Diabetes Care Decision Support System

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Abstract—Because of changing in lifestyle and diet, and lacking of moderate exercise, diabetes prevalence increases rapidly. Diabetes is an incurable chronic disease, but through proper care, patients can control the disease and prevent complications. A proper diabetes care plan requires different fields of professionals together to make up the plan according to patient’s personal need. So if it is done manually, it would restrict to the experience and knowledge of these professionals, and consume lots of these expensive medical resources as well. The main purpose of this study is to use artificial intelligence technique to generate personalized diabetes care plan. To do that, we use case-based reasoning to search matched diabetes care plan according to personal condition. This plan can be used directly or modify it to better fit current problem. The modified case is saved in our case database for next time usage. The expansion of case database making the system can propose care plan more in line with user requirement later. When there is no matched case, embedded in our system is a diabetes care ontology which can be consulted. The ontology generated a basic care plan to care professionals for adjustment. Again, this adjusted plan become the new case and the system deposit it in case database. The result of our research shows our system can provide personalized diabetes care plan efficiently. In the future, this system can be expanded to other diseases care and eventually becomes a total diseases care decision support system.

Case-based Reasoning, Ontology, Diabetes Care

I. INTRODUCTION

In recent years, advanced medical technology, improved living environment and better public health have bring population's life expectancy increases gradually. So now we are facing a substantial growing number of chronic disease patients. The death ratio of chronic diseases has replaced acute infectious diseases in the past and diabetes death is in the fifth place of leading cause of death [1]. Therefore, the seriousness of diabetes care cannot be understated. Currently, diabetes is a disease cannot be cured but can be controlled by drugs, diet, exercise and other helpful methods. If, unfortunately, family member with diabetes, it affected patients not only physically but also psychologically. Furthermore, it generates a lot of care cost to the family and even to community. Therefore, a good diabetes care may lead to a normal and vital life and also reduce medical costs. Diabetes care needs long-term care and the care team needs to include medical doctors, nurses, nutritionists, sports advisors, psychologists, social workers and so on. However, when the care plan is assessed and generated manually, differentiation of care experiences, knowledge among care teams would result in different care quality. Another drawback of this approach is it consumes a lot of medical man power. These two issues become more important and need a solution in the aging society.

In order to build a personalized care plan, this research combined case-based reasoning [2] and ontology [3] technology from artificial intelligence to solve this problem. One major feature of case-based reasoning is it can store successful solution of past problems(cases) in case base, and when there is a new problem (case) coming, it will search the case base to find similar cases' solutions to solve the new one. In other words, it solves the problem by the past knowledge and experience it gained in order to reduce redundant processing load. However, when using case-based reasoning, case base requires a considerable number of cases before they can fully provide personalized recommendations, so when the cases is insufficient or cannot match user's condition, we use another technology, ontology, to support this situation.

We collect diabetes care related knowledge, such as health information, pharmaceutical care, diet care, sports care and other knowledge, and then build a diabetes care ontology directly and structurally. When case-based reasoning cannot find similar cases, the system will initiate a querying process in diabetes care ontology and generate a basic care proposal for care professionals to adjust and save it. In this case, the system have a new care knowledge again. Advantages of using ontology can share and reuse knowledge easily. Together these two technologies, we are able to personalized diabetes care suggestion efficiently and thus reduce the cost of diabetes care.

II. LITERATURE REVIEW

A. Ontology and its applications in medical care

Knowledge can be divided into non-structural, structure or semi-structured knowledge. We hope to integrate all these kinds of knowledge to promote knowledge acquisition, knowledge creation, and knowledge sharing [4]. In this regard, ontology is available and can play a key role in knowledge management [5]. The meaning of the ontology is different from the meaning in the field of philosophy. Here, ontology represents one or more related objects and the object is composed of basic vocabulary items and relationships in a specific area [6]. Basically, ontology contains four parts:1. Classes: collection of objects; 2. Attributes: shared characteristics objects may have; 3. Relations: relation between objects; 4. Individual: instances of classes.
Ontology language is the key to achieve the knowledge representation we mentioned above. So far, many ontology languages have been developed for use, and because OWL (Web Ontology Language) is easier to express meaning than XML, RDF, RDF-S, and in this research, we need to establish complex relation among objects and then execute reasoning based on these relations, so we choose OWL DL (OWL with Description Logics) as the language of designing our ontology.

Another reason to use ontology is its capability of reasoning. Based on ontology’s owl file, there are several API available for reasoning. For example, JENA from HP Labs. To reasoning, a special query language, SPARQL (Simple Protocol and RDF Query Language) is used. SPARQL query languages contains three parts: 1. SELECT: assign query results to respond to the specified content; 2. FROM: will use the files for the specified URL location; 3. WHERE: query limits the development pattern formed by the triples. The example below shows a SPARQL query to find the relation, hasSolution, of case01 and Hypoglycemia from the given ontology (in Fig. 1), where case01 is an instance of a “Symptoms” class and Hypoglycemia is an instance of a “Solution” class.

![Figure 1. An Example of SPARQL Query](image)

B. Case-based Reasoning

Case-based Reasoning (CBR) was proposed by Schank and Abelson based on the characteristics of human using knowledge [7]. Case-based reasoning operation is a cyclic process (Fig. 2) and it includes four steps which are case retrieval, reuse, revision and retention. The following describes the four steps:

1. Case Retrieve: Given searching condition and through the similarity function, CBR will search case database to find similar cases’ solution.
2. Case Reuse: After step (1), reuse the retrieved case to try to solve the current problem.
3. Case Revise: After step (1), if the proposed solution does not meet user needs, users can modify it in order to fit the problem more properly.
4. Case Retain: After step (3), user keep and save the modified solution to case database and thus expands the knowledge of the CBR.

The similarity function is the most important function in CBR, it filters cases out that cannot pass similarity threshold value. Therefore, a good similar function can retrieve cases can reduce the effort of modifying case. Nearest neighbor algorithm compares problem’s feature to case’s features and weighting these features if necessary. When the cases are few in database, this method is better than other algorithms. So this research choose neighbor algorithm (1) as the similarity function [8,9].

\[
\text{Similarity}(x, y) = \frac{\sum_{i=1}^{n} w_i \times \text{simi}(x_i, y_i)}{\sum_{i=1}^{n} w_i}
\]

where \( x, y \): two cases, \( x_i, y_i \): features of \( x \) and \( y \), \( w_i \): weight of the features.

![Figure 2. The cycle of case-based reasoning](image)

C. Diabetes Care

Diabetes is a popular chronic disease. Over 18 million people in the United States, or 6 percent of the population, have diabetes (http://www.pamf.org/teen/health/diseases/diabetes.html). Statistical analysis from Department of Health, Executive Yuan, Taiwan, showed people over age 19 the prevalence of diabetes is about 4.35 percent. There are other indicators from other countries all showed diabetes is a major chronic disease. Currently, diabetes is a disease can not be cured but can be controlled by drugs, diet, exercise and other helpful methods. If, unfortunately, family member with diabetes, it affected himself not just physically but also psychologically. Further more, it generates a lot of care cost to the family and even to community. Therefore, a good diabetes care may lead a normal and vital life and also reduce medical costs.

Diabetes needs long-term care and the care team needs to include medical doctors, nurses, nutritionists, sports advisors, psychologists and social workers, and so on to provide a better care plan in all perspectives. However, when care plan is proposed manually, differentiation of care experiences, knowledge among care teams would result in different care quality. Since information technology advances fast, it is an urgent need to adopt IT in diabetes care [10] to provide more efficient care to save cost while increase care quality.

III. RESEARCH METHODOLOGY

To provide users with instant and personalized diabetes care plan, the architecture diagram of our system is shown in Fig. 3. The system consists of four modules, namely, the user interface module, case based reasoning module, ontology reasoning module and knowledge construction module. The following section briefly describes the function of each module.
Figure 3. System architecture

A. **User Interface Module**

This module is the place users enter their profile and health status. The entered data are transferred to the case-based reasoning module for further processing. Also, the function of showing results of the processing is in this module.

B. **Case-based reasoning module (CBR Module)**

This module is to retrieve the cases according to user’s query condition. Based on similarity function comparison, only cases passed the similarity threshold will send back to the user interface module for browsing. Users can select any one of the cases to see the detail information or modify the information.

C. **Diabetes care ontology module**

This system will reason diabetes care concepts and relations through the information passed from CBR. It is the case when the case-based reasoning module cannot found satisfied cases and the system will consult this module to have a general care recommendation. This recommendation is reviewed by professionals to confirm or revise, and it becomes a new knowledge and will be stored in case database for future use.

D. **Knowledge engineering modules**

This module is used to construct diabetes care knowledge database, i.e. ontology. The knowledge comes from diabetes care experts and is built by Protégé (http://protege.stanford.edu/overview). Protégé embedded a PELLET reasoning engine (http://clarkparsia.com/pellet) which can be manipulated by JENA API. Use this API, we can generate our query condition and process the result of the query.

IV. **RESULTS**

First, in Fig. 4, we show a partial result of knowledge engineering which is a visualized graph of our diabetes care ontology generated by Protégé. In this graph we can see the relation between care classes (diabetes and physiological_data) and concepts in these two classes.

Next, a user entry form (Fig. 5) is show to fill in an example patient’s data including: Sex, Man; Age, 54; Diabetes Type, Type 1; Before meal Glucos, 130; After meal Glucose, 260; HbA1c, 8; Cholesterol, 102; Triglyceride, 120; Diastolic blood pressure, 139; Systolic blood pressure, 65; Ketone, Positive; Urine protein, Negative; Heartbeat, 65; Complication, No; Activity rate, 1.35. These data will be the condition to search CBR database. With our similarity comparison, it calculates every case a similarity score, and the score is compared with our pre-defined threshold. All cases with higher score than our threshold showed in Fig. 7.

![Figure 4. Diabetes care ontology (partial)](image)

Entering the case no on the text box left to “enter” button and click “enter” button, we are able to enter the case revised form (Fig. 7). In the form, user is free to modify the text shown and then updated it, which make this a new case in our system. When CBR cannot find matched cases, then system post the query to diabetes care ontology to execute reasoning process and the result of reasoning is return to users(similar to Fig. 7, not shown here due to paper size limit). This result needs to be confirm or modify by experts and then it become a new case in CBR.

![Figure 5. An example of user query condition](image)

V. **CONCLUSIONS**

Currently, chronic patients grow constantly in aging society and require lots of health care resources. In order to demonstrate how information technology can be used to help chronic disease care, we proposed a system which combines CBR and ontology to generate personalized care plan. We choose diabetes care as an example to use this system for it needs multi-profession care. The result of our research shows, our system can provide diabetes care plan according to patient’s profile and thus can reduce the
Experiences learned from this system are useful for developing other disease care decision support systems as well. However, CBR is under the assumption of similar problems have similar solutions, and new problem can be solved by retrieving similar problems or adapting retrieved solutions. So a rich CRB case database is needed before it can match user’s condition. Otherwise, when consulting diabetes care ontology, care expert need to involve and review the proposed care plan. In order to better fit the user’s condition, adjustment is needed. Another issue is to structure such a comprehensive diabetes care ontology requires different fields of care experts to contribute and integrate his knowledge. It takes a lot of efforts to do it and afterwards, how to maintain this ontology effectively when concepts or relationships need to be adjusted is another issue. In the future, evaluating the potential of using this system in practice is worth to explore. In addition, this system is not limited to support diabetes care, use this system in other chronic disease care will be another research topic.

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