ForeTell: Facilitating doctor-patient conversation through interactive information visualization of risk prediction index

Pratibha Bhaskaran, Milind Kaduskar, Preeti Saluja, Smitha Tallimani, Sandip Bhaumik
Samsung India Software Operations Pvt. Ltd.
Bangalore, India
pratibha.pb, milind.vk, p.saluja, smitha.ut, sandip.bh@samsung.com

Sanghyun Yoo
Samsung Advanced Institute of Technology
Suwon, Korea
sam.yoo@samsung.com

***Abstract*— In this paper, we discuss a method of facilitating doctor-patient conversation through an interactive information visualization interface. Using risk prediction index and its discussion as the focus of the conversation, we present ways of using information visualization principles and interaction design to support and encourage this activity, and enhance the experience of the discussion.**

Keywords-information visualization, doctor-patient communication, interaction design, interface design, medical knowledge representation.

I. INTRODUCTION

Studies have proven the importance of effective communication of information from doctor to patient and the impact it has on the quality of healthcare that the patient perceives to have received [6]. Issues such as lack of time on the doctor's part and under-estimation of the patient's need for information have been pointed out as having negative effects on the patient's experience [7].

Through an observational study of doctor-patient consultation and non-invasive investigation sessions at a leading hospital in Bangalore, India, we verified the 5 A's paradigm that defines stages in doctor-patient consultation [11]. Of these five stages, we concluded that the discussion of patient's risk was a crucial part of the counseling. We make use of an interactive information visualization interface to achieve this goal.

Information visualizations have been proven to be effective tools for communication [8] [10] and have become popular in the medical domain [1] [5].

In a previous effort, we had made use of interactive information visualization in order to preserve the narrative of a patient's medical history, thus allowing the doctor to discover patterns in the data [2]. Once the doctor has a good understanding of the patient's history, he/she can undertake the task of counseling the patient. In the current paper, we address the counseling session and demonstrate the usefulness of information visualization for the doctor to communicate effectively, the risk faced by a patient for a particular disease.

Although there are tools already present for calculating and communicating disease risk index [3] [4], it has been identified that there still are several problems in the process of communicating the disease risk to the patient with some discussions on strategies to solve these problems [12] [13].

In our approach, we believe that the physician, if provided with a sufficiently sophisticated tool that concentrates on enhancing the conversation, can effectively communicate the risk to the patient and hold an engaging, meaningful dialog about a mitigation plan.

II. FORETELL: DESIGN SOLUTION

In this section, we describe ForeTell – an interactive information visualization interface, which helps support communication between the doctor and the patient during discussions of the patient's state of health and health risks. Please note that the term 'user' refers to both the doctor and the patient throughout this paper. The process of designing ForeTell consisted of three parts:

A. Identification and Classification of Information:

The first step was to identify and organize the information that needed to be conveyed.

1) Identification of Information: The two primary data entities to be represented in this interface are the parameters and the overall risk index. For each parameter, the following data dimensions must be represented:

a) Value: The absolute numeric or categorical value of the parameter. In the case of categorical variables, the values are of the binary type yes/no (presence or absence).

b) Severity: The extent of severity of the parameter's value, i.e. normal, borderline or abnormal.

c) Impact: We defined 3 main levels of impact of the parameter on the calculation of the risk index for a particular disease: high, medium and low; these are derived based on statistical calculations (the discussion of the same is outside the scope of this paper).

The overall risk index has two dimensions: value and severity. Impact is not a relevant dimension in the case of the overall risk index.

2) Categorization of Information: It was important to organize the set of parameters so as to enhance comprehension and facilitate a quick understanding of the data by both the doctor and the patient. The classification was as follows:

a) Profile: Includes demographic information, such as age, gender etc.

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b) Vitals: Includes measured vital signs and data from laboratory testing such as hemoglobin, HDL etc.

c) Patient History: Includes data pertaining to the patient's medical history, such as a history of diabetes, hypertension etc.

d) Lifestyle: Includes lifestyle habits such as smoking alcohol consumption, exercise etc.

B. *Visualization of Information*

The main objective in the design was to visualize tabular parametric data for faster cognition of the data by the doctor and the patient to enable them to continue the conversation while observing the visualization in parallel.

1) Parameter Visualization: As shown in figure 1, the parameter is represented by two textual elements (name of the parameter and unit, and value) and two visual elements (a square block and a rectangular bar). The two visual elements use the three characteristics of color, saturation and shape to represent the three dimensions (value, severity and impact) of the parameter as follows:

Figure 1. Visualization of individual parameter

a) Color: Color is used to represent the severity of the parameter value. In keeping with standard representations, we use the canonical colors of red (to represent abnormal parameter values), green (to represent normal parameter values) and orange (to represent borderline parameter values). Since color is an important preattentive feature [9], we use it to help the user identify, at a glance, which parameters are abnormal and which are not. Parameters such as age, whose values can be neither normal nor abnormal, are represented by a neutral grey.

b) Saturation: We use color saturation to denote the varying levels of impact of a parameter on the overall risk index. We defined 4 levels of color saturation for each color, with the highest level of saturation being used to denote high impact, and the lowest being used to denote the statistically insignificant parameters. More impactful parameters therefore appear more prominent than those of lower impact (see figure 2). Since intensity and brightness are key properties that support preattentive processing [9], the user can, at a glance, get a sense of which parameters are most impactful and important. This enables the doctor and the patient to concentrate on the conversation, while processing the information on the screen in parallel.

c) Shape: We use two shapes to represent the parameter (value, severity and impact). The rectangular bar primarily represents the value of the parameters through length. Since length can enable perceptual inference operations, the user, at a glance, can gauge whether the value is low, medium or high.

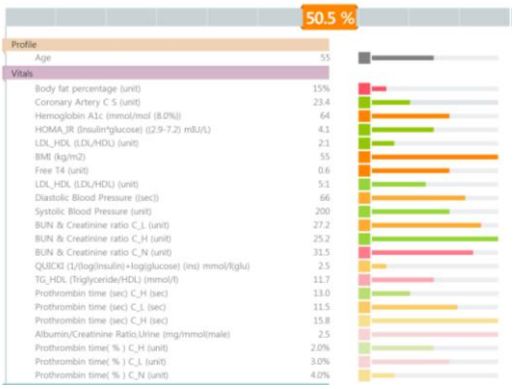

Figure 2. List of parameters visualized. On top of the visualization is the risk index strip depicting the risk index value in percentage. Varying saturation levels highlight varying levels of impact.

The square block is used primarily to denote the impact of the parameter on the calculation of the overall risk index. Although, the impact is implicit in the rectangular bar (through color saturation), after careful consideration, we took the decision of redundantly representing impact as a separate visual element in addition to it being represented through the saturation of the parameter bar since mapping multiple dimensions on to the same element was leading to obfuscation of information.

d) Ordering and Position: To avoid change blindness when the risk index value changes as a result of change in parameter values while interacting with this tool, we positioned the risk index strip at the topmost level of the interface (see figure 2). The position of the risk index value on the strip is also an indicator of the value. The higher the risk, the more it shifts towards the right. We sorted the parameters from high impact on top to low impact at the bottom for each category. This arrangement made it easier to comprehend the saturation difference as parameters went from high saturation to low saturation (see figure 2).

C. *Interacting with the Information*

In order to provide interactions which facilitate the counseling session between doctor and patient, apart from the basic interactions, we designed for planning the consultation session and managing the listener's attention.

1) Basic Interactions: We designed some basic interactions which were necessary out of a tool that would be used to communicate disease risk to patient. These were as follows:

a) Rollover: When the user mouses over a parameter, normal/abnormal ranges are displayed and current value of the parameter remains indicated. This state encourages the user to interact with the parameter by providing an affordance of being an interactive element, in the form of the display of normal/abnormal ranges (see figure 3).

Figure 3. Rollover state provides detail on demand.

b) Click: Single-clicking on a parameter selects a parameter. The user can hold shift and select multiple parameters by clicking to perform group operations (such as 'isolate parameters' – described further in the Modes/Views section)(see figure 4)

Figure 4. Clicked state of the parameter

c) Edit Parameter Values Using Double-click: Double-clicking on the parameter brings it into edit mode, as shown in figure 5. We deliberately mapped the action of activating edit mode of a parameter to double click. Mapping it to an interaction such as single click might result in accidental editing during the conversation, because users are prone to click on the elements that they are talking about to the listener. In Edit Mode, the user can change the value of the parameter, either by dragging the slider across the parameter bar or by manually entering a value in the text box. The colored ranges provide a visual guideline to the user. When the value of parameters is changed, the risk index updates to reflect the recalculated risk.

Figure 5. Edit mode with visual guidelines for normal/abnormal ranges.

2) Planning for the conversation: We designed some tools that specifically help the doctor plan for the counseling session with the patient.

a) Save state: When the doctor is assessing how to conduct the session, s/he might create a configuration of simulated values of parameters that s/he wants to retain for future reference. Using this tool, the user can continue exploring the data and come back to a saved state later. These saved states are listed in the lower right corner of the interface as seen in figure 6.

Figure 6. Saved States: The color next to each state denotes the risk index's severity. The text depicts the time stamp for when it was saved.

b) Link parameters: Sometimes, one parameter is related to and/or affects another. For instance, if a patient increases his level of exercise it could lead to a decrease in his cholesterol level. To remind the user of these dependencies, we provide a tool that allows the user to specify 'links' among a set of parameters. Now when the user selects a parameter, other parameters it has been linked to, are also indicated visually, as shown in figure 7.

3) Managing Listener's Attention: We allow the speaker to manage the conversation flow, direct attention wherever needed and ensure the listener's interest and understanding is maintained through following methods.

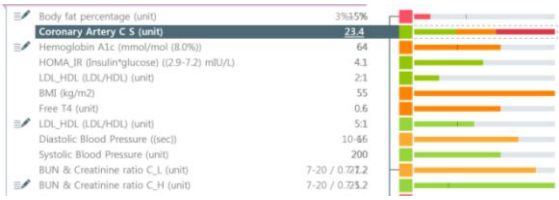

Figure 7. Indication of linked parameters .

a) Removing details not pertinent to the conversation – filter and collapse categories: There are some parameters that the user would like to remove completely from the interface since they have little or no relevance to the conversation flow. On the other hand, some categories of parameters might often not be relevant in the current topic of conversation but might be needed later on in the session. To address these different needs of removal of non-pertinent details, we designed two tools: filtering and collapsing categories. Filtering allows the user to view only those parameters which meet a user-specified criteria. On the other hand, clicking on the name of a category allows the user to collapse it into a minimized view. In this view, the user can still see a summary of the category's parameters as shown in figure 8.

Figure 8. Collapsed category

b) Laying of stress on pertinent details – Isolation View: When the conversation between the doctor and the patient is taking place, often, the doctor needs to bring only a specific parameter or a set of parameters into focus. We designed a new Mode/View to support this, that we call the 'Isolation View'.

Figure 9. Isolation view in the ForeTell Interface: Bringing parameters into focus in isolation view.

It allows the user to concentrate only on those parameters that are the topic of the conversation, and seamlessly send the parameters back into obscurity when they are no longer necessary to the conversation. When activated, Isolation

view draws up a semi-transparent sheet over the visualization. As the discussion between the doctor and patient progresses, the doctor can click on parameters to bring them to the front, above the sheet, and therefore into focus (see figure 9). The other parameters remain out of isolation in obscurity. Hence, among a large set of parameters, the patient's attention can be focused on a few of importance.

III. Scenario of Usage

We will follow Dr Wilson in a fictional scenario, who is consulting with patient John Smith. John is at risk for Coronary Heart Disease (CHD). Dr Wilson is going to consult with John to convince him to adopt lifestyle changes by show the alarmingly high risk John runs for CHD (parameters discussed in this scenario are hypothetical and do not necessarily belong to any risk prediction algorithm).

Dr Wilson prepares for the consultation by briefly taking a look at John's risk prediction index. It stands at 50.5%. He makes a few simulations on the parameters such as intake of oil, exercise habits and cholesterol level and links these parameters together. He then simulates an ideal state for John and saves that state of parameter values. He then resets the values to default (current state) before beginning the discussion with John.

At the outset of the counseling session, Dr Wilson shows John the screen and explains to him that 50.5% is too high a score and that he must be careful. John seems a little overwhelmed at the list of parameters that, for the most part, contains medical terminology. Dr Wilson quickly filters out all the low impact parameters and then collapses the categories that he wants to talk about later. Now John is left looking at only the parameters that make sense to him and those which matter the most for CHD. Dr Wilson activates the 'Isolation Mode', thereby sending all the parameters into the background. He then turns to John and explains that the cholesterol level measured in the last blood test was reported high. As he states this, he clicks on cholesterol and brings it to the foreground. Dr Wilson then rolls over onto cholesterol to reveal the normal range, and shows how much John's value overshoots. He recommends reducing the cholesterol value – and demonstrates simultaneously by double clicking on the parameter to edit it. He then points out that cholesterol is linked to oil intake and lack of exercise which increase blood pressure. He persuades John to manage his health through a regulated diet and exercise.

He releases all filters, expands all categories and then clicks on cholesterol and blood pressure to show their links to several more parameters. He informs John that managing cholesterol and blood pressure is imperative for his health and it will impact several aspects of his health. He brings up the saved state in which he had created an ideal situation for John to exemplify his advice. John feels convinced by what the tool has shown and discusses further with Dr Wilson about managing his health.

IV. Implementation Notes and Future Work

We implemented several exploratory iterations in Adobe Flash as mock-ups to get feedback from doctors and domain experts. We have also implemented portions of the ForeTell system at a prototype level using Adobe Flex and Java for front end development.

In order to further facilitate communication between doctors and patients, we plan to integrate features that allow for remote discussions using video communication.

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