From self-monitoring to self-understanding

Going beyond physiological sensing for supporting wellbeing

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Abstract— **Even though mental health is an important part of our wellbeing we believe that, so far, it has been overlooked in favour of physical health by most of the existing self-monitoring solutions. Our goal is to utilise context aware technologies in order to support people in understanding how various aspects of their lives influence their wellbeing, including their mental health. For that, we need to gain a deeper insight into the challenges of designing such solutions, from sensing to interaction paradigms. This paper describes our system, the design challenges we have encountered, the decisions we have made and our ongoing work in terms of system design as well as usage experiments.**

Keywords- context awareness, self-monitoring, self-understanding, wellbeing

I. INTRODUCTION

Advances in wearable technologies as well as the realization that self-monitoring systems help people become more aware and even change their behaviours [1][2] have helped create many solutions that deal with various health aspects. As defined by W.H.O. Constitution, health is "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*". The reality is that most of the currently available lifestyle management systems mainly focus on physical health through recording certain physiological data. We argue that it is time to take advantage of the varied data available through our smart environments and move from focusing only on *what* happened towards *why* it happened, while engaging the end user throughout the process. We believe that by using self-monitoring technologies that are able to create a more detailed and complex picture of our lives, we will be able to address the wellbeing at a holistic level, including mental health, rather than looking at various aspects in isolation. Our aim is to create systems that support users in self-understanding and self-reflection, allowing them to identify various stress factors within their daily activities. In this paper, we present the system we have built to address such issues and we discuss the various challenges we have encountered, especially in terms of information collection, modelling and visualization. We introduce our novel approach for creating interactive, personalized and informative systems. We conclude by describing our ongoing activities as well as plans for future exploitation and testing of our system.

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II. BACKGROUND AND MOTIVATION

Even though mental health is extremely important and a large number of people will suffer from a diagnosable mental condition at some point in life [3], the area remains poorly addressed by self-monitoring technological systems. There is, however, an increased realization that focusing only on certain aspects of health is not enough. When looking at existing solutions, memory loss is probably one of the best represented areas, both in terms of available products as well as research. Various systems exist for helping patients with memory problems keep track of their medication. Most of the systems allow patients or their caregivers to pre-program alarms for times when certain pills should be taken and some even use special pill boxes to track if pills have been taken [4][5]. Various research projects have also used camera-based systems, such as SenseCam, for supporting patients with more advanced memory problems [6]. Furthermore, stress is part of our lives and various methods exist to address it, most of them based on relaxation techniques. Biofeedback systems offer technological support for such processes. The main sensors used measure GSR (skin conductivity), heart rate and its variability, as well as EEG (brain activity).

Various visualizations and interaction methods are employed to manage stress and other issues. For example, certain systems use game-based interfaces allowing users to control functionalities in the games through controlling their physiological parameters [7][8]. Other systems use sounds, lights or charts to allow users to become aware of their stress level as well as enable them to control it [9][10][11][12]. While depression is probably one of the most common types of mental health issues, there are not many systems dealing with it. Most of the self-monitoring methods for depression focus on keeping manual mood diaries. Systems such as [13] provide some support for people with depression, by using an interactive questionnaire and prompting for a periodic recording of blood pressure.

Some research platforms, built to enable wellbeing applications, are described in [14][15][16]. However, very few of the available lifestyle management systems support users in understanding *why* something happened. In most cases, patients can monitor certain physiological aspects but have little idea about the context in which the data was collected, as correlations between the data recorded and events that might have influenced certain changes are mostly based on recollections, which are prone to memory errors as well as

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a lack of attention. While it is true that more diverse data collections can also increase acceptability concerns, we believe that the number of self-monitoring systems used and owned by individuals will continue to grow. We suggest this trend will be driven by an increased availability of sensors and sensor-based applications as well as by the higher degree of acceptance towards digitally recording life experiences that can be observed in younger generations [17].

III. System Design and Implementation

To better illustrate our system and goals, we start with a scenario:

It's the end of the day and Jane is feeling tired and upset but she cannot determine why. She opens the MyRoR system to see if the information it captured during the day can help her better understand what events could have affected her. By playing the daily story created by MyRoR, she can see that her main activities today were to work on the paper due next week, drive to the university, attend a meeting and then return to the paper writing. Watching the story, she can see that she became annoyed by something during the meeting. She now remembers that Mark kept interrupting during her presentation! She also checks the detailed view of information recorded during the meeting and she can see clearly how her emotional state changed. It also shows that she became less productive after the meeting, when she returned to working on the paper. Maybe it was because she was still bothered by Mark's comments? She adds a note to the system to explain to herself why and how she felt. She decides to mainly focus on the paper submission during the next days.

Our system, MyRoR, collects information about her daily activities from various sources, such as sensors, her work and private computers as well as her mobile phone and stores it in a local, trusted space that can only be controlled by her. Correlated recorded information helps her understand what has happened during the day and why. MyRoR uses the collected information to generate a story that helps her revisit the daily events in an engaging and summarized way. When she wants, she also has access to more detailed information, allowing her to see what she did, where she went, who was around, and how she felt. She can add notes and her own media to the system, to serve as additional context.

A. *Information gathering and processing*

The decisions regarding the information collected and sources used are governed by various requirements. Some of the most important criteria are that: (1) the collected information can provide useful support for self-understanding and reflective behaviours (i.e., help explain *why* something happened); (2) the system can deal with both static and mobile scenarios spanning various spaces and situations; (3) the system should include commonly used user devices such as PCs, laptops and mobile phones; (4) the system should include commercially available sensing devices; and (5) the number of sensors should be limited both because of the amount of required processing as well as to prevent systems that are too obtrusive or require too much time and effort to use.

Figure 1 shows the input sources and the input data we currently collect. Each input source stores data in its own format and own location but, once parsed, filtered and reformatted, the input information is eventually collected on a trusted server and stored in a MySQL database. Stored information is further processed and newly created information is either stored in the database or obtained on-demand during the visualization phase.

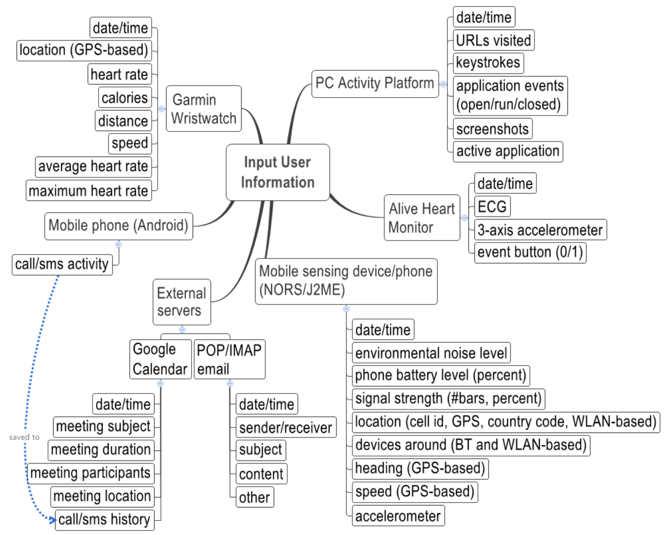

Figure 1. Input sources and data collected

An important phase in the information processing is to determine how the available information can be correlated to create various aspects of a user's context [18], such as:

- *Physical context*: location information (absolute, relative and at various granularity levels) obtained from various sensors (e.g., GPS, cell information, country code, wi-fi, meeting location, Bluetooth (BT) vicinity), as well as derived information such as distance, speed or heading.
- *Social context:* information about a user's social activities, obtained from sensors (e.g., people in vicinity from BT devices) or social communication tools such as emails, calendar, chat programs (through PC activity platform), call/messaging history (through phone).
- *Emotional context*: information about a user's emotional state obtained from physiological sensors, such as ECG and heart rate, and through virtual sensors, such as keyword-based filtering of keystrokes, email content, etc.
- *Mental context*: information about a user's interest both as topic and as intensity level, derived through web activity, applications used, keyword-based filtering of keystrokes, messages sent, and screenshots.
- *Activity context:* information about what the user was doing and the activity level, derived from physical sensors, such as accelerometer data and GPS, as well as from applications used, web activity, screenshots and calendar information.
- *Availability context*: information regarding availability of people (e.g., through identifying people around, checking calendar information) or devices (e.g., through BT vicinity, battery level, signal coverage).

- *Environmental context*: information about environmental parameters that can affect users, such as noise, temperature or lighting. We currently record only ambient noise but more sensors can be easily added.

In our system we decided to create a balance between information abstraction and transparency. This is to allow the end user access to certain unprocessed or lightly processed data, which can generate interpretations that a system designer might not have considered or could not even consider due to incomplete information. For example, in our initial scenario, the system can realize that *Jane*'s heart rate increased, her voice pitch raised and deduct that she was getting angry. However, Jane's status could also be a reaction to an increase in room temperature or to being in a crowded environment. Her emotional state might also be influenced by other hidden parameters, current or historical, such as previous experiences related to the people present, etc. In such situations, it is better to show the user through the interface that something unusual happened at a certain moment during the day (e.g., based on her heart rate) and let her deduct what happened and why, by allowing access to other collected information (e.g., who else was there, what else happened around that time, etc.). Another reason is that, even with all the advances in automatic emotion recognition, it is still hard to determine with certainty what the user feels, especially when considering real world settings (as opposed to controlled research laboratory experiments) [19].

B. *Information presentation and usage*

A major issue facing such a system is to visualize the diverse information. Currently, the most commonly used means available for presenting self-monitoring systems are graphs, maps or charts, but these have proved to be insufficient to easily and properly capture the wealth of information recorded. Our exploration of interactive information systems and natural ways of presenting 'life experiences' led us to *stories* as one of the most natural way of conveying information between people. Stories offer a way of organizing information as collections of *meaningful events* brought together either by following a timeline or a certain topic or character, as described by Brooks in [20]. Related work in this space has mainly focused on computer-assisted storytelling [21] or on creating stories based on image annotations [22]. An approach more relevant to our project is that of the Affective Diary [23], where the focus is on creating better visualizations for self-monitoring systems and supporting user creativity while hiding access to lower level information. Our vision is to create a system that can offer both a high-level, summarized view of information as well as allow access to more lower-level recorded data in order to increase user understanding. Hence, we use both stories and other means that allow for a more detailed representation. For detailed views, we use Google Visualizations-based modules to create correlations of two or more types of data. All visualizations are embedded into a diary-like interface built within a WordPress environment (http://wordpress.org/). WordPress is one of the most commonly used blogging platforms. It has many advantages, some major ones being: (1) day-based access to information through calendar; (2) familiar interface of a personal blog, which also allows users to add own data; (3) easy to access and modify from any device, including mobile devices. The story-based visualizations constitute one of the main aspects of our research, as we would like to better understand how to build such systems. A story is defined by the following elements:

- **Characters** or actors: Entities, either humans or other living beings, taking part in the story. Characters have various roles and are connected by certain relationships.
- **Storyline**: The plot of the story that is being formed by a sequence of meaningful events. An event is described in terms of various defined context types. The "*meaningfulness"* of an event can be determined through observing changes in (certain) contexts and through considering user annotations (based on the event button).
- **Setting** of the story: includes important elements that create the setting of a story or of an event, such as time, place, weather, etc.

A story can also have a **theme** (i.e., focusing on a certain aspect, such as emotional changes during the day) and a **point of view** (i.e., changing the way the story is created based on the intended audience).

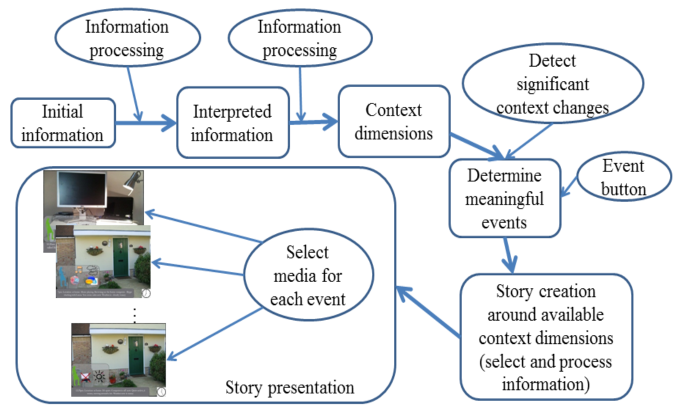

Figure 2. Creating a story

We currently develop mechanisms for automatically creating stories based on the data collected through the MyRoR platform. Figure 2 summarizes the story creation process. When creating a daily story, it is important to identify the meaningful events to consider, collect the information available for those events and select appropriate media to depict such information. The information in each event is grouped along the context dimensions described in Section III.

We have considered multiple tools that could be used for story creation. Among these, the *Scratch* environment [24] provides most inspiration because it allows for creating media rich stories where images, colours, texts, sounds and animations can easily convey the multidimensional space of events as well as the changes within a sequence of events. Users can add and customize media objects through scripts (e.g., to create movements or change appearance of characters), audio (e.g., voice recording or other), and change backgrounds. Such flexibility allows for conveying a sense of context change and user-based personalization of stories. Figure 3 below shows an example of an event within a story created based on data recorded by the system.

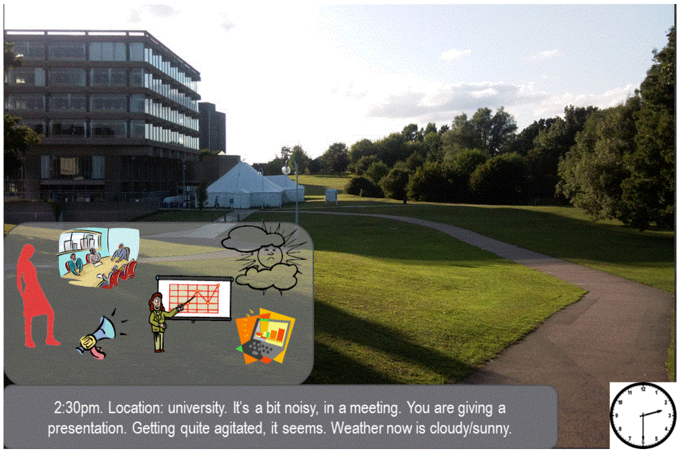

Figure 3. Example of an event from a story

IV. Ongoing and Future Work

At the moment, we have a working system that is able to: (1) collect information from the sources described above; (2) perform certain processing either after data is stored into the database or at a later time, when the information is actually needed; (3) create certain correlations through visualizations; (4) provide a blog-like interface that exposes information through a calendar view; (5) provide various detailed visualizations; (6) extract information from remote servers, such as email, calendar, call/message activity. We also created various models for what type of information could be extracted from the collected data. We additionally developed models for stories such as described in Figure 2, where various media is used to present user context in an engaging way.

The system incorporates various design choices that are informed by previous experiences with such systems, either our own or reported in existing literature or from our initial hands-on experience of using our MyRor system. Our evaluation framework aims to answer these main research questions: (1) What information is perceived as most useful? (2) What correlations are perceived as most useful? (3) How do people want to interact with the system? (4) How should stories be created to maximize self-understanding? (5) Why people consider certain events as being meaningful? The latter question is addressed through discussing their usage of the dedicated event button (see Figure 1).

We are currently exploring these issues through mixed end user evaluation methods, such as an online survey (available at http://ieg.essex.ac.uk/myror/survey/intro.php), as well as more dedicated user experiments involving hands-on usage of the MyRoR system and own story creation. While participants are free to choose their own scenarios, their focus is frequently on using to identify potential stress factors within daily activities. Though it is still early to present final results of our experiments, the initial response is very positive and it shows that people are clearly excited to be able to relate their physiological state during the day to concurrent events as it allows them to better understand why something happened. Further scenarios related to preventive health and monitoring of less critical conditions are addressed within the PAL project.

Given the design choices we have made in terms of data collected as well as the types of interactions created, we believe that MyRoR is very well suited for supporting various scenarios related to mental health, either as a self-reflection tool or as a more complex and unbiased personal diary.

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