Using Small, Simple, Wearable Devices for Large-Scale Data Gathering

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ABSTRACT
Collecting real-world, long-term data from work environments is a challenging exercise. There are many different, and well-established, techniques from the fields of psychology and HCI (such as ethnography, auto-ethnography, diary studies, video studies *etc.*) that aim to address this. The choice of which to use is often determined not only by the nature of the data being collected, but also the availability and suitability of both personnel and equipment for the environment in which people are being studied. While the continuing emergence of hi-tech solutions (particularly in areas such as video and voice capture) can help with this by providing less obtrusive ways of capturing information, they can still be problematic for large-scale data-gathering experiments. We are currently working in the domain of the New Zealand forestry industry with the aim of building up a large repository of data of workers' activity levels throughout the day (both when at work and at home) and sleep patterns at night, with the aim of supporting safety efforts. In order to achieve this we have chosen to use a low-tech solution: using lightweight, wearable activity trackers with the aim of creating an extensive record of forestry workers' activities and well-being. Our goal is to use this data to identify potentially hazardous workplace situations.

INTRODUCTION
The recent developments in personal activity trackers have seen the simple pedometer redeveloped into a data-capture device capable of a much wider variety of capabilities than just counting steps. This has led to a proliferation of such devices, as well as the development of associated mobile phone and 'smart watch' applications that provide visualisations and analysis of activity data. While the target users for these devices are typically individuals interested in personal fitness or their own health and well-being, the fact that these trackers are low-cost (typically less than NZ$150 per unit) and lightweight makes them ideal research tools for large-scale data collection. A description of our research domain follows.

In 2013, fatalities in the NZ Forestry industry were twice the annual average NZ workforce rate of 5/year [9], and overall NZs highest rate of workplace injury deaths [3], with numbers increasing. The rate of ACC[1] claims for the forestry sector is almost six times the rate for all sectors and currently costs over NZ$2.3 million per year [4]. Both the severity of accidents and long-time injury frequency are increasing. The NZ forestry accident rate is more than 6 times higher than that of the UK and the death rate is 34 times higher.

Forestry is labour-intensive (most workers undertaking 40-60 hours of work per week). The tasks of tree felling and breaking out are the main activities contributing to serious accidents. There is a general consensus that pressure points include fatigue, dehydration, distraction, isolated work, remote locations, high staff turnover and production pressure, however no systematic data has ever been recorded to test these hypotheses. Major stakeholders (e.g., worker unions, government agencies, forestry management corporations) have conflicting views of the most significant contributing factors to accidents.

In a study conducted in 2010 video recordings of eight workers gave some insight into the differences between work patterns of novices and experienced tree fellers [10]. In the initial study the researcher, Parker, tried to film workers in their everyday work environment. However he soon found that what he was recording was not the usual work practices of the tree fellers, but rather the activities of tree fellers trying to prevent the researcher getting injured in their hazardous work environment, or getting in the way of their work activities.. Subsequently Parker developed a light-weight wearable camera which was used in the next study, but the cost and availability of the equipment meant that this study was limited to just eight participants. Because it has been so difficult to gather accurate data on worker activities, much of the current research into safety efforts for NZ forestry is focussed on developing robotic solutions (to remove workers from the equation) or on managing worker behaviours rather than investigating underlying causes.

In order to understand the causes (and therefore consider the prevention) of accidents we need a much better understanding of all of the contributing factors. Typically when an accident is reported only the immediate circumstances are considered relevant (what the worker was doing at the time the accident occurred) whereas we contend that there may be a series of

[1] New Zealand's accident compensation scheme, which provides financial compensation to New Zealand citizens, residents, and visitors who have been injured in an accident.

Figure 1. Polar Loop, FitBit Flex and FitBit One

contributing factors that have happened in the time leading up to the adverse event (and this timescale may be days before, rather than immediately prior to, the accident). To examine this hypothesis further, we need a way to capture data over extended periods of time from large groups of forestry workers with the data including all of their activities, not just what they are doing at work. So if (as is often stated) tiredness is a contributing factor, what is the cause of the tiredness? Is it solely the physical effort of the job (estimated as equivalent to running a marathon a day) or is this exacerbated by the fact that many of the workers are involved in sports outside of work and have perhaps been playing rugby for much of the weekend, or have poor sleep patterns, or have a two hour drive to get to the workplace each day etc.

RESEARCH OVERVIEW

The longer term aim of our research is to predict (and ultimately prevent) hazards by harnessing the power of a new generation of lightweight, wearable technology (so-called fitness trackers). We aim to create an extensive record of forestry workers' activities and well-being to build up a contextual history. Mining this record, we will identify hazard patterns and ultimately look at ways of encoding pattern detection algorithms within similarly lightweight, wearable devices to provide real-time hazard warnings.

Our work is currently structured into six components:

- Comparing different activity trackers and their suitability for collecting the type of data we are interested in
- Pilot studies in the field with different categories of workers and different devices
- Refining the nature/type/scope of data to be gathered
- Large scale data gathering
- Data analysis and development of safety models
- Development of technological solutions

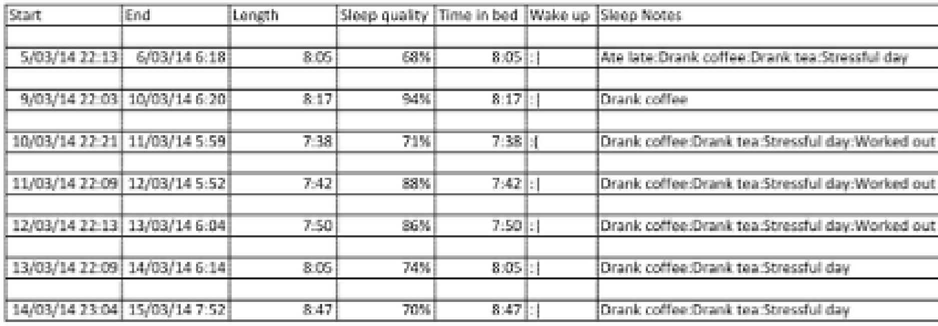
We are currently experimenting with activity trackers such as the FitbitFlex, Polar Loop, Fitbit One etc. shown in Figure 1. These have similar capabilities to each other including monitoring of steps taken by the wearer, identifying stair or hill-climbing activities, estimating calorie burn (based on steps taken and pre-set parameters for age and weight) and monitoring sleep patterns. The data produced is then provided to users by way of graphs and data logs (see Figure 2). The raw data can also be accessed via an API at a lower level of granularity, so it is possible to monitor activity on a minute by minute basis.

Our initial studies with these devices have enabled us to generate sets of data which we can use in our first experiments, and we are combining these with participant diary studies in an effort to match a user's record of their activity and well-being with the device data. We also have initial data regarding usability of the devices from the perspective of the user. This will enable us to consider things like how much effort is required to use the device (the less interaction our participants have with the device the better), how often the battery needs to be recharged, whether wearing the device has any effect on everyday activities, etc.

Our proposed solutions are based around our previous research expertise in the areas of ethnography [8, 7], formal modelling of interactive systems [1, 2], complex event processing [5, 6] and forestry safety [10, 11].

THE CHALLENGE

The major engineering challenge we are facing is how to use simple, cheap, lightweight, wearable devices (activity trackers) in smarter ways for large-scale data-collection. The availability of these devices and their low cost mean that they are an ideal choice for using in our research environment. We



Start	End	Length	Sleep quality	Time in bed	Wake up	Sleep Notes
5/03/14 22:13	6/03/14 6:18	8:05	68%	8:05	:|	Ate late:Drank coffee:Drank tea:Stressful day
9/03/14 22:03	10/03/14 6:20	8:17	94%	8:17	:|	Drank coffee
10/03/14 22:21	11/03/14 5:59	7:38	71%	7:38	:(	Drank coffee:Drank tea:Stressful day:Worked out
11/03/14 22:09	12/03/14 5:52	7:42	88%	7:42	:|	Drank coffee:Drank tea:Stressful day:Worked out
12/03/14 22:13	13/03/14 6:04	7:50	86%	7:50	:|	Drank coffee:Drank tea:Stressful day:Worked out
13/03/14 22:09	14/03/14 6:14	8:05	74%	8:05	:|	Drank coffee:Drank tea:Stressful day
14/03/14 23:04	15/03/14 7:52	8:47	70%	8:47	:|	Drank coffee:Drank tea:Stressful day

Figure 2. Standard Statistics for Sleep Cycle and FitBit Devices

can provide large groups of workers with the activity monitors and the devices are small and unobtrusive enough to be used over long periods of time to gather data. Conversely, many of these devices do not provide the ability to alter the parameters of the data being collected and cannot be programmed or extended to provide different kinds of feedback to users. We envisage that the simplest devices will be used for initial data gathering and experimentation, while more sophisticated devices (programmable smart-watches like the Pebble for instance) will be used for the final technological solutions.

Additional challenges of our work include:

- Identifying useful and informative patterns from large quantities of data
- Matching the patterns to hazardous situations
- Determining hazard predictions from the patterns
- Incorporating real-time alerting into small wearable devices

Of most interest here is the challenge of working with limited interactive devices rather than the more common problem of dealing with increasingly complex systems. In particular finding novel ways of making the most of their data capabilities as well as exploring options to enable them to act as warning mechanisms in a hazardous environment.

For our current domain of interest, the forestry sector, our goal is to use trackers which require minimal user interaction and which are as unobtrusive as possible, at the same time we want our final solutions to be able to collect a rich set of data. Adapting parameters to be captured and understanding how this can be achieved using these simple devices is an additional challenge we face. There are, of course, may other domains in which similar types of tracking may be useful and our work may be extended to investigate some of these as the project progresses.

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