Authoring Tool: Acquiring sharable knowledge for Smart CDSS

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Abstract— Clinical Decision Support Systems (CDSS) assist clinicians in making clinical decisions by using experts' knowledge stored in the knowledge base. However, sharing and reusing the knowledge is a challenging task. Many systems are developed to facilitate sharing of medical knowledge and allow its reusability. These systems are compliant to standard approaches such as HL7 Arden Syntax and HL7 CDA (Clinical Document Architecture) to incorporate medical logic in standard format. The main drawback with these systems is the complicated procedure in the development of clinical knowledge by ordinary clinicians. The proposed research work is focusing on developing authoring tool that creates sharable clinical knowledge base using standards such as HL7 Arden Syntax, HL7 vMR and HL7 CDA. Moreover, the authoring tool provides user friendly GUI to facilitate clinicians in creating standard based executable clinical knowledge base. We are closely working with oncologists and clinicians of a prominent cancer hospital to deploy the tool for Head and Neck Cancer diagnosis and treatment recommendations.

I. INTRODUCTION

There is substantial evidence that CDSSs are beneficial and assistant to clinicians in diagnosing and therapeutic decisions of patients [1]. Few of the important features of CDSS are shareable knowledge and integration with other systems. Healthcare standards (HL7, SNOMED, vMR, Arden Syntax) play pivotal role in achieving these objectives. Several efforts have been made to adopt these standards for shareable knowledge [2]. All these efforts have substantial success in development of shareable knowledge base, but lack facilitating the actual stakeholders (clinicians). Many existing approaches provide complex knowledge creation environment by involving clinicians too much in standard specifications related technical details. Keeping in view the preferences of clinicians, we developed CDSS called Smart CDSS that provides baseline infrastructure for sharable knowledge base to provide recommendations. Smart CDSS initial version provides recommendations to diabetes patients in home health environment [2]. It was observed that the system is lacking clinicians' involvement which is the key for the success of any CDSS. Therefore, we extended the Smart CDSS architecture by introducing an authoring tool that facilitates clinicians in developing the knowledge contents by themselves. This will help to assist clinicians in decision making process during diagnoses and treatment of HNC patients. Moreover, Smart CDSS has been integrated into home health environment to assist the elderly people and patients by providing useful recommendations. The treatment guidelines and recommendations are generated by reasoning on expert's knowledge in clinical knowledge base. Smart CDSS has a key component as knowledge base for maintaining the knowledge of domain experts. The knowledge base creation and enhancement in a traditional way is very tedious and time consuming for clinicians and knowledge engineers [2][3]. It requires extensive meetings among software developers and clinicians and needs complex programing [3].

Clinicians have lack of time to maintain and enhance the knowledge base using complex knowledge authoring tools. Knowledge base development and its maintenance is one of the key barriers in adoption of CDSS. To overcome complexity of authoring tools and facilitating clinicians we proposed an easy to use Authoring Tool as an integrated component of Smart CDSS. The Authoring Tool assists the expert clinicians to encode their domain knowledge and maintain it according to standard specifications for sharing purpose. Smart CDSS will use this knowledge base to make decisions and generate guidelines using Knowledge Inference Engine [4].

Sharing, reusability and maintenance are the key aspects of CDSS and are the main challenges for developers to fulfill [5]. In order to achieve these objectives, different standard initiatives are established to standardize the knowledge base. Arden Syntax is one of the standard languages developed by HL7 to represent the medical knowledge and evidences. Arden Syntax represents each unit of medical logic in coherent unit called Medical Logic Module (MLM) [6]. Knowledge base for a particular domain contains all relevant MLMs. Representation of clinical knowledge base also requires use of standard terminologies such as SNOMED CT.

We provide the SNOMED CT medical ontology at user interface level for creating rules. SNOMED CT is an international standard, has multilingual support and contains more than 311,000 active concepts [7]. Using the related concepts, clinicians create the rule which is validated with standard format of MLM. The valid MLM stored to MLM Repository and the code builder generates executable code of C Sharp language classes for that MLM. Afterwards the executable files are saved into executable knowledge base. MLM Repository is easily sharable with all HL7 compliant medical institutions.

II. RELATED WORK

There are many existing systems in literature focusing on development of authoring tools in the area of CDSS. A. Soumeya et al. [1] presented a UMLS based knowledge acquisition tool for CDSS. This tool allows the clinical

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experts to build and maintain clinical knowledge base in systematic manner. Although the tool provides benefits to clinical experts but it is not an easy to use tool for the clinicians due to more focus on intermediate phases to create a single rule. The phases include clinician to create domain ontology using UMLS browser initially, then selecting all related concepts for creating rule, and finally organizing an ascending order list to create actual rule. These phases put a lot of burden on the already burdened clinicians.

Nathan C. Hulse et al. [8] proposed Knowledge Authoring Tool architecture and uses CDA standard for sharable and reusable information documents. The complexity of the system is increased because the executable information is also embedded in CDA format. Relationship of multiple CDA for a single patient makes processing more complex. CDA is a preferable approach for sharing data only, but is not a suitable choice for sharing knowledge rules. Dustin Dunsmuir et al. [3], developed a Knowledge Authoring Tool by using a valuable Pattern And Outcome approach. This authoring tool is used in CDSS for anesthesia but its scope is limited and difficult to extend to other diseases. Also clinicians are directly exposed to work in XML file, requiring extra tedious task of XML training. Robert A. Jenders et al. [5] implemented standard based knowledge editor architecture which is used for knowledge dissemination and knowledge base sharing. Understandability of the system is difficult for clinicians and common users due to selection of appropriate object from the vMR standard data model. The end user can only use the system if they have fair knowledge about vMR standard and MLM structure.

Rachel Regier et al. [9] proposed a clinical rule editor for EMR, developed for knowledge and rule management. Also, its purpose is to remove difficulty of editing hard coded rules. To create a single reminder needs more than one primitives, and the creation of these primitives are fully dependent on software and knowledge engineers. The existing systems discussed in this section worked on rule creation using authoring tool. Although these initiatives reflect considerable efforts in the area of authoring tools development but still lack in facilitating clinicians in easy to use system. Our proposed system maintains higher priority on easy to use system for clinicians by hiding unnecessary and complex technical details of standards specifications.

III. Architecture And Methodology

A. Architecture

The proposed architecture for Authoring Tool of the Smart CDSS, shown in Figure 1, consists of four main components; *Rule Editor*, *Rule Validator*, *Compilation Module* and *Executable Environment*.

- *Rule Editor*: Rule editor provides user friendly and easy to use interface to clinician for creating and editing rules. It loads the SNOMED CT domain ontology to the editor. Example includes concepts of particular domain
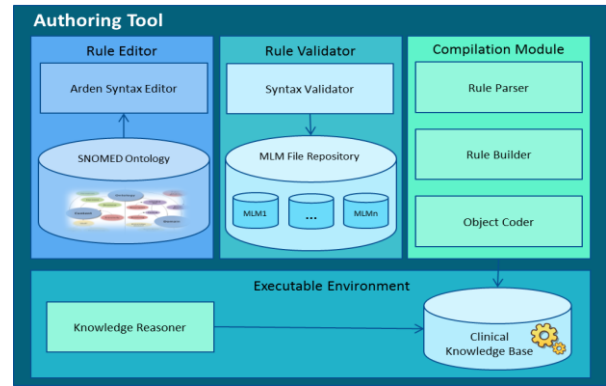

Figure 1: Architecture of Authoring Tool for Smart CDSS

such as HNC are loaded and become part of a logic module. The Rule Editor provides several GUI artifacts that use various construct of HL7 Arden Syntax. Example of constructs includes "IF-THEN", logical operators and clinical observations representing HL7 vMR clinical statements.

- *Rule Validator*: It allows validating different constructs of logic against schema of HL7 Arden Syntax specification. After validation it creates equivalent MLM having valid construct derived from HL7 Arden Syntax specification. The newly developed MLM is stored in MLM File Repository.

  MLM File Repository is used to store domain specific MLMs. The main purpose is to enable cross organization sharing of clinical knowledge.

- *Compilation Module:* This module is further divided into three sub modules. The *Rule Parser* tokenizes the valid MLM into different sub categories such as *maintenance*, *library* and *knowledge,* which represent standard structure of MLM.

  Rule Builder consumes the tokenized MLM and builds the executable code for the generated MLMs to run in the real environment of CDSS. We are considering C Sharp language classes as executable files.

  The *Object Coder* compiles the C Sharp language MLM classes into executable Clinical Knowledge Base (CKB). This MLM is then made part of CKB and executed by inference engine for related events.

- *Executable Environment:* It contains the repository of executable knowledge in the form of executable MLM rules. These MLM rules are used in real executable environment of Smart CDSS by Knowledge Inference Engine to make decisions and generate recommendations for patient diagnosis and treatment [4].

B. Methodology

Clinicians use the *Rule Editor* to create rules for diagnosis and treatment of HNC patients. The *Rule Editor* provides a very easy to use interface for creating rules. SNOMED CT ontology is used to facilitate clinician in creating rules using

standard terminologies. For example, concepts of HNC are loaded for constructing MLM related to treatment of patients. The *Rule Validator* validates clinician rule against HL7 Arden schema. After successful validation, a valid MLM instance is created. *Rule Validator* verifies the syntax of the created MLM for various Arden Syntax constructs specified in standard schema. The valid MLM instance created is stored in the *MLM File Repository* for sharing purpose with other clinical communities. Moreover, one copy of created MLM is transferred to *Compilation Module* for further process. *MLM File Repository* contains shareable MLM that can exchange with other organizations.

In Compilation Process, Arden Syntax MLM is tokenized into sub-categories i.e. *maintenance*, *library* and *knowledge* by *Rule Parser*. This categorization helps in recognizing the logical and executable part of MLM for other tasks. *Rule Builder* sub-module builds and transforms the rule into executable file of C Sharp language classes. This module manipulates the executable code in C Sharp language that is generated from the *logic* part of MLM. This further implements the main logic of rule to be used in Smart CDSS. *Object Coder* compiles the source MLM C Sharp language classes into object code and save it to the Smart CDSS executable environment, known as Clinical *Knowledge Base*.

Executable environment include knowledge inference that schedule all MLMs relevant to intervention of the Smart CDSS [2].

We handle the clinical database linkage to MLM by using HL7 standards CDA and HL7 vMR. MLM fetches related data from HL7 CDA through standard interfaces specified in HL7 vMR standard. The tool hides the complexity of HL7 CDA and HL7 vMR by incorporating easy to use GUI controls for constructing query part of HL7 Arden Syntax. This complexity is resolved by mapping service called Interoperability Engine [2,10,11]. Figure 2 shows the workflow of a rule creation by clinician.

IV. DESIGN OF AUTHORING TOOL

In this section we elaborate detail design of the proposed system.

Figure 3 depicts the interaction model for Rule Editor where OpenRuleEditor() opens the rule editor for clinician to create/edit a specific rule. The LoadSNOMEDOntology() loads SNOMED CT ontology and the CreateRule() function save the rule after validation process.

Figure 4 shows the interaction model of *Rule Validator* to validate the rule before saving into repostiry and passing to compiler for further processing. The physicain directly checks the rule by CheckValidation() function and internally the Rule Edit controller validates rule by ValidateRule() function that checks all input fields according to the criteria of fields validation. The Comparison() function compares and validates syntax of MLM against standard schema of HL7 Arden Syntax. MLM is saved to MLM repository by SaveMLMToRepository() function after successful validataion.
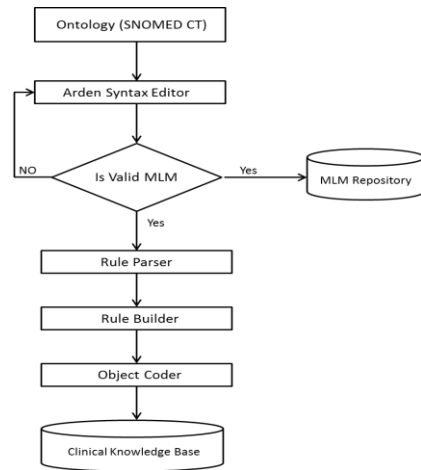

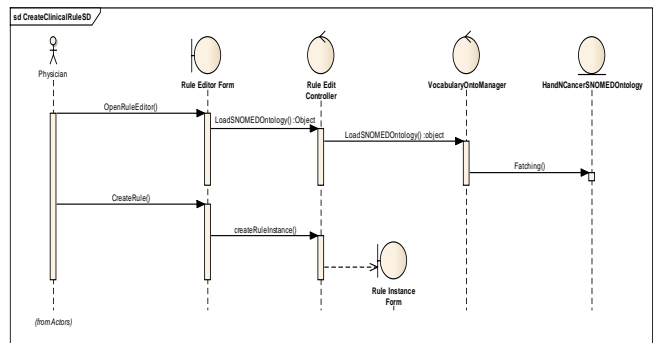Figure 2: Flow Chart of Authoring Tool for Smart CDSS

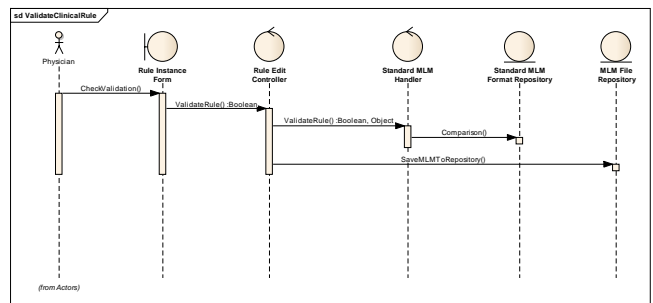Figure 3: Rule Editor in Authoring Tool Sequence diagram

Figure 4: Rule Validator in Authoring Tool sequence diagram

Figure 5 explains the sequence of *Compilation Module*. After successful validation, the rule is saved by SaveRule() function. The parseMLM() function parses MLM in *maintenance*, *library* and *knowledge* categories. After parsing MLM, the knowledge part of MLM transform to executable code of C Sharp executable programing language by the function GenerateExecutableCode() function. Finally a function named SaveExeFileToKnowledgeBase() saves object code file to clinical knowledge base.
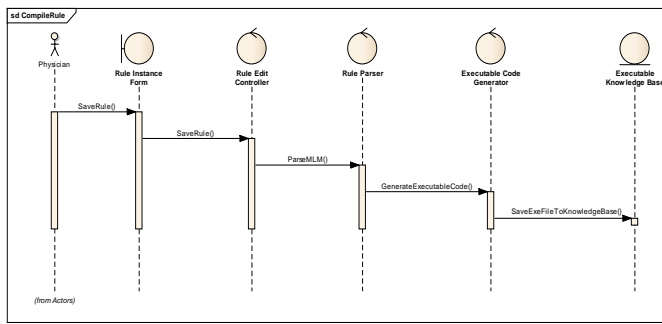
Figure 5: Compilation Module in Authoring Tool sequence diagram

Rules stored in clinical knowledge base are executed for utilization in decision making and recommendations generated by Smart CDSS. Knowledge Inference Engine of Smart CDSS takes decision to trigger required rules. Figure 6 depicts classes involve in development of Authoring Tool, class RuleEditHandler handles the main functionalities of editing rule, validating rule, creating MLM files, saving MLM to repository, compiling rule and storing executed files in *Clinical Knowledge Repository.* To perform all these functionalities, it uses different sub classes like; OntologyManager class loads ontology, MLMHandler class validates the MLM and saves to the *MLM File Repository,* RuleParser Class parses the MLM file into different categories.

V. CONCLUSION AND FUTURE WORK

An easy to use knowledge authoring tool is considered to be an integral part of CDSS. The user friendly standard compliant Authoring tool helps in developing shareable and reusable clinical knowledge base. Moreover, it overcomes the barrier of adopting CDSS as it provides clinicians with developing HL7 Arden Syntax rules from the clinical concepts visualized in natural and easy to use manner.

Current work is focusing on .Net technologies with MLM transformation into C Sharp classes. The underline architecture is technology independent and CKB can be extended to other object oriented languages such as Java. In addition to overcome complexity of standards such HL7 CDA, the solution will also be extended to adopt the Green CDA implementation.
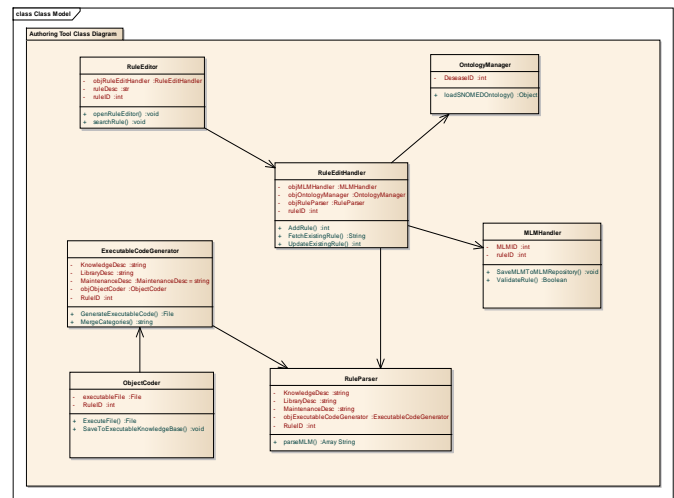
ACKNOWLEDGEMENT

Figure 6: Class diagram of Authoring Tool in Smart CDSS

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