MOBILE TIMELINE EMR SYSTEM
Support System for Doctors' Cognition/Analysis

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Keywords: Electronic medical records, Timeline, visualization of medical data, XEUS, Word completion, Adaptive data mergence, Social patient list, Mobile, XML.

Abstract: In this paper, we propose a novel electronic medical record system (EMR) based on a brand new concept to support doctors' cognition and medical analysis wherever they are. Conventional EMR systems have the advantage of helping doctors easily retrieve and manage mass medical records. On the other hand, medical records have been expected to support doctors' planning. Most conventional EMR systems don't have an appropriate function for such purpose, however. Because of its poor user interface, which is similar to legacy medical records written on paper, they can't help doctors analyze medical data that occurs chronologically. To attain that purpose, the system has to have the ability to visualize medical data that occurs over various time spans. This is because the relationship among the different medical data should be observable when we look at it over various time spans. In addition, doctors aren't always at their desks, so they can't always use EMR systems with a desktop PC. Therefore, in view of these problems, we propose a system that has timeline interface which visualizes medical data that occurs over various time spans and its client application works on a mobile device. In this manner, the system can support doctors' cognition and medical analysis wherever they are. In addition, we are verifying this system in the medical field.

1 INTRODUCTION

EMR systems are becoming popular in medicine (A.L.Rector. 1996 , Anderson JD. 1999 , David W. Bates *et al*. 2003 , Samuel J. Wang *et al*. 2003 , Jim Johnson. 2010). This is because the system enables doctors to manage mass medical data easily. As represented by POMR (Weed LL. 1968), medical record systems have been expected to support doctors' planning. But most of these EMR systems are merely electronic data storage of legacy medical records. For such purpose, the system has to have the ability to visualize medical data that occurs over various time spans. Because medical data often occurs over various time spans, doctors have to visualize it over various time spans for a medical analysis. With these systems, doctors can look at medical data for only a few days at most. Accordingly, doctors can't analyze medical data effectively. In addition, there is another problem that doctors don't have much time to use the EMR at their desks. As a result of these problems, doctors desire a system that can support their cognition and medical analysis anywhere. In view of these problems, we propose a mobile timeline EMR system that supports doctors' cognition and medical analysis. This system has the features listed below:

・ It has the ability to visualize medical data that occurs chronologically over various time spans.

・ Its client application works on a mobile device such as a mobile phone or a tablet PC.

・ In spite of the narrow bandwidth of wireless mobile networks, the system responds quickly.

In this paper, we introduce the conventional EMR systems in section 2 and reveal their problems. In section 3, to solve these problems, we introduce the mobile timeline EMR system and its technological features.

Ogawa K., Matsumoto K., Hashimoto M., Hamai T. and Kondo Y..
MOBILE TIMELINE EMR SYSTEM - Support System for Doctors' Cognition/Analysis.
DOI: 10.5220/0003287604050410
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2011), pages 405-410
ISBN: 978-989-8425-34-8

2 CONVENTIONAL EMR SYSTEMS

In this section, we introduce the conventional EMR systems. They can be divided into two types used in medicine as listed below:

・A system that has a user interface similar to legacy medical records written on paper (type-1).

・A system that has a user interface that summarizes the data of medical examinations over the last few days (type-2).

Figure1 shows the client application of a type-1 EMR system that displays SOAP information, the patient's information, and histories of medical exams. With these systems, by treating medical data as electronic data, doctors can search and manage their patients' medical data easily. This ability of mass data management is a significant advantage compared with legacy medical records.

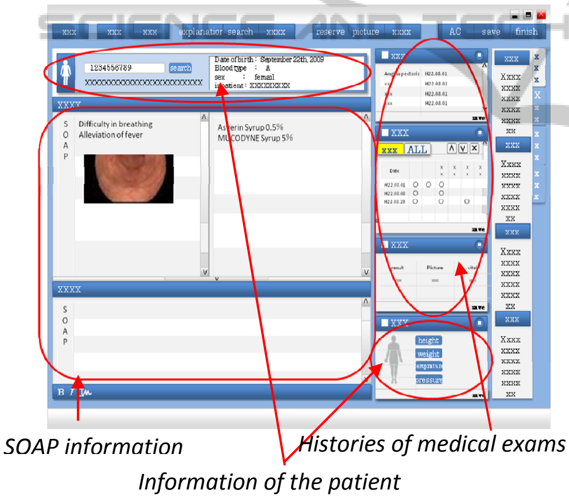

Figure 1: Conventional EMR system (type-1).

Figure2 shows the client application of a type-2 EMR system. It can display the data over the fixed term. Due to the restriction of the size of the display, in general, it displays the data over the short term.

However, there are various kinds of medical data occurring over various time spans. So with these systems, which can visualize medical data for only a few days, doctors can't always look at it and infer the relationship among them. In other words, though doctors can look at and understand the state of patients who come two or three times with these systems, they never can look at and understand the state of patients who are suffering for years, such as asthmatics, diabetics or patients suffering from hypertension. Accordingly, these systems don't attain the purpose of supporting doctors' analysis and cognition.

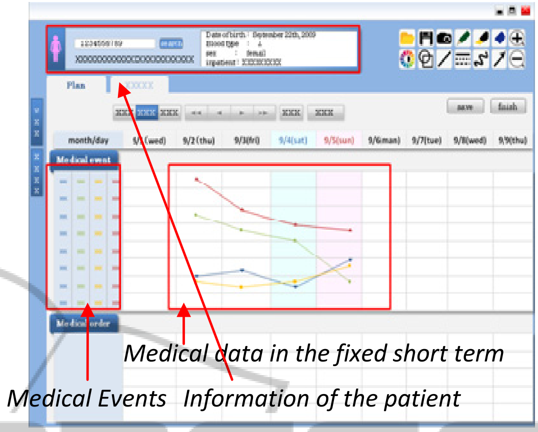

Figure 2: Conventional EMR system (type-2).

3 MOBILE TIMELINE EMR SYSTEM

As described above, in order to meet the demands of supporting doctor's cognition and medical analysis, the system must have a function to visualize medical data that occurs over various time spans and allow doctors to look at medical data from any perspective. So we introduced timeline interface to solve this problem. Timeline interface visualizes the medical data in chronological order. Timeline interface has a multistage time scale such as years, months and days, etc. With timeline interface, the system can visualize chronological data over various time spans.

In addition, to meet the demands of mobility and portability, we use a mobile device as a client of this system. By adopting a mobile device, the system gains a significant advantage in that doctors can inspect and analyze the data anywhere, but mobile devices have some problems as listed below:

(1) Difficulty with input and reading with a small display

(2) Low data transmission rate through mobile wireless network

To solve problem (1), we adopted the functions listed below:

・Advanced word completion using optimized lexicon for each medical branch.

・Social patient list that aims to reduce the input by reusing the search histories in each medical branch.

For problem (2), we adopted the functions listed below:

・ An Adaptive data mergence function that merges neighboring data objects adaptively. This reduces the amount of data transmitted.

・ An XML document encoding system that reduces the amount of data transmitted by transforming the XML plaintext to small binary data.

In this manner, we can realize the tool based on the concept of supporting doctors' cognition and analysis wherever they are. These functions are described below in detail.

3.1 Timeline Interface

Timeline interface is the most important part of this system. Figure3 shows it. Doctors can change the time scale to various time units by controlling the bar on the upper part. For example, by clicking the bar, doctors can change the day unit time scale to the month unit scale or the hour unit scale. By changing the time scale to a smaller unit scale, doctors can observe medical data over a short time span in detail. Conversely, by changing the time scale to a bigger unit scale, doctors can look at medical data over a long time span. Also, we can change the length of the time unit by pinch-in/pinch-out.

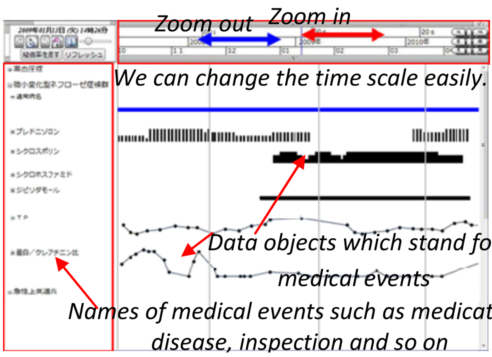

Figure 3: Timeline interface.

The reasons why we use this interface are described below:

・ There are various kinds of medical data. They occur chronologically and there are often several relationships among them.

・ When there is a relationship among the different data, the appropriate time scale to observe exists. By selecting the time scale properly, the system can visualize the relationship among the data.

For example, take the case where we can discover the relationships when we observe the data over a long time span, even if we can't discover it over a short time span. Conversely, we can't discover it with an overly long time span. Accordingly, the system must have a function that allows users to select the appropriate time scale.

With this timeline interface, doctors can change the time scale as they wish. Therefore, doctors can observe the various relationships between various data. In other words, doctors can inspect medical data from various points of view. Figure4 shows an example of observable relationships.

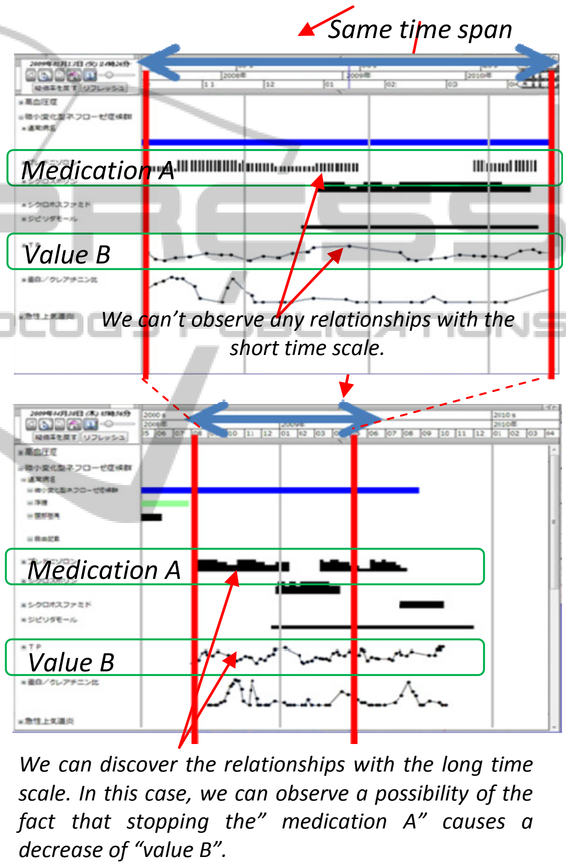

Figure 4: Visualization of the relationships among medical data.

In this manner, this system can be not only a management tool for medical data, but also a tool for supporting doctors' cognition and medical analysis.

3.2 Word Completion using Lexicon for Medical Data

The input method is not only an important factor that decides the usability of the system on mobile devices, but also a difficult problem. This is because mobile devices only have poor input accessories such as small touch panels and keyboards. In particular, in EMR systems, doctors have to input special characters for medical treatment using these poor input devices to write down the SOAP information or to search patients. To solve this, it is common knowledge that the word completion method using a lexicon of medical words is effective (Laird S. Cermak *et al* 1992, C. G. Chute et al 1999, Hiroyuki Komatsu *et al* 2001). However, the words used in medicine differ significantly among each branch. In other words, there is a problem that using the same lexicon among all the branches is insufficient. For example, the phrase nephrotic syndrome is often used by pediatricians, but is rarely used by ophthalmologists. Accordingly, we optimize the lexicon for each branch. Simply put, we changed the bias of the TRIE (Donald R. Morrison 1968) structure of the lexicon for each branch. Then for each branch, by summarizing and analyzing the doctors' input history commonly, the system succeeded in improving the accuracy of word completion. Figure5 shows an example of the TRIE structure in Japanese.

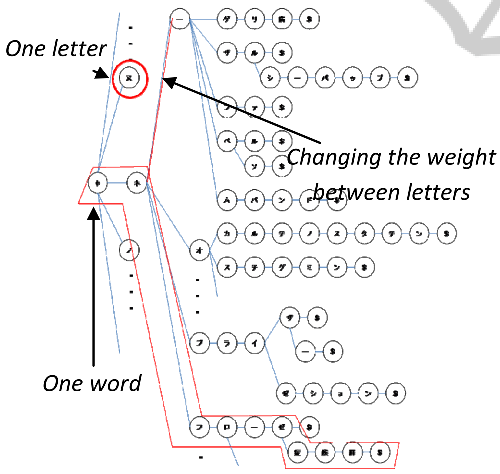

Figure 5: TRIE structure for lexicon of medical words in Japanese.

Here, we use φ for the head of the sentence and $ for the tail of the sentence. By adding word frequency of doctors' own input history, word frequency of other doctors' input history in the same branch and the cost of prediction to the tail of the sentence, we can make the TRIE structures for each branch.

3.3 Social Patient List

In this subsection, we introduce another function for the purpose of reducing input, which is called the social patient list in this system. By using the social patient list, doctors can search for patients using useful queries without using a keyboard that is difficult to use. Social patient list is a function that enables doctors to save search queries as a list of patients and have them in common in each branch. In other words, doctors in the same branch can utilize the useful search histories of other doctors as if they were their own. The figure presented below is an example of a social patient list. By clicking the display button, doctors can easily reuse the search queries of other doctors.

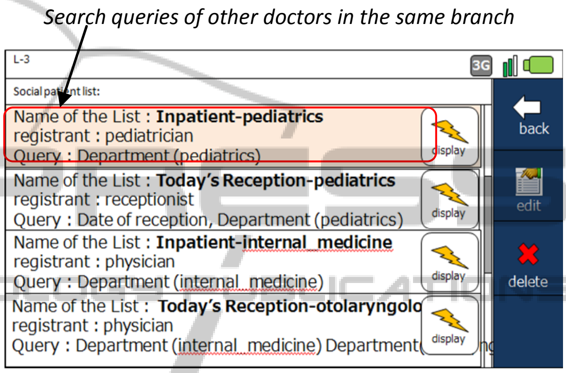

Figure 6: Social patient list.

3.4 Adaptive Data Mergence

The response speed of the system is a very important factor for deciding the system's usability. The advantage of timeline interface is, as we described above, the ability to visualize the relationships of medical data with various time scales. If doctors want to look at the data in the long time span, they can enlarge the time scale as they wish. In this manner, however, the system has to display a lot of data objects at once. On the other hand, in this system, since its client is a mobile device, the client only has narrow wireless communication bandwidth. In order to improve the response speed in this system, we use adaptive data mergence. Adaptive data mergence is a function that merges neighboring data objects adaptively. We use the formula below as a threshold to merge data objects.

$$\frac{Start\_time\_of\_objectA - end\_time\_of\_objectB}{timescale} < threshold : x$$

As we described in Figure7, when doctors enlarge the time scale, if the time gap of the data objects is smaller than the threshold, the system merges the objects to one object. In this manner, the system can reduce the amount of data and improve the response speed and usability.

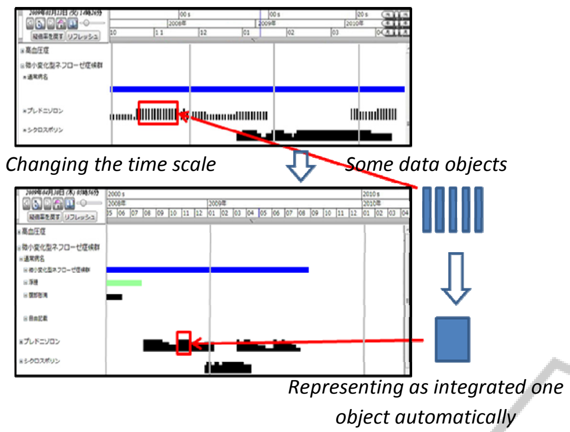

Figure 7: Adaptive data mergence.

In addition, there are various types of graphs for the data objects and the best graphs for the data objects are different from each other. If doctors want to observe the flow of medication data, a line graph is the best representation. In another example, if doctors want to look at the frequency of the examination data, a histogram is the best representation. Adaptive data mergence has the ability to select the best representation automatically by learning the history in the same branch. As represented below in Figure8, the system has the ability to change the representation depending on the data.

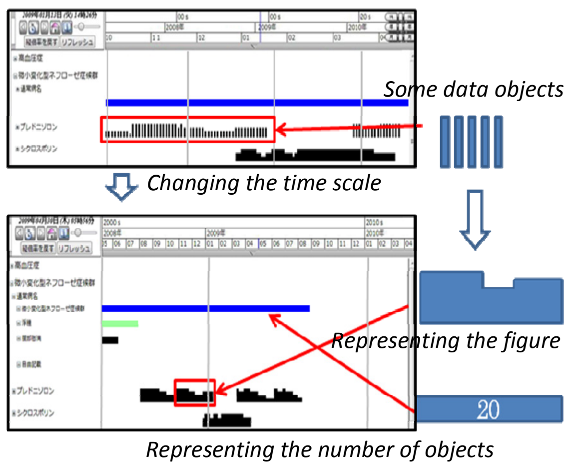

Figure 8: Various graph representations for data objects.

3.5 XML Document Encoding System

Recently, MML (Kenji Araki *et al.* 2000 , Jinqiu Guo *et al* 2003), which is the standard data format to transmit medical data between two different EMR systems, has been proposed. MML is a format based on XML. In addition, in this mobile timeline EMR system, we use a data format based on MML. The common XML document is the plaintext data, so it provides the advantage of high readability and high extensibility. XML also results in a disadvantage in respect to data size, safety and parse processing load in terms of data reception, however. Therefore, in this system, we solve these problems by adopting the XEUS (Kobayashi Arei *et al*. 2001) XML document encoding system. XEUS is the abbreviation of XML document Encoding Universal Sheet and a system for encoding XML documents. Now, we describe the procedure of the XEUS system.

1st step: Define the XEUS sheet which is a document that has the logical structure and a table of the encoding. The XEUS sheet is described by XML.

2nd step: By using this XEUS sheet in the encoder, we can encode the large plaintext XML document into a small binary document. This is because the encoder can separate the plaintext XML document into the logical structure and serialized data, and transforms it into small binary data. Then in the decoder, by using the same XEUS sheet, which defines the logical structure, we can decode the small binary document. Figure9 shows the concept of the XEUS system.

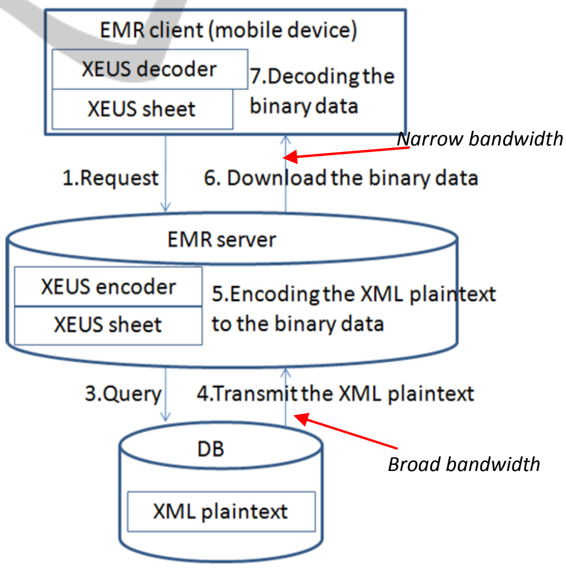

Figure 9: XEUS system.

In this mobile timeline EMR system, the EMR server that has medical data has the encoder and the mobile device that displays the EMR data has the decoder. In general, XML documents result in the data becoming one-fifth the original size. This is a significant help for the client of this system, which only has narrow wireless communication bandwidth.

4 CONCLUSIONS

In this paper, we proposed an EMR system based on the brand new concept. This system has a significant advantage to support doctors' cognition and medical analysis wherever they are. The system has the three features described below.

・ Since this system has timeline interface, doctors can look at and analyze medical data by using various time scales. This is a significant help for doctors' cognition and analysis.

・ Since its client is a mobile device, the system can support doctors' cognition and medical analysis wherever they are.

・ In spite of using a mobile device as a client, this system guarantees ease of use as much as possible.

In addition to the features described above, making use of the advantage of easy use, there is a possibility that the doctors can use this system as an educational tool.

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