Developing Prototype of Case-Based Reasoning System for Personalized Medical Care for Patients with Diabetes Mellitus Type 2

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Research Article

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Abstract

Personalized medical care is an individualized approach to managing and treating diseases in the healthcare system. It follows the personalized medicine concept and has recently received much attention from the governing, scientific and healthcare diseases communities worldwide. Personalized medicine is speedily impacting how patients are managed and treated and also how healthcare delivery is channelling its resources to maximize patient benefits. The management of Diabetes Mellitus Type 2 consists of major lifestyle (dietary pattern), drug administration and physical exercise. The main objective of this study was to develop a Case-based reasoning system for personalized medical care for patients with Diabetes Mellitus Type 2. Design science within knowledge engineering method and data gathering tools such as semi-structured interviews and document analysis were employed to develop a prototype system. The domain experts were selected by using the purposive sampling technique. The knowledge acquired from domain experts and through document analysis was modelled by using the hierarchical conceptual modelling method, and cases were generated and represented with the feature-value format. The prototype was implemented by using JCOLIBRI software and scored an F-Measure of 84% and user acceptance of 86.2% and 82%, respectively. Applying a case-based reasoning system in personalized medical care is very important to improve the quality of service delivery to address each patient's case through unique characteristics/attributes such as age, gender, blood pressure, fast blood sugar and others. Even if the porotype registered promising results, future research work is expected from different scholars in personalized medicine for more improvement.

Introduction

Personalized medical care is the cornerstone of the health care system, paving the way for quality service in managing and treating various chronic non-communicable diseases. It is the process of providing management and treatment for individual patients based on their heterogeneity. It is also the reverse process of traditional understanding and treating diseases (Lasalvia, 2021).

Diet is one of the causes of health problems for human beings, particularly diabetes mellitus type 2 (T1DM) (Magkos et al., 2020). Dietary pattern is characterized by consuming a diverse selection of nutritionally distinct and wholesome foods that encourage nutrient adequacy and improved health outcomes. A healthy diet is characterized by a correct caloric intake and mainly focuses on consuming plant-based foods. Moreover, it favours the intake of unsaturated, rather than saturated, fats, low amounts of animal source foods, and small amounts of refined grains, highly processed foods and free sugars (Caprara, G.,2018).

Personalized medicine is the concept that deals with an individualized method for the management and treatment of the disease. It can change the prevention, prediction, and management ways of T2DM. It is also the lengthening and the evolution of the "one-size-fits-all" approach to patient management (Ramaswami et al., 2018). Unlike the "one-size-fits-all" approach, personalized medicine is mainly preventive and proactive rather than reactive (Mathur & Sutton, 2017).

One of the main goals of personalized medicine is to improve safety by lowering adverse drug reactions (ADRs), promoting a healthy diet, and identifying individuals who will benefit from medicine and those who will not. Its major goal is also to optimize personalized medical care and outcomes for each individual, which include treatments, pharmaceutical types, dosages, and/or prevention tactics that change from person to person, resulting in outstanding patient care (Goetz & Schork, 2018).

According to a study conducted by Torrent-Fontbona and López (2018), incorporating CBR for individualized medical care improves management and treatment processes. Using case-based reasoning assists health professionals in organizing and retrieving patients' unique characteristics information (patient heterogeneity) to provide tailored medical care and make judgments (Paruchuri & Granville, 2020; Bentaiba-Lagrid et al., 2020).

Personalized medicine has the potential to advance the performance of therapy for individual patients by distinguishing and capitalizing on patient heterogeneity. It is one of the main promises of the Human Genome Project (HGP), which began three decades ago and is now a new therapeutic paradigm. With its arrival in the era of developing drugs to suit all patients, often having to withdraw a promising new one because a minority of patients were at risk. Even though it had proved valuable for the majority, it was consigned to history, as were trial-and-error strategies being the predominant means of tailoring therapy(Leila El-Alti, 2019). However, it plays a crucial role in treating individuals through targeted treatment. It helps to reduce adverse drug reactions, reveal additional targeted uses for medicines and drug candidates, increase patient adherence to treatment, avoid invasive testing procedures and help to control the overall cost of health care (Personalized Medicine Coalition, 2017).

There is a scarcity of specialists in T2DM speciality. According to the data for 2021 and 2022 that was obtained from Jimma University Medical Center Health Management Information System (HMIS), the ratio of available specialists to the number of T2DM patients highly varies. For instance, there is one DM specialist for 346 patients who need continuous medical follow-up at different intervals. On the contrary, early management and treatment of T2DM are necessary, with effective management and treatment through personalized medical care that can deliver care to the right person according to their unique characteristics (patients' heterogeneity). Therefore, the development of an organized knowledge base greatly impacts the quality of the service delivery system, cost-effectiveness, and improvement of the overall management and treatment process in the health sector.

To the researchers' knowledge, there is no developed personalized medical care, a Case-based reasoning system that supports patients and health professionals to combat chronic non-communicable diseases, specifically T2DM, which leads to other complicated diseases. Hence, this study attempted to answer the following research questions:

1. What are the T2DM patients' cases suitable for developing a case-based reasoning system related to personalized medical care?

2. How would the acquired patients' cases be modelled and represented in developing a case-based reasoning system for personalized medical care for T2DM?

3. What types of knowledge are used to develop CBR for personalized medical care of T2DM?

4. To what extent does the developed prototype get user acceptance by the domain experts (health professionals) and T2DM patients in Jimma University's Medical Center?

OBJECTIVES OF THE STUDY

The main objective of this study is to design and develop the prototype of a Case-based reasoning system for personalized medical care for patients with T2DM. **Specific objectives**

Ø To identify patients cases suitable for personalized medical care by dietary pattern and drug therapy for patients with T2DM patients.

Ø To model and represent the acquired patients' cases to develop CBR personalized medical care for T2DM patients.

Ø To acquire tacit and explicit knowledge from domain experts and secondary data sources to develop CBR personalized medical care for T2DM patients.

To test and evaluate the performance and user acceptance of the designed CBR for personalized medical care for T2DM patients.

Methods

The well-known research methodologies are design science, qualitative and quantitative. Since it offers specific guidelines for evaluation and iteration within research projects and combines different research methods for qualitative and quantitative research, a design science research design was followed for this study. It also includes knowledge acquisition, knowledge representation, and modelling, and finally developed a prototype case-based reasoning system for personalized medical care. Design science typically involves the creation of an artefact that aims to improve the understanding of information systems (Deng & Ji, 2018).

In this study, both primary and secondary data collection methods were employed to collect the required domain knowledge from primary and secondary data sources. In addition, for this study, non-documented sources of knowledge were also collected from health professionals or experts who are working in Jimma University Medical Center. For this reason, as the primary data collection method, the researcher conducted the semi-structured interview to acquire domain knowledge and knowledge elicitation methods to filter the acquired knowledge.

The cases of 45 T2DM patients were collected from Jimma University Medical Center. The total number of attributes used in the prototype development are 19 attributes. The cases were modelled by hierarchical conceptual modelling and represented by the feature-value representation method.

Results And Discussion

The cases of 45 diabetes mellitus Type 2 were collected from Jimma University Medical Center, a specialized teaching hospital of Jimma University. The prototype was designed and developed by considering patients' attributes, dietary patterns and drug administration for continuous follow-up to reduce the disease complication. The screenshot of the designed and developed prototype is depicted in Table 1 and the architecture in Fig. 1.

Table 1
The Case Structure for Personalized Medical care

Attributes	Parameters
Patient gender	Description
Patient age	Description
Patient Blood pressure	Description
Patient Pulse Rate	Description
Patient Fasting blood sugar	Description
Patient weight	Description
Patient Fatty distribution	Description
Patient Race	Description
Patient family disease history	Description
Patient Blood type	Description
Patients Medical Registration Number	Description
Patients address	Description
Drug type	Solution
Drug Frequency	Solution
Drug dose	Solution
Drug duration	Solution
Drug route	Solution
Food type	Solution
Food amount	Solution
Number of times food is eaten per-day	Solution
Physical Exercise	Solution

The developed prototype was evaluated in terms of precision, recall, F-measure and user acceptance. As a result, the system has an average precision value of 83.4%, recall of 81%, F-measure of 84%, and user acceptance by domain experts and T2DM patients is 86.4% and 82%, respectively. Improving service delivery by any means is one of the target activities in the health sector by using available resources on time.

As the health sector serves numerous patients, it is expected to modernize its service quality and coverage by integrating different technologies. Personalized medicine is one of the technologies which

has entered the health sector lately to address the issue of each patient according to their heterogeneity in terms of different factors. For example, chronic diseases that need continuous follow-up use different resources for a long time for management and treatment. Therefore, proper management and treatment for proper patient support minimize resource waste.

Emily (2020) conducted a literature review on the personalized medicine and treatment of diabetes mellitus type 2, and personalized medicine greatly impacts the management and treatment of diabetes mellitus type 2. Consequently, the main emphasis of the literature review was looking at the evidence-based recommendations for utilizing personalized medicine in the treatment of type 2 diabetes to help determine which secondary line of medication is optimal for individual patients with type 2 diabetes.

The designed and developed case-based reasoning system for personalized medical care for patients with diabetes mellitus type has solved the limitation of the studies conducted by Kiragu Mark Kirani (2016), Benamin, *et al.* (2018), Kedir *et al*. (2020), which focus only on diagnosis and treatment for diabetes. These researchers focused on the diagnosis and treatment criteria for different patients, not personalized to each specific individual patient.

Conclusion

The study was conducted with the main goal of developing a prototype CBR system for personalized medical care for patients with T2DM by using knowledge engineering processes. During the prototype development, 45 T2DM patient cases were collected from Jimma University specialized hospital. After the acquired knowledge is modelled, a case-based reasoning technique was used to represent the knowledge. Finally, cases were represented in attribute-value format. The prototype system CBRSPMC is developed by using the jCOLIBRI Programming tool. When measuring the performance of the system, promising results were found. The standard measures of information retrieval (recall, precision and F-measure) are used to measure the retrieval performance of CBR. The average recall, precision and f-measure results 81%, 83.4% ,84%, respectively, are also promising to apply CBR in personalized medical care. In addition, the prototype's performance was evaluated by both the potential users' (health professionals) and T2DM patients of the prototype and scored user acceptance of 86.4% and 82% performance, respectively.

RECOMMENDATIONS

The study has achieved its objective: developing a case-based reasoning system for personalized medical care for patients with T2DM. However, the following issues need more investigation and intention from all interested professionals.

- The prototype system was developed by a case-based reasoning system, and the researcher recommended that other rule-based knowledge system should be developed by integrating different

programming languages such as .NET, C#, and python to bring a sober and wonderful system that support personalized medical care.

- The study focused on developing case-based reasoning personalized medical care prototype system for T2DM, and the scope should be developed and broadened to other chronic non-communicable diseases.
- The researcher recommends that research that includes hybrid case-based reasoning, which employs two or more representations (such as rule-based and case-based) of expertise to emulate reasoning in some domains, should be developed by different researchers.
- Jimma University Specialized Hospital should pave the way for health professionals' skills and knowledge development to adopt and implement the developed case-based reasoning personalized medical care prototype.
- Different researchers in the Artificial intelligence discipline, specifically in the area of knowledge base systems, should incorporate patients' laboratory test results, other unique characteristics/attributes, genomes, and biomarkers (drugs genome) which are out of the scope of this study.

Declarations

Conflict of Interest

The authors declare that there is no conflict of interest regarding this study.

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Ethical approval for a study entitled: "Developing Prototype of Case-Based Reasoning System for Personalized Medical Care for Patients with Diabetes Mellitus Type 2" was obtained from the Institutional Research Ethics Board of Jimma Institute of Technology, Jimma University.

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Figures

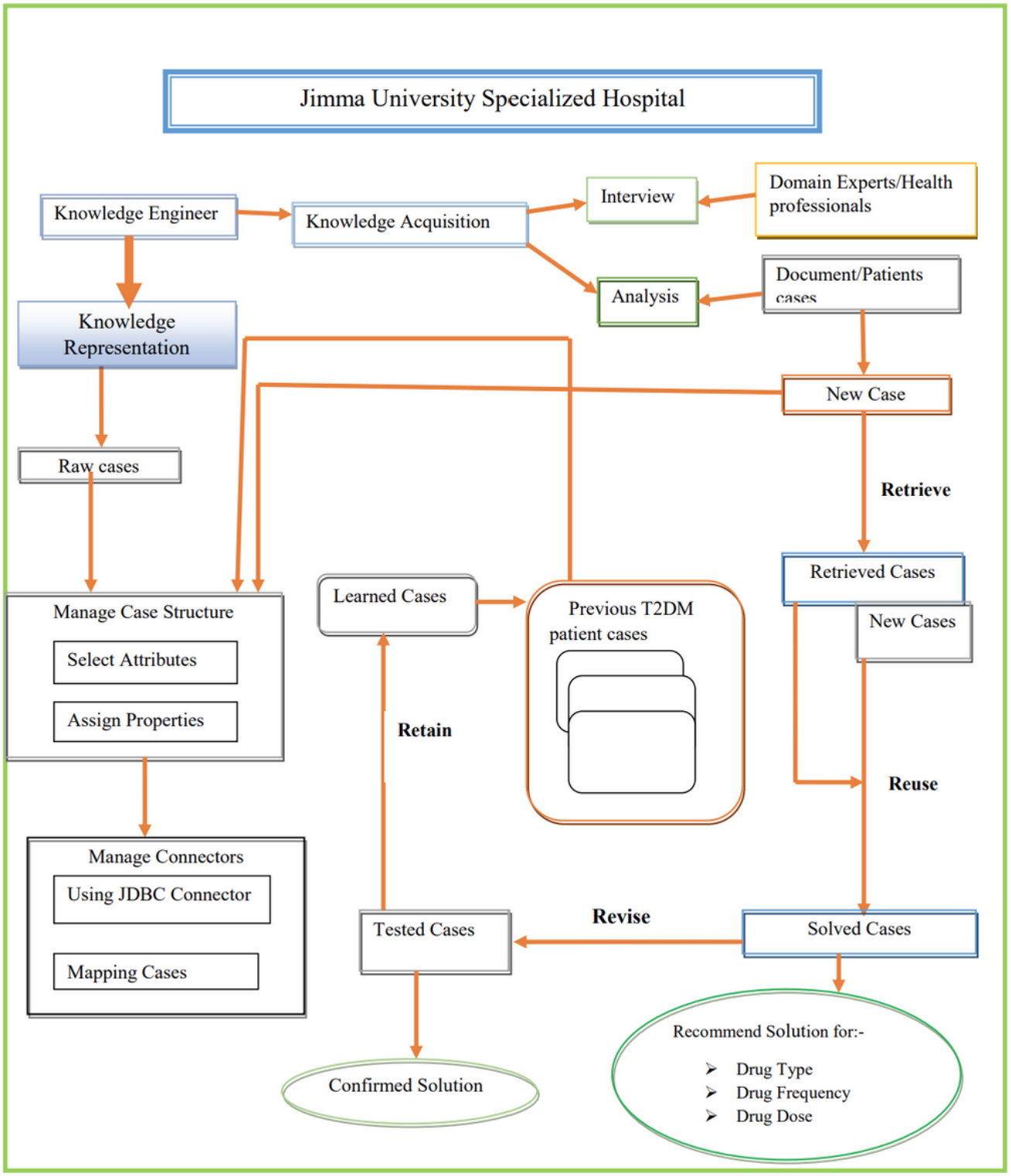

Figure 1

The Architecture of the Case-Based Reasoning System for Personalized Medical Care for T2DM