Discovering Context from Physiological Sensing

Jonathan Farringdon, Ray Pelletier & Chris Kasabach

Bodymedia.
4 Smithfield St. Pittsburgh. PA. 15222. USA.
jonny@bodymedia.com +1 412 288 9901

ABSTRACT

Worn on the upper arm our device collects motion, heat flux, skin temperature, and galvanic skin response data, 24 hours a day, 7 days a week, from a pool of subjects. We interpret the data to produce personal "physiological documentaries", automatically identifying context activities.

Keywords

physiological monitoring, wearable sensors, body monitor, context detection

INTRODUCTION

In an ongoing study we wish to map physiological sensor data to everyday human activities. Automated, inconspicuous, and un-noticed by the wearer, our device can gain an understanding of their past and current activity, and make this information known to nearby devices.

Physiological sensors supply physiological signals, by definition. However such signals rarely correspond to usability features or high level functionality within a consumer electronics (CE) device. To this end we are undertaking an extensive study of physiological data gathered both inside and outside the laboratory. Much of our data is gathered in free living, 24 hours a day, 7 days a week (24/7). This abstract describes our activity to develop algorithms which interpret the physiological sensor signals to provide high level context cues.

The consumer electronics industry surrounds us and equips us with devices which take no account of ourselves - our situation, our feelings, and so forth, (Picard, 1997). It is in consumer electronics and “smart environments” where the application of physiological sensing will impact the most people, by mediating our interaction with everyday objects.

We are using "context" to describe a person's activity, location, or situation. For example, activities may be "driving a car", "playing soccer", or "watching TV". Locations may be "at the office", "at home", or "in a park". Situations include "in the rain", "in the dark", "hungry" or “happy”. Human interaction with computers for the purpose of computing is a very small part of our data pool as we are collecting free-living data 24/7. Manufacturers of objects such as cars, mobile phones, or even buildings would like to understand their users context in order to make their products behave more sympathetically to the user’s immediate circumstances. For example, a car that can detect the driver falling asleep can take corrective action, a mobile phone that knows you're driving can go hands-free for safety, and a building which knows you're lost and hungry can direct you to the refectory.

THE BODY WORN SENSOR

For this study we are using our own commercially available sensor unit. The SenseWear Pro Armband is the first wireless, wearable body monitor for sensing clinically accurate calorie burn, sleep quality, and activity state data (such as sitting, driving, watching TV) outside a lab environment.

Worn on the upper arm SenseWear collects motion (2-axis), heat flux, skin temperature, and galvanic skin response data. We are continuing to collect data and develop algorithms to interpret this data into the wearer's calorie burn, sleep quality and context identification. After a wearing session, the data is wirelessly uploaded from the armband through a small desktop cradle at the user's PC, where the algorithms are applied in software. Here a wearer can view personal "physiological documentaries" of the body on simple interactive graphs. With five days of continuous collection ability, SenseWear permits continuous and accurate viewing into a wearer's lifestyle patterns. The armband is shown in Figure 1.

Figure 1. The Bodymedia armband, physiological monitor.

The smooth, ergonomic design of SenseWear makes the monitor feel less like a medical device and more like a personal health and fitness accessory. Importantly for collecting realistic data 24/7, the wearer quickly forgets they are wearing a device at all. The armband is approximately 85.3x53.4x19.5mm in size and weighs 85grams. Heart rate data is stored if the user is also wearing a standard commercial heart strap. Battery capacity is 3 days, with memory for 5 days between data downloads, sampling at 32 hertz and storing various statistical summaries each minute.

Combinations of sensors are used to achieve accuracy over a range of activities. A number of combined sensors have been studied elsewhere mainly motion sensing combined with one other sensor. Heartrate sensing with motion (Rennie, *et al*, 2000, Luke, *et al*, 1997) demonstrated improved accuracy over either approach used in isolation for energy expenditure measurement. However this combination had difficulty with detecting non-ambulatory activity, by its very nature difficult to detect by motion sensing.

24/7 DATA

A wide range of contexts are scheduled for this study, which got underway with motoring, exercising, resting, getting in and out of bed, sleeping, and energy expenditure. Studies of other contexts are ongoing.

The subjects are employees or friends of staff at Bodymedia. Consequently most of the 200+ motoring journeys recorded are in the Pittsburgh PA metropolitan area, with some long distance journeys, totaling 91+ hours. Both cars and busses are included, for drivers and passengers. The data is annotated at this level for future study, while currently all “motoring” data is pooled for developing a motoring detector. Exercising was defined as any strenuous activity sustained for more than ten minutes. This included going for a walk, working out at the gym, dancing, or taking an aerobics class. Again data is annotated with the specific activity, but all exercising data is being pooled currently. Restful activities include watching TV, reading a book, etc. Sleeping and energy expenditure physiological data was collected in a laboratory setting with labels being supplied by current “gold standard” laboratory bound equipment. PSG in the sleep lab, and VO2 in the energy lab. Two rounds of data collection have taken place through winter 2001 into 2002. During this period there was a mix of seasonal weather.

The data was collected in a "free living" environment, which is to say at the discretion and convenience of the subject as they went about their daily lives and routines. Subjects would typically collect two events a day, though many currently submit 5 or more different activities a day. 17 free living subjects are currently collecting daily sleeping data, an official annotation of this study, while only 4 subjects are annotating eating and bathroom visits, which are among the 100 optional annotations.

PRELIMINARY RESULTS

Data gathering and analysis is ongoing. Preliminary results are promising with each of our chosen contexts appearing to be discernable with sensors in the armband, but without the use of heartbeat data.

Context	Subjects	Positive Data hours	Negative examples hours	True Positives	True Negatives
Exercising	14	> 90	>788	63.8%	98.3%
Motoring	16	>122	>782	25.7%	95.0%
Resting	12	> 91	>357	53 %	97 %
In & Out of bed	14	54 samples	99.4%	93.4%	
Sleeping	9 sleep 16 non sleep	8	16	95.7%	93.8%

Some of these results have a purposeful bias in favor of high true negative’s. If you sleep for 1/3rd of the day, then 1% of your wakeful day is roughly 14 minutes. Whereas 1% of a 30 minute exercise session or drive is only 0.3 minutes (18 seconds).

CONCLUSIONS

Interpreting high level “context” from low level physiological data is proving to be possible, at least for the contexts we have started to analyse. The Bodymedia SenseWear armband is allowing for the easy collection of physiological data outside of the laboratory, mainly due to its wearability. As the catalogue of automatically and accurately identified contexts grows the design and interaction between people and objects can change dramatically.

We currently analyse the data after the event, producing physiological documentaries. For activity detection to impact the usability of an object these contexts and activities shall have to be identified on the fly. Fortunately there is plenty of computing capacity available and idle in our data gathering device.

REFERENCES

1. Luke A; Maki KC; Barhey N; Cooper R; McGee D; (1997, Jan). “Simultaneous monitoring of heart rate and motion to assess energy expenditure.” *Medicine and Science in Sports and Exercise*, 29 (1): 144-148
2. Picard, Rosalind W; (1997, Sep). “*Affective Computing*.” MIT Press.
3. Rennie K; Roswell T; Jebb SA; Holbuen D; Wareham NJ; (2000, May). “A combined heart rate and Movement sensor; proof of concept and preliminary testing study.” *European Journal of Clinical Nutrition*, 54 (5): 409-414