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AN OVERVIEW OF SELF-MONITORING SYSTEMS

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ABSTRACT

The advancement of mobile devices, battery longevity, and low cost sensors is a confluence of enabling technologies, which have led to the creation of self-monitoring systems. This paper is a review of technologies within the field of self-monitoring or Quantified Self systems. Additionally, an original framework is presented for classifying such systems. The framework is intended to aid in evaluation of existing or proposed systems, managing research, and applications of self-monitoring systems. Technology gaps and applications are then addressed to highlight what topics are under-developed or covered by existing work. Knowing these topics could then be used to direct research and development to a certain degree.

Keywords

Self-Monitoring, Quantified Self, Sensory Augmentation, Data Mining, Situational Awareness, Predictive Analysis

INTRODUCTION

Portable devices such as mobile phones and wearable devices combined with improved battery technology and low cost sensor systems have enabled the development of self-monitoring systems. With the availability of cheap massive storage devices, the gathering of long histories and multiple types of personal data can be achieved. Web technologies and communications mediums allow for transference and sharing of data. Finally, intelligent software systems collect, monitor, and analyze data that can be used to gain insight and even predict certain realities about oneself and surrounding environment. The act of self-monitoring through technology has led to a movement known as Quantified Self. Gary Wolf and Kevin Kelly in part created the Quantified Self movement in an effort to collect and document self-monitoring and tracking tools (Quantified Self 2012; Wolf, 2010). Traditionally, self-monitoring has been limited in devices available or software services and tools. With the advancement in component technologies; devices have become easier and cheaper to manufacture. As manufacturers begin to produce new devices, a method to classify and describe such devices is needed. Currently, self-monitoring devices are loosely organized by the types of data they monitor, and described by marketing according to their benefits. Devices instead can be generally categorized into one of many types according to their form: portable, wearable, placeable, consumable, and implantable. The services and applications of self-monitoring technology is provided as a function of devices and their implementation of sensors and software. Services can be grouped as one or more classes relating to their function within self-monitoring: biometrics, mood, perception, and behavior.

DEVICE CLASSIFICATION

With the invention of new technologies often lies an area of classification that needs defining, especially as that technology sector begins to grow. These categories are used to describe the form: representing size, shape, weight, or other physical characteristics of the devices; as function and form are often closely related. The type of self-monitoring device can be labeled as a portable, wearable, placeable, consumable, or implantable device. Each class of device shares the same common basis of operation: they have a combination of hardware sensors or software applications to collect information. Devices may use various methods of data transfer (portable media, wired, or wireless) to enable utilization within applications.

Portable Devices

Portable devices are lightweight, tend to be energy efficient, but meant to be carried; their functions are invoked on demand. For this reason, a portable device must also be easily handled by an individual and convenient in its use. Portable devices can provide many functions primarily associated with data that cannot be automatically collected by sensors: such as manual status updates and user input over time. Mobile phones or special purpose monitoring systems are examples of portable self-monitoring devices.

Wearable Devices

Wearable devices are lightweight as well such that they can be worn on clothing or part of the body. Wearable devices have a mechanism for attachment to the body; perhaps even exist as an article of clothing or accessory. Energy efficiency of wearable devices may not be a concern, depending on manufacturers' intended frequency of use. Wearable devices are often started and stopped automatically when beginning and ending an activity to monitor for instance. These types of devices are also worn throughout an activity or period of time, rather than worn only temporarily and removed again (such infrequent use items may be better classified as portable). Wearable devices expose functions that require close proximity to the body such as but not limited to recording movements of the body.

Placeable Devices

Placeable devices are strategically located for their usage; attached to common objects, permanent mounted, or located near specific areas to gather data. Placeable devices are therefore designed for monitoring environmental changes, interaction between objects, and observation of a specific subject matter. Psychology sometimes has an effect on the location of these devices as well; like placing an electronic scale within a bathroom as opposed to a garage, it would likely get more use in a bathroom. Such devices can be quite ordinary having existed for many years, but with upgraded technology: wireless-connected treadmills and weight scales for instance. Placeable devices are not limited in their weight, size, or battery consumption properties.

Consumable Devices

Consumable devices are still in technological infancy and limited primarily to medical or military uses. The commercialization of these devices is restricted because of cost, practicality, small component availability, and medical regulation. Persistent storage and battery life, that can be maintained within the body, is a technological limitation for these devices. Consumable devices do have the requirement of being very tiny, nano sized, such that they can be taken internal to the body. For this reason, consumable devices do not have long battery life, their purpose being specific and disposable.

Implantable Devices

Implantable devices are very similar to consumable with the exception of longevity; they are long term to subject lifetime. Implantable devices can be grafted to skin and tissue, incorporated into or on the body itself. Consumer availability of these devices is non-existent. Instead, they currently exist within the medical or military domain only. Medical regulation and operating requirements forces a high level of reliability and stability as it is contained within a subject's body. The nature of implantable devices therefore limits them primarily to these sectors; specifically in part because of their purpose for monitoring critical health issues.

SERVICE CLASSIFICATION

As self-monitoring devices are classified to their form, the classification of services or applications of the technology are by their function. Services can assume one or more classes, based on the quantity and types of information they provide. The service classes are broad but share a common appliance to individuality rather than group or social functions. Service classes are also not limited to a specific domain of application such as health or military. Instead, service classes resemble a product or output from devices; that may be applied to any number of fields. Applying devices and services in conjunction enables many current uses but also opens exciting future applications of these systems; that is in essence the Quantified Self.

Biometrics

Biometrics is a broad category of self-monitoring services and likewise has the majority of devices available to provide them. Most, if not all biometrics monitoring devices are wearable devices as they need to be proximate to the person to sense body functions such as movement and heart rate. Body functions are perhaps also the most interesting when it comes to the evaluation and capabilities of self-improvement due to their potential in healthy lifestyle promotion. Major athletic apparel and fitness companies have heart rate, pace, position tracking, galvanic skin response, and other similarly capable devices. Combined, these sensors allow for the collection and analysis of physical activity performance (BodyMedia, 2012). Other devices such as those used to collect caloric intake and expenditure, body mass index, and blood pressure enable dietary activity tracking (Withings, 2012).

Mood

Mood or emotional status is difficult to monitor by any hardware or software system. Often times mood is subjective, depending on ones mood. There are a few wearable and portable devices, mostly software services that are used to monitor emotional status. Emotional status can be collected by user feedback, mobile applications, or games that have roots in psychoanalysis. Brain activity patterns are also feasible to monitor, but still cumbersome or awkward to wear (Emotiv, 2012). They are also not as reliable or lacking confirmable results as would be provided by user feedback. As technology improves though, likely will the capabilities of wearable devices. For now though, there exists a prevalence of software applications running on portable devices (T2 Mood Tracker, 2012).

Perception

Still photos and video captured by mobile phones or other recording devices can capture the observable perceptions of a persons surrounding space. Devices that collect perceptual data tend to be wearable or placeable; this is both due to convenience and to prevent distraction. Perception based services are not limited to visual data, and that which is directly observable (Dorminey, 2012). Audio and video recordings of a subject for performance monitoring and behavioral correction are the oldest self-monitoring technologies whereby they are used in sports and activities training (Gizmag, 2007).

Behavior

Behavior based services are classified as such because they indirectly collect data from a person. Instead, behavioral monitoring devices are placeable devices. Such placeable sensors could be located on objects a person interacts with on a daily basis such as a toothbrush (Krejcarek, 2011), or an infrequent basis such as garden tools. These types of services are especially useful in tracking behaviors, manipulation of objects, relation to the environment, and predict how they relate to daily life. Interaction between objects and a person can be useful for studying habits or behavioral tendencies (Buettnner, Philipose, Prasad and Wetherall, 2009).

TECHNOLOGY GAPS

As useful as the aforementioned technologies appear, there can also be hidden pitfalls or consequences of using them. When using technology to monitor and perhaps alter ones activities and behaviors the dangers of blindly making changes can be counter productive perhaps even dangerous. The dangers of self-monitoring are not completely limited to physical consequences as there are legal, societal, and other technological implications to consider. As self-monitoring technology matures and expertise applied to fixing issues; old technology gaps will close while others may open.

Personal Data Security

Security issues surround any system involved with collecting personal data. Self-monitoring is no exception to this fact. With the abundance of web services and hosting sites, it becomes incredibly easy to share personal information (Francesca, 2012). The thought of having health or lifestyle based information available to others whether it be to insurance providers, marketing companies, or simply hosted securely on a web site is still disconcerting for many. Government policies exist such as the Health Insurance Portability and Accountability Act (U.S. Dept. of Health & Human Services, 2003) to protect consumers and other parties. Even with such acts, personally recorded data may or may not fall within the protective boundaries of the policies. Similar policies require data security and specific information handling procedures, but accidents and security breaches are still known to occur.

Personal Data Misuse

What is commonly overlooked by those involved or considering the application of self-monitoring services is the misuse of information. As helpful as self-quantification systems may be, they must also be evaluated with care. Dieting guidance systems such as those that aid in balancing caloric intake can easily be misused leading to perhaps more severe health problems (Moore, 2001) Systems involved in providing performance metrics, physical and mental health evaluation can lead to paranoia that something is wrong with a subjects body or behavior (Muench, 2010). Cautionary usage messages may need to be provided with self-monitoring devices and services; much the same way mapping applications warn about following suggested routes (Clark, 2011) The legal system may need to account for improper uses of devices to protect companies as well as individuals, potentially resulting in new forms of certification and regulation.

Information Interoperability

With a variety of self-monitoring applications and their respective methods for collecting and storing data, comes an equally wide array of formats, for which the data is stored. Additionally, devices may bound to their specific manufacturer; having a distinct registration process and collected data inaccessible external to their website. There are some services (Microsoft, 2012; Google 2011) attempting to fill this technology gap; however, their future relies on consumer appeal and device

manufacturer design and marketing support. Another hurdle in mining and applying applications of the collected data is getting the data in a reusable format. Common formats that self-monitoring applications use or can export their collected data to is CSV, XML, or Excel. However, there are no implemented standards providing a common and portable data format for personal data. In some instances, applications keep the data proprietary or viewable only through a website. The typical practice to unifying and combining data from multiple applications tends to be manual data entry, import from a recognized format, or some type of data scrubbing process (Machulis, 2011).

Societal Impact

The benefits of self-monitoring are appealing but their affects on society are not fully realized. Services that track and compare results among others could potentially create fanatical competition to be better than everyone else or other ill side-effects (Kohn, 1992). Opinions of private data could shift over time, resulting in an insensitivity and carelessness as personal data is moved into the cloud. The implications of this are not difficult to determine, exploitation is one of them. Government policies and procedures may come to touch our personal data; similar to how personal trainers often require certifications (NASM, 2012). Similar to how social media and mobile phones have changed the way we interact, self-monitoring technologies could change the way we act as a whole; our lifestyles linked together (Kurzweil, 2006).

TECHNOLOGY APPLICATIONS

The benefits of participating in self-monitoring and applying the tools and data are numerous. Both short term and long term benefits related to health, personal fulfillment, goal reaching, knowledge, and other beneficial aspects can be obtained through self-monitoring devices and services. The hardware designs and software algorithms that used to be considered complicated or unsolvable have become more commonly known amongst engineers (Kurzweil, 2006), leading to breakthroughs in technology. Not only have the applications and therefore benefits begun to enter into readily available products and common consumer use, but they are now mainstream. Major companies are investing in self-monitoring technology as athletic equipment (Nike, 2012) and even video game accessories (Nintendo, 2012).

Self-Knowledge

Knowing the bodies current state and perceptions is the key to further knowledge about oneself, also known as self-knowledge. Knowledge is not necessarily derived from any single device, device classification, or service. Applications can use collected data to build models, visualize performance, or otherwise augment existing sensors. Services that provide temperature and sleep cycle habits could be integrated to provide a profile of what temperature range allows a person to sleep better. Data mining techniques and computationally expensive predictive analysis algorithms currently reside primarily at a higher application level, but as technology improves, they may reside within hardware. Similar to how the brain processes information within specialized sections, self-monitoring devices could incorporate the various services in specific analytical modules (Kurzweil, 2012).

Self-Discovery

The human body in many ways is still a mystery. To learn new things and better oneself it is beneficial to first know as much about the idea of the self as possible, or the process of self-discovery. Discovery begins by finding and understanding bad habits, improper dieting, anger issues, attention deficit, or any other quirks within our life. Some behaviors may be very subtle in nature, not even apparent to observing parties. By collecting information about how we live our lives and further analyzing it, can lead to uncovering patterns or interesting events (Han, Kamber and Pei, 2011). For instance, recording how often a person forgets to turn out a light, could predict how likely they are to do it again; useful for an automatic reminder system. Self-discovery is a bridge, on one side is knowing, and the other side is improvement; one can not get from one side to the other without understanding.

Self-Improvement

Self-improvement is a thoughtful and deliberate attempt improve ones self in any number of ways. Self-improvement is not limited to any physically measureable attribute, it can be strictly based on the perception a person has of themselves. By learning the inner workings of the body, personal performance, habits, daily routines, and other statuses the data can be analyzed for ways to continually improve (Imai, 2012). Various types of studies (Landau, 2012; Mitra, 2012; Wurtman, 2011) have been done using physical activities, emotional status, perceived time tracking, medical reminders, and others. A common form of self-improvement is weight loss. Using biometrics tracking and planning applications, acting on the suggested plan could lead to a healthy and sustainable weight loss program. Behavior tracking and analysis of sports such as golf could improve ones body mechanics and eventually scoring. Whether the improvement is simple such as becoming calmer in traffic, or having better dental hygiene; all of these applications of self-monitoring can lead to personal improvements.

CONCLUSION

Using device classification and service classification methods provides a framework for the logical categorization of devices and their functions. In Table 1 the framework is used to classify existing products, enabling a consumer for instance to easily choose a biometrics capable device that is worn rather than carried. The application and use of the framework may be used in directing research, development, and ongoing innovations. Development within the self-discovery phase of self-improvement would be to improve on usability of devices for elderly, children, or other subjects such as pets. Additional devices capable of sensing specific, and less common, attributes or behaviors would also contribute to the self-discovery phase by enabling new metrics to be collected and studied. Research of historical data and trends for specific patterns within activities, actions resulting from work habits, hobbies, social gatherings and the like could provide insight for the self-knowledge phase. By learning about trends and their underlying cause / effect relationship, plans could be designed for corrective actions. Integration and aggregation of a services individual improvements from multiple lifestyle facets: diet, mood, sports, and other components, could lead to breakthroughs within self-improvement. It is difficult to predict where improvements may lead, especially if all the sources of improvement are not correlated or incorporated into a common data model. Regardless of the existing current technology gaps, future technology and advancements within the field may come to resolve them. However, the process of self-improvement will remain the same: self-knowledge by monitoring, self-discovery through studying, and self-improvement by acting to get results.

Device Class	Service Class	Physical Characteristics	Product
<i>Wearable</i>	<i>Biometrics</i>	<i>Wristband</i>	<i>FitBit One</i>
<i>Wearable</i>	<i>Biometrics</i>	<i>Wristband</i>	<i>Nike+ Sportwatch</i>
<i>Portable</i>	<i>Biometrics</i>	<i>Armband</i>	<i>Withings Blood Pressure Monitor</i>
<i>Portable</i>	<i>Mood</i>	<i>Mobile phone</i>	<i>Apple iPhone w/T2 Mood Tracker App</i>
<i>Placeable</i>	<i>Biometrics</i>	<i>Moveable weight scale</i>	<i>Withings Wireless Scale</i>
<i>Placeable</i>	<i>Biometrics</i>	<i>Treadmill with docking module</i>	<i>iFit WiFi Module</i>
<i>Implantable</i>	<i>Biometrics</i>	<i>Biocompatible subcutaneous module</i>	<i>Biotronik BioMonitor</i>
<i>Placeable</i>	<i>Perception</i>	<i>Moveable directional monitor</i>	<i>Flightscope X-Series</i>
<i>Portable</i>	<i>Behavior</i>	<i>Toothbrush and docking station</i>	<i>Oral-B Triumph 9910</i>

Table 1. Application of Device Class and Service Class Framework to Products.

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