Electronic Medical Record Visualization for Patient Progress Tracking

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Abstract: Patient progress tracking is important to a doctor in a treatment process. In order to have enough information about a patient and the treatment made for the patient, a doctor has to view a lot of medical data about symptoms, test results, drugs and their dosages in a period of time. With electronic medical records, it is convenient for the doctor to view and search for any information he/she needs as compared to paper medical records. It would be even better if all the related electronic medical records over time of each patient are visualized appropriately to support the doctor in patient progress tracking. Therefore, our EMR Visualization system is proposed as a web-based application on tablet computers for visualizing all the related medical data in an integrative manner. The system provides an interactive visualization with accurate data at different detail levels, quick access and convenience for a doctor to keep track of the progress of each patient over time. Its demonstration with the real data of gastroenterological Vietnamese patients in Thong Nhat Hospital, Ho Chi Minh City, Vietnam, has been conducted and showed that every interaction of a doctor can be accomplished in at most two steps.

Keywords: Medical Treatment, Temporal Data, Interaction Method, Tablet Computer, User-Computer Interface

1. INTRODUCTION

Medical data visualization has received much attention all over the world due to its usefulness and significance as discussed in [12]. The existing visualization systems are often divided into two groups: the systems in [1, 2, 5, 7, 9-11] for single patient-related visualization, and the ones in [3, 4, 6-8] for patient group-related visualization.


In the aforementioned systems, a web-based interface was often developed. Desktop or laptop computers for end-user’s operations were used for system deployment except for tablet computers in [1, 11] and mobile phones in [2]. Although tablet computers and mobile phones are more portable than desktop computers, their small screens require an efficient user interface’s design.

In our work, a visualization system named EMR Visualization is proposed with medical data visualization on tablet computers for patient progress tracking. Our system provides doctors with the functionalities for extracting and visualizing clinical symptom data, test results, and drugs and their dosages over time in a treatment process in an integrative manner. More calculation is also made for derived information about the patient progress, via calculating differences in test results and about the drugs and dosages that the patient has taken for a certain period. A demonstration has been conducted for doctors on the real data of gastroenterological Vietnamese patients in Thong Nhat Hospital, Ho Chi Minh City.

Compared to the existing works, the domain and tracking purpose of our system are different from those of the systems in [1, 2, 5, 7, 9, 10, 11]. Such differences lead to our distinct visualization design for presentation and interaction on tablet computers. Besides, our work considers and visualizes unstructured symptom data, which are common in healthcare, in a quantitative approach, instead of a keyword-based approach in [3]. Moreover, in our system, medical data are supported in various types.
2. USER REQUIREMENTS

Closely working with the gastroenterological doctors in the hospital, we discover both functional and non-functional user requirements about the need of visualizing EMRs for patient progress tracking.

For functional user requirements, the medical laws and regulations in the hospital are examined. The treatment process and the duty of a doctor in the process are studied. Expectations of a doctor who is using a computer-based health information system are considered. Particularly in a treatment process, a doctor has to record all of the clinical symptoms of a disease that a patient is being diagnosed with. The doctor may have some tests done for the patient so that more information can be obtained and analyzed for the disease and medication. Drugs and their dosages can be then decided.

After the patient takes the prescribed medicine, the doctor visits the patient and repeats the treatment process with recording the symptoms, giving some further tests if needed, and medication accordingly. The patient progress is tracked over time so that the doctor can make sure that the drugs can be prescribed for the disease adaptively and effectively until the patient gets better.

As a result, symptoms, test results, and medication need to be visualized in that sequential and integrative manner. In addition, the doctor wants to know how better the patient can get if the drugs are used in a certain time period and how much the drugs should be taken in that period. Besides, information extraction on demand is desired so that the doctor can have a particular view on the status of the patient in treatment over time.

With these functional requirements, our system focuses on visualizing the data related to symptoms, test results, and medication of each patient. Their temporal aspect is also considered. Furthermore, the system concentrates on interaction to provide medical information on demand via selection, search, panel collapsing, chart collapsing, and closing commands. Derived information via calculation on test results, drugs, and their dosages is also prepared.

For non-functional requirements, accuracy with different detail levels, quick access, and convenient operations are given and discussed. Different detail levels imply the data of each patient in the collection level and in the individual level. At both levels, the visualized data must be the same as those in the real medical records. For this requirement, our system needs data extraction from the real medical records correctly. It also needs to visualize the extracted data at these different detail levels.

Quick access means that a doctor can have access to any element of interest as fast as possible. Thus, from the perspective of system development, every interaction between a doctor and our system needs to be designed with the minimum number of required steps.

Convenient operations enable a doctor to use the system in a treatment process in an easy manner with no distraction. It shows the usability of our system in practice and, at the same time, the feasibility of a computer-based application in the medical domain. In order to meet this requirement, all of the factors of a standard information system have been considered. They are hardware, software, information, network, and people.

Particularly, we choose an implementation on a tablet computer on the end-user’s side. This application is connected via the Internet with the application and database server for any request on demand. With a tablet computer and wireless connection, a doctor can carry the tablet computer to anywhere at anytime, and has access to any information of each patient during a treatment process, instead of a collection of paper medical records. Moreover, the interface needs to be familiar to doctors so that they can operate the system smoothly. Thanks to the participating gastroenterological doctors at Thong Nhat Hospital in Ho Chi Minh City, our system’s design is completed with their considerable assistance.

3. THE PROPOSED SYSTEM

In this section, we propose the EMRVisualization system to support doctors to keep track of patient progress in their treatment process. By tracking, a doctor can figure out the treatment effectiveness as soon as possible. For this purpose, our system development starts with user requirements in the real world so that its design can be made as a bridge between doctors and computers with EMRs.

Figure 1 shows the architecture of our system with its main modules. In our system, doctors are end-users. EMRs are assumed to be available in the database for data extraction.
3.1 Data and their types

Treatment notes are rich of medical data that are important and suitable for being used in tracking the progress of each patient. They contain the details of clinical symptoms, test results, and medication that a doctor gave a patient. These data are stored in a database.

As typed in the database, medical data of symptoms can be classified into the following groups:
- Discrete data: binary, categorical, ordinal, or
- Continuous data: numeric.

For test results, a numeric value of each variable in a test is provided with its normal range. Medication is given by a doctor. Drugs and their dosages are temporally prescribed. The doctor wants to see the relatedness between such medical data and the changes of symptoms and test results in patient progress tracking.

3.2 Visualization design

a. Layout of the system’s single screen interface

In our system, single screen interface is used to give doctors effortless access to integrated data of symptoms, tests, and medication on a tablet computer. Figure 2 shows the layout of our single screen interface in English.

![Figure 2: Layout of our system’s single screen interface](image)

In this single screen interface, on the right side is the largest main panel for visualization of clinical symptoms, test results, and drugs and their dosages over time. On the left side is the smaller panel for selection with check lists and searching for the clinical symptoms, test results, and drugs. We also have a list of icons for different interactions presented in Section 3.3.c.

b. Charts

For specific visualization, line and bar charts are used by default. Both symptom and test data are essential signals for a treatment process. Their changes inform the effectiveness of a treatment. In order to present their values and changes, line charts are chosen.

Besides, different marker types are used. Filled circles (•) are used for numeric data, filled triangles (▲) for binary data, and filled squares (■) for categorical data. They have a textual description for each numeric value. By contrast, bar charts are chosen for medication so that what medicine and how much the patient took can be clarified. Nevertheless, other charts can be selected alternatively upon user’s desire using the setting control.

The time axes of all the charts are united into common time axes. We place one common time axis on the top and another one at the bottom of the right panel. They are with explicit time points at the finest time granularity up to the temporal aspect of visualized medical data. For each chart, a grid is embedded so that data points can be aligned with their values and time axes.

c. Interaction

In our design, interaction is important to the system’s usability. It enables and then motivates doctors to communicate with the system. Characteristics of a tablet computer’s screen are thus examined and the design is optimized with the best practices.

For a tablet computer with a limited touchable screen space, our system avoids using its keyboard as much as possible. Instead, click events are exploited for interaction by touching. In order to catch doctors’ attention, popular icons with conventional meanings are used as follows:

- Icon ▼: a collapsing control to hide the left panel and enlarge the right panel for larger charts of medical data.
- Icon ▲: a note control to open the note dialog and provide a place where a doctor can take a note on the patient’s status, after viewing medical data in treatment.
- Icon ◼: a setting control to open the chart setting dialog and allow changing the default design choices.
- Icon ▶: a checking control in a check list to select an item of interest in a symptom, test, or drug list. A chart corresponding to the selected item is then visualized in the right panel. If the list is long, a scrollbar appears and helps a doctor to explore all items over the list.
- Icon ◼: an un-checking control in a check list to de-select an item in a symptom, test, or drug list. This control makes the existing chart of the item disappear in the right panel and the item de-selected from the list.
- Icon ◼: a search control for an item of interest in a symptom, test, or drug list. This control provides a quick access to a shorter list of items of interest if the original list is long. Only the items that contain the search string inputted by a doctor are in the check list for selection.
- Icon ◼: a hiding control, aka a chart collapsing control, to hide a selected chart temporarily in the right panel. This is useful for an application on a tablet computer as providing more space for viewing other charts.
• Icon  
  : an un-hiding control to unhide a selected chart and make it appear in the right panel for being reviewed.
• Icon  
  : a closing control to remove a selected chart from the list. This control is equivalent to the un-checking control in the left panel. However, it provides a quick access to de-select an item of interest and remove its chart after its data have been viewed.

In addition to the interactions behind the icons, interactions are also integrated into charts and caught via click events. By default, time series data for each symptom, each variable in a test, or each drug are visualized in a chart at the collection level.

In order to make each chart less complicated with data labels, no detail of each value is shown in a chart. Therefore, visualization at the individual level is provided by a single-click event on a chart. Touching a data point in a chart brings the details of that point, which consist of its timestamp, marker, value, unit, and description if any.

For more derived information, a doctor can interact with a test or drug chart using a double-click event and a single-click event. For a test chart, a difference between two points in time in test results is calculated and shown in a pop-up dialog. For a drug chart, drug amount in a period of time is computed and shown in a pop-up dialog.

Our system’s design is made as simple as possible. Therefore, doctors do not have to remember any sequence of operations. Indeed, all the main interactions are placed on the main dialog with the single screen interface. The others are designed as pop-up, additional for derived information and for other actions of low use frequency.

In summary, our system’s design aims at interactive data visualization. It is kept simple but informative for a treatment process. Simplicity makes the system feasibly deployed in practice, while rich information makes the system helpful for doctors, i.e., its end-users.

3.3 System prototype

In our system’s demonstration on a Samsung tablet, we use the real data of gastroenterological patients at Thong Nhat Hospital, Ho Chi Minh City, from the treatment notes entered by doctors. They are in Vietnamese with English medical terms and drug names.

a. Single screen interface with different detail levels

When visiting a patient, a doctor can look at patient’s medical data, namely, symptoms, test results, and medication made so far. A corresponding screen is turned on for a given patient shown in Figure 3, with three sections on the right panel, namely, “Triệu chứng lâm sàng” (symptoms), “Kết quả xét nghiệm” (test results), and “Thuốc điều trị” (drugs and dosages). This screen matches the single screen interface layout in Figure 2.

Figure 3: A screen shot on a tablet computer

Figure 4: Clinical symptom details

Figure 5: Screen collapsing to enlarge the right panel

(a) Before chart collapsing

(b) After chart collapsing

Figure 6: Chart collapsing to switch the focus

For more specific values at a certain point in time, a doctor can touch a data point on a chart. Demonstrated in Figure 4 by touching a data point on “Sốt” (fever) chart, the details of “Sốt” (fever) symptom on 30/11/2017 are presented. At 08:00 on that day, the patient had a high fever (“Cao”). Similarly, the details of test results, drugs and dosages can be presented by touching on demand.
b. Reconfiguration for more space on a tablet computer

Touching the collapsing icon in the header allows the left panel to be hidden and the right panel to be enlarged. Figure 5 shows the interaction result for more space in the horizontal view. By contrast, the chart collapsing icon in the right panel brings more space in the vertical view. In addition, interaction with this icon makes the current display less detailed. It also allows a doctor to switch the focus to other items. Demonstrated in Figure 6, (a) shows two charts for “Ý thức” (Consciousness) and “Sốt” (Fever), while (b) shows only one chart for “Sốt” after chart collapsing for “Ý thức”.

c. Search for more specific items of interest

Figure 7: Keyword-based search for test results with the keyword “hồng” (red)

In case of a long list of symptoms, test results, or drugs, keyword-based search can generate a shorter list of more specific items. In Figure 7, we use a keyword-based search for test results with the keyword “hồng” (red). Before this search, the test variable names with this keyword are not on top of the list. That makes a doctor hard to find the related test results. After this search, the test results are filtered and only the test variable names that contain “hồng” (red) appear in the list for further selection. This is also applied to symptoms and drugs.

d. Calculation for further data exploration

Introduced earlier in Section 2, a doctor may want to see if a patient gets better during a treatment process. For this purpose, our system calculates test results and dosages. The doctor can obtain the results by a combination of a double-click event and a single-click event. A double-click event is caught by double touching a starting data point and a single-click one by an ending data point.

In Figure 8, a difference between two test values of WBC at two time points is derived in value change and percentage. Such a difference alerts the patient status change and lets the doctor know if the current treatment is effective. Similarly, more information is calculated for each drug and its dosages. The doctor can have further analysis on such information with the corresponding symptoms and test results. This helps the doctor realize if drugs have sufficiently been used for treating the disease.

4. SYSTEM EVALUATION

As an evaluation, our system fulfills the requirements in Section 2. For functional ones, interactive visualization of all data required for patient progress tracking has been made. For non-functional ones, all system’s factors have been analyzed and built under the doctor-centered view.

Medical data can be extracted accurately from the database of EMRs and then visualized in both set-based and individual-based forms. Quick access has been ensured with the single screen interface where each interaction requires at most two steps.

For the commercial systems in [1, 11] for tablet computers, their technology was not presented in details. According to their descriptions in [1, 11, 12], both systems did not visualize the temporal medical information of a patient in the sequence of clinical symptoms, test results, and then medications. By contrast, our system presents them in an integrative manner just like the data use sequence of doctors in their treatment.

Besides, their demonstration is not completed with the information of gastroenterological patients, while ours is done with those and aims at other chronic diseases. Among the supported data types, our system takes into account clinical text, normalizes and quantifies them for visualization, while [1] had no mention of such data type, and [11] handled unstructured medical records with entity-based relation graphs. That is also why only our system visualizes clinical symptoms, while the others mainly presented vitals over time as time series.

As for [1], the time axis and its granularity were not explicitly presented, while they are given on the top and bottom of the right panel in our system, so that doctors can quickly know the temporal aspect of any data. In addition, drugs and their dosages over time are visualized in bar charts by our system, while they were not in [1]. Furthermore, a normal range of each variable was not explicitly visualized in [1], while it is given in line charts by our system. So, our system provides quicker access to
normal and abnormal values of each variable in treatment.

To the best of our knowledge, our EMR Visualization system, which exploits medical data of clinical symptoms, test results, and medications, in an integrative manner, is the first medical information visualization system on a tablet computer for patient progress tracking.

5. CONCLUSIONS

In this paper, we propose the EMR Visualization system as a solution to bridging the gap between medical doctors and computers as EMRs are created, stored and utilized. The proposed system can support doctors to view EMRs of their patients accurately, conveniently and quickly in a long treatment period. All the treatment history of each patient can be queried and visualized on a tablet computer when a doctor visits that patient. The patient progress can be easily tracked with visualized clinical symptoms, test results, and drugs in treatment over time. Every interaction can be made with at most two steps. This characteristic enables a doctor to communicate instantly with the system for required information. Thus, the system can assist the doctor significantly in practice.

As our future works, more interaction techniques on tablet computers will be examined including speech recognition. Extending the system with access to the data of multiple other patients during treatment is considered. Above all, largely deploying the system in practice for more evaluation and improvement is currently carried out.

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REFERENCES


