A Hypothesis-generating Support System Using Medical Records for Clinical Knowledge Acquisition

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Abstract—The authors developed a support system for finding hypotheses about clinical knowledge from medical records accumulated electronically in hospital information systems. In order to support the development of various hypotheses, we matched a variety of medical and clinical information with each case and utilized the information comprehensively. This information includes clinical documents, examination information, medical practice information, and other minor factors. The system uses coverage-oriented views showing targeted medical records, in whole or in part. We selected appropriate methods to provide coverage-oriented views of natural language data, numerical data, and coded data, making use of snippets, graphs, and tag clouds, respectively. In addition, users can narrow the search results utilizing keywords, ranges of values, and labels of codes, respectively. The coverage-oriented views and the narrowing methods utilizing the views make the retrieval system interactive. We predicted that users could find hypotheses by grasping features of targeted cases using coverage-oriented views based on interactive retrieval. We evaluated the developed prototype in terms of its potential for helping users find hypotheses about clinical knowledge and we received positive responses from doctors.

Index terms—Clinical knowledge, Hypothesis-finding, Medical records, Interactive retrieval, Coverage-oriented views.

I. INTRODUCTION

EMR has been working for the past 10 years in Kyoto University Hospital as well as other institutions. As a result, a vast number of medical records have been accumulated. Medical records are written as doctors provide medical care to patients. Medical records include information on the conditions of patients and of medical treatments for patients. If medical personnel can extract clinical knowledge from accumulated medical records, we would provide higher quality medical care by more precise usage of the clinical knowledge. In this study, clinical knowledge is defined as universe relationship between subjections and objections of patients, diagnoses and medical practices for patients. Namely, we treat universal relationships in medical records as clinical knowledge.

Generally, in order to obtain knowledge from large and variant information, we limit the amount of data to information having specific characters and conditions. When narrowing the information, it can be easy to find trends of narrowed information. We can also generate hypotheses based on the trends. Narrowing information is realized by using a retrieval system. However, users require various kinds of knowledge and this knowledge may not be clear understood. Hence, it can be difficult for the user to choose an appropriate query and to convey the user’s request correctly. Therefore, Huynbh et al. and Yamamoto et al. developed systems on which users clarify their search intentions through interaction between the users and the systems [1, 2]. Since the systems treat non-structured documents on the Web, the system provides a list of keywords to users for interactive retrieval. However, when documents somewhat structured like medical records are treated, a system can provide several kinds of information to users. The users can grasp results of data retrieval with several points of view and select query from a wide range of choices.

II. OBJECTIVES

In this study, we develop and evaluate a hypotheses-generating support system using medical records for clinical knowledge acquisition. The system shows targeted medical records in whole or in part using coverage-oriented views. These coverage-oriented views include queries that users can use to narrow the selection of medical records. Namely, the coverage-oriented views including queries realize interactive retrieval between the system and users. The interactive retrieval helps users to choose query and to generate hypotheses that users need.

III. MATERIALS AND METHODS

A. Medical and Clinical Information

In this study, a patient’s hospitalization and treatment history are labeled as one individual case. In addition, patients with multiple hospitalizations have each individual hospitalization labeled as one separate case.

Kinds of medical and clinical information we treat are discharge summaries, information of blood tests, disease names, and medical practice information, which includes information of operations and prescription. We selected the information because almost all cases were related to the information. Since discharge summaries are consisted in important information, they were used in many studies [3, 4].

Blood tests are one of the fundamental tests and more than one blood test corresponds to almost every case. However, there are many examination items and each blood test includes a part of them. Hence, rare examination items correspond to a minority of the cases and cannot be used to provide coverage-
oriented views. Therefore, we selected generally important examination items based on a discussion with doctors. The selected examination items are “the white blood cell count”, “the red blood cell count”, “the number of platelets”, “γ-GTP”, “AST/GOT”, “ALT/GPT”, “HDL cholesterol”, “LDL cholesterol”, “CRP”.

Disease names and medical practice information are coded and can be extracted as order information of disease names and medical practices in Kyoto University Hospital.

The medical records that the developed system treats are the medical information of the cases in fiscal year 2008 in Kyoto University Hospital.

B. Aggregation of Medical Records and Making Coverage-oriented Views

Users can overview medical records from the point of view of a specific kind of information. For example, when a user focuses on the red blood cell count, the user can see the distribution of the red blood cell count of all the cases. However, various forms are used to express each kind of medical information. Hence, it is important to select appropriate methods to overview medical records according to kinds of medical information. Precisely, discharge summaries are natural language data, information of blood tests is numerical data, and disease names and medical practice information are coded data. In this study, we make use of snippets, graphs and tag clouds to provide coverage-oriented views of natural language data, numerical data and coded data, respectively. A snippet is a list of sentences each of which consists of a keyword and a string around the keyword. Snippets are often used to show the results of retrieval in search engines. However, snippets are difficult to provide coverage-oriented views when the size of results is large. A tag cloud is used as a visual depiction of tags. In a tag cloud, more frequently used tags or more popular tags are shown larger or more emphasized. Yamamoto et al. used tag clouds to support users’ decision of choosing keywords which are utilized to re-rank the results of retrievals [2].

The distribution of each examination item is shown by using a bar graph. Also, the system provides tag clouds exploiting abnormal values of examination items. For instance, when medical records are narrowed down to records with high values of the red blood cell count, a label “red blood cell count ↑” is shown to be larger in size.

Figure 1 depicts the interface of the developed hypothesis-generating support system for clinical knowledge acquisition.

C. Interactive Medical Record Retrieval

Users can limit medical records using above coverage-oriented views. When the users limit natural language data, numerical data and coded data, they use keywords, ranges of values, and labels, respectively. These keywords, ranges of values, and labels can be found on coverage-oriented views. When keywords are given to the system, the system uses the n-gram method to return medical records whose discharge summaries include the given keywords. When a range of value is given to the system, the system returns medical records whose value of the examination item falls in the range. For example, when the system receives examination item “AST/GOT” and the range of values is between 49.8IU/l and 99.6IU/l, the system returns medical records whose values of AST/GOT are between 49.8IU/l and 99.6IU/l. The label can correspond to a disease name, a medical practice or an abnormal flag of an examination item. When a label is given to the system, the system returns medical records which have a disease name, a medical practice, or an abnormal flag of an examination item corresponding to the label.

Figure 2 depicts the flow of retrieval using the developed system.
First, the system aggregates medical records of all cases and makes coverage-oriented views (figure 2-1). Users can add their search criteria based on the provided views (figure 2-2). The system narrows the medical records so that the result satisfies the search criteria (figure 2-3). Moreover, the system aggregates the result and makes coverage-oriented views again (figure 2-4). Additionally, the system provides a snippet to show medical documents. Users can browse the full text of a discharge summary by clicking an item of the snippet. Users can continue to add a new search criteria based on the provided views and obtain new coverage-oriented view from the system (figure 2-5, 6). The authors thought that, in this process, users repeat interactive retrieval based on coverage-oriented views continually and they can get any ambiguous requests to be made clear.

D. Evaluation Methods

We, the authors, evaluated whether information of snippets, graphs and tag clouds provided by the developed system are valuable. We also evaluated whether the information supports users to generate hypotheses for clinical knowledge acquisition. The evaluation was performed by two doctors. One of the doctors possesses more than 10 years of experience in clinical medicine. The other is a young doctor who possesses five years of experience in clinical medicine.

These doctors used the developed system and evaluated it on the following three points: the coverage-oriented display of information for supporting searches, the display of results that comport with doctors’ own feelings and experience, and the display of information that may lead to new clinical knowledge. Additionally, we made systems whose functions are restricted and compared the restricted systems with the systems whose functions are not restricted. Each restricted system provides coverage-oriented views by using only one of the snippets, graphs or tag clouds and narrows medical records using only one of the keywords, ranges of values or labels, respectively. We tried to evaluate whether treating several kinds of medical records comprehensively is effective or not.

IV. Results

First of all, the evaluation item concerning the coverage-oriented display of information for supporting searches elicited the following response; “You can get a coverage-oriented view of a range of information about the case. Displaying things that have a higher rate of incidence at a larger size is interesting. It’s easier to understand intuitively than a simple list. It helps to draw your attention to the information.” In addition, doctors reported that when there are no explicit information requirements, information is displayed that helps to find new keywords (queries), which assists with searching.

Next, the evaluation item concerning the display of results that comport with doctors’ own feelings and experience elicited this response; “You get the impression that the results comport with your own feelings and experience”. For example, if you use the keyword “cataract” to narrow down a group of cases, “diabetes” appears larger in the disease name tag cloud. It is relatively well known that cataracts and diabetes tend to be linked.

The evaluation item concerning the display of information that may lead to new clinical knowledge elicited this response; “You get the impression that the information presented may very well represent new knowledge”.

Furthermore, with regard to the effectiveness of handling a variety of retrieved medical records more comprehensively than in a system with limited functions, we received the following opinion; “Displaying information as a tag cloud and search results distributed in graphs is interesting and intuitive. However, it’s difficult to check what sort of people form the population with only a tag cloud or distribution of search results, and since the actions that can be selected are limited, you get the impression that there will be few opportunities to use these functions.” In addition, the following aspect received praise; “It’s good that you can see a range of information whether you use the tag cloud or graphs, and that you can see which people form the population for the information displayed”.

Opinions that were not related to any evaluation item were as follows.

- It would be good if the search results could be changed according to where in the discharge summary the keyword appears (for example, medical records before admission to hospital or at the time of admission).
- Although there is no problem with the information concerning disease names, tests and prescriptions used in the system, there is too wide a range of information about treatments and operations, which may hinder the acquisition of accurate knowledge.
- When there are several test results for the same case in relation to a single test item, it would be good if it were possible to select freely between information relevant to first admission to hospital, before or after the operation and so on.
- It would be good to increase the options for test items.

V. Discussions

The results of the evaluation of displaying information holistically suggest that displaying medical records with snippets, graphs and tag clouds promotes intuitive understanding, is inherently interesting, and makes the viewer want to look at the medical records. Regarding interactive searching, the evaluation suggested that the comprehensive display of medical records for groups of cases helps in the selection of new queries and supports searching. Therefore it is presumed that repeated interactive searching is effective for discovering hypotheses that lead to clinical knowledge. In addition, rather than searching for medical records with a clear purpose, the system appeared suitable for working towards a hypotheses leading to clinical knowledge, or simply viewing medical records without a particular purpose. The evaluation showed that users liked the ability to see which people form the population for the information displayed. Therefore, it is
presumed that doctors want to be able to see the information for each case in order to confirm the knowledge obtained from the medical records. This suggests that the function for displaying discharge summaries based on the search results is useful.

With regard to the validity of the system, the response to the effect that information is displayed that comports with doctors’ own feelings and experience suggest that the characteristics of the cases displayed by the system and the characteristics of the cases assumed by doctors match to some extent.

With regard to the evaluation item concerning whether the system is useful in obtaining new clinical knowledge, we were not able to obtain a clear, positive opinion. However, when using the system ourselves, we confirmed that information was displayed that was useful in establishing a hypothesis. Specifically, if you use the keyword “diabetes” to narrow down a group of cases, “hepatocellular carcinoma” appears larger in the disease name tag cloud. That diabetes increases the risk of hepatocellular carcinoma is a fact that has become clear in recent years, as identified in a famous article published in 2005 [5].

With regard to the effectiveness of handling a variety of medical records comprehensively, the evaluation suggested that compared to a system with limited functions, this aspect enables the user to understand multifaceted medical records and leads to the discovery of hypotheses.

Among the opinions unrelated to any particular evaluation item was the opinion that there is too wide a range of information about treatments and operations. In the current system, medical records classified as treatments or operations is extracted from File F and is classified as a treatment or operation in accordance with the data classification conforming to the treatment code in the computerized receipt processing system. In other words, the data classification conforming to the treatment code in the computerized receipt processing system does not match the perception of the user. Therefore it is necessary to reconsider the method by which treatments and operations are classified. In addition, we were advised to increase the options for inspection items. However, some inspection items are linked to only a part of the cases, and it may be impossible to achieve coverage-oriented display of the characteristics of the medical records accurately. Therefore when adding test items, it would be desirable to consider linking them to cases.

REFERENCES