified in the design of a pre-production prototype for more extensive field tests.

CONCLUSION

The system has proved effective in limited trials with some loss of service due to difficulties with the sensor belt keeping ECG electrodes in place under everyday activities (eg bending down, reaching up to shelving) as the sensors move over the skin the ECG signal was prone to "vertical displacement" which made it difficult to read. It is also reported that the sensor belt was uncomfortable when worn for long periods. These matters may be overcome by the design of a more comfortable sensor harness. The cost is sufficiently low for wide ranging application including personal purchase, especially where there is already a household PC available. This is often the case for the growing generation of so-called "silver surfers".

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Authors Details

Professor Robert M Parkin*
Dr Michael R Jackson**
Mr Sung Je Chun*

* Mechatronics Research Centre
Loughborough University, UK

** Iensys Ltd,
Loughborough, UK (www.iensys.com)

Corresponding Author R.M.Parkin@Lboro.ac.uk