Unified model for representation of modality-specific CDS content

Clinical Decision Support Consortium

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Motivation

Currently, different CDS modalities[1] have their own knowledge representation schemes that vary significantly from each other in their form (e.g., compare Arden Syntax to the draft HL7 order set specifications). This creates two issues:

1. Inefficiencies due to multiple skills and expertise and tools required for knowledge engineering
2. Potential inconsistencies in the CDS knowledge across modalities within the same healthcare organization

Furthermore, the distinction in CDS modalities is getting blurrier as the features of different CDS modalities are enhanced. For example, an order set may be instantiated/recommended/triggered by a rule, a reminder can include context aware information resources, and those resources can include links back to actionable CDS such as order sets.
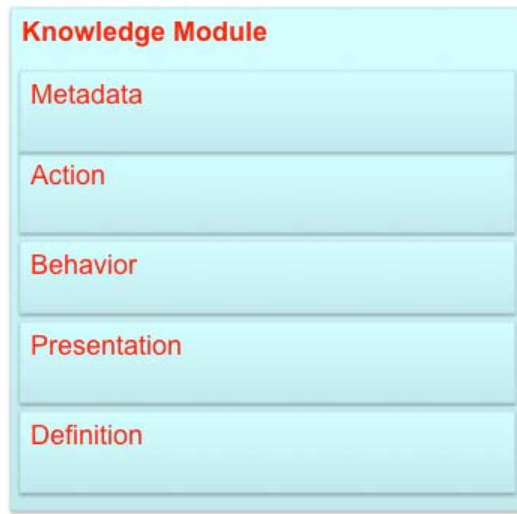
Model for Modality-specific Content

Building upon earlier work performed in the CDS Consortium and the Advancing CDS projects, we are developing a knowledge model that can represent content for a variety of CDS modalities. The model is based on the insight that all CDS modalities recommend assessments and actions based on the clinical context, and what differs among the modalities is how the context is realized and how actions and assessments are presented.

The knowledge model is illustrated in the figure below. The knowledge module element represents an instance of content for a CDS modality, e.g., an order set or a reminder rule. The key elements of the knowledge are behavior, action, and presentation. Behavior specifies the clinical context, and includes concepts such as triggers, rule logic, and value constraints. Actions and assessments (collectively referred to as actions in our model and in this document) are specified using the object model developed in the CDS Consortium. This allows us to create a structured specification for an executable action that can be implemented in an EMR or CPOE environment. The presentation element can model how
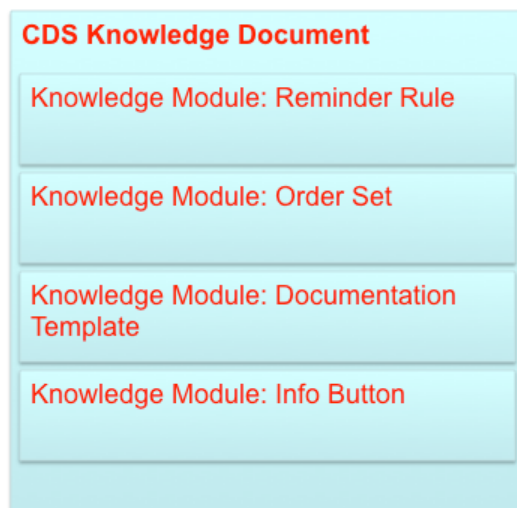
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[1] We define a CDS modality as a CDS intervention type such as an alert or reminder, an order set, or an infobutton.

actions are displayed to the target user. For example, we can model how actions can be grouped and sorted under headers in an order set.

Knowledge Module

- Metadata
- Action
- Behavior
- Presentation
- Definition

In addition these key elements, the knowledge module also contains a metadata element and zero or more definition elements. The latter provides a structured means to model ambiguous terms or terms that must be used consistently across knowledge modules. The definition element is used to represent value sets for example.

We have created an XML schema to represent this model. The root element of the XML file is a CDS Knowledge Document. This document can contain multiple knowledge modules of different modalities (as illustrated below). For example, a CDS knowledge document for diabetes management can contain a reminder rule for hemoglobinA1c measurement, and an order set with recommended medications, tests, and other actions for managing uncontrolled diabetes.

CDS Knowledge Document

- Knowledge Module: Reminder Rule
- Knowledge Module: Order Set
- Knowledge Module: Documentation Template
- Knowledge Module: Info Button

In order to allow the XML schema to represent multiple modalities, the model is necessarily very flexible. To support the creation of high quality CDS content, we constrain the contents of the XML based on the modality. To do so, we use an ISO standard called schematron to

create rules that require or disallow content elements, as appropriate for a knowledge element.

Feature coverage

Knowledge Components

Component	Support in CDSC Schema v3
Triggering	Modeled as behavior, needs minor work on trigger taxonomy
Logic	Modeled as behavior
Access to Input Data	Patient information model and GELLO select expressions
Access to Value sets	Modeled as Definition
Notification	MessageRequest object in Action model
Acknowledgement of notification	<mark>Not sure</mark>
The intervention presentation	
format (component elements)	Can model multiple actions, display order
displayed information	MessageRequest, textAlternative
Requests for additional user input	Modeled as ObservationRequest
Offered user actions	Model multiple actions and the ability to offer choices (1 of n, n of n)
User actions taken	Not a feature of knowledge representation scheme but of execution environment
User documentation	<mark>Not sure what is meant here</mark>
Tags for searching (topic, provenance, supporting organizations, etc.)	Metadata
Usage logging	Not a feature of knowledge representation scheme but of execution environment

Intervention types

Modality	Development progress
Immediate critiques and warnings (e.g., in response to an order – "immediate alerts")	Needs minor work on modeling trigger taxonomy
Event-driven or time-driven alerts and reminders	Needs minor work on modeling trigger taxonomy
Relevant data summary displays for a patient's conditions/events	Near completion
Orders/order sets and care plans	Completed – see example below

Parameter guidance (usually within ordering)	In progress
Smart documentation templates	Not started
Filtered reference information and knowledge resources	Completed – see example below
Diagnostic advice or expert workup guidance	==Would this be modeled as a rule? If so, then we are close to completion.==
Analytic calculations	In progress

Examples

Infobutton

```xml
<?xml version="1.0" encoding="UTF-8"?>
<?schematron-schema href="../schema/infobuttonconstraints.sch"?>
<CDSKnowledgeDocument xsi:noNamespaceSchemaLocation="../schema/cdsknowledge.xsd"
    xmlns:mif="urn:hl7-org:v3/mif" xmlns:sch="http://purl.oclc.org/dsdl/schematron"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" schemaVersion="3">
    <metadata>
        <coverage>
            <focus>taskContext</focus>
            <code displayName="Medication order entry" code="MEDOE"
                codeSystemName="HL7 V3 Coding Systems"
codeSystem="2.16.840.1.113883.5" />
            <description></description>
            <type>inclusion</type>
        </coverage>
        <contributor>
            <roleType>Developer</roleType>
            <organization>
                <name>Advancing CDS</name>
            </organization>
        </contributor>
        <identity>
            <title>Query Parameters:</title>
            <description>Medication-Related Patient Education Infobutton -
This artifact was based on Partners HealthCare System's KnowledgeLink Manager and
adapted from work done for ACDS project.</description>
        </identity>
        <implementation>
            <knowledgeType>Reference Information</knowledgeType>
        </implementation>
    </metadata>
    <knowledgeModule knowledgeElementId="15">
        <action xsi:type="KnowledgeAssetRequest" actionId="1">
            <resource>
                <knowledgeResourceType displayName="Patient Education"
                    code="311401005" codeSystem="2.16.840.1.113883.6.96"
                    codeSystemName="SNOMED Clinical Terms" />

    <location>http://www.thomsonhc.com/infobutton/librarian/access?mainSearchConcep
t</location>
                        <!-- ![CDATA
[http://www.thomsonhc.com/infobutton/librarian/access?mainSearchConcept=^^^^#queryText
#&contentTarget=C^HL70242^^^^&applicationContext=MedicationList^HL7IBAppContext^^^]]><
```

```xml
/location> -->
                    </resource>
                    <target code="116154003" codeSystem="2.16.840.1.113883.6.96"
                            codeSystemName="SNOMED Clinical Terms"
displayName="Patient" />
                </action>
                <presentationGroup>
                    <title>Micromedex DrugNotes</title>
                    <action>1</action>
                </presentationGroup>
        </knowledgeModule>
</CDSKnowledgeDocument>
```

Order Set

```xml
<?xml version="1.0" encoding="UTF-8"?>
<?schematron-schema href="../schema/ordersetconstraints.sch"?>
<CDSKnowledgeDocument xsi:noNamespaceSchemaLocation="../schema/cdsknowledge.xsd"
      xmlns:mif="urn:hl7-org:v3/mif" xmlns:sch="http://purl.oclc.org/dsdl/schematron"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" schemaVersion="3">
      <metadata>
            <identity>
                    <title>Obesity Management</title>
                    <description>Obesity Management: Obesity screening and management
assessment in patients between the ages of 18-65yo. Adapted to version 3 schema from
artifact created for ACDS schema</description>
                    <relatedResource>
                            <resource>
                                    <title>Screening for Obesity in Adults</title>
                                    <description></description>

      <location>http://www.uspreventiveservicestaskforce.org/3rduspstf/obesity/obesrr
.htm</location>
                            </resource>
                            <type>associatedResource</type>
                    </relatedResource>
            </identity>
            <implementation>
                    <knowledgeType>Order Set</knowledgeType>
            </implementation>
      </metadata>
      <knowledgeModule knowledgeElementId="23">
            <metadata>
                    <identity>
                            <title> Vital signs </title>
                    </identity>
            <implementation>
                    <knowledgeType>Order Set</knowledgeType>
            </implementation>
            </metadata>
            <action xsi:type="ProcedureRequest" actionId="1">
                    <procedureCategoryCode displayName="Taking patient vital signs"
                            code="61746007" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                    <procedureTypeCode displayName="Body height measure"
                            code="50373000" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                    <implementationTime>
                            <period value="0" unit="days" />
                    </implementationTime>
```

```xml
                            <textAlternative></textAlternative>
                </action>
                <action xsi:type="ProcedureRequest" actionId="2">
                        <procedureCategoryCode displayName="Taking patient vital signs"
                                code="61746007" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <procedureTypeCode displayName="Body weight measure"
                                code="363808001" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <implementationTime>
                                <period value="0" unit="days" />
                        </implementationTime>
                        <textAlternative></textAlternative>
                </action>
                <action xsi:type="EncounterRequest" actionId="3">
                        <encounterProvider displayName="Weight Monitoring"
                                code="307818003" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <encounterType displayName="Patient referral" code="3457005"
                                codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                                <textAlternative>Refer to Weight Management
Program</textAlternative>
                </action>
                <action xsi:type="EncounterRequest" actionId="4">
                        <encounterProvider displayName="Patient Referral to Dietician"
                                code="103699006" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <encounterType displayName="Patient referral" code="3457005"
                                codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <textAlternative></textAlternative>
                </action>
                <action xsi:type="EncounterRequest" actionId="5">
                        <encounterProvider displayName="Follow-up 1 month"
                                code="183623000" codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <encounterType displayName="Patient referral" code="3457005"
                                codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                        <textAlternative>Schedule 1-month Follow-up
Appointment</textAlternative>
                </action>
                <action xsi:type="KnowledgeAssetRequest" actionId="6">
                        <resource>
                                <title>Exercise Prescription</title>
                                <knowledgeResourceType displayName="Patient Education"
                                        code="311401005" codeSystemName="SNOMED Clinical
Terms" codeSystem="2.16.840.1.113883.6.96" />
                                <location></location>
                        </resource>
                        <target displayName="Patient" code="116154003"
codeSystemName="SNOMED Clinical Terms"
                                codeSystem="2.16.840.1.113883.6.96" />
                        <textAlternative>Exercise Prescription</textAlternative>
                </action>
                <action xsi:type="KnowledgeAssetRequest" actionId="7">
                        <resource>
                                <title>Weight Loss Education Leaflet</title>
                                <knowledgeResourceType displayName="Patient Education"
                                        code="311401005" codeSystemName="SNOMED Clinical
Terms" codeSystem="2.16.840.1.113883.6.96" />
```

```xml
        <location>http://www.nhlbi.nih.gov/health/public/heart/obesity/aim_hwt.pdf</location>
                        </resource>
                        <target displayName="Patient" code="116154003"
codeSystemName="SNOMED Clinical Terms"
                                codeSystem="2.16.840.1.113883.6.96" />

                        <textAlternative>Weight Loss Education Leaflet</textAlternative>
                </action>
                <action xsi:type="KnowledgeAssetRequest" actionId="8">
                        <resource>
                                <knowledgeResourceType displayName="Reference
Documentation"
                                        code="308911008" codeSystemName="SNOMED Clinical
Terms" codeSystem="2.16.840.1.113883.6.96" />

        <location>http://www.uspreventiveservicestaskforce.org/3rduspstf/obesity/obesrr
.htm</location>
                        </resource>
                        <target displayName="Physician" code="309343006"
                                codeSystemName="SNOMED Clinical Terms"
codeSystem="2.16.840.1.113883.6.96" />
                                <textAlternative>Screening for Obesity in
Adults</textAlternative>
                </action>
                <presentationGroup>
                        <title>Vital Signs</title>
                        <action>1</action>
                        <action>2</action>
                </presentationGroup>
                <presentationGroup>
                        <title>Referrals/Consultations</title>
                        <action>3</action>
                        <action>4</action>
                        <action>5</action>
                </presentationGroup>
                <presentationGroup>
                        <title>Patient Education</title>
                        <action>6</action>
                        <action>7</action>
                </presentationGroup>
                <presentationGroup>
                        <title>Physician Resources </title>
                        <action>8</action>
                </presentationGroup>
                <behavior xsi:type="ConstraintTerm">
                        <appliesTo>

        <knowledgeElementType>KnowledgeModule</knowledgeElementType>
                        </appliesTo>
                        <constraintType>ApplicableScenario</constraintType>
                        <applicability>
                                <focus>patient</focus>
                                <code displayName="Adult" code="133936004"
codeSystemName="SNOMED Clinical Terms"
                                        codeSystem="2.16.840.1.113883.6.96" />
                                <description>patient</description>
                                <type>inclusion</type>
                        </applicability>
                        <applicability>
                                <focus>careSetting</focus>
                                <code displayName="Outpatient" code="373864002"
codeSystemName="SNOMED Clinical Terms"
```

```xml
                            codeSystem="2.16.840.1.113883.6.96" />
                    <description>outpatient</description>
                    <type>inclusion</type>
            </applicability>
            <applicability>
                    <focus>clinicalFocus</focus>
                    <code displayName="Obesity" code="414916001"
codeSystemName="SNOMED Clinical Terms"
                            codeSystem="2.16.840.1.113883.6.96" />
                    <description>Obesity</description>
                    <type>inclusion</type>
            </applicability>
            <applicability>
                    <focus>clinicalFocus</focus>
                    <code displayName="Overweight" code="238131007"
codeSystemName="SNOMED Clinical Terms"
                            codeSystem="2.16.840.1.113883.6.96" />
                    <description>Overweight</description>
                    <type>inclusion</type>
            </applicability>
        </behavior>
    </knowledgeModule>
</CDSKnowledgeDocument>
```