Context Awareness by Analysing Accelerometer Data*

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Abstract

In this paper we describe continuing work being carried out as part of the Bristol Wearable Computing Initiative. We are researching processing techniques for data from accelerometers which enable the wearable computer to determine the user's activity. Techniques already employed by others have been explored and we propose new methods for analysing the data delivered by these devices. We try to minimise the number of devices needed by using a single X-Y accelerometer device. Using our techniques we have adapted our GPS based Tourist Guide application to vary it's multimedia presentation according to the user's activity as well as location.

This is a condensed version of a Technical Report [1] issued by the Department of Computer Science, University of Bristol, U.K.

1 Introduction and Background

We are exploring the concept of situated computing [2] by using sensors to determine the where, what and how of the user. We have used GPS and 'Pingers' [3] to provide location awareness, and we are now investigating the use of accelerometers to provide activity awareness.

Previous research in this field, such as the wearable Context-Awareness Component [4], employed accelerometers to detect basic activities such as sitting/standing/walking/running. More complex projects included the Acceleration Sensing Glove [5] using multiple hand mounted accelerometers which combined accelerometers with a variety of other low-level sensors.

To minimise complexity, size and power consumption, we have researched data processing techniques which provide a higher level of activity analysis without the use of multiple sensors.

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2 Architecture

The Crossbow ADXL202 Accelerometer Evaluation Board is designed specifically to help the designer understand these devices and provides a compact module which can be interfaced to any PC with a RS232 serial interface. It provides outputs corresponding to the X and Y G-forces applied to the board. To enable testing to take place for long periods with a minimal infrastructure we have interfaced this with a Matsucom onHand PC with the sensor worn in a trouser pocket. This simple arrangement enabled programs to be tested which could later be incorporated into our 486 Linux based Cyberjacket.

Our wearable computer is connected to a variety of sensors using an event manager. In a steady state the main processor will be switched off and the sensors are the only active parts. The sensors are to be programmed by the main processor to power-up the main processor when an interesting situation arrives. The requirements from the various application programs will be combined to program each sensor to send an event in a particular case [6].

3 Data Processing

We collect samples at a relatively low frequency (5 Hz; to aid in low power design), and from only two data sources - the X and Y axes of the accelerometer. From these samples we extract 4 features. These features can be calculated cheaply; they can work across a range of people; and are robust. We then use a clustering algorithm - a neural network - to infer what the user is doing.

To experiment with various features and clustering algorithms we have first collected a ground-truth of 10 people performing various activities: **Walk**ing, **Run**ning, **Sit**ting, walking **Up**stairs, **Down**stairs, and **Stand**ing. We use this ground truth to train and evaluate our system. As can be expected some activities are easy to distinguish, however distinguishing between walking and walking upstairs is more difficult. We have studied various features that can be extracted from the sensor data cheaply. It turns out that extracting a total of 4 features from the 2 sensors is sufficient:

the RMS and integrated values of both sensors over the last 2 seconds. We have determined that using this technique it is unnecessary to carry out any further analysis such as determining frequency components. It is important to stress that the features discussed are person and clothing specific. The strength of these features is that for every person that we have data for, these four features allow the recognition of the user's activities. However, one person walking can give the same results as another person running.

We initially trained our network on a ground truth, and analysed the results after further person specific training. Our initial results shown that we can infer the user's activity with a high accuracy (85-90%). Verifying which 10-15% is "wrongly" classified, we observe that this is often the person going upstairs via a small landing. Landings are difficult to resolve: the real activity is walking, whereas it is labelled as going upstairs in our ground truth. A temporal filter can take those errors out, but this will make the system sluggish in its response. The actual accuracy of detecting peoples activities is around 95%; with a temporal filter we can increase that further.

4 Application - the Well-Behaved Wearable

We have previously developed a Tourist Guide application for our Cyberjacket incorporating a CardPC; GPS receiver; hand held display and audio interface. Web pages and audio notes were rendered using this configuration dependent only on location. A drawback of this design was the untimely rendering of media information e.g.a distracting audio commentary being played while hurrying across a busy road.

As a first example of the potential use of a single accelerometer, we control the media rendering to ensure that the presentation of information is appropriate to the user's activity and consistent with the sensed event. For example, we do not wish to render any information if the user is running; we also know that if the user is not moving then an event triggered by a change in location cannot be generated. A simple set of rules can thus be formulated to form an etiquette for our wearable computer.

We designed our application to operate according to the users activity. Events signifying interesting locations with associated web pages and/or commentary can only be triggered while the user is walking. The commentary is played to alert the user to the place of interest, and the web page is only displayed once the user has stopped walking. The application is suspended when the user is running.

This arrangement improved our user interface and reduced irritation caused by untimely and inappropriate rendering of information. We are now considering the potential of developing a more complex set of rules which could be implemented with additional sensors such as microphones to determine when the user is speaking and/or being spoken to.

5 Results and Conclusions

We have demonstrated that with a single X-Y accelerometer we can distinguish various activities of the user, even very similar activities. We have determined that only two easily computed features need to be calculated: RMS and integration of the last 2 seconds of measurements. A clustering algorithm, a neural network, was then used to infer the user's activity. This activity sensor has been added to our Tourist Guide application to select the appropriate output mechanism to be used at any time.

This work has shown how the use of a single context sensor to determine the user's activity can provide a valuable source of data to improve the behaviour of wearable computers.

References

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