

A MEDICAL INFORMATION RETRIEVAL BASED ON RETRIEVERS' INTENTIONS

Osamu Takaki

School of Knowledge Science, Japans Advanced Institute of Science and Technology, Nomi, Japan

Koichiro Murata

School of Medicine, Kitasato University Hospital, Sagamihara, Japan

Noriaki Izumi

*Social Intelligence Technology Research Laboratory, National Institute of Advanced Industrial Science and Technology
Tokyo, Japan*

Koiti Hasida

*Social Intelligence Technology Research Laboratory, National Institute of Advanced Industrial Science and Technology
Tokyo, Japan*

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Abstract: This paper introduces a methodology to retrieve information from medical databases based on intentions and viewpoints of retrievers, who retrieve some information from databases. The methodology above helps a retriever to organize his/her intention and viewpoint and to make a proper query based on the viewpoint. It also helps a retriever to record historical data of retrieving with intentions. This paper introduces a series of ontologies to organize a relationship between intentions, viewpoints and keywords that are used to make queries and each of that has interpretations based on viewpoints of retrievers, and explains the methodology based on the ontologies.

1 INTRODUCTION

1.1 Background

Recent years, medical database systems, that include ordering systems of medicines and so on, have become widely used in Japan with digitalization of medical information (cf. (Ministry of Health Labour and Welfare of Japan, 2005) and (Monthly New Medicine of Japan, 2009)). On the other hand, the kind of users of medical databases has been growing. Nowadays, various users including patients regularly utilise medical databases. So, it becomes more significant to enable many different kinds of people to easily retrieve medical information from multiple databases, and thus, it is important to address the

problem of diversity of concepts or interpretations of keywords in the databases. In the following paragraph, we explore this problem in more detail.

Health is a common concern to people throughout the world. In fact, the knowledge related to medicine is enormous, difficult and growing significantly not only as scientific knowledge but also knowledge about institutions, economics or philosophy. Moreover, the meaning of a concept in medicine varies from the viewpoint of a person who considers it. For example, let consider a concept of "a *proper* duration of hospital stays for a patient who gets bowel cancer in an early stage".

From the scientific viewpoint, it would mean the duration between the day when he/she gets bowel cancer and the day when he/she gets cured of the

cancer under the assumption that he/she gets proper treatment. However, the average of real-life durations of hospital stays for patients who get bowel cancer in early stages often differs from the "ideal" duration above. The reason seems to come from the fact that the length of real-life duration is determined by a complex mix of problems of medical care processes, institutional problems, problems of management, patient's individual problems, and so on.

1.2 Objective of this Paper

As noted above, in order to make clear interpretations of keywords by retrievers, it is often helpful to know their intentions and viewpoints and to consider the interpretations of keywords based on them. Thus, we introduce a methodology to retrieve information from medical databases based on viewpoints and intentions of retrievers, where a "retriever" denotes one who retrieves some information from databases with some statement what data he/she require. We call such a statement a "query". More strictly speaking, we introduce a methodology to assist a retriever to (i) organize his/her intention, (ii) find a viewpoint related to the intention, (iii) make a query based on the intention and/or the viewpoint, and (iv) record a historical data of retrieving with the intention. When one performs retrieval, he/she has a certain intention. So, the methodology formalizes such a retriever's intention and utilizes it to retrieve medical information more appropriately.

1.3 Outcomes and Structure of this Paper

The core component of the methodology of intention-based medical information retrieval is a series of ontologies to organize relationships between retrievers' intentions, retrievers' viewpoints and retrieval keywords that are used as parameters in queries. Each keyword has a single or multiple definitions (interpretations) based on viewpoints (or certain patterns of intentions) of retrievers. The reader will notice that historical data of retrieving with intentions are useful to consider not only how to interpret given keywords but also what keywords retrievers should select as parameters in queries.

Moreover, as a foundation of the retrieval system, we introduce an ontology-based retrieval system for large-scale medical data warehouses. The data warehouses are real-life, that are in operation in center hospitals. The retrieval system is developed

based on a developing tool of an ontology called "Semantic Editor" (K.Hasida, 2010) and an ontology-mapping tool called "D2RQ" (C.Bizer, 2010).

The remainder of the paper is structured as follows. In Section 2, we explain related work as a foundation of the research of this paper. In Section 3, we briefly explain a process to retrieve information from medical databases based on retrievers' intentions and the structure of an abstract intention-based retrieval system. In Section 4, we explain ontologies to organize relationship between intentions and viewpoints of retrievers and several concepts related to medical information retrieval. In Section 5, we add supplemental remarks about utilizing historical data of retrieving to make queries. In Section 6, we explain an ontology-based retrieval system for medical data warehouses. We conclude this paper in Section 7.

2 RELATED WORK

In general, it is not easy to retrieve desired information from multiple databases in a lump with an existing keyword-based retrieval system, since the databases may have structures that differ from each other. One of the techniques to address this problem is semantic-based retrieval, in particular, ontology-based retrieval. A semantic-based retrieval system denotes a system that retrieves data with concepts that have the same meanings as given keywords. Semantic-based retrieval systems for medical databases also have been investigated and/or developed actively (cf. (Kementsietsidis et al., 2009), (Kohler et al., 2003), (Perez-Rey et al., 2006)).

In technical aspects, a lot of ontology-based retrieval systems employ two methodologies "ontology-mapping" and "query-expansion (with ontologies)". Ontology-mapping denotes a methodology or a technology that maps between an ontology and a (relational) data model. Ontology-mapping integrates data in multiple databases that may have different structures of schema, by constructing a proper ontology and assigning the ontology to the data models of the given databases. Ontology-mapping also enables one to retrieve data from multiple databases with different data models, by queries that are defined at some abstraction level. In general, this technology has been investigated actively (cf. (Kalfoglou and Schorlemmer, 2005), (Konstantinou et al., 2008), (Noy, 2004)).

As a research of ontology-mapping for medical information retrieving, Aronson et al (Aronson, 2001) developed an algorithm that maps information in biomedical texts to concepts in the UMLS Metathesaurus (Bodenreider, 2004). Moreover, Farfan et al (Farfan et al., 2009) point out several issues on ontology-based retrieval of documents from EMR (Electronic Medical Records) and propose a solution to the issues by using descriptive logic. They also introduce a retrieval algorithm based on HL7 (HL7-International, 2010) and SNOMED-CT (IHTSDO, 2010).

On the other hand, query-expansion denotes a methodology that aims to make a exhaustive query by finding keywords having the same meaning as that of the keywords in a given query based on thesauruses on medicine and by complementing the given query with the keywords (cf. (Bhogal et al., 2007), (Billerbeck and Zobel, 2004)). As researches query expansion based on medical thesauruses, one can refer to (D'iaz-Galiano et al., 2009) and (Wollersheim and Rahayu, 2005).

Both of the methodologies above often utilize thesauruses or repositories of medicine or biology such as ICD (WHO, 2010), SNOMED-CT, GO (Stevens et al., 2000), UMLS, MeSH (S.J.Nelson and B.L.Humphreys, 2001), if the ontology-based retrieval system deals with data in medical domain.

In this paper, we utilize ontology-mapping and query-expansion as a fundamental methodology. Moreover, we newly consider a series of ontologies (see Section 4) to organize retrievers' viewpoints and intentions to realize retrieval based on retrievers' intention and/or viewpoints.

3 CONSTRUCTION OF THE METHODOLOGY

In this section, we show a process to retrieve data from medical databases based on a retriever's intention. For practical use, we will use some ontology-based retrieval system plus several ontologies defined in Section 4, keywords that are used to make queries and that are organized with the ontologies, and historical data of retrieving (see Fig. 1). The set of ontologies above is called "Intention-based Medical Retrieval Ontologies (IMRO)". Until Section 6, we regard the ontology-based medical retrieval system above as an abstract one.

Historical data of retrieving denote a series of data related to retrieving that retrievers have performed. The data include not only queries but also intentions (purposes) to make the queries. These

intentions are organised and recorded as well as viewpoints based on IMRO.

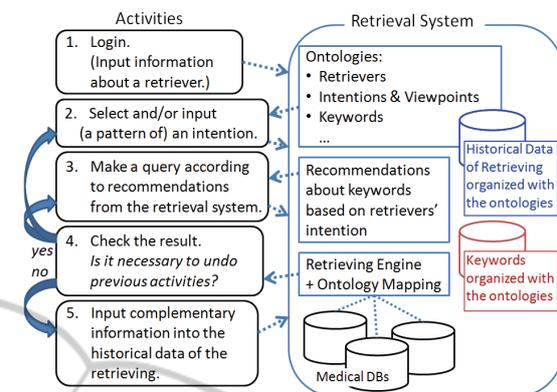


Figure 1: Process to retrieve medical information based on retrievers' intentions with a retrieval system.

Here we show a process to retrieve data in the environment that is described in Fig. 1, as follows.

i. The retriever first login into the system (cf. Step 1 in the left side of Fig. 1). Then, the system checks his/her fundamental information such as the type of a job and historical data that he/she has achieved until now. After that, according to the fundamental information and the historical data, the system selects one or several candidates of viewpoints, patterns of intentions, and intentions themselves, and shows them.

ii. Then, the retriever selects a viewpoint, a pattern of intentions and an intention among candidates that the system lays out at (i) above. He/she also inputs a new intention when he/she cannot find a desired one among candidates (cf. Step 2). Then, the system selects one or several candidates of templates of a query.

iii. Then, the retriever makes a query by selecting a template among candidates that the system lays out at (ii) above and by inputting keywords (parameters) that the system keeps up (cf. Step 3). Moreover, for each keyword, he/she checks interpretations of the keyword and selects the best one. Note that for each keyword the system lists up and orders interpretations of the keyword according to the data about the intention in (i) and (ii) above and historical data of retrieving, which are organized with IMRO. The retriever also can refer to queries in the historical data of retrieving, by checking intentions and/or viewpoints that are attached to the queries.

iv. After the retriever establishes a query and submits it to the system, according to the query and additional data including the retriever's intention, it retrieves information from databases that are con-

nected with the system.

v. Then, the retriever checks the result of the retrieval in (iv), and if he/she can confirm the result to be a desired one, he/she goes to the activity (vii) below (cf. Step 4). If the retriever is not satisfied with the result, he/she can undo the previous activity (iii) or (ii). Moreover, the retriever also improves the query with checking the definitions of keyword in the query, when it is necessary.

vi. When the query is completed, the system transforms the query to some query in the SQL-language the given medical database use by mapping keywords in the query to indexes and by mapping the query in an ontology-based language to another one in SQL. Note that, from a query that the retriever makes, the system may generates multiple queries when the system connects to multiple databases that have different schema (and/or different indexes) and/or different query-languages.

vii. If it is necessary, the retriever input complementary information into the historical data of the query (cf. Step 5). Remark that the system also records data how to make the queries that may include not only the queries themselves but also how the queries were constructed, in particular, new intentions and/or keywords the system required.

4 ONTOLOGIES FOR INTENTION-BASED RETRIEVAL

Not only in retrieving medical information, but also in all kinds of tasks, one performs his/her tasks based on his/her own intentions, even though retrievers themselves are sometimes not fully aware of their intentions to retrieve information. While a retriever's intention may differ from one retrieving to another, in many cases, he/she has a tendency of his/her intentions to retrieve information. In many cases, such a tendency can be regard as his/her viewpoint. Moreover, a retriever's viewpoint strongly depends on which type of an actor he/she is or which kinds of jobs he/she does. Let consider a doctor as an example. The typical viewpoints that a doctor tends to have when he/she try to retrieve data from medical databases would be the following viewpoints.

- i. Researches of medical knowledge such as diseases or medical care based on statistical data.
- ii. Pursuit of highly productive medical service based on statistical data.

iii. Solution of a problem of a special patient or a special group of patients based on statistical data about the (group of) patient(s).

iv. Improvement of medical management based on statistical data.

While the first viewpoint is that of a doctor as a researcher of medical science, the second one is that of a staff who tries to improve a medical setting. On the other hand, while the third viewpoints is that of a professional of a medical care who tries to solve a problem of a (group of) particular patient(s) own, the fourth one is that of a manager of a hospital who tries to restore his hospital.

Take an intention to research relationships between incidence rate of bowel cancer and age of patients as an example. Then, this intention can be regarded as an element or an instance of the viewpoint (i). On the other hand, another intention to investigate monthly cost of medical care for patients of cancer in the medical expense system with DPC can be regarded as an element of the viewpoint (iv).

Here, we introduce ontologies to organize relationships between intentions and viewpoints of retrievers, types of jobs of them, and interpretations of keywords that are defined based on their viewpoints. We call these ontologies "Intention-based Medical Retrieval Ontologies (IMRO)".

In this section, we only show the ontology that organizes the relationship between intentions and viewpoints (Fig. 2) and another one that organizes the relationship between keywords and viewpoints (Fig. 3).

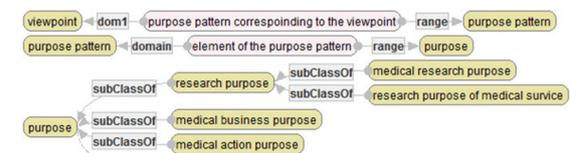


Figure 2: Ontology of intentions and viewpoints.

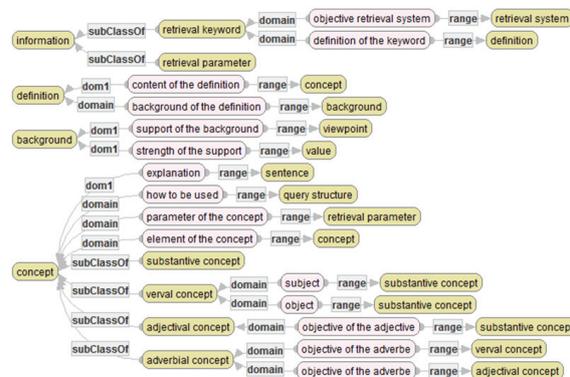


Figure 3: Ontology of retrieval keywords.

In this paper, we consider a viewpoint as well as a pattern of intentions as a set of intentions. The ontology in Fig. 2 indicates that there are patterns of intentions and that each pattern has a unique viewpoint. We consider each pattern to have a unique viewpoint that is a super set of intentions. We define concrete viewpoints and patterns of intentions in Table 1, which are formalized as instances of the concepts in Fig. 2.

Table 1: Viewpoints and typical patterns of intentions.

Viewpoint	Typical pattern of intentions
Viewpoint of Researchers	Investigation or analysis of statistical data related to every kind of phenomena in medical world
Viewpoint of Health Professionals	Learning and/or stepping up of medical knowledge, medical skills and/or medical technologies
	Improvement of healthcare
Viewpoint of Executives	Improvement of hospital management (Profit Improvement)
	Improvement of working environment
Viewpoint of Medical Business	Total Optimization (Waste reduction)
	Business management (Checking of violation of regulation or)
Viewpoint of Policy	Gathering of statistical data as routine work
	Improvement of whole society
Viewpoint of Patients	Review and/or improvement in healthcare system
	Survival
	Improvement in the quality of a patient's life
	Pursuit of happiness of patients and patients' families

On the other hand, the ontology in Fig. 3 indicates the relationship between keywords, the definition (interpretation) of keywords and viewpoints. Each keyword has at least one definition, and each definition has just one concept in Fig. 3 as the content of the definition and at least one background. Each background of a definition corresponds to a pair of a single viewpoint and a single strength value that we will explain later. So, we can assign to each keyword several definitions and to each definition several viewpoints and strength values.

As an example, we show two definitions of a keyword "first visit" in Fig. 4. The first definition "first visit: Def.1" in Fig. 4 indicates that "first visit" denotes a visit by a specified patient to a specified department in a specified hospital and that the visit had not existed for a specified duration to the relevant period but it existed at the period. On the other hand, the second definition "first visit: Def.2" in Fig. 4 indicates that "first visit" denotes a visit by a specified patient to a specified hospital when the patient first gets an ID-number of the patient at the hospital.

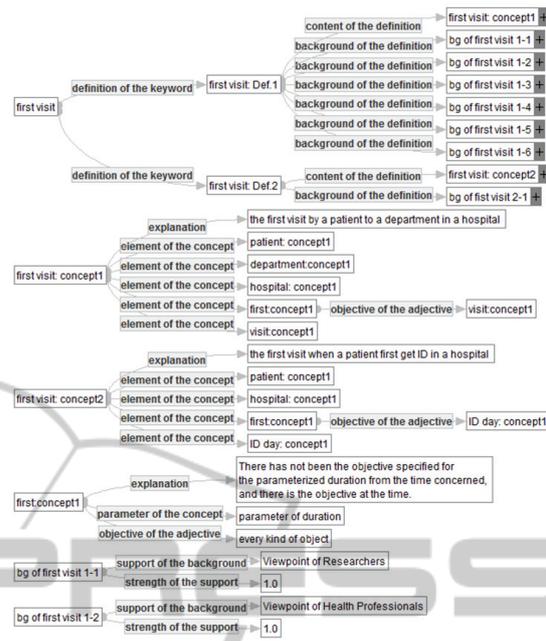


Figure 4: Two definitions of the keyword "first visit".

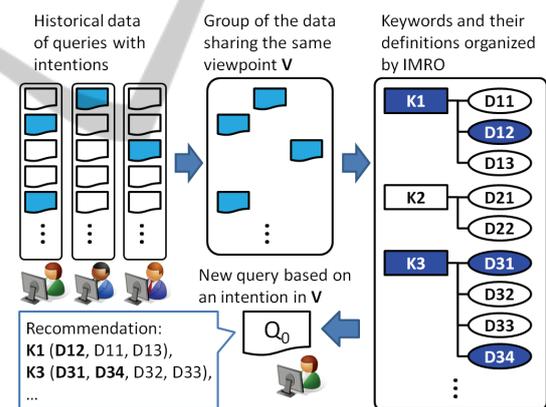


Figure 5: Information obtained from a potentially grouped historical data of queries sharing V.

The first definition is universal and we assign to it all viewpoints in Fig. 5. On the other hand, the second one is a particular one and we assign to it a viewpoint "Viewpoint of Medical Business" in Table 1. Note that, in "first visit: Def.1" in Fig. 4, the strengths of the support to the definition by each viewpoint is assigned to the same value as any other's one. Here, the strength of the support to the definition by a viewpoint denotes a value how much the viewpoint supports the definition. This value will be dynamically changed by the historical data of queries. More strictly speaking, if a retriever make a query based on a viewpoint and he/she

employs a definition of a keyword in the query, the strength value of the definition by the viewpoint increases. On the other hand, when the retrieval system assists a retriever to keyword in the order of the value of the definition by the viewpoint of the retriever. We will detail this point in the next section.

5 MAKING A QUERY BASED ON RETRIEVERS' INTENTION

In this paper, we do not explain concrete language of queries, though we actually employ a query-language SPARQL (W3C, 2008) (cf. Section 7). However, we briefly explain how to utilize a retriever's intention or viewpoint formalized by IMRO in Section 4, when he/she make a query.

In Section 4 we explained that each keyword was assigned a single or multiple definition(s) according to viewpoints of retrievers. However, when a retriever make a query, he/she can consider not only how to interpret keywords but also what keywords to be used, by using historical data of retrieving with others' viewpoints or intentions. We explain this with two examples of making queries. As the first example, let consider a retrieval of the lengths of durations of hospital stays from an intention to increase efficiency of hospital beds. From the viewpoints of economics, it would be desirable to analyze the result with classifying the set of the lengths in terms of costs of beds or profits from patients, since these factors strongly affect the hospital's earning and expense. In fact, from the set of the lengths of the durations only, one cannot analyze the result since he/she cannot know the meaning of each length. On the other hand, let consider another retrieval of the same values from an intention to analyse the problem of social hospitalization. Then, the retriever needs to classify the set of the lengths in terms of not only economic aspects but also patient-specific aspects including patients' ages and their family structures. This means that retrievers' intentions or their viewpoints are often related to how to classify or how to order the retrieval results.

Thus, it is useful to consider concepts to organize relationships between intentions, viewpoints and a certain set of keywords. Although we avoid explaining concrete sets of keywords that would be related to certain kinds of viewpoints, we briefly explain how to make and reuse a set of keywords that are deeply related to a given viewpoint, as follows.

1. Let consider a case to make a query Q_0 based on a viewpoint V .

2. The system has a list L that consists of keywords and their definitions organized with IMRO. Then, the system extracts keywords (for example, $K1$ and $K3$ in Fig. 5 above) in L that have definitions (for example, $D12$, $D31$ and $D34$ in Fig. 5) in L , and recommends the retriever of Q_0 to use the keywords and definitions to make Q_0 , more strictly speaking, to make conditions of results data, to make conditions of patients and to classify the result data.

3. The priority of recommendations of certain keywords and their definitions is decided according to the value of strength that is assigned to definitions with V .

4. If the retriever employs existing keywords and/or existing definitions, then the values of strengths related to the keywords and/or existing definitions and V will be increased.

5. If he/she consider new keywords or new definitions to make Q_0 , then the system add the keywords or definitions above to make L as an information related to V .

Remark that the retriever can utilize not only his/her historical data of retrieving but also historical data of others' retrieving. This means that a retriever with viewpoint V can refer to information obtained from a potentially grouped historical data of queries sharing V . Therefore, this method is especially useful for retrievers who have clear intentions or clear viewpoints but who are not familiar with medical knowledge. Typical types of such retriever would be patients.

6 PROTOTYPE OF AN INTENTION-BASED MEDICAL RETRIEVAL SYSTEM

In Section 3, we describe an ontology-based retrieval system, which joins IMRO and historical data of retrieving. In this section, as a foundation of the retrieval system, we introduce a prototype of an ontology-based medical retrieval system for large-scale medical data warehouses, which is currently under development.

Though the development of the prototype originally began with the intention of retrieving data relevant to patients of cancer, it will be improved to cover all patients.

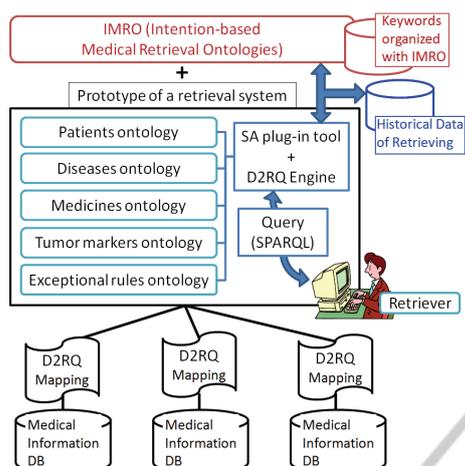


Figure 6: Prototype system plus IMRO.

The prototype consists of the following components (cf. Fig. 6).

- i. Data warehouses that are developed with RDBMS.
- ii. A series of ontologies of patients, medicines, tumor markers and exceptional rules.
- iii. Mapping components between schema in the given data warehouses in (i) and concepts in the ontologies above.
- iv. An engine that assists retrievers to make queries based on the ontologies in Fig. 5 and retrieves data from the data warehouses in (i).

The data warehouses in (i) above are real-life, that are in operation in center hospitals.

Patients ontology in (ii) consists of fundamental concepts relevant to patients such as names, genders, ages, and so forth.

Diseases ontology consists of concepts of disease that are organized according to ICD 10 (World-Health-Organization, 2007). Each concept of disease has attributes of the name, the code in X10 and the type of the classification according to X10.

Medicines ontology consists of concepts of anticancer drugs. Each concept of an anticancer drug has attributes of the code that is defined by Ministry of Health, Labour and Welfare of Japan, the names, the class item, diseases the drug is effective against and exceptions to the applications of the drug.

Tumor markers ontology consists of concepts of tumor markers. Each concept of a tumor marker has attributes of the code, the name, diseases that the marker is effective against and exceptions to the applications of the marker.

Exceptional rules ontology consists of exceptions to the rules of prescription or examination by tumor markers.

A mapping component in (iii) assigns each concept in one of the ontologies in (ii) to some index(es) in one of the data warehouses in (i). The mapping components are implemented with D2RQ (C.Bizer, 2010).

D2RQ is a platform that consists of a mapping language, a RDF-based retrieval engine and an interface (a server). The mapping language are used to transform concepts (classes and properties) described in RDF into schema and attributes in the schema. On the other hand, the RDF-based retrieval engine transforms queries described in RDF-directed graphs into SQL of relational databases, and vice versa. By D2RQ-platform, one can retrieve data from RDBMS with a RDF-query language called SPARQL.

The retrieval engine in (iv) is implemented with D2RQ and a platform to develop ontologies, which is called "Semantic Editor (SE)".

Since this system has a unique mapping file for each medical database, the prototype can retrieve medical data from multiple databases in a lump. In fact, we are trying developing the prototype system, by which one can retrieve data from three real life databases in center hospitals. We are supposed to develop an intention-based medical information retrieval system by combining the prototype system with IMRO.

7 CONCLUSIONS

This paper introduces a methodology to retrieve information from medical databases based on intention of retrievers. Information about intentions of the retriever helps he/she to make more appropriate queries or to check the quality of them by explicitly checking meanings (definitions) of given keywords in the queries. It also enhances reusability of historical data of queries. The methodology of this paper helps a retriever to organize his/her intention and to find a viewpoint related to the intention, and to make a query based on the viewpoint. It also helps a retriever to record a historical data of retrieving with intentions.

In Section 4, Intention-based Medical Retrieval Ontology (IMRO) is introduced. IMRO organizes the relationship between intentions, patterns of intentions, viewpoints and definitions of retrieval keywords. By virtue of IMRO, one can organize his/her intention or viewpoint and select keywords based on the viewpoints.

In Section 6, this paper introduces a prototype system of an ontology-based retrieval system for

large-scale medical data warehouses, which are in operation in center hospitals. The prototype system is being developed with an ontology-developing tool “Semantic Editor” and an ontology-mapping tool “D2RQ”, and it enables a user to retrieve data relevant to patients from multiple medical databases in one lump. We aim to connect the prototype with IMRO to develop an intention-based medical retrieval system.

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