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Linh Hoang Nguyen
University of Ballarat, inh.nguyen.061288@gmail.com

Zhaohao Sun
University of Ballarat, z.sun@ballarat.edu.au

Andrew Stranieri
University of Ballarat, a.stranieri@ballarat.edu.au

Sally Firmin
University of Ballarat, s.firmin@ballarat.edu.au

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Linh Hoang Nguyen
School of Science, Information Technology and Engineering (SITE)
University of Ballarat, Australia
Email: linh.nguyen.061288@gmail.com

Zhaohao Sun
School of Science, Information Technology and Engineering (SITE)
University of Ballarat, Australia
Email: z.sun@ballarat.edu.au

Andrew Stranieri
Centre of Informatics and Applied Optimization (CIAO)
University of Ballarat, Australia
Email: a.stranieri@ballarat.edu.au

Sally Firmin
School of Science, Information Technology and Engineering (SITE)
University of Ballarat, Australia
Email: s.firmin@ballarat.edu.au

Abstract

Managing diabetes using intelligent techniques is a recent priority for healthcare information systems and the medical domain. Diabetes is one of the most widespread diseases around the world including Australia. Numerous intelligent systems supporting diabetes management (DM) have been widely deployed, yet how to effectively develop a DM system integrating intelligent techniques remains a big issue. Case-based reasoning (CBR), as an intelligent technique, has been applied in various fields including customer services, medical diagnosis, and clinical treatment. This paper proposes a case-based lifecycle for DM consisting of case-based symptoms, case-based diagnosis, case-based prognosis, case-based treatment, and case-based care. The lifecycle is integrated with a web-based system in which CBR as an intelligent intermediary. The approach proposed in this research might facilitate research and development of diabetes management, healthcare information systems and intelligent systems.

Keywords

Healthcare information system, diabetes, diabetes management (DM), lifecycle, case-based reasoning (CBR).

INTRODUCTION

Diabetes is one of the most prevalent and perilous diseases around the world and the instances of its reported cases have been increasing significantly. Studies undertaken to predict the likelihood of diabetes in 216 countries from 2010 to 2030 found that the number of diabetes cases in developing countries increased by 69% while the corresponding number in developed countries increased by 20% (Shaw, Sicree, & Zimmet, 2009). In a WHO report (Alberti & Zimmet, 2004), the American Diabetes Association (ADA) reported the cost of diabetes in USA 2002 to be $132 billion and is set to become $192 billion by 2020. In Australia, diabetes costs over $14.6 billion with the cost of treating a diabetes patient with complications running up to $9,645 per year (Diabetes Australia, 2013). Therefore, an effective management system for diabetes is an imperative need complying with national interest. Attention has been drawn on diabetes management (DM) recently by Akter et al. (2009), Omar and Ati (2011), and Marling et al. (2013), yet the DM lifecycle demands depth investigations.

As an intelligent technique, case-based reasoning (CBR) solves problems using previous similar cases (Sun, Han, & Dong, 2008). CBR has been successfully applied in many fields including healthcare information systems, medical diagnosis and clinical treatment. CARE-PARTNER (Marling, Montani, Bichindaritz, & Funk, 2013) is an example of successful integration of CBR and web technology. It is a web-based system which stores data about diseases, symptoms, procedures and medications to support healthcare professionals' decision making processes. CBR has also been recognized as being especially suitable for developing medical applications to support clinical processes (Bichindaritz & Marling, 2010). However, how to use CBR to properly manage diabetes remains open. Another significant issue arising from the above discussion is how to integrate the case-based DM lifecycle into the web-based system.

This article addresses the above issue by proposing a case-based DM lifecycle and discussing the implementation of a case-based DM web system (CWDM). The case-based DM lifecycle consists of five phases: case-based symptoms, case-based diagnosis, case-based prognosis, case-based treatment, and case-based care. CWDM is a website that integrates the DM lifecycle, CBR, and web technology. To this end, the remainder of this article is organized as follows: the background of diabetes, diabetes management, and web technology is provided before reviewing CBR and its application in the medical domain. The article then examines a case-based lifecycle for DM by exploring each of the five phases. Meanwhile, the paper presents five practical cases of diabetes and summarizes them in accordance with the structure of the proposed case-based five-phase DM lifecycle. Then, this article deals with the implementation of a case-based DM web system. The final section ends the paper with the conclusion and the directions for future research.

BACKGROUND

This section provides a background on diabetes, diabetes management (DM), and web technology which are the basis for the research.

'Diabetes' or 'diabetes mellitus' stands for a group of different diseases in which glucose levels are unregulated because the body cannot generate sufficient insulin or the existing insulin itself does not work sufficiently (Alberti & Zimmet, 2004). Diabetes has no cure, however the proper management of blood glucose, blood pressure and cholesterol can reduce risks associated with diabetes and its complications. To some extent, appropriate primary care or self-care is considered to be more effective than hospital-care (Renders, et al., 2001). There are two main types of diabetes: type 1 (T1D) originates in the natural failure of the body to generate enough insulin to produce sufficient energy for daily operation, whereas type 2 (T2D) proceeds from the fact that the body cannot efficiently utilize the insulin (Alberti & Zimmet, 2004). They are also treated as two distinct diseases because of the difference in causes, occupations' ages, symptoms, or even treatment methods (Chiu, Wray, Beverly, & Dominic, 2009). Type 1 diabetes occurs naturally and is unlikely to be treated or prevented while type 2 appears essentially as a result of unhealthy lifestyle choices and can be treated to some extent. Due to the diversity of their prevalence and other features (see Table 1.), this article focuses on T2D.

Table 1. Classification of diabetes (Alberti & Zimmet, 2004)

Features	Type 1	Type 2
Onset	sudden	gradual
Age at onset	mostly children	mostly adults
Body habitus	thin or normal	often obese
Endogenous insulin	low or absent	normal, decreased or increased
Prevalence	about 10%	about 90%

Renders et al. (2001) defined DM mainly as the treatment and interventions of diabetes. Furthermore, Omar and Ati (2011) proposed a system to manage diabetes by collecting patients' data to provide feedback. They defined DM as the process of treating and providing intervention recommendations to people with diagnosed diabetes. In our opinion, diabetes could be better managed if the system can detect diabetes from the very first symptoms till the time diabetes is appropriately treated. We therefore propose a new diabetes management lifecycle with sufficient phases.

Web technology involves distinct but interconnected technologies to enhance online users' experiences over the Internet. A web system normally consists of a display tier, business logic tier, and a database tier (Turban & Volonino, 2011). In this research, we develop CWDM using a website building tool called Weebly (www.weebly.com). Weebly is a tool that provides the ability to build a website without the knowledge of any programming languages. It offers ready-made layouts and themes for users to customize the GUI (graphical user interface) of their websites at their own demand. Weebly also provides tools to track visitors as well as allows search engines to find its websites.

CASE-BASED REASONING

This section reviews case-based reasoning (CBR) and its application in the medical domain. CBR provides a basis to propose the diabetes management (DM) lifecycle for developing a web-based DM system.

CBR is an intelligent technique used for decision making support. CBR supports problem solving and decision making by adopting knowledge generated from experienced cases with successful solutions (Montani, 2010). CBR is fundamentally a reasoning approach to solve problems using previously successful cases. In the progress of appraising the functionalities of CBR, experts have implemented it from different perspectives (Sun, Han, & Dong, 2008). The very first perspective of CBR is cognitive CBR. Others subsequent perspectives such as logical or intelligent CBR have also been examined and widely applied in problem solving and decision support. Process CBR is another CBR perspective that classifies CBR into four-R processes (4R model): retrieve, reuse, revise, retain. Finnie and Sun (2003) then expanded to a R5 model in which an additional phase called 'case repartition' was added to help reduce the intricacy of cases and enhancing case retrieval.

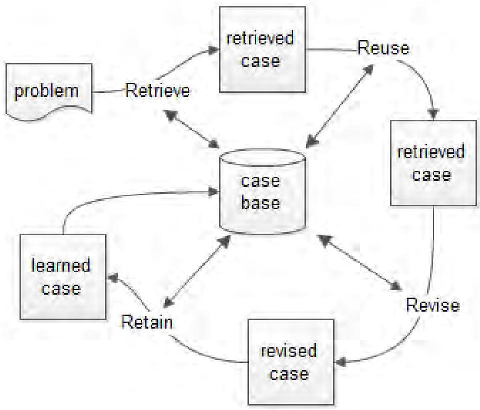

Figure 1. Process-oriented CBR (Sun, Han, & Dong, 2008)

Intelligent CBR involves a system called ICBRS – intelligent case-based reasoning system (see Figure 2.) which consists of a case base (CB), a CB manager, and a CBR engine (CBRE); these elements distinguish an ICBRS with a common database system or a knowledge-based system (Sun, Han, & Dong, 2008). A CB normally consists of many previously experienced cases. The CB manager handles the whole processes of a CBR lifecycle and the CBRE is responsible for determining possible solutions for the system. Two of the CB's superior characteristics are to be able to store a larger amount of data, and efficiently maintain data, because mixed knowledge is translated into cases. For instance, a CB of a disease can possibly store hundreds or thousands of cases with different experimental attributes and result attributes. Case retrieval and case adaptation are the most important tasks of the ICBRS, done by the CBRE and are the most critical tasks in CBR due to the increasing number of cases and attributes. The function of CBRE is also similar to the inference engine in any other knowledge-based system.

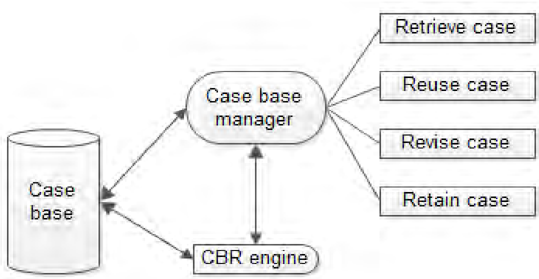

Figure 2. A general architecture of an ICBRS (Sun, Han, & Dong, 2008)

CBR plays an important role in disease management process. Sun, Finnie and Weber (2005) explained in detail the implementation of CBR in the medical domain, especially the diagnosis and treatment processes. Similar to example 1 (Sun, Finnie, & Weber, 2005, p. 959), patient *P* presents to the doctor *D*, with the symptom 'fatigue'. The doctor's diagnosis process is as follows:

diabetes → high blood glucose; unhealthy lifestyle → diabetes; and

diabetes → fatigue; diabetes → obesity

to infer from fatigue and diabetes → fatigue that the patient *P* suffered diabetes based on adductive reasoning[1].

Then the doctor measures *P*'s blood sugar. Based on previous experience knowledge "high blood glucose → diabetes", the doctor finds the patient has high blood sugar. *P* is also obese. Based on these diagnostic findings, the doctor provides a treatment method for the patient based on deductive reasoning, for example, several tablets of aspirin against high blood sugar, and weight management to lose the weight. The doctor infers the need for aspirin and weight management from previous experiences

aspirin →high blood sugar; and weight management →obesity

This illustrates the process of deductive reasoning for clinic treatment.[2] According to Thagard (1997), a great deal of medical diagnoses can be described as abduction whereas treatment is more akin to deduction. Abductive and deductive CBR can be integrated in clinical practice, as shown in Figure 3. (Sun, Finnie, & Weber, 2005).

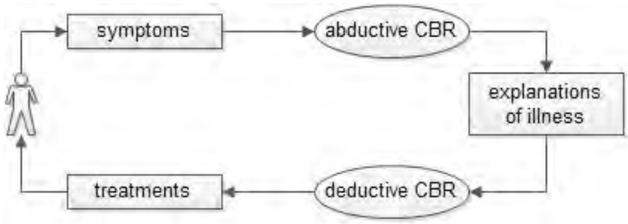

Figure 3. Abductive and deductive CBR in clinical processes (Sun, Finnie, & Weber, 2005).

Real world experiences of CBR have been applied into health science to support decision making and situation solving. CBR is considered a close fit for developing medical and healthcare management systems, because it is based on previous experiences which play a monumentally important role in detecting, diagnosing and curing diseases (Bichindaritz & Marling, 2010). Together with the rapid development of intelligent technologies, more intelligent systems have been developed for supporting and managing healthcare issues, in which CBR has been implemented to provide conclusion and recommendations. In the medical domain, CBR manifests all its strengths and may require further examination.

Case retrieval and case adaptation are two core processes in CBR. There have been algorithms of case retrieval, which have proved to be effective, however there are also problems regarding rules for case adaptation. Case retrieval finds and matches similarities between cases, while case adaptation needs to alter and supplement experienced solutions for resolving new cases. For this issue, some have suggested that CBR has not been successful in the medical domain (Bichindaritz & Marling, 2010). For instance, a similar issue existed in CASEY, a CBR heart failure diagnosis system that was not sucessfully implemented because of challenges with adaptation.

Akter et al (2009) built a knowledge-based system for diagnosis and management of diabetes. The purpose of their intelligent system was to reduce cost and to provide better support for diabetes patients. Omar and Ati (2011) also developed a smart diabetes management system to collect data, analyze these data and propose a corresponding diagnosis of diabetes. Its objective was to reduce physical visits to hospitals due to the high volume of people with diagnosed diabetes. These examples of CBR applications in the medical domain illustrate the possibility of developing a CBR system for diabetes management.

CASE-BASED DIABETES MANAGEMENT LIFECYCLE

Lifecycle is a fundamental concept in software engineering indicating a model of different processes including planning, analysis, selection, design, implementation, testing, use, and maintenance (Scacchi, 2001). This section examines diabetes management (DM) by presenting a case-based DM lifecycle and examining each stage of the lifecycle. This case-based DM lifecycle consists of case-based symptoms, case-based diagnosis, case-based prognosis, case-based treatment, and case-based care.

Case-based Symptoms

Case-based symptoms include the most common symptoms for diabetes recognition based on medical experiences and knowledge of diabetes. Diabetic-related symptoms could not be recognized at early stages (pre diabetes) which can last several years before symptoms become visible (Eckman & Zieve, 2011). To respond the demand of recognizing diabetes in a timely way, Grootenhuis et al. (1994) created a Type 2 Diabetes Symptoms

[1] Abduction is the syllogism that involves a true rule if *A* then *B*, and a true fact *B* to lead to inference that *A* is true.
[2] Deduction involves a true rule If *A* then *B*, a true fact *A* to lead to an inference that *B* is true.

Checklist (DSC-Type 2) including 34 diabetes-related symptoms being classified into six major dimensions: hyperglycaemic, hypoglycaemic, psychological, cardiovascular, neural, and ophthalmological. The most common diabetic symptoms are: fatigue, weight loss, excessive thirst or hunger, abnormal urination, skin itching, and feet and vision's issues (Ferry, 2012). DSC-Type 2 has been considered as a standardized and reliable checklist for diabetes recognition.

To some extent, depression is also a symptoms indicating diabetes. About 16% of the world population have depression at least once in a lifetime and women are more susceptible to have depression than men (Nefs, Pouwer, Denollet, & Pop, 2011). This research showed that the number of diabetic patients being detected to have depression is about double of those without diabetes and about one in every four diabetic patients afflicts depression at least once every 2.5 years. Depression is considered both a diabetes-related symptom and an awareness of diabetes and its development.

Case-based Diagnosis

Case-based diagnosis is the stage to clarify the cause of diabetes-related symptoms and the treatment methods. Lab tests are used to detect diabetes based on the past experiences and medical knowledge of diabetes. All tests' indexes are collected from previous diabetes cases to ensure reliability. There are two basic groups organized according to glucose level: *impaired fasting glucose (IFG)* and *impaired glucose tolerance (IGT)*. People with IFG are in pre-diabetes while IGT indicates a diagnosed diabetes (Ferry, 2012). These tests mentioned below are most commonly used for diagnosis of diabetes.

Fasting Plasma Glucose (FPG). This is a standard for diabetes diagnosis, a blood test that requires no food or drink consumed during 8 hours prior to the test (Simon & Zieve, 2011). There are three FPG levels (mg/dL): normal (under 100), pre-diabetes (between 100 and 125), and diabetes (more than 125). However, even with a FPG under 100mg/dL, there is also a risk of diabetes and in this situation, body mass index (BMI) can be used to define the level of diabetes risk (Dankner & Roth, 2012).

Haemoglobin (HbA1c). This is entrusted and recommended by diabetes professional for pre-diabetes and diabetes diagnosis (Silverman, et al., 2011). There have been hypotheses about accuracy level of HbA1c in diagnosing diabetes (Ferry, 2012), however it is recognized as one of the most reliable and accurate tests (World Health Organization, 2011). These are the four levels of HbA1c (%) (Eckman & Zieve, 2011): normal (under 5.5), diabetes risk (5.5-6), pre-diabetes (6-6.4), and diabetes (over 6.5).

Body Mass Index (BMI). BMI indicates obesity level and is calculated by dividing weight (kilograms) to height (meters) squared: BMI = weight (kg) / height^2 (m^2). BMI, along with HbA1c, is a simple, practical but also reliable diabetes predictor (Chan & Mantzoros, 2009). BMI varies according to ages, gender, and other conditions such as pregnancy or muscular density. A BMI over 25 indicates overweight while a BMI over 30 is considered obese. The higher the BMI, the higher potential for diabetes.

Case-based Prognosis

Case-based prognosis looks at possible diabetic complications based on the past experience and medical knowledge of diabetes. Prognosis in medicine means the prediction of possible progress of a disease or health status. Prognosis estimation is quite accurate in large scale calculation as the statistic truly corresponds to what really happened. It could be easily perceived that diabetes prognosis is taken based on previous real diabetes cases. Diabetes leads to various forms of diabetic complications including micro- and macro-vascular diseases.

The occurrence of microvascular complications can be noticed at diagnosis phase and this form of complication have been detected from 5-35% diagnosed T2D cases. There are three types of microvascular complications: diabetic retinopathy which occupies 4.8%, diabetic nephropathy occupying 10.5%, and diabetic neuropathy which makes up about 10.5% of total cases (Raman, Gupta, Krishna, Kulothungan, & Sharma, 2012). Risk factors for microvascular complications include increasing age, blood pressure, and haemoglobin.

Macrovascular complications include common dangerous diseases such as stroke, peripheral vascular diseases, coronary diseases, heart diseases, or cardiovascular diseases. Cardiovascular diseases lead to death in both T1D and T2D and draw most attention in healthcare industry (Nazimek-Siewniak, Moczulski, & Grzeszczak, 2002). Hyperglycaemia is use to predict stroke, a cerebrovascular disease, and a major cause of death for T2D patients (Fowler, 2008). Obesity is associated with cancer leading to death (Larsson, Adami, & Wolk, 2006).

Depression is also a diabetic complication and has been detected from one in every four T2D patients (Nefs, Pouwer, Denollet, & Pop, 2011). It is a psychological symptom and directly associates with a lower quality of life or poorer health, worse glycaemic control or higher blood glucose level, increased diabetic complications, and also greater mortality risk. Risk factors that contribute to the development of depression include smoking, unhealthy life styles, and poor weight control (Chiu, Wray, Beverly, & Dominic, 2009). Depression can also cause heart diseases or high blood pressure.

Case-based Treatment

Case-based treatment involves medical remedies for diabetes based on the past cases and medical knowledge of diabetes. Medicine is used to adjust blood glucose level and is called insulin therapy. There have been many papers examining different insulin therapy, however we think of another direction due to the fact that T2D mainly arises from unhealthy lifestyle, therefore T2D patients may need more than just insulin.

Traditional Chinese medicine (TCM) herbs are often used in conjunction with insulin for treating diabetes and enhancing health (Li, Zheng, Bukuru, & Kimpe, 2004). For instance, Radix Astragali seu Hedysari, the roots of Astragalus membranaceus, can be used to adjust blood glucose and also treat diabetic neuropathy; Radix Ginseng, the roots and rhizomes of Panax ginseng, are used for healthcare and blood glucose levels as well as treating hyperglycaemia, controlling metabolism, and regulating insulin activities.

In brief, the treatment of diabetes in TCM is a combination of various therapies, not only to lower blood glucose level but also to ameliorate the standard of external environment and internal metabolism (Li, Zheng, Bukuru, & Kimpe, 2004). TCM takes care of the body and eliminates existing medical symptoms. The main TCM therapies are natural herbs and proper diet. The recipes for diabetes usually contain more than several medicines because each treats one specific symptom/part of the body and diabetes is treated by treating all relevant symptoms/parts of the body simultaneously. Essentially, there are more than 30 Chinese medicines for diabetes and its complications, also about 13 natural products being used for dietary. Li et al (2004) suggested the combination of Western medicine to lower their blood glucose level and Chinese medicine to take better care of their body.

Case-based Care

Case-based care involves various lifestyle interventions for treating diabetes based on the past cases and medical knowledge of diabetes. Lifestyle intervention is a practical and effective way to maintain health including smoking, eating, drink, and exercising, which is really important to T2D patients.

An appropriate diet regime is necessary for reducing diabetes and its complications as dietary fats can stimulate insulin activities in human bodies in a good manner (Riserus, Willett, & Hu, 2009). There are various forms of normal fat: saturated fatty acid (SFA) which is contained in butter, cream, fatty milk, palm and coconut oil, meat; trans fatty acid (TFA) in vegetable oil, fast food, fried food, bake food). Replacement recommendations for these two include: mono-unsaturated fatty acid (MUFA) being found in red meat, whole milk, nuts, cashews, olives, avocado; poly-unsaturated fatty acid (PUFA) in seeds, nuts, peanut butter, soya bean, tuna, salmon. The suggested replacements generally improve insulin sensitivity of the body and hopefully can reduce T2D risks (Dankner & Roth, 2012).

Weight control is also important in diabetes treatment and care progresses as it relates to nearly 90% of T2D patients (Lau, 2010). Weight control is actually a part of lifestyle intervention which concentrates on reduction of excess body fat by diet or physical activities. One important reminder is that weight control, or weight management, means not only weight loss but also weight maintenance and weight gain prevention. A suggestion for weight control is a combination of diet, physical exercise, medical and behavioral therapy. For instance, a diabetic patient or even a person who has high obesity level is required to do exercise about one and a half hour per day of normal walking or half an hour of tougher exercises such as climbing (Chan & Mantzoros, 2009). Achieving those exercises significantly prevent or reduce the risk of weight gain and diabetes. The weight loss should reach 7% of their body weight.

Diabetes Cases Summarization

The article summarizes five practical diabetes cases according to the proposed case-based diabetes management lifecycle to demonstrate its application.

Table 2. Cases summary using the proposed DM lifecycle.

	Case 1	Case 2	Case 3	Case 4	Case 5
Symptoms	None	Hypoglycaemic, psychological, neuropathy	Neuropathy	Neuropathy	Hyperglycaemic, hypoglycaemic, cardiovascular, neuropathy
Diagnosis	FPG=235, HbA1c=8.5,	HbA1c=10.2, BMI=28	FPG=94-135, HbA1c=8.5,	FPG=12, HbA1c=7.5,	FPG=166-178, HbA1c=8.1, BMI=32.6

	BMI=33		BMI=31	BMI=31	
Prognosis	Macrovascular	None	Microvascular	Microvascular and macrovascular	None
Treatment	Western medicine	None	Western medicine	Western medicine	TCM
Care	None	None	None	Smoke control	None

CWDM: CASE-BASED DIABETES MANAGEMENT WEB SYSTEM

A case-based DM web system, named as CWDM, has been implemented using a web development tool called Weebly. A GUI of CWDM has been continuously designed and can be accessed via cwdm.weebly.com.

CWDM is a website that integrates the proposed DM lifecycle, CBR, and web technology. The DM lifecycle classifies the system into five distinct phases which contains the users' data about symptoms, diagnosis, prognosis, treatment, and care of diabetes. CBR plays the role of the system's inference engine which includes the case bases and the CBR engine to manipulate data. CWDM is based on client-server architecture. The user can use client computer's user interface to interact with the CWDM. The server of the CWDM is a computer that stores the cases from the user interface into the case bases. The user interface is shown in Figure 4.

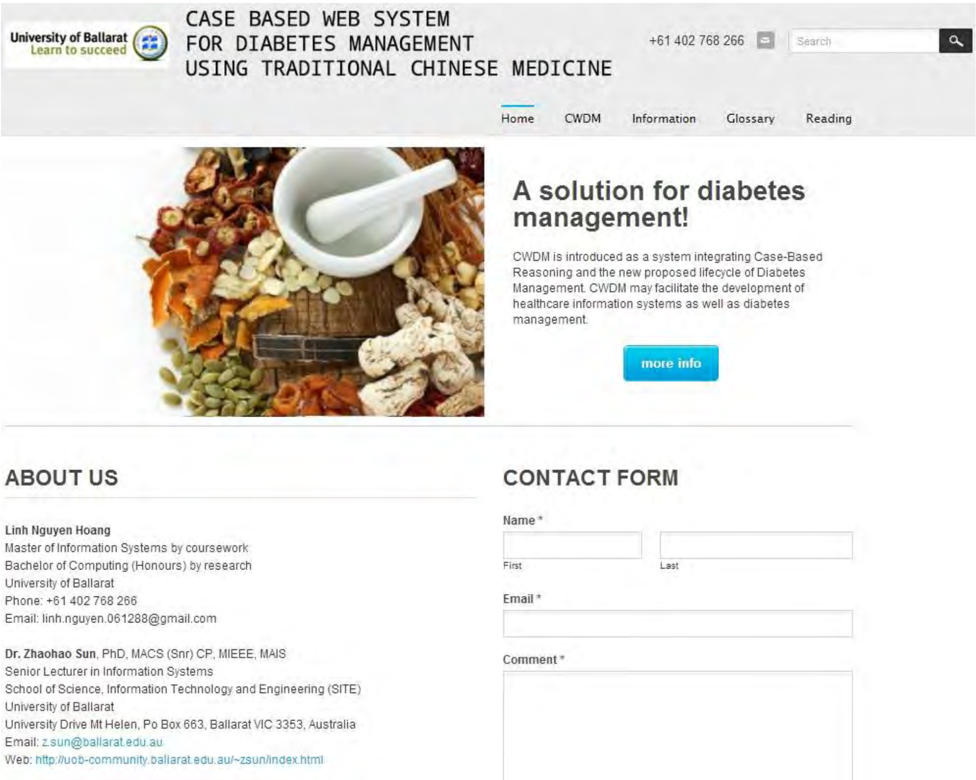

Figure 4. The homepage of CWDM prototype (http://cwdm.weebly.com).

The case-based lifecycle plays an important role in the CWDM and may contain numerous cases. The architecture of CWDM is presented in Figure 5. CWDM web system consists of five sub-pages for case-based symptoms, diagnosis, prognosis, treatment and care respectively, based on five phases of the proposed DM lifecycle. Each of these webpages includes basic information and related forms for users to fill in and submit online in order to obtain recommendations for diagnosis, prognosis, treatment and care of diabetes respectively. The data of each case is manipulated using the system's CBR engine and case bases. There are five case bases based on the DM lifecycle. In return, CWDM provides users with a report with automatically generated conclusions and recommendations. New cases are then stored in the case base to be reused for solving later emerged cases. Therefore, CWDM may provide reliable diabetes predictions, diagnosis as well as recommendations for caring. The diet recommendation system of Khan and Hoffmann (2003) was also designed based on the similar architecture and mechanism.

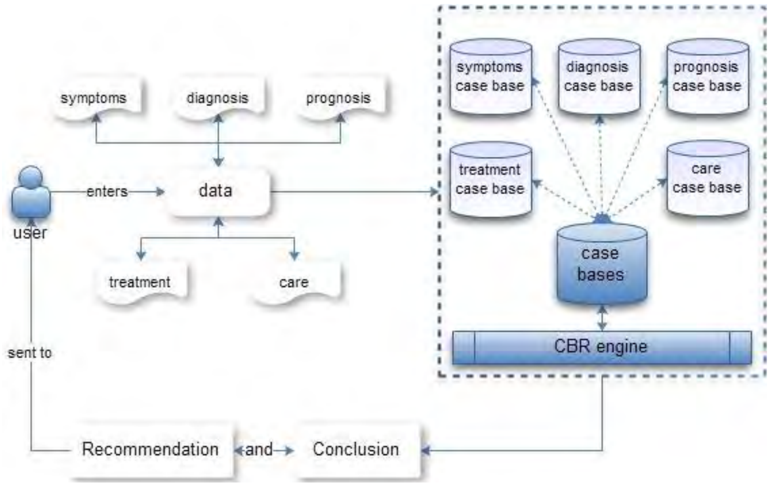

Figure 5. General architecture of CWDM.

Figure 6. A sample of how a user enters data of their particular case into CWDM.

CWDM's case bases store previous diabetes cases. There will be two tasks of building a case base: appropriately defining a case with relevant attributes and values, and designing a simple but accurate similarity measure metric. A sufficient diabetes case base may contain millions of records. Therefore, Sterling and Ericson (2006) proposed a similarity matching metric which implemented SQL commands to handle case retrieval and adaptation. One advantage of this metric is that the SQL functions are easy to understand and manipulate. In brief, they used queries to give out results in percentage (%) indicating the level of matching between the current and stored cases in the case base. The case adaptation rule can also be a reference for developing a unique adaptation mechanism, as it has been somewhat successfully implemented in the diet recommendation system (Khan & Hoffmann, 2003).

A mobile version of the system will increase its mobility as users can access the system anywhere with their touchscreen smart phones. Marling et al. (2013) introduced the 4 Diabetes Support System (4DSS), which also supports DM using CBR. They developed a touchscreen smart phone interface for 4DSS for users with only one finger. The mobile version of CWDM helps not only save users' time but also improve productivity.

CONCLUSION

This article examined how to form an effective DM lifecycle and how to integrate CBR to build a case-based DM lifecycle. This article also presented a web-based case-based DM system (CWDM) to collect data and use CBR technique to manage diabetes. One of the major findings of this paper is that the principle of CBR is useful to develop a web based DM system.

The implication of this work for researchers and developers is that they might use the case-based DM lifecycle to develop their own case-based systems for DM or improve their healthcare information systems for DM based on the CWDM. The implication of this work for diabetes patients and stakeholders is that they can improve their understanding of DM based on the case-based DM lifecycle and CWDM. The implication of this research for diabetes specialists is that they can deepen their understanding of DM based on the proposed case-based DM lifecycle and have potentials to collaborate with us by providing practical cases of diabetes to improve CWDM to make it into a real online decision support system for DM in the near future.

There are at least two limitations of this research. One is that the investigation for each stage of the case-based lifecycle is still preliminary. More real word cases of diabetes should be integrated into each stage taking into account symptoms, diagnosis, prognosis, treatment and care respectively. Another is the developed CWDM has not yet verified by diabetes specialists. In future work, we will address these limitations as parts of improving the CWDM and developing its mobile version for managing diabetes.

REFERENCES

Akter, M., Uddin, M. S., & Haque, A. (2009). Diagnosis and Management of Diabetes Mellitus through a Knowledge-Based System. *ICBME, 23*, 1000-1003.

Alberti, K., & Zimmet, P. (2004, July 19). Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Provisional report of a WHO Consultation. *Diabetic Medicine, 15*(7), 539-553.

Bichindaritz, I., & Marling, C. (2010). Case-Based Reasoning in the Health Sciences: Foundations and Research Directions. *Studies in Computational Intelligence, 309*, 127-157. doi:10.1007/978-3-642-14464-6_7

Chan, J. L., & Mantzoros, C. S. (2009). Diagnosis, Evaluation, and Medical Management of Obesity and Diabetes. In J. L. Chan, C. S. Mantzoros, & C. S. Mantzoros (Ed.), *Nutrition and Metabolism* (pp. 289-328). Humana Press. doi:10.1007/978-1-60327-453-1_16

Chiu, C.-J., Wray, L. A., Beverly, E. A., & Dominic, O. G. (2009, April 3). The role of health behaviors in mediating the relationship between depressive symptoms and glycemic control in type 2 diabetes: a structural equation modeling approach. *Soc Psychiat Epidemiol, 45*, 67-76. doi:10.1007/s00127-009-0043-3

Dankner, R., & Roth, J. (2012). Predicting Diabetes. In R. Dankner, & J. Roth, *Prevention of Type 2 Diabetes* (pp. 81-102). Springer New York. doi:10.1007/978-1-4614-3314-9_6

Diabetes Australia. (2013). *A National Diabetes Strategy and Action Plan.* National Expert Advisory Group. Retrieved July 2013

Eckman, A. S., & Zieve, D. (2011, June 28). *Type 2 Diabetes - Symptoms, Diagnosis, Treatment of Type 2 Diabetes*. (A.D.A.M., Inc.) Retrieved November 2012, from The New York Times: http://health.nytimes.com/health/guides/disease/type-2-diabetes/overview.html

Ferry, R. (2012). Diabetes Mellitus. WebMD, Inc. Retrieved November 2012, from http://www.emedicinehealth.com/diabetes/article_em.htm#diabetes_overview

Finnie, G., & Sun, Z. (2003). R5 model for case-based reasoning. *Knowledge-Based Systems, 16*, 59-65.

Fowler, M. J. (2008). Microvascular and Macrovascular Complications of Diabetes. *Clinical Diabetes, 26*(2). Retrieved January 2013, from http://clinical.diabetesjournals.org/content/26/2/77.full

Grootenhuis, P., Snoek, F., Heine, R., & Bouter, L. (1994). Development of a Type 2 Diabetes Symptom Checklist: a Measure of Symptom Severity. *Diabetic Medicine, 11*(3), 253-261.

Khan, A. S., & Hoffmann, A. (2003). Building a case-based diet recommendation system without a knowledge engineer. *Artificial Intelligence in Medicine, 27*, 155-179.

Larsson, S. C., Adami, H.-O., & Wolk, A. (2006). Obesity, Diabetes, and Risk of Cancer. In C. S. Mantzoros, & C. S. Mantzoros (Ed.), *Obesity and Diabetes* (Vol. 3, pp. 233-254). Totowa: Humana Press. doi:10.1007/978-1-59259-985-1_14

Lau, D. C. (2010). Diabetes and weight management. *Primary Care Diabetes, 4*, S24–S30. Retrieved January 2013, from http://www.elsevier.com/locate/pcd

Li, W., Zheng, H., Bukuru, J., & Kimpe, N. D. (2004). Natural medicines used in the traditional Chinese medical system for therapy of diabetes mellitus. *Journal of Ethnopharmacology, 92*, 1-21.

Marling, C., Montani, S., Bichindaritz, I., & Funk, P. (2013). Synergistic Case-Based Reasoning in Medical Domains. *Expert Systems with Applications*. doi:http://dx.doi.org/10.1016/j.eswa.2013.05.063

Montani, S. (2010, April 26). How to use contextual knowledge in medical case-based reasoning systems: A survey on very recent trends. *Artificial Intelligence in Medicine, 51*, 125-131. doi:10.1016/j.artmed.2010.09.004

Nazimek-Siewniak, B., Moczulski, D., & Grzeszczak, W. (2002, August 27). Risk of macrovascular and microvascular complications in Type 2 diabetes: Results of longitudinal study design. *Journal of Diabetes and its complications, 16*, 271-276. Retrieved January 2013

Nefs, G., Pouwer, F., Denollet, J., & Pop, V. (2011). The course of depressive symptoms in primary care patients with type 2 diabetes: results fromthe Diabetes, Depression, Type D Personality Zuidoost-Brabant (DiaDDZoB) Study. *Diabetologia, 55*, 608-616. Retrieved February 2013

Omar, W. M., & Ati, M. (2011). Smart Diabetes Management System Based on Service Oriented Architecture. *LNCS, 6719*, 290-295.

Raman, R., Gupta, A., Krishna, S., Kulothungan, V., & Sharma, T. (2012, March 24). Prevalence and risk factors for diabetic microvascular complications in newly diagnosed type II diabetes mellitus. Sankara

Nethralaya Diabetic Retinopathy Epidemiology And Molecular Genetic Study (SN-DREAMS, report 27). *Journal of Diabetes and Its Complications, 26*, 123-128. doi:10.1016/j.jdiacomp.2012.02.001

Renders, C. M., Valk, G. D., Griffin, S. J., Wagner, E. H., Van, J. T., & Assendelft, W. J. (2001, October). Interventions to Improve the Management of Diabetes in Primary Care, Outpatient, and Community Settings. *Diabetes Care, 24*(10), 1821-1833.

Riserus, U., Willett, W. C., & Hu, F. B. (2009, January). Dietary fats and prevention of type 2 diabetes. *Progress in Lipid Research, 48*(1), 44-51.

Scacchi, W. (2001). *Process Models in Software Engineering.* University of California, Institute for Software Research. New York: John Wiley and Sons, Inc. Retrieved February 2013

Shaw, J., Sicree, R., & Zimmet, P. (2009, November 6). Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice, 87*(2010), 4-14. doi:10.1016/j.diabres.2009.10.007

Silverman, R. A., Thakker, U., Ellman, T., Wong, I., Smith, K., Ito, K., & Graff, K. (2011, September). Hemoglobin A1c as a Screen for Previously Undiagnosed Prediabetes and Diabetes in an Acute-Care Setting. *Diabetes Care, 34*(9), 1908-1912. doi:10.2337/dc10-0996

Simon, H., & Zieve, D. (2011, May 5). *Type 2 Diabetes: In-Depth Report: Diagnosis*. (A.D.A.M., Inc.) Retrieved November 2012, from The New York Times: http://health.nytimes.com/health/guides/disease/type-2-diabetes/diagnosis.html

Sterling, W. M., & Ericson, B. J. (2006). *Case-based reasoning similarity metrics implementation using user defined functions.* Retrieved July 2013, from www.google.com/patents/US7136852

Sun, Z., Finnie, G., & Weber, K. (2005). Abductive Case-Based Reasoning. *INTERNATIONAL JOURNAL OF INTELLIGENT SYSTEMS, 20*, 957-983. doi:10.1002/int.20101

Sun, Z., Han, J., & Dong, D. (2008). Five Perspectives on Case Based Reasoning. In D.-S. Huang, D. C. Wunsch, D. S. Levine, & K.-H. Jo, *Advanced Intelligent Computing Theories and Applications. With Aspects of Artificial Intelligence* (Vol. 5227, pp. 410-419). Heidelberg: Springer. doi:10.1007/978-3-540-85984-0_50

Thagard, P., & Shelley, C. (1997). Abductive reasoning: Logic, visual thinking, and coherence. In M.-L. Dalla Chiara et al (eds), *Logic and Scientific methods* (pp. 413-427).

Turban, E., & Volonino, L. (2011). *Information Technology for Management: Improving Performance In The Digital Economy* (7 ed.). Hoboken, NJ: Wiley & Sons.

World Health Organization. (2011). *Use of Glycated Haemoglobin (HbA1c) in the Diagnosis of Diabetes Mellitus.* Geneva: World Health Organization. doi:WHO/NMH/CHP/CPM/11.1

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