Optimal Continuity of Care Document (CCD) Visualization Based on User Centered Principles

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ABSTRACT
Effective, efficient visualization of clinical data remains a largely unsolved problem. Three Continuity of Care Document (CCD) visualization approaches were created, each emphasizing one of three somewhat divergent principles for a national health IT challenge competition. Based on feedback and analysis we conclude that there is no one optimal interface rather a tradeoff is required among the principles of speed of access, flexibility and level of detail. Thus, to facilitate physician decision making without sacrificing efficiency, requires a new technology that can dynamically balance these different data visualization principles depending on physician specialty, the specific use case for which the record is being accessed and the type of patient.

INTRODUCTION
Based on federal leadership and incentives significant health information technology investments are being made. The 2009 American Recovery and Reinvestment Act (ARRA) sets aside around $25 billion for improving health care information technology, much of which is aimed at encouraging the national adoption of EHRs. The Certification Commission for Healthcare Information Technology (CCHIT) was established to certify commercial EHRs and to ensure they address issues related to functionality, interoperability, and security. Senior IT executives increasingly understand that IT can have a positive impact on healthcare delivery, according to the 21st Annual HIMSS Leadership Survey. A recent survey of the literature supports this view.

In any robust EHR a large amount of clinical data is available representing the past, present and potential future health status of and care provided to the patient. The challenge is to present the user with the most relevant information at any point in time and to provide rapid and intuitive navigation through the large amount of other information present. As a result, the visualization techniques used for display of patient data have a direct impact on the usability of an EHR system. These interrelated concepts of data visualization and usability have to be balanced to create a widely adopted and “meaningfully used” EHR system. But neither usability nor data visualization techniques are historically given the same level of attention as software features, functions and technical standards.

It is important for hospitals and clinics implementing EHR systems to understand that successful adoption of these systems depend on the satisfaction of primary users, most notably physicians. Even though there are numerous vendors to choose from and much has been done in terms of setting common data and data exchange standards there have been relatively few advances in the field of usability and data visualization of EHR systems. At least in part as a result, a recent survey showed that only 37% of physicians solely store patient health information electronically. Another national study reported that only four percent of physicians used a fully functional, advanced system and that 13% used systems with only basic functions. These figures document a poor adoption rate and suboptimal utilization of EHR systems. They strongly suggest the need for new, innovative approaches to the physician-EHR interface.

Much analysis has been done and many recommendations have been made for EHR user-interface design. Recently the Agency for Healthcare Research and Quality (AHRQ) made recommendations for EHR design and development of best practices and standards for design, testing, and monitoring of the usability of EHR systems after concluding that they weren’t currently available. At the same time innovation is clearly possible. Current research in patient health information visualization includes time-based technology that aligns textual reports, medical images and waveforms with respect to a timeline. The LifeLines project presents a timeline for each kind of clinical event, and labels key clinical events, indicating where more details are available. CareVis and Integrated Viewer are two similar projects. Other visualization techniques involve classifying EHR data according to human body parts.
example, PEN&PAD\textsuperscript{15} uses simple maps or charts of the human anatomy to navigate to the related information. Recently, Sundvall \textit{et al.} used Google Earth as a navigational tool paradigm and provided a similar navigational approach\textsuperscript{15} based on a 2D human body model. IBM’s ASME (the Anatomic and Symbolic Mapper Engine) project is similar, except that it uses a private 3D human model to navigate the EHR\textsuperscript{17}. Jiye \textit{et al} propose a dynamic patient information visualization system that classifies patients’ EHRs into different levels of detail according to their clinical relevance. It uses a combination of human body visualization with time and source oriented navigation for visualization of the levels\textsuperscript{18}.

\section*{METHODOLOGY}

This paper proposes another approach based on the three principles of speed of access (how quickly any arbitrary element of patient data can be accessed), flexibility (user-level ability to change the visual presentation) and level of detail (the granularity of the data presentation). We extracted data from a standard Continuity of Care Document (CCD)\textsuperscript{17} and used the metadata contained therein. Our aim was to make an interface that is useful in different device form factors and was also platform and proprietary software independent. To accomplish this, the interfaces avoid high graphical animation and complex language processing to reduce system requirements. Our interfaces can be adapted to any EHR system that can read CCDs.

The three prototype approaches were developed for the “CONNECT Code-a-Thon Challenge” held from April 28 thru April 29, 2010 at Florida International University in Miami, Florida (http://hit.fiu.edu/challenge.htm). The challenge was to build a GUI that facilitates decision making by physicians in different settings taking calls from an unfamiliar patient after office hours. Adhering to the competition rules, the GUIs created don’t have any information input features but they could easily be integrated into the prototype interfaces. The three methods illustrated here were awarded first (level of detail principle based GUI), second (flexibility principle based GUI) and third (speed of access principle based GUI) place in the challenge competition which was open to both student and commercial entries.

\section*{Three CCD visualization and navigation methods}

Bemmel\textsuperscript{18} summarizes the three orientations for health records: time-oriented, problem-oriented, and source-oriented. Almost no health records can be purely classified into any one of these categories. Similarly, we propose three “orthogonal” principles for EHR graphical user interfaces i.e. speed of access, flexibility and level of detail. For display of patient health data a GUI based on any one principle is, at best, a compromise solution. Rather, we propose that at different points in the care process -- depending on the patient type, the specialty of the physician and the use case -- one of the three principles is optimal or at least of primary importance to help the physician make effective and efficient clinical decisions.

\section*{RESULTS}

In the next section we go over the details of each visualization principle. In the following two parts we deal with design considerations and the benefits and draw backs of a GUI based primarily on each principle.

\subsection*{Speed of access principle based GUI}

This GUI optimizes quick user access to any section the CCD document of a particular patient. The metaphor used, a dial, is beneficial in two ways. First, the screen space required to display the sections of the CCD document is minimized. Second, the cursor movement required to jump from one section to another is also minimized. Figure 1 illustrates the prototype GUI. The information displayed when the cursor hovers over a particular section is a summary of recently recorded data. When the user clicks on a section the entire contents are displayed. There are two “clinical dials” present in the prototype GUI. One dial represents the more critical health related sections found in the CCD (e.g. vital signs; problems and plans; tests, procedures and results; medications, allergies; immunizations). The second dial contains the other sections of the CCD (e.g. advance directives; payers; family history; functional status; encounter notes; and medical equipment). The user can switch between clinical dials by clicking on buttons that are labeled as “Patient Health” and “Other” information. The GUI can be used in desktop as well as netbooks. A special version, made for touch screen phones, supports finger touch events.
**Figure 1**: Rapid access principle based GUI showing a tooltip when the cursor hovers over the “Vital Signs” section.

The physician’s mental model has been taken into consideration in the placement of each section of the dials. For instance, the problem, procedure and result sections are placed in a manner that the physician can access the problem section and look at the steps taken to address them in the next sections. The information window displayed on hover is translucent to help the user see the sectional names in the background.

**Flexibility principle based GUI**

This GUI gives users a highly flexible visual display enabling them to arrange information according to their mental model for handling a particular problem. This approach has a fluid interface. Figure 2 gives a screen shot of the implemented GUI. The top section presents patient demographic information. The interface centers around three primary *clinical* sections: Analytics, CCD Data, and User Context. The left Analytics section presents key summary or abstracted patient data to focus on important clinical issues. The right User Context section is customized based on each user’s (typically a physician) areas of specific interest. The central section presents the CCD Data. The sections that surround the CCD Data can be hidden, if desired. The central section can be expanded to fill the entire screen. The sectional tabs can be expanded or collapsed by clicking on them. In expanded form the user is able to see the contents of a particular tab in detail facilitating comparison with the data shown elsewhere.

The CCD Data section has several expandable tabs, each representing a clinical component of the CCD. The Analytics and User Context sections have fixed pre-defined tabs. These are intended to display critical clinical information (much like the Clinical Information dial described above) and, depending on the user’s mental model, can be changed by the system manager to display different sections of the CCD. The interface is primarily targeted at larger displays such as desktops, notebooks or tablet computers.
Figure 2: Flexibility principle based GUI showing the “Results” tab expanded in the CCD Data section and two tabs displayed in each of the User Context and Analytics sections.

This customizable interface gives the user the ability to choose the placement of each of the tabs in the different sections in a way that makes clinical sense and facilitates crisp decision making. This interface can effectively handle patients that have a large amount of medical data in their CCD.

Level of detail principle based GUI

This GUI presents patient health information most relevant to the present clinical problem(s). This helps the user to focus in on the patient’s presenting problem(s). Figure 3 gives a screen shot of the prototype GUI. The interface starts by giving basic demographic information for selection of the patient and then proceeds to the problems recorded for the particular patient. Based on the problem selected, the most clinically relevant information is displayed. The interface also has sectional tabs. The tabs shown are not static but depend on user selection. The interface presents measurements in both tabular and graphical form. Here the specific detail displayed is based on the problem selected by the user. This approach helps focus the user and save time by presenting only detailed information that is relevant to the problem the user is concentrating on. This interface can handle a large amount of medical data and divide it effectively based on the problem section of the CCD. This interface requires considerably less screen space than the flexibility principle based GUI but more than the speed of access principle based GUI. The interface was built to run on desktops, netbooks and smart phones.
Figure 3: Level of detail principle based GUI showing the information related to “AV Nodal Reentry Tachycardia”.

Here the assumption is that the physician is most interested in knowing more about a particular problem. The information for each problem is tailored based on clinical relevance and requires considerable clinical intelligence in the interface itself. This interface also entails some preprocessing of the CCD information to tailor the information display around problems. This processing is not very complex and requires minimum recourses as the association between disease and clinical indicators are static having been previously derived from medical literature.

Software implementation

The three single principle-based interfaces are all web based and can work on the most widely used standard browsers without any pre-requisite software. The browsers used for testing were Mozilla Firefox 3.6 and Google chrome 9.0. One of the key aims is to make the interfaces easily navigational for different modalities and form factors (e.g. smartphones, notebooks/netbooks, and full size displays). Another consideration was to build paradigms that are ‘easily’ implementable without any specialized technologies (e.g. such as displaying data against a detailed diagram of the human body that would demand larger, high resolution displays to be effective). To achieve this we used an open source software platform. For smart phones the interfaces were customized to give a better user experience. This is due to the heterogeneity of the operating systems used in present smart phones. All of the interfaces use HTML and CSS markup language for display purposes. The speed of access principle based GUI uses JavaScript. The flexibility principle based GUI uses jQuery JavaScript Library v1.4.2. The level of detail principle based GUI uses script.aculo.us JavaScript Library v1.8.3, MochiKit JavaScript Library v1.4.2 and PlotKit Autoload Javascript Module.

DISCUSSION

The present influx of capital into the electronic health record (EHR) and health information exchange (HIE) market will undoubtedly stimulate innovation. There is the corresponding opportunity to guide that innovation in ways that benefit a significant majority of clinical health IT users. Toward that end, we put forward these three principles based GUI’s to help developers better understand the components that are to be considered while displaying patient health information. They not only convey the different factors that must be kept in mind while displaying data but can help usability experts more clearly
understand the clinical user data visualization needs and the strengths and limitations of various approaches.

One of the most challenging issues in the health IT field today is to anticipate what information clinicians need and then deliver it in a way that is tailored for their unique views. To satisfy these needs we need to make GUls that mimic the mental model that physicians have in mind when treating patients. When the work flow is in line with this model then the system helps the users in point-of-care decision support. When vital data is not presented at the right time then the physician either has to take time to search for them or try to short cut the decision making process without that information. For example, even when information resources are readily available, clinicians may forgo searches that are expected to require more than 2 minutes to complete. Some have even suggested that, in the busy hospital settings, this time is closer to 30 seconds.

The speed of access principle based GUI uses a clinical dial metaphor to provide the physician with any available clinical information in the most rapid manner. In future versions visual clues could be provided by varying the size of each section depending on the amount of information present and possibly the most contextually relevant information. To help effective information retrieval, sections where anomalies are found could be highlighted after simple pre-processing is done. The interface can only have one tooltip open at a time but full information windows can be compared side-by-side. But the amount of data that would be present in those windows and the ability of the user to find relevant information is a point of concern.

The flexibility principle based GUI helps the physician in rapidly changing the context of information displayed. It is very customizable to make the interface map to the user’s mental model. A useful addition would be for the GUI to auto detect the patient’s main problem and customize the sections based on it. The basis of customization would be the physician’s past data viewing behavior. One of the main issues is the physician trying to find the most contextually relevant sections of the CCD. It is possible that the user would have to access many sectional tabs to review all the potentially useful diagnostic information. Another issue is linking any abnormalities to corresponding information present in other sections of the interface.

The level of detail principle based GUI provides a problem oriented approach to help the physician make quicker, more accurate clinical decisions. The interface first puts forward the problems associated with a patient and gives the option to focus on a particular problem and look into the associated clinical measures. Another approach would be to give the user the option to choose the central theme around which the information should be organized. This could help the physician detect changes after a particular event (e.g. hospitalization). The main drawback is the user must explore the patient’s health status through one particular section of the CCD and there is no methodology to access patient data section-by-section. It forces the user to follow its static model of relating clinical information to specific problems and may lack sufficient flexibility, particularly when the clinician is faced with more complex patients presenting multiple problems at once.

CONCLUSION

We conclude that no single principle based interface can satisfy all physician requirements for effective visualization of patient data and also deliver an enhanced usability experience. Possible enhanced versions of the three approaches to clinical data presentation are discussed in this paper. These somewhat orthogonal data visualization techniques, if used selectively and in proper combination to satisfy different needs of physicians, could very well increase the efficiency and the quality of care provided. Our narrow goal was to identify and highlight UI design criteria that are necessary but cannot all be satisfied at once. Hopefully, these criteria will help guide future GUI designers to balance the usability and visualization challenges of presenting clinical data.

In practical settings we think that the three single principle UI designs might be used in sequence. The rapid access principle could be used to get a quick over view of a patient. The physician could then switch to the flexibility principle based interface to compare or simultaneously access clinical data of interest. Once a potential problem or issue is detected, the physician could switch to the level of detail principle based interface to hone in on that problem and extract the corresponding clinical information.
An interface that can intelligently and dynamically detect these phases of decision making and change the visual display appropriately might be a near perfect one.

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