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Design and Implementation of Healthcare System for Chronic Disease Management

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Abstract

Chronic diseases management can be effectively achieved through early detection, continuous treatment, observation, and self-management, rather than a radar approach where patients are treated only when they visit a medical facility. However, previous studies have not been able to provide integrated chronic disease management services by considering generalized services such as hypertension and diabetes management, and difficult to expand and link to other services using only specific sensors or services. This paper proposes clinical rule flow model based on medical data analysis to provide personalized care for chronic disease management. Also, we implemented that as Rule-based Smart Healthcare System (RSHS). The proposed system executes chronic diseases management rules, manages events and delivers individualized knowledge information by user's request. The proposed system can be expanded into a variety of applications such as diet and exercise service in the future.

Keywords: *Rule-based engine, Chronic Diseases Management, Decision support system, Healthcare*

1. Introduction

At present, the birth rate in Korea is low, and the aging society is progressing rapidly [1]. As a result, medical expenses and welfare costs are increasing. According to the National Health Insurance Corporation, in 2017, the average monthly medical expenses per capita in Korea increased by 8.7% year-on-year to KRW 51,247 to KRW 111,147 [2]. In particular, the prevalence of chronic diseases such as hypertension and diabetes is rapidly increasing due to changes in the health environment, such as westernization of lifestyle, and various management projects and improvement measures are being proposed nationwide. Chronic illness is more important than anything else, such as improving lifestyle, and it is important to prevent it beforehand. Even after visiting the hospital, it can be continuously observed and managed. When u-healthcare service technology is utilized well, chronic patients such as hypertension and diabetes can measure their health level through devices at home, measured data is analyzed in real time, it can improve the customized management and lifestyle of patients.

In this paper, we analyze health data for patient's situation and self-management for chronic disease

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management, propose rule - based knowledge expression model, and implement rule-based smart health care system based on this. The rule-based smart healthcare system utilizes the Personal Health Record and works with existing hospital information systems to implement guidelines based on changes in the status of chronic illnesses and provides personalized knowledge information for medical staff and patients.

This paper is composed as follows. In Section 2, we describe the knowledge transformation methods and rule-based expert systems of the clinical guidelines as related studies. Section 3 describes the guideline model for chronic disease management and the rule conversion method based on this. Section 4 describes the architecture and core components of a rule-based smart health care system for chronic disease management and describes the implementation of the system. Section 5 presents conclusions and future research.

2. Related Works

2.1 Chronic disease management services

Medically, a chronic disease refers to a disease that lasts more than 6 months or more than 1 year. It is said to be a chronic disease because its symptoms gradually appear and last for a long time.

In Korea, chronic diseases account for seven of the ten causes of death, and the proportion of deaths is also steadily increasing. The existing chronic disease treatment and management system has problems such as lack of integrated treatment and management system, and neglect of patient 's role and activities. Therefore, it is necessary for the patients themselves to establish a system capable of self-performance and management, and to develop a service model suitable for them.

The purpose of chronic illness services is to treat chronic diseases first, and secondly to manage thorough medical and social sequelae and complications after treatment. Therefore, health care services should be provided according to the medical services of the medical institutions and the evidence-based medical guidelines. In addition, in order to prevent the recurrence prevention and complications of chronic illnesses, self-management should be possible by themselves, and healthcare contents should be continuously provided and services should be provided to enable them to practice in everyday life [3].

2.2 Computerized Guideline

In the late 1980s, interest in the development of Clinical Practice Guidelines (CPGs) centered on developed countries was amplified due to the lack of quality management guidelines for medical practices along with an increase in medical expenses [4]. To change the clinical guidelines into the form of computerized care guidelines, GLIF(The Guideline Interchange Format) [5], Arden Syntax [6], EON [7], PRODIGY, PROforma [8] [9], SAGE (Standards based) Shareable Active Guideline Environment) [10] [11], and many practical efforts have been made.

Computerized care guidelines can be coded based on evidence-based recommendations and automatically produced recommendations tailored to individual patient situations. It can also guide practice more effectively when compared to conventional paper-based CPGs, by providing easier access to clinically accessible references and selective access to guideline knowledge. In addition, the quality of the guideline itself can be pursued through the circulation process of finding and evaluating the vulnerability of the guideline itself.

The development of the Clinical Decision Support System (CDSS) through the case study shows that the recycling of knowledge is difficult and the cost of adding and changing knowledge is high. Previous studies have largely focused on the development of a shared model to express decision making and clinical care guidelines. However, sharing a viable medical knowledge on a computer requires more time than formalizing medical logic. Developing a reusable knowledge base of care guidelines requires an infrastructure that includes a medical record query interface, terminology medication, and an act interface.

2.3 Rule-based expert system

Rule-based systems are one of the expert systems that make and manipulate decisions of specific problems as rules. In a rule-based system, knowledge is treated as a set of data that is represented as a rule and matches the fact. The rule has a set of states that actually test the attribute and the behavior that performs a particular task.

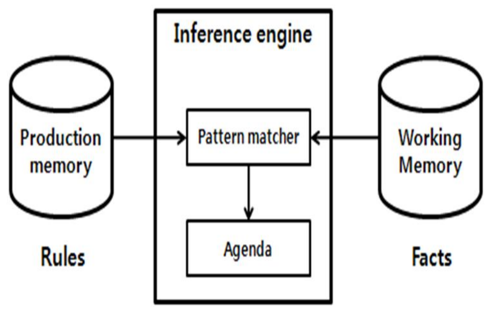

Figure 1. Conceptual Rule-based reasoning engine

Rule-based systems generally consist of three components: a knowledge base, an inference engine, and a working memory, as shown in Figure 1. A knowledge base is a specialized database that provides functions to manipulate knowledge. The inference engine corresponds to the brains of an expert system and provides an inference method to find solutions from knowledge. Working memory the repository information uses an inference engine. The Rete algorithm is also a fast pattern matching algorithm and is widely used to implement rule-based systems. Drools is a rules engine that uses a more precisely categorized rule-based approach as the implementation and generation of expert systems [12]. The most important advantage of the rule base execution environment is that the implementation logic and the domain knowledge are separated from each other, so that it is possible to expand and change the knowledge easily [13].

2.4 Rule-Based Engine Application of Healthcare Service

In general, decision support systems are defined as interactive computer based systems that help decision makers to solve unstructured problems using data and models. Several studies have reported that the quality of health care services can be improved through the use of computerized Decision Support System [14].

MYCIN (1976), a HELP system developed by LDS Hospital, and the Regenstrief medical record system of Indiana University [15], are examples of computerized decision support systems using rule-based systems. Arden, which was started in HELP in 1975, has been used up to now. EON of USA has gone through GLIF2 and GLIF3 and has recently been led to SAGE project.

In Korea, institutional demand for rule-based decision support systems has not yet matured. However, other industries are already actively using the rule engine, so if you convert the rules expressed in the new way into a form that can be used by the rule engine, there is a possibility.

3. Rule Model for Smart Healthcare

3.1 Clinical Rule Model

In rule-based smart healthcare system (RSHS), clinical rule and clinical guidelines are expressed and managed in Clinical Rule Model. The Clinical Rule Model provides an information model specific to clinical rule representation.

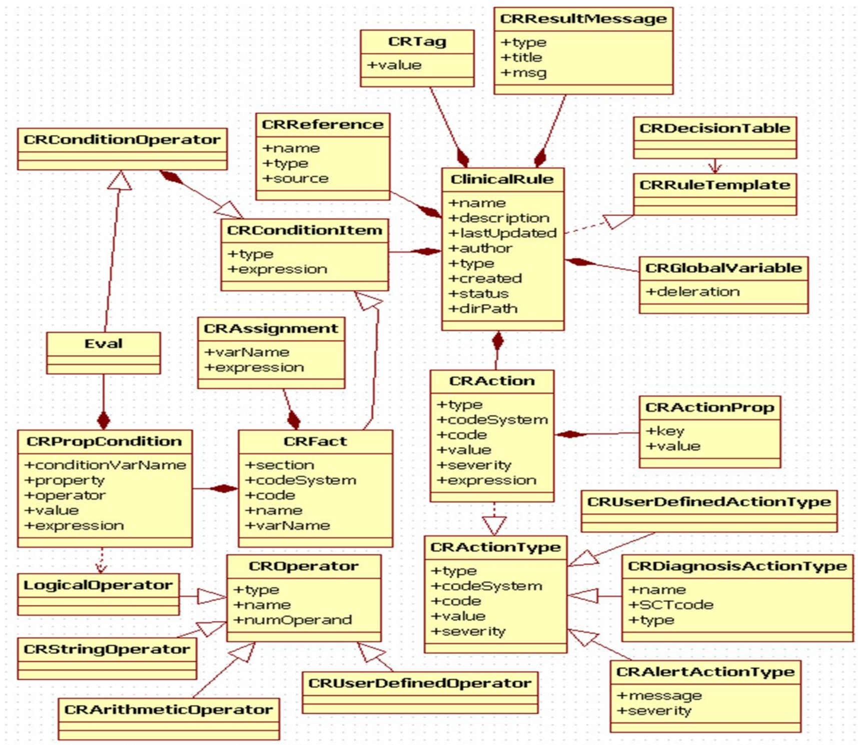

Figure 2. Clinical Rule Model

Figure 2 shows the class diagram of the Clinical Rule Model. In general, a rule-based model has a structure in which a condition is checked by inputting facts and an action is performed when the condition is satisfied.

The Clinical Rule Model presented in this paper is based on the HL7 Standard [16] as follows: Problem, Medication, Allergy, Vital Sign, Test Result, Procedure, Immunization, Social History and Traditional Drug, Genomic Data. We define it as a fact [Table 1] and use it as a condition of a rule. It also defines an action that generates clinical rule outcomes such as alert, diagnosis, treatment, general event, and general result.

Table 1. Fact of Clinical Rule Model

Facts	Description
Problem	Problem name
Medication	Medication information
Allergy	A number of conditions caused by hypersensitivity of the immune system to typically harmless substances in the environment
Vital Sign	A group of the 4 to 6 most important signs that indicate the status of the body’s vital functions
Test Result	A medical procedure performed to detect, diagnose, or monitor diseases, disease processes,

	susceptibility, and determine a course of treatment
Procedure	A course of action intended to achieve a result in the delivery of healthcare
Immunization	The process by which an individual's immune system becomes fortified against an agent
Social History	A portion of the medical history (and thus the admission note) addressing familial, occupational, and recreational aspects of the patient's personal life that have the potential to be clinically significant
Traditional Drug	Chinese medicine
Genomic Data	The genome and DNA data of an organism

3.2 Conversion of rules of chronic disease guidelines

The Clinical Practice Guideline groups several clinical rules to assist in making decisions in the clinic, and has a processing order and time constraints between each rule.

Clinical Rule Flow is a rule model that provides a basis for transforming these clinical guidelines into flow rules of a series of individual clinical rules and converting them into rules that can be easily understood and operated by the system. Clinical Rule Flow has an Activity Node that represents various medical activities according to the conditions specified in the Clinical Guidelines, a Dependency that expresses the relationship between them and a Control node such as initial, final, and a branch. Table 2 shows an example of the components of the Clinical Rule Flow Model. Models made of these elements are converted and operated into executable modules of a form that can be processed by the system.

Table 2. Clinical Rule Flow Model Component

Element	Description
	**Initial** Starting point of Clinical Rule Flow
	**Final** Termination of Clinical Rule Flow
<<Treatment>> Mono therapy	**<<Treatment>> Action** Action Node that defines user's medical and related behavior
<<Result>> Assess every Diagnosis or year	**<<Result>> Action** Action Node for notifying the result of rule processing to the user
<<Measurement>> Blood Pressure	**<<Measurement>> Action** Action Node for receiving a specific PHR item from the user
[Triglyceride Test] Triglyceride < 150mg/dL	**Decision** Branching Note by a given condition

The time constraints of the clinical guideline are that each active node is activated for a certain period of time and then transitioned to the next state. In Clinical Rule Flow, this temporal constraint is specified as an attribute of each activity node, and these attributes are managed and operated in the scheduler of the system. Another form of temporal constraint may be a situation that does not control the flow of clinical rules until an external event occurs. The event that re-activates this flow is generally used to input data as a result of a medical practice. The system provides an event handling function that can wait for events on these data inputs and notify them to the Clinical Rule Flow. Figure 3 shows an example of modeling diabetes management guidelines in the form of a rule flow that can be executed in the system.

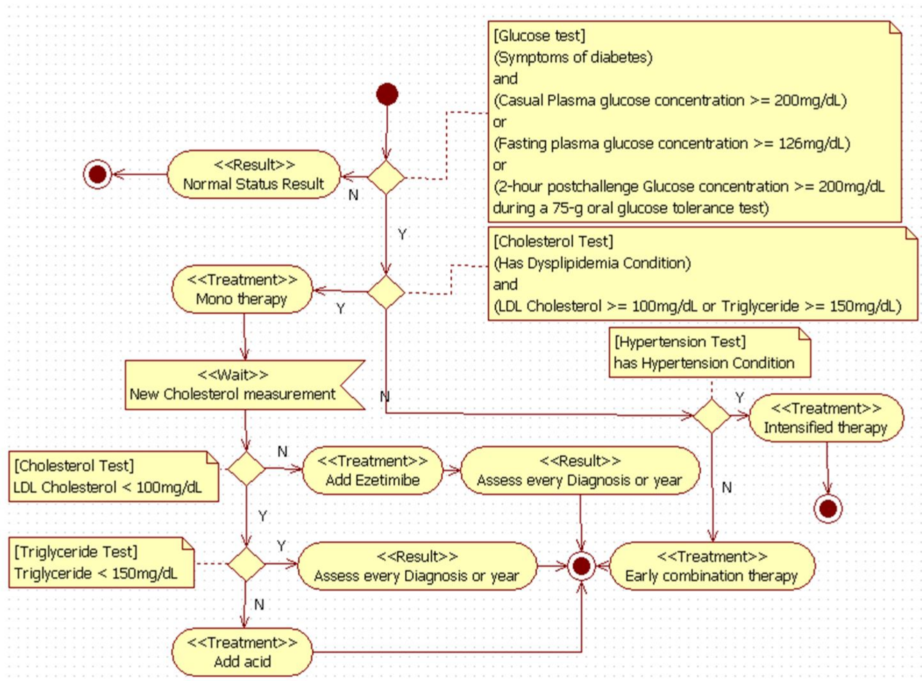

Figure 3. Rule Flow Modeling Example

4. System Implementation

4.1 System Architecture

To implement RSHS proposed in this paper, we construct a smart healthcare environment as shown in Figure 4. User's body information and medical examination information are interfaced with existing hospital information systems such as EMR and OCS, or are interfaced with PHR (Personal Health Record) which can store and manage individual's health record. There is a knowledge data management part for extracting and managing knowledge from various medical information sources such as clinical guidelines and related research papers. A rule engine part for executing, creating, editing and managing a chronic disease rule, and a service part provided to chronic patients and medical staff for chronic disease management.

The rule-based Smart Healthcare System (RSHS) consists of three main components: Clinical Rule Editor (CRE) for creating clinical rules and guidelines for clinical rules, Clinical Rule Manager (CRM) for managing life cycle such as storing, changing, and deleting created clinical rule models, and Clinical Rule Processor (CRP) that changes the Rule Model into an executable module and performs it. These three components interoperate to provide the core functionality of a full rule-based Smart Healthcare System (RSHS).

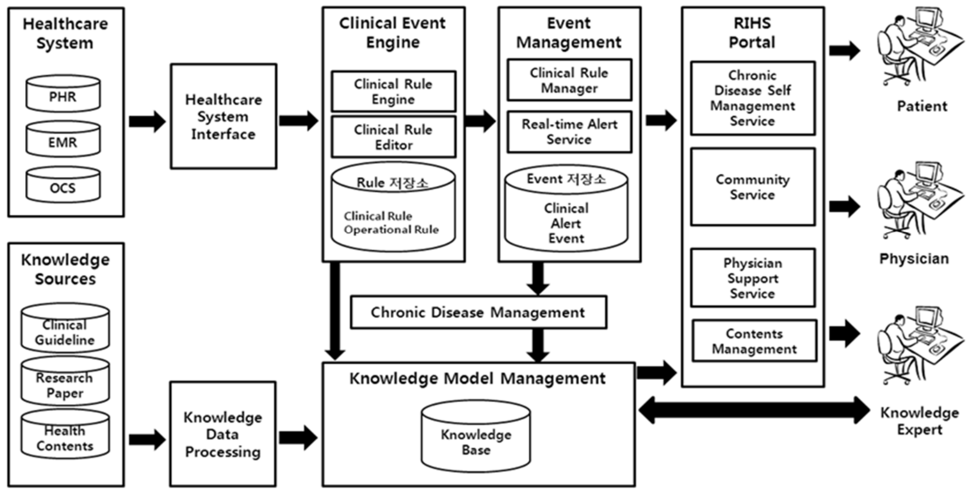

Figure 4. High level architecture of Rule-based Smart Healthcare System

CRE is a Web-based clinical rule making tool that helps clinicians have a quick and easy way to create clinical rules through a web user interface. In particular, the CRE has its own built-in SNOMED-CT terminology, code, and the ability to search for drug information, providing specialized editing features for clinical rule creation. CRM implements its own repository to manage the life cycle of the Clinical Rule Model created through CRE. CRP converts Clinical Rule Model stored in CRM into executable module, performs it according to user's request, and stores and manages the result event. Figure 4 shows the overall architecture of the RSHS system and Figure 5 shows the core components of the system.

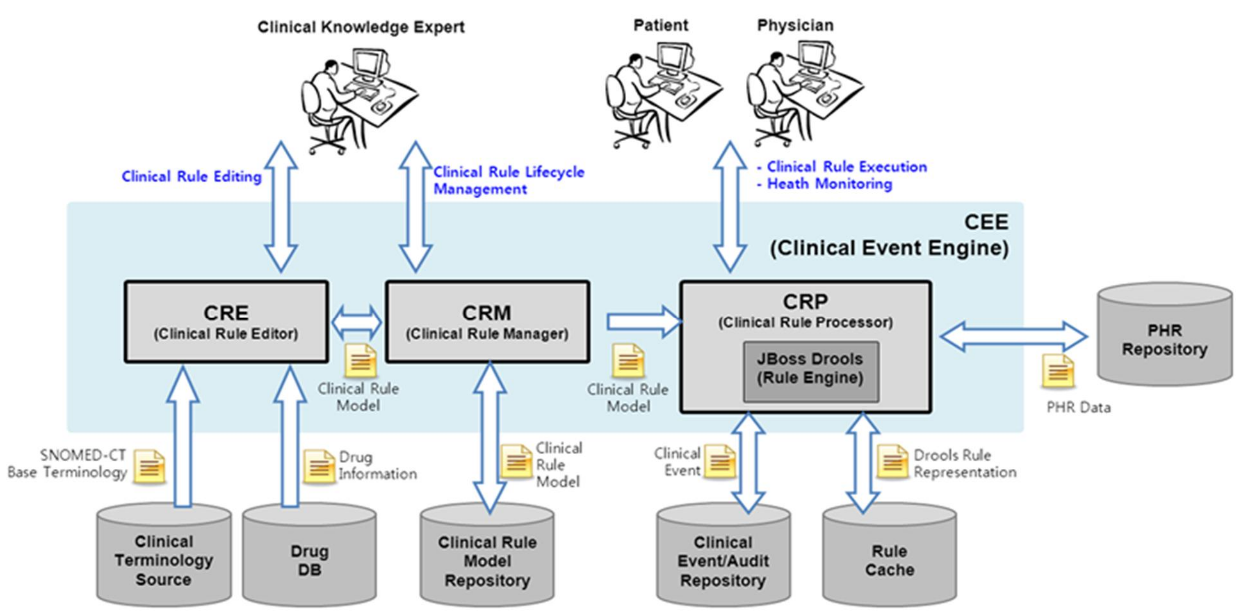

Figure 5. Clinical Rule Engine Component

4.2 Results

This chapter describes the results of implementing a rule-based Smart Healthcare System (RSHS) using the Clinical Rule Model. RSHS can request clinical information in conjunction with existing hospital information system. In addition, we receive physical information and medical information of chronic disease patients through PHR and perform decision support (DSS) through RSHS based on Clinical Rule Model. They can provide knowledge information based on guidelines and help them provide customized diagnosis / treatment / management information for chronic illnesses.

The actual RSHS was implemented using Jboss Drools [17], a Java-based rule engine. Drools is a business rule management system that provides a standards-based open source business rule engine that makes it easy to change and manage business policies.

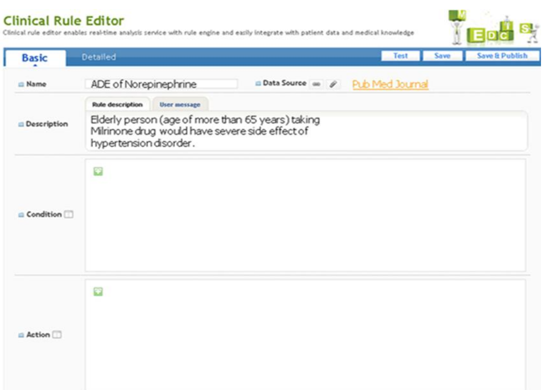

Figure 6. Clinical Rule Editor

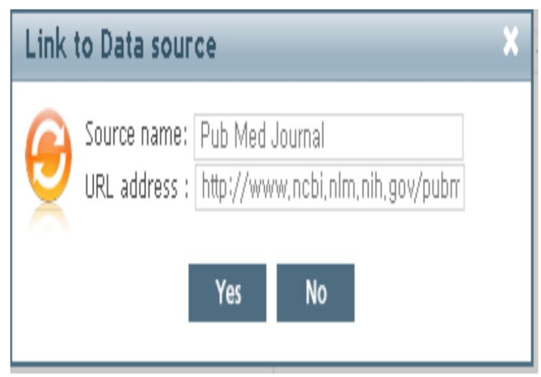

Figure 7. Rule Data Source addition

Figure 6 is an interface for creating guidelines for chronic disease management and frequently used knowledge information in RSHS. When you want to create a new rule, enter the name, description, condition and actions of the rule. In addition, it is possible to accumulate a knowledge base based on Evidence by specifying the source for the knowledge source as shown in Figure 7. When creating a clinical rule, it is possible to provide an interface for referring to the SNOMED-CT terminology, to search for a matching keyword by considering the convenience of input, or to reduce the range of the list searched by pressing each alphabet button. Figure 8 is the drug addition screen shown when you want to input medication information "Medication" from the condition.

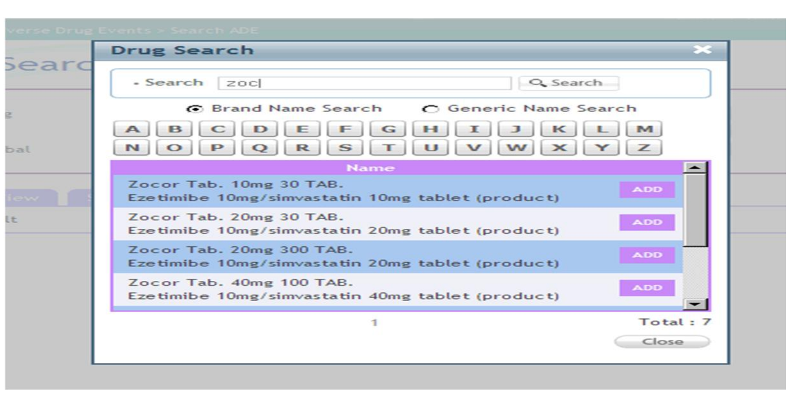

Figure 8. SNOMED-CT based Drug Search

5. Conclusion

In this study, we developed a rule-based smart healthcare system (RSHS) that analyzes medical data and provides appropriate treatment based on the analysis for effective management of chronic diseases. Clinical Rule Flow provides the basis for transforming the clinical guidelines required for chronic diseases into a rule that can be understood easily by users and can be operated by the system by representing the flow graph of a series of individual clinical rules. The Clinical Rule Editor is used to create and manage the Clinical Rule Flow, and the generated rules are used in the inference process in the RSHS rule engine to provide the knowledge information required for diagnosis / treatment / management according to the change of the condition of the chronic disease. Medical staff can use RSHS to continuously monitor the patient's condition and perform rule-based tracking management.

Future research will quantitatively examine the effects of the management system through development and supplementation of various chronic disease management rules, service diversification, simulation, and practical application.

Acknowledgement

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