Arden Syntax Studio: Creating Medical Logic Module as Shareable knowledge

Taqdir Ali
UC Lab, Department of Computer Engineering, Kyung Hee University, South Korea,
Email: taqdir.ali@oslab.khu.ac.kr

Maqbool Hussain
UC Lab, Department of Computer Engineering, Kyung Hee University, South Korea,
Email: maqbool.hussain@oslab.khu.ac.kr

Wajahat Ali Khan
UC Lab, Department of Computer Engineering, Kyung Hee University, South Korea,
Email: wajahat.alikhan@oslab.khu.ac.kr

Muhammad Afzal
UC Lab, Department of Computer Engineering, Kyung Hee University, South Korea,
Email: muhammad.afzal@oslab.khu.ac.kr

Byeong Ho Kang
School of Computing and Information Systems, University of Tasmania, Australia,
Email: Byeong.Kang@utas.edu.au

Sungyoung Lee
UC Lab, Department of Computer Engineering, Kyung Hee University, South Korea,
Email: sylee@oslab.khu.ac.kr

***Abstract*—Clinical Decision Support Systems assist the physicians to make critical decisions during the diagnosis and treatment of the patients. CDSS envisions an extendable, shareable and reusable knowledge base to generate shareable guidelines and recommendations. Existing systems utilize HL7 standard Arden Syntax MLM and data model vMR schema for shareability and interoperability purpose. Understanding the Arden Syntax and vMR schema classes is tedious task for physicians, therefore an easy to use knowledge authoring environment is required to overcome the barrier of acquiring clinical knowledge. We are presenting Arden Syntax based authoring environment called Arden Syntax Studio that provides an easy to use interface to the physicians for creating shareable MLM without understanding the HL7 standard Arden Syntax. The created MLM can easily integrate with other healthcare systems by using HL7 standard data model vMR. The system hides the vMR layer from physicians by replacing vMR schema class's layer with corresponding understandable healthcare system's concepts. Therefore, the physician does not need to learn and understand complete Arden Syntax and vMR data model to create shareable rules in form of MLM. The system also provides the Intelli-sense functionality to enhance the knowledge rule creation process and reduce the possibilities of physician's errors. Furthermore, to enhance the interoperability feature our system capitalizes standard terminologies of the SNOMED CT concepts. The terminologies that are specific to organization, environment or region are handled with localized concepts in addition to SNOMED CT concepts.**

Keywords—Arden Syntax; vMR data model; Domain Ontology; Intelli-sense functionality; User friendly; Authoring Environment

I. Introduction

In health care systems, the Clinical Decision Support System (CDSS) has high prominence to support and assist physicians and other health professionals in making decisions during patient care [1][2]. A typical CDSS consists of three parts, a) *medical knowledge base* b) *inference engine* and c) *communication mechanism* [3]. The worth of medical knowledge base increases by the shareability aspects with other clinical institutions. The shareability feature of knowledge base can be realized by using standard knowledge representation units of Medical Logic Modules (MLMs) that are created with HL7 Arden Syntax [4]. Arden Syntax is HL7/ANSI standard specifications, designed specifically for defining and sharing medical knowledge among clinical communities [6][7].

A single MLM consists of three main categories; *maintenance*, *library* and *knowledge* [5][6]. These are used to represent medical knowledge in the form of Arden Syntax artifacts. The *knowledge* category of MLM contains the basic logic and conditions of guidelines that generate recommendations and alerts. Mostly physicians interact with this critical part of MLM. The intention of HL7 Arden Syntax standard is to enable physicians to transform the clinical knowledge into MLMs which are easily understandable by physicians and also executable by computer system [7]. Despite the fact of HL7 Arden Syntax as friendly representation for physicians, still most of them feel uncomfortable to represent their knowledge. This barrier blocks the knowledge acquisition and adaption of health care standards in medical institutes and thus results in increased medical costs.

From shareability perspective, it has been witnessed that most of knowledge acquisition tools are not successfully adopted due to minimal support of compliance to clinical information models and associated terminologies [8]. The CDSS community has recognized that a common information model would be of great value and this information has been referred to as virtual medical record (vMR) [9][10]. The main objective of HL7 vMR project is to provide a standard information model for representing clinical information for scalable and interoperable clinical decision support systems [9]. Furthermore, various terminologies are exists that can be incorporated in data of CDSS to enhance the interoperability and understandability of the system [9]. SNOMED CT is one of the standard terminologies that provide more than 0.3 million medical concepts [11]. These concepts are easily understandable for the physicians and medical practitioners worldwide as it comes with multi-lingual support. [5][11].

In this paper, we extend our previous work [5] by focusing on user friendliness of *Rule Editor*. In *Rule Editor,* the physicians create rules using the standard information model HL7 vMR with standard terminologies of SNOMED CT concepts and different artifacts of HL7 Arden Syntax. Initially, we provided physicians with the prototype version of our system, and they were uncomfortable with vMR and Arden Syntax concepts and were at ease with SNOMED CT concepts. However, learning and memorizing HL7 Arden Syntax artifacts and all schema classes with their attributes of vMR data model is tedious task for physicians. Therefore, acquiring shareable knowledge needs a tool that helps the physicians to create shareable MLM but hides the complex layers of Arden Syntax artifacts and vMR data model. The Rule Editor in [5] is further enhanced with sub components that include Arden Syntax Studio which covers the scope of this paper.

The *Arden Syntax Studio* provides a user friendly interface to physicians for rule creation. A higher layer of abstraction is provided by hiding the technical details of vMR schema for physician's understandability. This is achieved by introducing a layer that has semantic knowledge of Health Management Information System (HMIS) concepts and vMR schema layer. The familiarity of physicians with HMIS concepts makes its use easy for them for knowledge creation. In similar way, complex artifacts of HL7 Arden Syntax have been transformed into understandable labels. Furthermore, the Arden Syntax Studio provides the Intelli-sense like functionality to provide all the related SNOMED CT concepts according to the vMR schema class behind selected HMIS concept. All the related SNOMED CT concepts display in a list to the physician and allow the physician to select single, appropriate and preferred concept. It increases the recall ability of physicians to use SNOMED CT concepts in creating rule, and also decreases the ratio of physician's errors while transforming their knowledge into the knowledge base.

Rest of the paper is structured as: Section 2 explains existing systems that utilizes HL7 standards for knowledge creation. Section 3 discusses the methodology of the system by explaining the detail of internal components of the proposed system. Section 4 explains a case study while section 5 provides some discussion on the strengths and limitations of the proposed system. In the end, section 6 concludes the paper.

II. RELATED WORK

Existing systems in the literature have utilized authoring of rules in form of Arden Syntax MLM. Jenders, R. A. et al. [12] proposed an easy to use tool for creation of MLMs. It provides three phases for development of single MLM. In first phase the system creates and composes the *Library* category of the MLM, it maintains the information about the author, specialist, MLM purpose and keywords. In second phase the user composes the logic part of the rule using controlled vocabulary and conditional operators. In third phase the user specifies the decision of the rule as output message. This system provides a systematic way to compose the MLM, but the controlled vocabulary and the structure of rules are limited to conditional operators only. The controlled vocabulary and support for limited set of operators narrows down the use of the system to a single organization.

Enhanced version of this work is presented in [13], the authors achieved goals of bibliographic linkages and standardized database linkages. The system sends the query request to PubMed server and retrieves the related articles. The selected references add to Arden Syntax Knowledge Editor in appropriate slots of MLM. The users may select appropriate object from the data model vMR and query will be executed using the selected vocabulary. This improved version of the system resolved the limitation of database linkages up to some extent but still lacks complete interoperability. It is because the system is not using the concepts of any standard terminologies. A. Soumeya et al. [14] describes a rule editor for clinicians that creates MLMs for knowledge base with standard Arden Syntax format but its use is difficult for clinicians due to intermediate phases of ontology selection. The system does not use any standard data model for external database linkages. It only covers some specific artifacts of standard Arden Syntax and requires help of expert physicians for solving the redundancy and conflicts issues in MLMs.

M. Samwald et al. [15] presents the detailed implementation of Arden Syntax based clinical decision support system to handle a wide variety of clinical problem domains like hepatitis serology interpretation, monitoring nosocomial infections and melanoma patients. The authors explain development environment, compiler, rule engine and application server for Arden Syntax. The system used a standardized interface of vMR for integrating with external databases of medical information system. But the Arden Syntax IDE is used by the experts with localized terminologies to create MLM. The use of local terminologies instead of standard terminologies reduces the interoperability of the system and enhances the difficulties of integration of the system with other organizations.

Nathan C. Hulse et al. [16] proposed an XML-based flexible authoring environment to the physicians for acquiring knowledge into knowledge base. The authors have used Clinical Document Architecture (CDA) format for sharing the rules among clinical communities. Using CDA enhance the complexity of system because the executable statements are also embedded into CDA and relationships among more than one CDA for a single patient results in the complexity of processing. CDA is recommended and standard format for sharing data; it is not a preferable choice to share the rules [5]. It is because the rules in CDA format are only shareable with CDA compliant organizations. The system does not use any standard terminology concepts in creating rules, avoiding the use of standard terminology which decreases the level of interoperability.

III. METHODOLOGY

We presented the overall architecture of I-KAT in our previous work [5] as shown in *fig 1*. It shows the abstract view of I-KAT

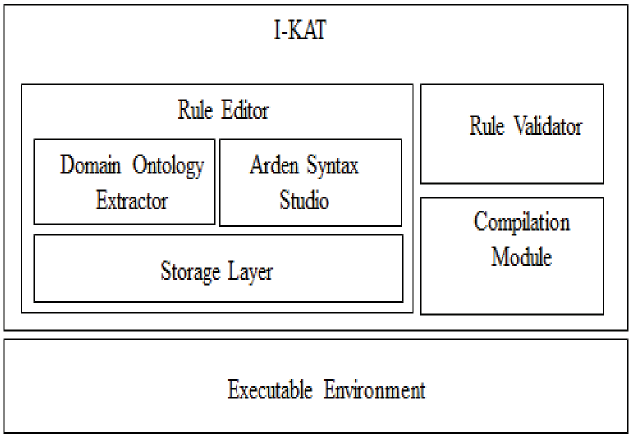

Fig. 1. Abstract architecture of Intelligent Knowledge Authoring Tool [5]

and highlights three main modules *Rule Editor*, *Rule Validator* and *Compilation Module*. *Rule Editor* has three sub modules *Domain Ontology Extractor*, *Arden Syntax Studio* and *Storage Layer*. The sub module *Domain Ontology Extractor* [17] extracts the domain concepts from the whole SNOMED CT ontology to enhance the Intelli-sense searching process. The extracted domain ontology provides the standard concepts to the *Arden Syntax Studio* that is used by physicians to create rules. The rules are validated by *Rule Validator* and the valid rules persist in the MLM repository [5]. The MLMs contained in MLM repository can easily be shared with other clinical organization for reusability. To execute these MLMs by Smart CDSS [18], the *Compilation Module* builds and compiles the MLM and persists into the clinical repository in an executable environment for execution [5]. The main focus of this paper is internal working of *Arden Syntax Studio* that provides a user friendly interface to physicians for acquiring their knowledge into the knowledge base.

Fig. 2 depicts the extension of I-KAT architecture by focusing on core components of *Arden Syntax Studio*. The *User Interface* provides authoring environment to physicians with the help of two separate tool boxes of Arden Syntax artifacts and the concepts of different legacy systems like Hospital Management and Information System (HMIS). The vMR schema classes are not easily understandable by physicians; therefore we establish mappings between HMIS customized terms and vMR concepts. The mapping provides higher level abstraction and hides the vMR concepts layer from physicians and shows the HMIS concepts to physicians that are mostly understandable for them.

The *Arden Artifacts Controller* provides frequently usable artifacts of standard Arden Syntax provided by HL7 community [19]. These artifacts and language syntax of the standard Arden Syntax are specially designed for authoring the clinical knowledge in standard format of MLM. This facilitates the physicians to write down the rules with use of maximum number of Arden artifacts. These artifacts are categorized in control structures like IF, THEN, ELSE, END IF, WHILE, FOR and others. Some artifacts are listed under the logical operators category like AND, OR, NOT. Similarly comparison operator category includes comparison operators, some of them are GREATER THAN, LESS THAN, and EQUAL. This controller also handles the temporal operators such as AFTER, BEFORE, TIME OF DAY, and AGO.

The *vMR Controller* substitutes the vMR schema concepts with understandable HMIS concepts by visualizing them in toolbox to the physicians. The *vMR-HMIS Mapper* module in the *Ontology Mapper* layer performs mapping between the vMR concepts and HMIS concepts. Both of these types of concepts are stored in *vMR Ontology* and *HMIS Ontology* respectively at *Storage* layer. Currently, we have mapped the HMIS (developed for Head and Neck Cancer) concepts and vMR schema concepts and verified the mappings from the physicians and certified experts of HL7 standards. Table I shows some of the mappings between the concepts of HMIS and corresponding vMR schema concepts. After verification of these mapping the mapped concepts are stored into *vMR-HMIS Mapping* repository.

The *Intelli-sense Controller* facilitates the physicians to recall and use the SNOMED CT concepts in rule creation at run time. The Intelli-sense functionality enhances the efficiency of rule creation process due to quick selection from set of recalled concepts. It also minimizes physician's errors in knowledge rules creation process. To achieve the Intelli-sense functionality the *Intelli-sense controller* uses *vMR SNOMED Mapping* repository, *Query Manager*, *vMR SNOMED Mapper*, *Domain Ontology* and *vMR Ontology*. *vMR SNOMED Mapper* provides mapping between the vMR schema concept behind the physician's selected HMIS concept and the top level

TABLE I. SOME MAPPING BETWEEN HMIS CONCEPTS AND VMR CONCEPTS

HMIS Concepts	**vMR Schema Concepts**	**Purpose**
Site/Subsite	BodySite	A body site affected by some adverse event.
Treatment	ProcedureBase	Procedure is a series of steps taken on a subject to accomplish a clinical goal.
Clinical/Pathology Staging	ObservationBase	Observation is the act of recognizing and noting a fact.
Disease/Head and Neck Cancer	ProblemBase	Abstract base class of problems, which are clinical conditions that need to be treated or managed
Current Event	EncounterBase	Abstract class for an encounter of an EvaluatedPerson with healthcare system

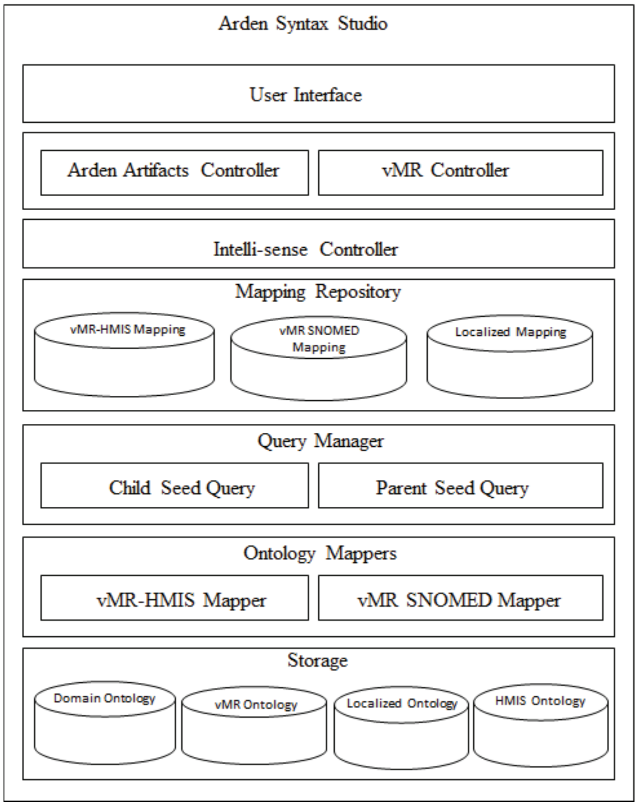

Fig. 2. The internal architecture of Arden Syntax Studio

SNOMED CT concept. Each vMR concept maps with at least one top level concept of SNOMED CT [17]. This mapping identifies the scope and boundary of possible values of selected vMR schema concept from the corresponding SNOMED CT hierarchy. These mapping are used from our previous work of domain ontology extractions [17]. For example the vMR schema class "ObservationBase" has three attributes "observationFocus" that maps with SNOMED CT's top concepts "Clinical Finding" and "Observable Entity", similarly the second attribute is "observationMethod" that maps with SNOMED CT's top concept "Procedure", likewise the attribute "targetBodySite" maps with "Body Structure" [17]. Therefore, the *vMR SNOMED Mapper* provides mapping between top level concepts of SNOMED CT and attributes of vMR schema classes. These mapping are generated from *vMR Ontology* and *Domain Ontology* matching and persists these mappings in *vMR SNOMED Mapping* repository. Some concepts are localized and belong to some specific locality or some specific organization, therefore are stored in the *Localized Mapping* repository.

The *Query Manager* creates *Child Seed Query* and *Parent Seed Query* likewise our previous work [17]. The only difference in this case is the *Query Manager* creates query for a single seed concept because physician selects single concept at a time and recalls the related concepts from corresponding single hierarchy. For example when physician select "targetBodySite" vMR schema class's attribute; the Intelli-sense only shows concepts form "Body Structure" hierarchy of SNOMED CT domain ontology. The *Parent Seed Query* is usually same as the top level concept of SNOMED CT i.e. "Clinical Finding", while the *Child Seed Query* is created for any seed concept. Each parent seed concept has a single child seed concept like "Head and Neck Structure" is seed concept under the parent seed concept "Body Structure". Currently, we have defined the child seed concepts with the help of physicians. The *Query Manager* runs the SPARQL query according to these parent seed and child seed concepts and fetches the child concepts of the child seed concept from particular hierarchy. This hierarchy is specified in parent seed concept and all fetched concepts are presented to the physician on *Arden Syntax Studio*. Sometimes the physician wants to write a concept that does not exist in *Domain Ontology* then system searches that concept from *Localized Ontology*. In section IV we show the complete workflow of *Intelli-sense Controller* with the help of *Query Manager*, *Mapping Repository* and *Ontology Mappers*.

IV. Intelli-sense Case Study

For proof of concept a case study is presented in this section with the help of Intelli-sense workflow as shown in *fig 3*. The physician interacts through "User Interface" for rule creation. The physician selects the Arden Syntax artifacts and HMIS concepts from the corresponding tool boxes and writes down the rule in the editor box as shown in Table II. Physician selects IF structure control from the Arden Syntax artifacts tool box and "Clinical Staging" from the HMIS concepts tool box. When physician selects equal sign from artifacts then the Intelli-sense control fetches all the possible values of the left side term of equal sign from SNOMED CT domain ontology. Here the term is "Clinical Staging" and it's possible values from SNOMED CT are T1-3, N1-3, T4a and some others. In same way, when physician selects HMIS concepts "Treatment" after AND operator and selects equal sign then the Intelli-sense fetches all possible values of "Treatment". The terms "Clinical Staging" and "Treatment" both are HMIS understandable concepts to physicians. In created MLM these HMIS concepts will be substitutes with corresponding vMR schema classes by vMR Controller. The *vMR Controller* substitute the concept "Clinical Staging" with corresponding *vMR Concept* which is "ObservationBase". Then *vMR SNOMED Mapper* maps this concept with top level concepts of SNOMED CT using the *vMR Ontology* and *Domain Ontology*. In this case the vMR schema class "ObservationBase" maps with "Clinical Finding". After finding decision the corresponding mapped top level SNOMED CT concept is sent to *Query Manager*. If the mapping doesn't exists in the *vMR-SNOMED Mappings*, then the search query is forwarded to *Localized Mappings*. Localized Mappings can also face the situation of non-availability of mappings, otherwise corresponding mappings are retrieved from the repository. If mapping doesn't exist in *Localized Mappings* then physician enters the mapping in the *Localized Mappings* and then these new mapped concepts proceeds for further processing to the *Query Manager*.

The *Query Manager* considers the received concept as parent seed concept and provides the corresponding child seed concept in the form of *Child Seed Query*. Then *Query Manager* sends a SPARQL query with input arguments of parent seed

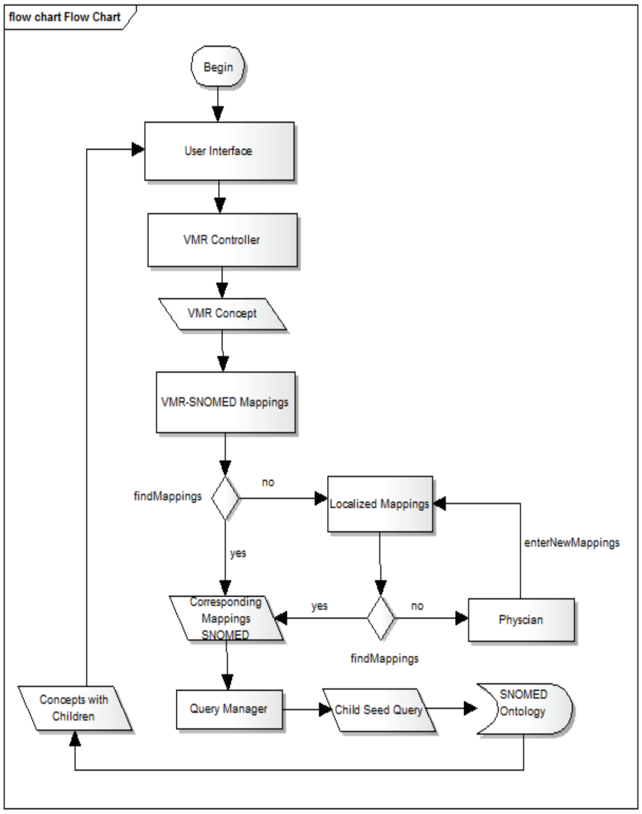

Fig. 3. Internal workflow of Intelli-sense Controller

TABLE II. SAMPLE RULES

Example 1
IF Clinical Staging = T1 AND Treatment = Chemotherapy
And Comorbidities = Yes
THEN Treatment = Radiotherapy
ELSE Treatment = Surgery END IF
Example 2
IF Clinical Staging = T3 OR Clinical Staging = T4a
And Surgical Evaluation = Benign
Then Treatment Plan = Next Follow-up
Example 3
IF (Patch on gums = Yes
Or Patch on tongue = Yes)
And (Pain in Mouth = Yes
Or Bleeding in Mouth = Yes)
And (swelling of Jaw = Yes)
Then diagnose = Cancer in Oral Cavity

concept and Child seed concept to domain ontology. The ontology is searched for the child seed concept in the specified hierarchy in form of parent seed concept. In this case the child seed concept is searching in "Clinical Finding" hierarchy only, and ignores all the remaining hierarchies of Domain Ontology. It fetches all the child concepts and displays to physician for selecting the appropriate concept. This procedure is followed for the Intelli-sense after equal "=" operator on base of vMR class behind the selected HMIS concept.

Similarly physician selects the AND operator from tool box of arden artifacts and then selects a "Treatment" concept from HMIS concepts tool box. With same procedure the system finds the corresponding vMR schema class of "Treatment" that is "ProcedureBase". Again the *vMR SNOMED Mapper* finds the mapping concept of "ProcedureBase" in top level concepts of SNOMED ontology, it maps with "Procedure" concept. With same procedure the *Query Manager* creates queries accordingly and searches the children in "Procedure" hierarchy and show all the fetched concepts to physician. Here the selected concept is "Chemotherapy", it comes under the hierarchy of "Procedure". The system follows the same procedure for all the slots of rule like THEN and ELSE part. Finally, the physician creates the rules based on his/her knowledge with easy to use interface. This Intelli-sense reduces the possibility of errors during creation of rules.

V. DISCUSSION

Arden syntax MLM is designed for sharing knowledge and HL7 community developed this standard syntax for physicians to write rules and easily share with other clinical communities. But physician tends to avoid using this syntax as it is time consuming and tedious job to learn the complexities of this syntax. Our system provides an authoring environment for physicians that create rules in standard format of Arden Syntax MLM. This system hides the complexity of the standard from physicians and allows them to interact only with usable Arden artifacts. But there are some Arden artifacts in specification which are difficult to understand for physicians. Therefore, a simple and understandable high level abstraction layer is required to use instead of complex Arden artifacts. It will hide the complex artifacts from physicians and will provide understandable alternative concepts.

Use of HL7 standard vMR schema in standard Arden Syntax MLM achieves the shareability and interoperability in system. vMR schema classes also help in Intelli-sense feature of the system. But vMR schema is not understandable for every physician; therefore our system provides a layer of HMIS concepts over the layer of vMR schema from the physicians, and these HMIS concepts are mostly understandable for physicians. Mostly clinical institutions are using same concepts as HMIS concepts in our system, but it may be possible that some institutions have little bit different concepts in their legacy systems. In this case, system needs a standard mapping mechanism to handle their specific concepts. Such type of mapping mechanism enhances the interoperability level of this system.

The specified seed concepts reduce the time complexity in searching relevant concepts from the domain ontology during the Intelli-sense process. If these seed concepts are more relevant to a particular domain then the output of Intelli-sense will have more coverage of the physician's desired concept. Currently, we have used the seed concepts that are verified by the clinical domain experts. An automatic extraction of seed concepts is needed to minimize physician's involvement during system's configuration.

Sometimes the physicians want to use some localized concepts that are specific to a particular region, clinical institution, or a particular environment, which are not available in the domain ontology. For maintaining such type of localized concepts our system provides a mechanism to persist into a *Localized Ontology*. Once those concepts become part of our system's *Localized Ontology* then it can be used for future interactions. This concept of *Localized Ontology* also enhances the searching functionality and reduces the chance of errors during rule creation.

The prototype version of this system is currently working for Head and Neck cancer domain, but the domain according to disease can change by changing the domain ontology that we can extract in [17]. This system can acquire knowledge for any MLM based clinical decision support systems. In different medical institutions, learning systems are using for the students learning and training phases. This tool can also use to acquire knowledge for the recommendation and MLM based learning and training systems.

VI. Conclusion and Future Work

We have discussed and elaborated the core part of user friendly authoring environment is presented in this research to enhance the clinical knowledge in the knowledge base for clinical decision support systems. The knowledge base basic features of shareability and interoperability is achieved by using the HL7 standard Arden Syntax MLM. Similarly, the use of standard data model of HL7 vMR and standard terminology of SNOMED CT has increased the shareability and interoperability of the knowledge base. On the other hand, the physicians usually avoid acquiring their knowledge due to difficulty in understandability of Arden Syntax and vMR schema classes. *Arden Syntax Studio* provides an easy to use authoring environment to hide the vMR schema layer and provides understandable concepts to use in rules authoring. This system also provides Intelli-sense to help the physicians in recalling the usable clinical concepts.

In future we will focus on the complexity of Arden Syntax artifacts and will provide a data model and mapping mechanism to handle such complexity. In this system we are facing a problem of handling the aggregate functions of Arden Syntax. We will provide some mapping systems to map the concepts of different legacy system like HMIS with vMR standard schema classes. We will also work to automate the extraction of seed concepts in future.

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