Temporal Data in a Health Self-Management Application

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Abstract
Individuals frequently take an active role in managing day-to-day aspects of their health, like improving nutrition or increasing physical activity. Clinicians also increasingly teach health self-management skills to patients with a range of chronic illnesses, such as diabetes, hypertension or arthritis. In this position paper, we present our initial work in designing and developing *Salud!*, a web-based platform for supporting health self-management. *Salud!* will allow its users to track personally-relevant aspects of their everyday life, and provide visualization and analytics tools with which to make sense of the resulting datasets. In effect, *Salud!* is a health-oriented, capture and analysis tool for temporal data. We describe the features of *Salud!* that will enable users to easily capture temporal data, and to use this data in a number of ways. We conclude by discussing how we have structured *Salud!*'s data storage system, and our plan for addressing the challenge of designing temporal data visualization and analytics tools for a broad, lay user base.

Keywords
Health self-management, temporal data, analytics

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Patients with a chronic illness, such as diabetes, heart disease or asthma, are often called upon by clinicians to actively participate in the day-to-day management of their health. Health self-management, which may include making healthy decisions about diet or exercise, quitting unhealthy habits and solving other health problems, complements traditional healthcare practices and supports patients in living the best possible quality of life with their condition. Studies have found that successful health self-management education and group support programs improve patient outcomes and reduce healthcare costs [1,4].

Figure 1. WeightWatchers e-Tools allow users to chart their progress toward a weight goal.

A feeling of self-efficacy—confidence to carry out a behavior necessary to reach a desired goal—is central to effective health self-management. It is enhanced when patients succeed in solving problems which they themselves identify. Improving self-efficacy and motivation is also important for individuals without chronic illness, but who are trying to lose weight, eat better or otherwise promote their health and wellness.

A growing number of commercial and research systems attempt to support individuals in achieving their health goals. For example, Fish'n'Steps [3] and Chick Clique [6] leverage competition and peer-pressure to motivate users to become more physically active. Consumer technologies, such as iPod Nike+, potentially support motivation and increase self-efficacy by allowing individuals to track their progress in achieving a specific goal. Similarly, many online services such as WeightWatchers e-Tools (Figure 1) allow individuals to record and track a wide range of information (often temporal) relating to health and wellness [2]. The features which these services provide have only limited support for health self-management, however. Most provide only basic views of a user's data, which may be laid out in a table or calendar, or plotted as a line through time. While this may help users stay motivated by visualizing long-term trends, there is little support for decision-making or identifying and overcoming obstacles to improvement. Additionally, users are limited to the particular measurements a service supports (e.g., weight), which may be insufficient for a range of health goals.

To begin addressing some of these limitations, we are designing and developing *Salud!*, an open, web-based platform for personal health self-management. *Salud!* has three main design objectives: support users in capturing a wide range of data about their everyday experience; allow users to visualize this data and provide a repertoire of easy-to-use analytics tools for identifying patterns and trends; and structure problem-solving activities which lead to achievement of users' health goals. The goal of our research is to learn if, and how, such a tool can help users better understand the factors which affect their health, and support them in attaining self-identified goals.

The Salud! Platform

Users' interactions with *Salud!* are centered around Logbook objects. A Logbook stores a temporal record of some measurement or variable which the user is tracking. For example, a user may create a Logbook to record information about all of her meals and snacks during the day. Each entry in the Logbook would record the time of the meal or snack, and any pre-defined annotations, such as a photo of the meal, its approximate calorie count and/or a list of its primary contents. Other Logbooks could be used to record the users' blood pressure, self-reported stress level, and other types of data. While *Salud!* will be pre-populated with Logbooks for common health and wellness metrics which users can being using immediately, users will be able to create new Logbooks to track other variables which are important or interesting to them.

Salud! will also provide users with easy-to-use tools with which to visualize their data and perform simple data analysis. Users will be able to track trends over time, explore relationships between different variables, and manipulate the data in other ways. Because all of the data is timestamped, we are considering a range of temporal visualizations with which to provide views of the data, in order to allow users to answer a variety of questions. We are also building a number of statistical tools into *Salud!,* which would allow users to smooth noisy data, compute correlations, and perform other kinds of simple analysis on the data.

The final element of *Salud!* will be a set of guides and decisions-support mechanisms which will support users in defining and reaching concrete health goals. Depending on how *Salud!* will be deployed, these tools may be designed to be used by individuals themselves, or with support from a clinician or health educator. A detailed discussion of these tools is out of the scope of this position paper. In the remainder of this section, we will more thoroughly describe the data capture and analytics tools that we are building into *Salud!*.

Capturing Temporal Data

Capturing pertinent health and wellness measurements is a key aspect of effective health self-management. Individuals managing a chronic illness often keep written diaries or simple computer records of the behaviors and measurements which are significant to their condition [5]. Diabetics are encouraged to monitor their diets and blood glucose readings, individuals trying to lose weight may log their exercise routine as well as their weight measurements, etc. However, aside from the obvious issue of motivation, manual data capture is often difficult because individuals need to remember the specifics of an event (or even that one occurred), until it can be recorded. Because of the effort and overhead involved, individuals rarely track more than a few variables.

11 Dec 2008 8:35 AM

Calories: 250

Contents
Fried egg
Fruit Salad
Coffee

11 Dec 2008 12:22 PM

Calories: 700

Contents
Spinach
White rice
Steak
Diet Coke

11 Dec 2008 6:49 PM

Calories: 800

Contents
Bread
Roast beef
Veggies
Water

Figure 2. Sample data which may be recorded in a Logbook.

We are building a number of different data capture methods into *Salud!*, which we hope will significantly ease this task, making it possible for individuals to keep more consistent and more detailed records of a greater number of variables. In addition to a web-based interface, *Salud!* will accept new data records via email, instant messenger, and SMS/MMS messages. This will allow users to record an event (e.g., a meal, onset of pain, etc.) at the time of its occurrence, or log a measurement (e.g., blood pressure) immediately after taking it. Additionally, *Salud!* will allow users to create reminder schedules for measurements they would like to record regularly. The system will then send them reminders via a specified communication medium, and the replies to these reminders will be parsed and added to the appropriate Logbook.

Consider a hypothetical user, Sareen, who would like to change her eating habits so as to cut calories, while avoiding fatigue (i.e., maintaining her "energy levels") between meals. Sareen wants to track the calories and contents of her meals and snacks in one Logbook, and routinely self-report how fatigued she feels, on a scale from 1 to 5, in another Logbook. She can collect meal data by photographing her meals and snacks with her camera phone and immediately sending the picture to *Salud!*. The photo would serve as a placeholder for the meal, and record its time. Every evening (or every several days), Sareen can then log in to *Salud!*'s web interface and annotate recently added photos with their contents and calorie counts. To collect data about her energy levels throughout the day, she can create a reminder schedule which will send a short question to her work email address every weekday, at 10:30 AM and 4:00 AM. By replying to that message with '1', '2', '3', '4' or '5', Sareen can easily track this variable.

Because we cannot foresee all of the types of data which users may want to collect, or how they may find it convenient to do so, we have created a simple REST API through which data entry occurs. The email, IM and SMS/MMS functionality is implemented as independent services that interact with this API. Other services, which we may implement in response to user demand, or which may be created by other researchers or technically-oriented *Salud!* users, could allow data streams to be captured by in-home sensors (e.g. "smart" scales, glucometers or sphygmomanometers) or be imported from other online data sources (e.g. another website, Facebook or even a weather service).

Visualization and Analytics Tools for Temporal Data

The second main component of the *Salud!* platform is a visualization and analytics system. This system will allow for open-ended exploration of captured data, and should also support users in addressing specific questions or problems regarding their health. We expect that having the ability to view and analyze a history of their data over time will make it easier for users to manage their health by establishing goals, monitoring progress and solving problems which stand between them and their goals.

Most of the data visualizations we are currently planning to include in *Salud!* will provide views of the users' data on a timeline. However, a flexible UI is needed to enable users to address different questions and concerns. Consider Sareen, our hypothetical user from the previous section, who is interested in understanding the relationship between her diet and fatigue. She may start her exploration of by plotting several weeks' worth of energy level self-measurements on a timeline, and explore various

theories by superimposing meal-related data over this graph. By adding a dot to the timeline for every meal or snack she has, she can explore whether she experiences more fatigue if she skips breakfast or lunch. Later, she might want to see the meals' calories plotted as well, and highlight times when she had eaten specific food items ("Do I have more energy when I eat a low-calorie meal that includes dairy?"). To see if her weekly calorie intake has been dropping, however, Sareen would need a different view—perhaps a bar graph, with total calories bucketed by week.

Simple analytics tools will also be available to Salud! users. For example, applying a moving average line or a linear regression to a plot could help smooth out the noise in day-to-day changes of certain variables (e.g. weight), and better display overall trends. If presented appropriately, statistical tools like correlation coefficients may also help users think and act more confidently. Finding the right set of tools to meet users' needs, and providing access to these tools in an effective, usable way is the main challenge we foresee in the development of *Salud!*. In the next section, we will describe our plan for meeting this challenge.

Key Challenges

In this section, we describe two design problems which we have considered in our work with *Salud!*. First, we describe how we have structured the temporal data store. We then discuss our plan for iteratively designing *Salud!*'s visualization and analytics tools.

Structuring the Personal Health Dataset

Salud!'s data storage system is designed to allow timestamped data to be submitted and edited through a variety of interfaces, and then to make this data available to visualization and simple analytics services. From a user's perspective, data entry and data analysis involve two different ways of working with temporal data. For input and navigation, grouping multiple data fields in a Logbook—e.g. "meal photo," meal "contents list," and "calories"—helps the user easily track and review semantically related data. However, during the analysis process, it is usually necessary to isolate specific data fields, or manipulate multiple data fields from different Logbooks.

To allow for both types of modes of use, we structured our data store in the following manner. A user's dataset consists of one timestamped data stream for each individual data field they track. Each data field can be associated with at most one Logbook—in the example above, "meal photo", "contents list" and "calories" are each data fields associated with one Logbook ("Meals & Snacks"). Users then capture data at the Logbook level. When a user creates a data record, the system records a timestamped entry in a specified Logbook, and also adds timestamped entries to those associated fields which the user included in the data record. For example, sending a photo of a meal to *Salud!* would create a new entry in the "Meals & Snacks" Logbook, and a new entry in the "picture" field. Later, when the user adds the meal's calories and contents, new entries would be created in the "calories" and "meal contents" fields, with the timestamps matching the timestamp of the Logbook entry. The timestams of Logbook entries thus serve as a kind of primary key, making it easy to iterate over all entries in a Logbook and to look up the data fields in each entry. Because individual data fields are also timestamped, they can be isolated easily as well—even if a data field doesn't have a value for each Logbook entry.

This data storage mechanism results in some amount of redundancy (timestamps are stored multiple times), but has the benefit of making UI development more straight-forward. By associating multiple fields, Logbooks allow individual users to structure data collection in a way that is logical to them. Also, because each Logbook consists of data streams which may be accessed independently, it is straightforward to create analytics tools that allow users to visualize and manipulate multiple data fields from different Logbooks.

Designing the Visualization and Analytics Tools

The most important challenge we face going forward is designing *Salud!*'s visualization and analytics tools. While we hope to provide our users with a robust and relatively powerful system for understanding and making decisions about their health, we are keenly aware of the need to keep these tools intelligible and easy-to-use for a lay audience.

We will need to understand how users think about the trends and changes in their health in order to design useful tools. In particular, the ways in which users conceptualize data—in terms of frequency, durations, aggregation, etc.—will dictate the types of data views and visualizations that will be most important to include. The meanings which users will want to extract from the data, and the types of questions they will want to ask will similarly provide guidance for *Salud!*'s analytics tools. We will need to strike a balance with the number of features and options, how structured interactions are, and even the terminology and jargon in the interface, to provide an application that is sufficiently open-ended, without being overwhelming or unnecessarily technical.

We plan to develop these features of *Salud!* iteratively, working closely with a group of 12-15 early adopters who are specifically motivated and interested in using such a system. We will provide these individuals with a prototype version of *Salud!* and examine how they begin to appropriate its features into their health management strategies. We will iterate on the design and functionality of the system by rapidly acting on their feedback and feature requests. In this way, we expect to converge on a version of *Salud!* ready for more widespread deployment with a broader user base.

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Author Bios

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