Translation Protégé Knowledge for Executing Clinical Guidelines

Jeong Ah Kim[1], BinGu Shim[2], SunTae Kim[3], JaeHoon Lee[4], InSook Cho[5], Yoon Kim[6]
[1]Kandong University, Computer Education Department, KOREAclara@kd.ac.kr,
[2]Seogang University, Computer Engineering Dept, KOREA anore@gmail.com,jipsin08@gmail.com
[3] Ajou University, Industrial Engineering Department, promesum@nate.com,
[4]Inha University, Nursing Department, insook.cho@inha.ac.kr,
[5]Seoul National University, Medical Department, yoonkim@snu.ac.kr

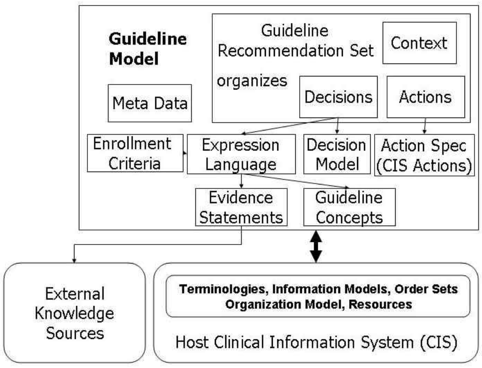
Motivation

Many researchers have proved that computerized decision support system (CDSS) in clinical guideline can lead clinician's compliance with suggested best practices in patient care. So CDSS can improve the quality of patient care. In CDSS, a core component is guideline which specifies best practice and evidence-based knowledge. For clinical guideline, several different approaches for modeling the clinical guideline have been proposed. Arden syntax, EON, PRODIGY, GUIDE, GLIF, and SAGE (Standard-based Sharable Active Guideline Environment) are the most popular modeling formalism. With these guideline modeling formalisms, knowledge engineers specify the decision model and data for each clinical practice of point of care services or other administrative services.

Clinical protocol guidelines (CPGs) contain systematic statements of evidence-based policy rules or principles to assist clinicians and patients make decisions on healthcare alternatives. The SAGE Guideline Model is a computable knowledge representation "format" for encoding the content and logic of executable CPGs [3, 4]

SAGE guideline model encodes guideline knowledge needed to provide situation-specific decision support and use standardized component for interoperability [1]. SAGE workbench provides knowledge authoring tool based on Protégé. Also SAGE defines the knowledge deployment process and knowledge execution architecture. Therefore, SAGE can be a strong and concrete knowledge representation model for clinicians.

Major component of SAGE guideline model is Fig.1



<Fig.1> Guideline Component Model Architecture [2]

The problem of SAGE is that there is not publically available execution engine yet. Since there are no practical and efficient guideline execution engines for clinical guidelines modeled in SAGE, IT developers may resort to understanding the encoded guidelines and implementing in programming languages. After implemented with programming languages, knowledge engineer cannot access that knowledge any more as what they understand. There are several reasons for that. Their guidelines are embedded in application logic so it is not easy to indentify or to separate the knowledge from other application functionalities. Also programming language is not easy for knowledge engineer to understand and verify. These are obstacles make it hard to spread CDSSs widely and reuse the encoded medical knowledge among the hospital information systems.

Several researches reported commercially available rule engine system can be an execution engine for clinical knowledge [1, 2]. In this paper, we suggested an approach and architecture for implementing scalable and maintainable clinical decision support service with process engine and rule engine, which are already used in business areas. We evaluated 2 kinds open source engine for clinical knowledge and applied these engines to execute the SAGE guideline model. The SAGE process model is based on activity graph formalism and used WPDL (Workflow Process Definition Language) for basic process semantics. The SAGE rule model is based on ontology so rule defines the clinical concepts and criterions.

For executing the SAGE-based knowledge, we should integrate process engine and rule engine. And we evaluated this integrated knowledge engine in terms of performance and correctness with several guidelines, which is not modeled in SAGE. We prove that commercial rule and process engine can be interpreted guidelines. But this integrated knowledge engine has its own knowledge formalism different from SAGE formalism. Therefore, we should translate SAGE-based knowledge into other formalism of knowledge engine.

Knowledge Translation

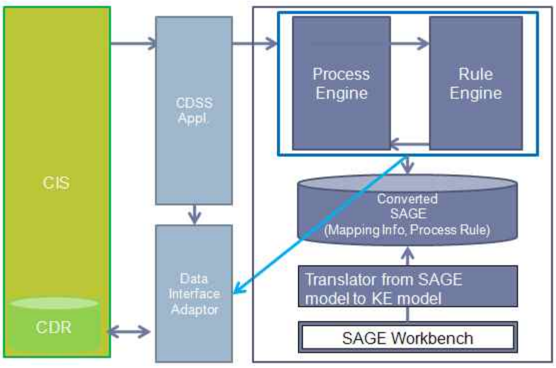
Table 1 shows the SAGE model and correspondence features of knowledge engine.

Table 1. SAGE model and features

SAGE model	Meaning	features
Guideline	Collection of associated Recommendation Set	Process
Recommendation Set	Decision Map or set of activity graph	Sub-Process
Context	Where the recommendations associated with the Context node is applicable.	Rule
Expression	Expression language that can be used with any object-oriented model.	Rule
Concept	Constant atomic term	Rule
Variable	Meaningful result from executing the internal logic	Rule
Evidence Statement	represents a relationship between clinical conditions and interventions and additional contextual information and supporting references	Rule/Process
Activity graph	inter-related activities.	Process
Action	flow-of-control information	Process
Decision	representation of decision knowledge required to recommend a choice among alternatives	Process /Rule

According to Table 1, we validate the feasibility of knowledge engine (process engine + rule engine) as execution engine of SAGE

Fig 2 shows the architecture of knowledge engine. From SAGE guideline model, translator translates the guideline representations to KE knowledge model and stores them in knowledge repository. KE retrieve the knowledge from repository according to event from CDSS application. For executing the knowledge, knowledge engine should retrieve the patient data in run time.



<Fig 2> Knowledge Engine Architecture

Data interface adaptor component access the clinical data repository and return to Knowledge engine.

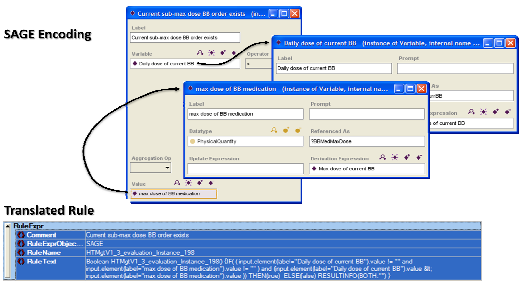
For translating the SAGE guideline, we evaluate 2 approaches. SAGE guideline can be modeled with XML or OWL. One way to translate the guideline element defined in OWL tag to model element of knowledge engine. The other way is using object model of SAGE. SAGE defined Knowledgebase object model so translation from properties of SAGE object model to properties of knowledge engine. In our prototyping second approach is more efficient for translating and more correct. We analyze the SAGE object model and identify the relation with object model of Knowledge engine, listed in Table 2.

Table 2. mapping between SAGE class and Rule Element

SAGE Class	Rule Element
Transition	Block Model Structure
Decision	SwitchActivity
Action	ActionActivity
CompoundAction (etc)	ComplexActivity (Switch + Brain + Actions)
Context	ContextActivity
Variable	ProcessVariable, Interface Model XML
Criterion	Rule Expression
Data Value(Quantity)	Rule Expression or Domain Model XML
VMR Query	Built-in Function

In this paper, we describe the simple examples of translation. In Sage, a Conditional Expression an expression designed to provide a way to specify alternative data values based on a patient-specific decision criterion. It has three additional slots: *condition* (instance of Criterion), *if_true_condition* (instance of Expression), and *if_false_condition* (instance of Expression class).

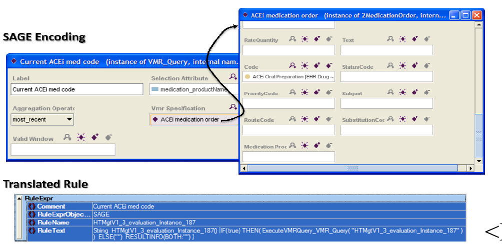
If the comparison you want to make cannot be formulated comparing the value or time of a VMR instance to some value or time, then you should consider the **Variable_Comparison_Criterion**, which simply compares the value of a variable to some other value.



<Fig.3> Translated result of Variable_Comparison_Criterion

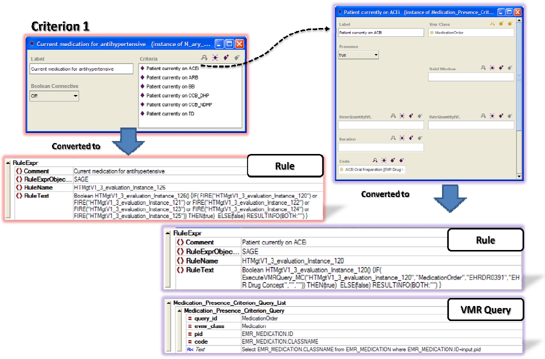
Each SAGE expression is translated into rule with unique rule ID. The value of 'References As' slot is translated into the element of interface XML. Interface XML defines the elements what are provided from outside.

The **VMR_Query** class allows the specification of a subset of GELLO expressions that can be formulated as a constraint on the values of a single **VMR** class. The constraint (*VMR_specification* property of **VMR_Query**) is expressed as an instance of a **VMR** class that has selected attributes specified.



<Fig.4> Translated result of VMR_Query

To access EMR record, we implemented execute_VMR_Query( ) function. If the expression is a BOOLEAN combination (AND, OR, or NOT) of simpler criteria, then use **N_ary_Criterion.** The following example is the part defined in Hypertension management guideline.



<Fig 5> Translated result of N_ary_Criterion

Each condition statement is translated into rule with unique ID and connected with logical operator.

Case Study

To validate our knowledge translator, we developed hypertension guideline on SAGE. Our research group consists of knowledge engineers and IT engineers. Knowledge engineers are domain expert and their background is clinician or nursing. Knowledge engineers capture the knowledge from several sources about hypertension and define the knowledge in ontology with concepts and axioms. Then they specify the knowledge in SAGE guideline model with SAGE workbench. In SAGE model, 137 indication rule and 6 medication class and 58 activities and 26 recommendation set is defined. With translator component, hypertension knowledge repository is constructed and is available for knowledge engine.

To verify the correctness and completeness of knowledge repository, we apply black box testing. Knowledge engineers define the test case what consists of input test case and expected results. With this test case, our test oracle generates input interface file to knowledge engine and compare the result from knowledge engine with expected results. For black box testing, 60 test cases and 18 factors in 60 test cased were tested. As the result, value of 1080 element was compared with expected results and all values are exactly matched. So we conclude our converted knowledge is correct and knowledge engine is available for clinical guidelines.

We have successfully integrated the process engine and rule engine and apply knowledge engine for executing clinical guideline. In the research, we apply knowledge engine to SAGE guideline model. But, almost guideline model are based Task-Network model, which are same model of process engine and based rule model. So, our architecture can be applied into several clinical guidelines. Our future research will focus on knowledge modeling process and knowledge representation constraints for efficient knowledge execution in knowledge engine since clinical guideline models don't restrict modeling process or constraints. In some case, translated knowledge is very redundant and ambiguous for execution.

References

1. Vipul Kashyap, et al., "On Implementing Clinical Decision Support: Achieving Scalability and Maintainability by Combining Business Rules and Ontologies" AMIA 2006, 414-418
2. Haward S. Goldberrg, et al., "Evaluation of Commercial Rule Engine as a Basis for a Clinical Decision Support Service," AMIA 2006, 294-298
3. http://sage.wherever.org/model/model.html
4. Samson Tu, Julie Galsgow, SAGE Guideline Model :Technical Specification, SAGE Consortium, 2006