Wireless Activity Monitoring Device Enabling Mobile Ubiquitous Healthcare

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Abstract

The explosion in number and use of mobile devices like smartphones and music players has enabled deployment of wearable medical sensors and applications for ubiquitous health monitoring. As health awareness increases in society and technology continues to push the boundaries, there is an increasing demand for small low powered state of the art medical devices that provide round the clock assessment of the subject's general well being. The vision is to engineer a smart environment infrastructure enabled with motes capable of interacting with various types of mobile devices (figure 1). One class of these will be body worn sensors for sensing EKG, pulse, blood oxygen, blood glucose, temperature, gait, limb movement, etc. Continuous monitoring of these parameters is of immense value for patient and fitness monitoring, preventive and recuperative feedback, emergency alarm, gaming and many more. This stream of data can be locally processed on a mobile device and anomalies and outliers can then be sent over the internet to a central monitoring station in the cloud that is supervised by a healthcare professional. This telemedicine will be the next generation in-home care delivery.

Keywords – Activity monitoring, wireless health, embedded systems, body area networks, smartphone, classification, Parkinson's disease.

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Working towards this vision, we have prototyped a wireless activity monitoring device that communicates with a smartphone. The prototype device has on board a digital 3 axial accelerometer and digital 3 axial gyroscope. It also has on board an ANT AP2 drop-in module that provides the physical, data link, network and transport layer wireless solution. The device application is embedded on the on-board ultra-low powered MSP430F2619 microprocessor by Texas Instruments. The microprocessor communicates with the accelerometer and the gyroscope over an I2C bus and with the AP2 module over an SPI bus. The entire device is powered by a 3V coin cell battery. This custom design facilitates complete control over the functioning of the device. This also allows us to program it for lowest power consumption and thus maximize the time the device can function on one battery.

The ANT protocol is an ultra-low power wireless sensor network protocol that runs in the 2.4GHz ISM band. It is being increasingly used by applications in the field of fitness monitoring as the low-power, low data rate RF protocol. Various members of the ANT+ alliance manufacture small portable wireless devices for measuring heart rate, bike speed, cadence, weight, location and other such parameters. Using this protocol automatically buys us compatibility with this entire suite of devices and apps tailored for activity monitoring

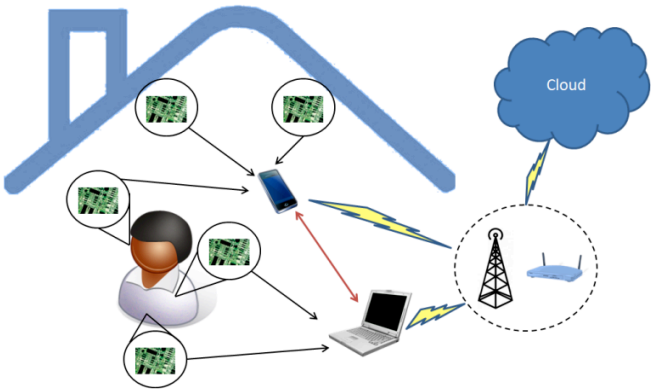

Figure 1: Depicts the idea of a smart environment that enables personal health monitoring.

Figure 2: a. Back (top left) and Front (top right) of prototype devices, b. iPhone (bottom) c. Fisica Key (bottom right)

Wahoo Fitness manufactures ANT+ Fisica Key, an ANT transceiver dongle for the iPhone/iTouch. For developers, they also provide an API to configure, transmit and receive messages from the dongle. This dongle is used as the RF interface between the iPhone and the activity monitoring device. An objective-C app written in the Xcode developer environment for iOS 4.2 provides the user interface and feedback.

It also encapsulates the activity monitoring and classification algorithm. At the heart of this algorithm is a complementary filter that uses 3 axial data from the gyroscope and the accelerometer provided from three sensors to detect and classify activity. As of this proposal, the non real-time version of the algorithm which takes data collected from the sensors and stored in a text file as the input has been calibrated, tested and verified on subjects in a controlled environment. The activity monitoring devices, the Wahoo dongle and the iPhone with the custom app forms our activity monitoring system (figure 2).

Our demonstration shows a prototype of a wireless, low-powered, compact device for activity monitoring of a subject in conjunction with an iPhone. A few real-time applications of this setup are:

1. Classify activities like sitting, standing, walking and running and provide fitness monitoring.
2. Provide real-time auditory feedback by means of external cueing to Parkinson's patient during 'freeze of gait' event.
3. Detect relative position of limbs during action in sport and suggest improvements. E.g., pitching in baseball.
4. Detect potentially dangerous postures while lifting heavy load and provide audio or a tactile warning.

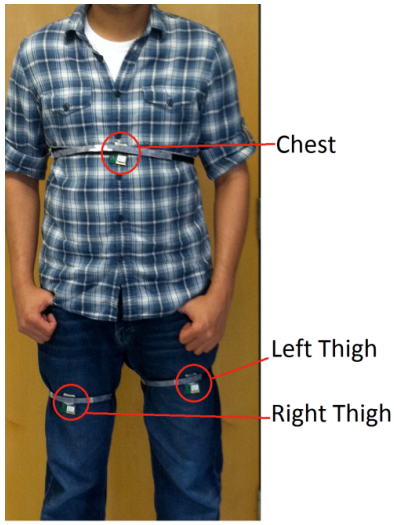

Figure 3: Devices mounted on a human subject.

Consider an employee at the baggage services at an airport as the subject in the fourth example above. Squatting is generally considered a good way to lift heavy loads. Stooping while lifting a heavy bag can damage the employee's spinal cord as there is no knee bending during lifting with excessive forward lean. A preventative solution for this issue can be provided by our device plus iPhone setup. The employee can strap on three sensor devices – one on chest and one on each thigh (figure 3). These sensors continuously transmit the three axial acceleration and gyroscope data to the phone over an RF channel. The algorithm on the phone determines whether the person is squatting and the lean angle of the back. Using this data, the algorithm can then classify if that posture for lifting weight is dangerous. On determining a danger, the phone then provides an auditory feedback to warn the employee.

This demonstration shows this device plus smartphone setup will facilitate development of multitude of applications and when combined with a smart-room context, will provide a powerful solution to better the lifestyle of the user.