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Supporting introspective human behaviours through technologies

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Abstract. Almost all technology supported activities we perform today involve a device with computational power that can collect data that can give information about our activities as well as, with the appropriate sensors, about our physiological status. While recording user data is not particularly novel, in our work, we concern ourselves with methods that people can use to gather and analyze data about themselves as they go about everyday work and leisure activities in order to better support self-monitoring and self-understanding. Our aim is to enable people to detect causality relationships in their behaviours either for serving their curiosity or, as we hope, for really empowering them with a tool for self-changes. In this 'work in progress' paper we describe ongoing work towards these ends. We start out by a motivation and short description of our work, followed by an exemplar scenario on 'preventive healthcare' for the system we envision. Then we describe some of the most relevant and influential related work before describing the system design and the main challenges, followed by an overview of the current status and our future vision.

Keywords. Affective technologies, context awareness, self-reflection, self-monitoring

Introduction

Self-improvement is essential for human development and is considered as one of the higher goals of any human being [18]. Modern societies experience a huge demand on self-help books, as a quick search on Google or Amazon will prove. Self-understanding plays a very big role in this process as it allows people to analyze their feelings, thinking, and behaviours. However, our attention is limited and sometimes it is hard for us to remember and, therefore, understand, why and how certain things happened. Technology can help us because of its almost ubiquitous availability, continuous miniaturization, and its endless means of capturing various data that we might or might not notice otherwise. Technology can also help bringing together various types of data, allowing users access to more detailed views of their daily lives, making it easier for them to find relations between events. We envision a system that could, for example, help people better understand their and others' emotions, which is essential in developing social and emotional intelligence [1] or in identifying and better controlling stress factors that negatively affect their daily lives.

By combining concepts from user understanding with user-centred technologies, we set out to create an integrated system that can offer support to a user in better understanding what and why something happened as well as its physiological impact

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on the user. Life data collection is studied in multiple research projects but we believe that the areas of data correlation and interpretation, information visualization and user interaction still offer big opportunities for novel and challenging research work. In order to support this hypothesis we intend to design and build a "proof-of-concept" system which takes the form of a "companion" system that, by combining knowledge from various technological domains with user understanding, can support an individual in their process of self-monitoring and self-understanding.

In this paper we will mainly focus on presenting the system we are currently building. We start out by presenting an exemplary use case of the system we envision, followed by related work. We then set out to present our envisioned system design, followed by a description of our current status and the main challenges, before concluding the paper with our future vision.

1. A case study: Preventive Healthcare

Consider the following scenario:

Bob is 55 and he has just found out that he has high blood pressure with a risk of developing a heart condition. The visit to the doctor made him aware that he needs to make adjustments to his lifestyle if he wants to avoid any worsening of his situation. The nurse recommended some lifestyle changes but Bob found it very hard to continuously be aware of his behaviour so he decided to use the new MyRoR system that allows for automatically collecting and integrating data about his daily routines. The MyRoR system helps Bob better understand how his heart is affected by the various activities he performs during the day and supports him in making decisions about lifestyle changes. By using the MyRoR system Bob can see how his busy work schedule is affecting his heart by collecting information about his meetings, his eating habits, and other behaviours from Bob's devices (e.g., mobile phones and computers).

This focus on self-monitoring for chronic disease is one of the usage scenarios we are currently considering. Chronic diseases are a major global problem and they affect a high number of people worldwide but the vast majority of such patients fall into the category of *low risk*, which means that, with the right support, they could learn how to manage their disease and this could prevent complications, and avoid or delay deterioration. Lifestyle choices, such as smoking, alcohol, physical inactivity, and poor diet, have such an influence that some of these chronic diseases are now being called "lifestyle diseases". Technology-assisted lifestyle self-monitoring and understanding could provide timely support for chronic conditions and benefit both patients and clinicians as they can record and combine data that is sometimes forgotten or discarded.

2. Background and related work

The vision for ubiquitous computing, initially formulated by Mark Weiser in [6][7] was "inspired by the social scientists, philosophers, and anthropologists at PARC". The psychology-technology connections were further strengthened through user-centered areas such as affective computing, formulated by Picard [3] and captology (persuasive technologies), formulated by Fogg [4], as well as more recent work on context-awareness (defined by Dey and Abowd in [4]). Affective computing involves, among others, giving a computer an awareness of its user's emotional state. In some cases this information is used by applications to adapt their behaviours (see work by Picard and others in [9] and Leon *et al.* in [15]) and in other cases this information is used with an informative goal, with data presented back to the user through various visualizations, as described by Lindström *et al.* in [10]. In our work, we are interested in emotional awareness in the context of self-understanding. In [8], Picard *et al.* make a case for a unified theory on using affect in learning as, they argue, one's emotional self awareness is very important in learning and developing an emotional intelligence, a concept described first by Salovey and Mayer [1] and later by Goleman [2]. One of the most relevant projects for us is the Affective Diary, described by Lindström, Ståhl *et al.* in [10] [11]. The Affective Diary was a very interesting user interface-focused experiment that represented abstracted physiological and activity user data in a more user friendly way involving emotion-informed shapes and colours. A user study conducted on the Affective diary showed that people do like to look back on their daily activities, much as they would do it through a diary [11]. The study also showed that some people became quite attached to the system as it helped them look back and better understand what happened and why. This work provided us with insight as well as verified our own views on visualizations, as we believe not everybody relates the same way to certain imposed visualizations.

Fogg's book on principles of persuasive technologies [4] provides us with a significant amount of information on how technology can be used to influence human behaviours in a positive way. Many of the system and interface designs presented are informed by social psychology. Self-monitoring is one of the persuasive technology tools described in the book, as it leads to self-understanding and changing of behaviours. While we envision our system mainly as a support for remembering and reflecting over events and physical reactions, we do expect that enabling people with this type of self-awareness will result in positive behaviour changes, as it also happened in [11].

One good example of how technology can support people's self-awareness is in fitness-related self-monitoring, which became an important market with many companies, like Garmin, Polar, Suunto, *etc*. selling various types of devices. These devices employ physiological sensors and various visualization methods to help people track their fitness related history. Fitness self-monitoring is designed to help people better understand their body's reaction to exercising and, in the process, support them in making changes in their behaviour.

Interaction and visualization is very important for our project and our ideas are shaped and informed, amongst others, by work in affective HCI and empathic interfaces from Picard *et al.* [12][9] and the work described by Lindström *et al.* in [10][11].

3. System design and development

This section includes a detailed look at both system design considerations and the system development. We start by presenting the system architecture and then follow with a look at each main component of the system, both in terms of design and current development status.

3.1. System architecture

The goal of our system architecture (Figure 1) is to allow for collecting a variety of (distributed) data across various input sources. This data exists in various formats, needing integration into a common data pool in order to be used for end user interaction.

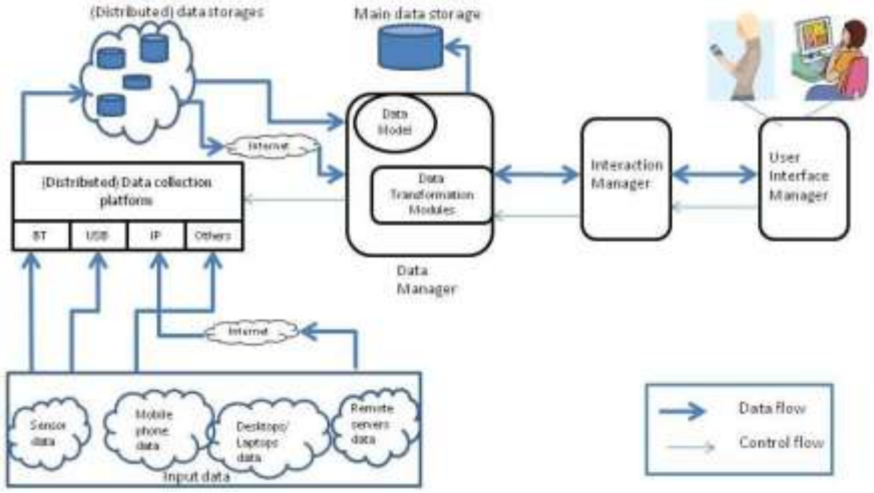

Figure 1 System architecture

It is the role of the *Data Collection Platform* to obtain data from the various input sources. Data can be collected from and can reside on various computing or sensing devices, so appropriate connectivity modules have to be provided by the platform.

In order to integrate the collected data into the system, it will need to be converted before being centrally stored and further interpreted. The *Data Manager* oversees all the data-related transformations and storage control. It includes various types of transformation modules, from input data formatting to more advanced data interpretation. The data operations are governed by the *Data Model*, containing semantic information about the collected data and the data that can be derived from it. The *Data Manager* is centralized to address potential security and privacy concerns that come with the sensitivity of the collected data.

The *Interaction Manager* coordinates various types of interactions between the system and its user(s), based on the collected data. We envision interactions for personalization, system configuration, data retrieval and new data creation.

The *User Interface Manager* is in charge of visualizing the information on a variety of different interfaces. For this, potential adaptations to the interaction or the underlying data need to be performed.

3.2. System Development

This sub-section includes a closer look at the current status of implementing the above outlined system design.

3.2.1. Data Collection Platform

The usefulness of our system relies on having relevant and rich data that can help users remember what happened during the day. To enable an almost ubiquitous user data gathering, we use mobile devices (*i.e.*, existing wearable monitoring systems and mobile phones) together with stationary devices (*i.e*., desktops and laptops). Some examples of data considered: affective state (obtained through various means such as GSR, heart rate, voice tone level, gestures, *etc*.), location (*e.g.*, GPS, indoor infrastructure), activity (*e.g.*, Internet browsing, watching TV, talking, physical, *etc*.), messages sent/received, phone calls made/received, media created/received (*e.g.*, photos, videos), environment data, and any other information that is relevant to the user and can be collected with a reasonable amount of effort. Data is collected through various means and over multiple connectivity protocols. Sensor data can be obtained from wearables or from the environment. Computer-recorded activity data can be obtained from log files on local or remote machines.

Our strategy is to use as much off-the-shelf hardware as possible and our current experiments use a Garmin ForeRunner 305 wristwatch to gather GPS, heart rate, and interpreted GPS-based data such as distance, running pace, *etc*. We are also using the wireless Alive heart monitor [14] that provides ECG and 3D axis accelerometer. A Nokia N95 phone provides us with messaging and calling activity, images, audio and video recordings, GPS data, WLAN activity, and is also used as a sensing gateway for attached sensors, utilizing the sensor platform described by Trossen and Pavel [13]. From computers, we have been looking at various available activity monitoring platforms that collect information about messaging, communication, web browsing, *etc*.

Our ambition is to create a proof-of-concept system that whilst not presenting a complete picture of the factors affecting a person’s daily experiences (as that would be unrealistic) takes a more pragmatic approach by focusing on certain data that we consider most relevant. We anticipate that other use cases developed as this research goes forward will influence what type of data is collected. It is also envisioned that the user could specify (through the user interface) which parameters they find most interesting in order to further guide the data gathering process.

3.2.2. Data Manager

Data collected from the input sources is gathered into a central database. We have chosen MySQL [16] because of its proven robustness and easiness of use.

The data collected exists in various formats and it needs to be reformatted before storing. So far, we have created data formatting modules to extract sensor data from the Alive Heart Rate Monitor and from the Garmin ForeRunner 305.

Furthermore, we extract additional derived information from the raw sensor data. For instance, the ECG data of the Alive monitor is used to derive heart rate information. The accelerometer data will also be interpreted to provide the user with physical activity information.

Further interpretation, based on the Data Model, is envisioned once more data is added to the system and combined, but an appropriate balance has to be found between too much abstraction and offering transparency. As Ståhl *et al.* note [11], some people prefer to have an understanding of how abstraction is performed through access to lower level data. Also, in certain cases, when parameter changes could be due to multiple causes, it is preferred that data is not highly interpreted: *e.g.*, raised voice tone could mean the user is getting agitated (*e.g.*, angry) but also that the environmental noise or call quality forced her/him to talk louder. In these cases, it might be sensible to not interpret the data, given the ambiguity of the situation. We also expect that certain data abstractions might come directly from the user, through annotations. For example, while we might try to interpret certain input data as emotional state, it would be good to also allow the user to name that state.

3.2.3. Interaction Manager

As mentioned above, the main interactions we envision are for: personalization, system configuration, data retrieval and new data creation.

As part of the *personalization* interaction, the users should be able to customize their user interface through various means: *e.g.*, colours, images, avatars, etc. They also should be able to select which parameters are shown, which views are created (see next section) and what time range is selected. As part of the *system configuration* interaction, users have to be able to select the data to be collected and create certain privacy and access control policies that govern individual pieces of data. As part of the *data retrieval* interaction, users should be able to query the system, to see explanations for certain abstracted data (*i.e.*, what data has been used for abstractions), get support in finding causality relations (*i.e.*, why certain things happened), or get support in finding "critical" moments during the day when something special happened. As part of the *new data creation* interaction, users should be allowed to create new data through various types of annotations (*e.g.*, text, images) and also add new data into the system, such as email, images, music, *etc*.

It is worth mentioning that we do not consider real time interaction scenarios at this point, where the focus would be on alerts triggered by changes in context. Our scenarios will be, for now, focused on retrospective evaluation of collected data.

3.2.4. User Interface Manager

It is most important for such system that it uses intuitive and engaging visual interfaces that allow users to relate to the information presented and understand it. Obviously, the UI Manager is highly connected to the Interaction Manager. However, it is the job the UI Manager to select the best way of displaying information for a user.

We believe that the user should have access to both low and high level information available. For low level, the user can select which data they would like to see. We are currently envisioning the following high-level views: *emotional*, *spatial*, *activity* and *social*. As part of the *emotional* view, one of the interesting aspects is to help users find a relation between physiological data and recorded activity data. For example, by recording affective information (given by heart rate, modified skin conductivity, *etc.*) and correlating it with activity data a user could realize his bodily reaction to certain events that happened during the day, like receiving a phone call or meeting with a certain person. The *spatial* view would create a location-based picture of his activities during the selected time period. The *activity* view would emphasize the activities performed during the day. The *social* view would be built based social communication activities performed during the day, such as meetings, emails sent, sms messages sent, calls made and received, etc.

The user interface should also offer users "zoom-in" functionalities that allow seeing snapshots of various data captured at certain moments in time. Various user interface paradigms are currently explored and multiple means are considered (*e.g.*, sounds, colours, animations, *etc.*). Available graphical tools/environments like Piccolo, Alice, Scratch and Prefuse [17] are considered either for usage or for ideas.

The UI Manager will have to be aware of the technical characteristics and constraints that the display medium has and adapt accordingly. We are currently focused on a desktop-based visualization environment but we can easily foresee that in the future such system could be used on other types of devices, especially when we will be moving towards more reactive type of scenarios.

3.3. Main system challenges

A design as outlined in this paper does not come without any challenges. The following presents only a subset, albeit the most important ones from our perspective, of these challenges:

- **Data security**: Collected data in our scenarios is considered highly sensitive. Hence, data security is very important. To address this, we chose a centralized design, allowing the data to be stored securely and backed up regularly.
- **Privacy**: The sensitive nature of the data requires precautions for preserving privacy. We currently only envision a single user, this user being the sole owner of the data collected. In the future however, we envision a policy-annotated data model, also capturing multi-users cases in which the collected data has attached privacy concerns, *e.g.*, in the case of images, medical information, *etc.*.
- **Scalability**: Two major aspects relate to the scalability challenges, namely the size of the database and potential distribution of data sources. As for the former, we rely on the scalability of commonly available database technology, handling nowadays tens of megabytes of data on single desktop machines. We intend to optimize our data model of efficient database storage by re-formatting the often XML-based input formats. The distribution of devices is not expected to be a challenge in the near future since our pool of data is limited with respect to a few servers for, *e.g.*, email or images, and a few sensor devices. Since the design is single user centered, an explosion of devices is not expected.
- **User interface variability**: the advent of different form factors, *e.g.*, mobile devices, touchscreen PDAs, netbooks, desktops and many others poses the challenge of catering to various user interfaces. Currently however, we focus our design on desktop-based interaction with the end user, not excluding future mobile use however. In a multi-device scenario, we would need to rely on advances in interface adaptation through techniques like, *e.g.*, CCPP, UAProf.

4. Conclusions and future work

This paper presents work in progress of our system, the main aim of which is to support a user’s need for self-understanding through employing various sensing and sensor fusion means, reasoning over various data, and by using suitable interfaces and interactions. We focused in our presentation on an overall view of the system, starting from its architecture and main components, including development status and ideas as well as envisioned usages and main challenges. We used related work to frame our work and also show where we expect innovation to occur.

As the topic spans technical and user understanding issues, the expected results will also be split into these two categories. In the *technological* part, the expected outcome will be the design and implementation of a computer system that is able to gather and provide to its user data about their daily activities, using various input sources and appropriate interaction paradigms. The novel research results are expected to come more from the areas of information visualization and user interactions, while the data gathering and aggregation will make use, as much as possible, of existing solutions. On the *user understanding* side the main goal is that, by allowing users to envision and interact directly with such a system, we can gather knowledge about how, when and by whom such system can most effectively be used and what would be the impact on the users of having such a system available all the time. It is also interesting to identify which user parameters (as part of and in addition to affective state) are most useful in supporting self-understanding. The findings of such user studies should be fed back into the system design and should also help advance the research into supportive technologies.

Our system will also be used in a new research project starting summer 2009 funded by the UK TSB/EPSRC that investigates scenarios as the one described in Section 1 but in the larger context of infrastructure support for future healthcare.

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