DATA VISUALIZATION IN A PERSONAL HEALTH RECORD USING RICH INTERNET APPLICATION GRAPHIC COMPONENTS

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Abstract: Patients with chronic diseases such as diabetes have to monitor complex sets of medical observations and behaviors. This includes blood glucose, weight, cholesterol, HbA1c, blood pressure, as well as diet, exercise and medication. We have developed a set of web-based, highly interactive graphic modules that are integrated in a personal health record to provide an easy and pleasant way for patients to browse through their historical data. By using a Web 2.0 framework with technologies such as AJAX and Flash/Flex, coupled with a mechanism of loading data on demand, we minimized the amount of data passed between the server and the browser and we were able to build a highly interactive and responsive graphic user interface that displays two-dimensional graphs for diabetic patients. As a result, the patients are using their personal health record on a daily basis, resulting in a more accurate, complete and useful application.

1 INTRODUCTION

Chronic diseases requiring repetitive tests and procedures often result in the collection of large amounts of medical observations and data over a long period of time.

In recent years, web-based Personal Health Records (PHRs) have been providing a way to store, display and share medical observations. These applications can be very useful not only for the patient and their caregivers, but also for their relatives/friends to monitor and communicate important health information (Ralston et al. 2004) (Lowes R. 2006).

Studies have shown that, when patients are provided with proper tools that promote involvement, empowerment and active management of their illnesses, better results can be observed in both health status and clinical outcomes (Stroetmann and Pieper 2003).

Presentation of medical data to internet patient users via a web application can be a challenging task, especially for users with little or no medical background (AHIMA 2005). While it is important to provide as much relevant medical information as possible to the users, it is crucial to keep the application interface simple, easy to use and appealing (AJMQ 2006), so the users keep using it on a regular basis (Hassol et al. 2004). A PHR will also be valuable if it provides instant feedback on health conditions as well as improve personal satisfaction (Andry et al. 2008).

In this paper, we describe how we have designed and implemented a set of rich internet graphic components and integrated them into the LifeSensor personal health record for patients with type 2 diabetes.

2 DATA COMPLEXITY

2.1 Tracking Observations

Diabetes is a chronic disease that requires long-term monitoring and treatment. Medical observations such as weight, cholesterol and HbA1c have to be measured on a regular basis, some of them (blood pressure, blood glucose) up to several times a day. In addition to this, it is important for the patient to keep track of their medications, diet, exercise and skin condition to avoid complications. A regular and

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Table 1: Granularity of Health Related Observations for a Diabetic Patient.

	1 day	7 days	30 days	12 weeks	12 months	3 years
Blood Glucose	☑	☑	☑	☑		
Weight		☑	☑	☑	☑	
Exercise		☑	☑	☑	☑	
Diet		☑	☑	☑	☑	
Medication		☑	☑	☑	☑	
Cholesterol					☑	☑
HbA1c					☑	☑
Blood Pressure & Heart Rate		☑	☑			

systematic recording of these vital signs, conditions and behaviours are even more important for patients that have a combination of multiple chronic diseases (diabetes, coronary heart disease, arthritis, asthma, kidney and/or heart conditions, etc.).

Graphs and charts are visual representations of numerical or spatial data. Health related observations are well suited to graphs, however designing graphs that are easy to read and interpret is not trivial (Cleveland and R. McGill 1985). Certain principles can be applied when creating graphs:

- Data should stand out from the rest of the graph (e.g. not mixed with labels).
- Reduce clutter on the graph (e.g. avoid too many tick marks).
- Overlapping symbols or lines must be optional and easily recognized

A common property of medical observations, and the patient behaviour we want to capture, is that they are associated with a time stamp (a specific date and time), and hence can be all represented along a common time axis. This makes comparison and correlation between observations easier. For example, by comparing an exercise or a diet chart alongside the blood glucose chart, the user can see the benefit of exercising or dieting to better control blood glucose. Moreover, by using a common generic observation object representation, we facilitated the storage, transmission and manipulation of these observations.

2.2 Granularity of Observations

The frequency of health related observations for a diabetic patient is not identical for each type of observation (e.g. blood glucose has to be determined several times a day, whereas cholesterol or HbA1c analysis are done only few times a year). As a result, it is important to display certain observations with a very granular time frame (e.g. daily blood glucose results before and after each meal) and only display other types of results over a longer period of time (Table 1).

In addition, observations do not have the same types of values, so we separated them into two different groups and represent them by two different types of graphs:

- Health Targets (blood glucose, weight, cholesterol, HbA1c, blood pressure, heart rate)
  These observations have a specific value and unit (mg/dL, kg, etc) associated to them. We represent them with 2D line charts and candle -like charts for average values views.
- Activities (exercise, diet, medication)
  We have rated these observations using ordinal values such as poor, fair, good, or very good. We used histograms for their representation.

3 PHR DATA MANAGEMENT

3.1 Add-on to LifeSensor PHR

The graphic visualization components we developed to display the patient observations were integrated into the diabetes module of InterComponentWare's (ICW) personal health record (PHR), branded as LifeSensor. This PHR is a layered, multi-tier web application accessible by a web browser, a set of web-services or a software development kit (SDK).

The patient observations are acquired and managed either by the general PHR health record application (e.g. weight, height) or by the specific diabetes module add-on (e.g. blood glucose).

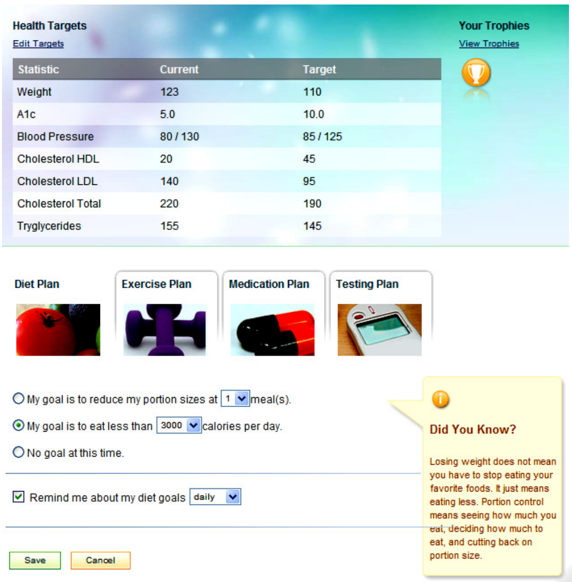

Figure 1: Health targets overview in LifeSensor Diabetes.

The diabetes module of LifeSensor is specifically designed to optimize data acquisition (Andry et al. 2008). It also offer overviews (Figure 1) of vital signs and critical observations together with motivation information—goal progress and action plans pertaining to important disease management issues—that can be a starting point to drill down to specific historical data visualization.

A log section is used to enter and update measurements (e.g. self-monitored blood glucose levels and blood pressure readings). The log section uses Web 2.0 technology such as Asynchronous Javascript and XML (AJAX). The data input is facilitated by dynamically offered tips and recommended default values from professional associations such as the American Diabetes Association. This validation of the observations is done immediately field by field with no need to submit the entire page. Also, each observation field is immediately assigned a color background (green or red) to indicate that the observation is within an acceptable value range. The log section uses Web 2.0 technology such as Asynchronous JavaScript and XML (AJAX).

The log section offer overviews (Figure 2) of the vital signs and most critical observations together with motivation information, goal progress and action plans pertaining to important disease management issues that can be a starting point to drill down to specific historical data visualization

Improvements in patient observation acquisition would include auto-completion functionality for certain data entry fields and the aggregation of data using LifeSensor device integration support.

Figure 2: Log section in LifeSensor Diabetes.

Using either the LifeSensor SDK or ICW's Tele-monitoring solution, it is possible also to automatically import observations from various medical devices (glucometers, arm blood pressure monitors, weight scales, etc). The data can also be exported to Care and Disease Management systems (CDM) to be used by the physicians and nurses.

4 ARCHITECTURE

4.1 Data Visualization Architecture Requirements

Navigating through a large amount of data using a web browser can be difficult. Since the data resides on the server, it is important to minimize the exchange of data between the server and the browser in order to maintain good application performance and to continue to offer a good user experience. A combination of techniques such as caching and dynamic data upload can be used at runtime to solve this problem.

In addition to this, it is better to try to render the graphic views/images on the client than sending large images across the network between the server and the client.

The architectural requirement was to design a graph container that provided the ability to:

- Parse the data on client side and render graphic view, rather than sending large processed images across the network between server and the client.
- Minimize the exchange of data between the server and the browser in order to maintain a good performance
- Easily add, remove or modify a particular data visualization module,
- Provide features at runtime to offer pluggable rules to compare data between observation types,
- Easily customizable
- Minimize the footprint of the application in the browser

By using a combination of Web 2.0 technologies such as HttpService calls to fetch raw data on demand from the server in JSON format (a technique very similar to AJAX), and Flash/Flex graphic components on the client, we managed to make web pages feel more responsive. Most of the processing necessary to render the graphic user interface is done on the client in the Flash player.

4.2 Modularization

We have created a generic graph container module that has the ability to load and unload modules from the server based on the context of the data visualization and the need of the user. A set of eight modules (Exercise, Diet, Medication, Blood Glucose, Weight, Cholesterol, HbA1c, Blood Pressure/Heart Rate) can be dragged and dropped into a visualization zone where two graphs can be displayed and synchronized on the time axis.

Another advantage of such modularization is that the components can be repackaged easily in other web containers/applications. In fact, some of the modules have been re-packaged as widgets and portlets.

4.3 Integration with LifeSensor

The graph container (Flex application) acts as a data controller. It requests data from PHR LifeSensor either when a new graphic module (Flex module) is loaded, or when the user navigates beyond the default data 'tiled' time span for each module. The default data time span is typically a couple of months of data before and after the date cursor used for data browsing. Initially the current date cursor of a loaded module is the current day and time.

A java servlet in LifeSensor answers HTTPService calls from the Flex graph container and supplies very compact JSON formatted data including a combination of a key and value for the observation, time stamp, as well as target and standard values for the observations (optionally shown as overlays on the graph). The data is then sent to an observation filter to extract the values necessary for the current graph (Figure 3).

4.4 User Interaction

The Flex modules are embedded into the statistic tab of the diabetes component (JSF/HTML) with the same look and feel as the rest of the page augmenting the application with highly interactive features. Each graph has a horizontal axis representing a specific time period, from a single day to several years. The graphs also have one or two vertical axes to show a combination of data results. Graphs such as cholesterol test results, blood glucose values, and hemoglobin A1c percentage use only a single y-axis. Multiple y-axes are used to display data pairings such as weight and body mass index or blood pressure and heart rate.

The user can also decide to dynamically overlay

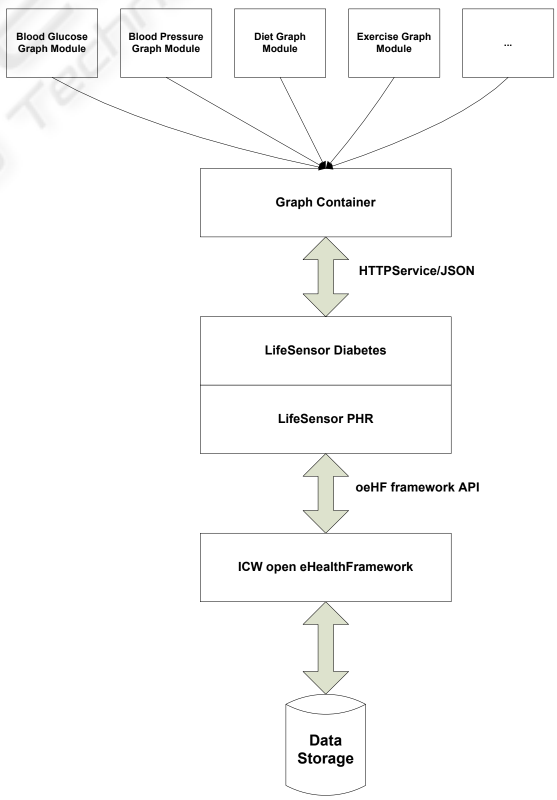

Figure 3: Module integration with LifeSensor.

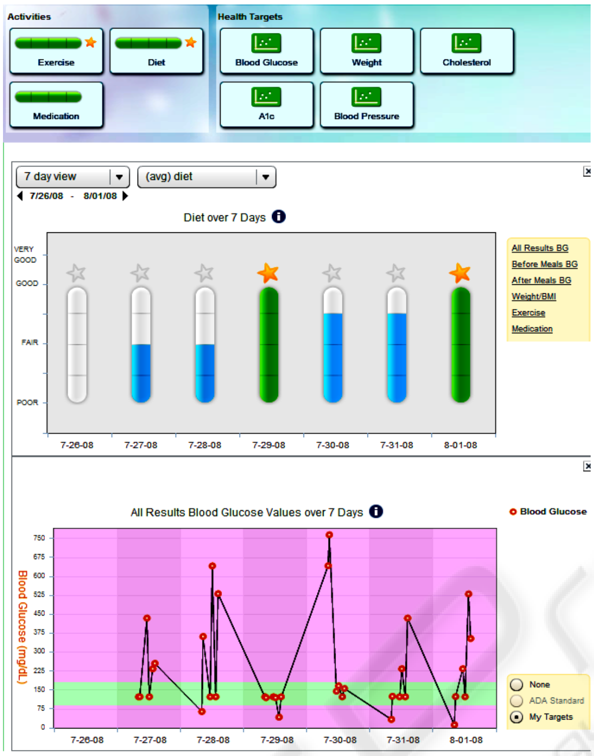

Figure 4: Synchronization between Diet and Blood glucose graphs.

"normal" ranges. These "normal" ranges are either specified by the user or recommended by health experts such as the American Diabetes Association. Dynamic tool-tips are used to provide contextual help and to reveal detailed data.

The user can very easily navigate to a specific date by clicking on the previous or next date period span displayed above the top. If the viewing area contains two graphs, both graphs will be modified and synchronized (Figures 4). This will also happen when the user chooses a different time period (1 day, 7 days, 30 days, etc).

The associated graph at the bottom of the viewing area can also be removed or replaced based on the result of the user choice (Figure 5).

The Flex graphic rendering is a vector-based format that makes the look and feel more professional and portable across various client platforms.

4.5 Toolset and Platform

The LifeSensor PHR itself is built upon the ICW eHealth Framework. This framework provides lower-level infrastructure modules and libraries conforming to HL7 and other standards. The framework enables health application developers to build interoperable, cutting-edge web applications.

The Framework is based on proven open source technologies and tools such as AJAX, FLEX, JSF, Java Enterprise, Spring, Hibernate, Maven and Eclipse.

Parts of this proprietary framework have been released as open source software in the Open eHealth Foundation (OeHF) established by ICW, SUN Microsystems, and Agfa HealthCare at HIMSS08.

5 CONCLUSIONS

Data visualization in a Personal Health Record should be complete and precise, but simple enough not to overwhelm the user with information.

The use of Web 2.0 technologies makes the graphic user interface more interactive, appealing and pleasant to use. Performance is also crucial in order to offer a pleasant user experience. This allows the patient to display personalized information based on his or her specific conditions and helps track medical observations.

The ability to navigate through historical data with various level of granularity is a powerful tool for communication between the patient and his/her

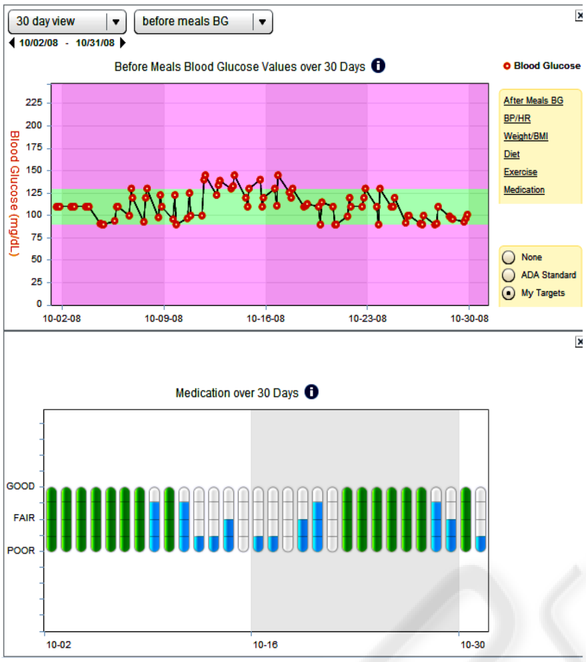

Figure 5: Synchronization between Medication and Blood glucose graphs.

care givers. It also gives the patient a sense of empowerment that is very valuable in helping to manage chronic diseases.

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