Using Semantic DMN to Represent Logic in Cognitive Support Tools

Jane Shellum
Mayo Clinic
BPM+ Health Community
Supporting the Strategy

- Knowledge is our most scalable asset

- Knowledge represented in human-only readable artifacts is not routinely actionable and is difficult to scale

- Knowledge buried in code, rather than surfaced in manageable artifacts based directly on clinical vocabulary and domain models, is technical debt and in the long run is unsustainable
Imperatives for Knowledge Management at Mayo Clinic

• **Facilitate knowledge curation:** Support clinical knowledge curation as a core part of the Mayo Clinic through improved tooling, knowledge representation and methodology support.

• **Know what we know:** Generalize the knowledge content management system to manage knowledge lifecycle and delivery for multiple knowledge formats.

• **Deliver curated knowledge:** Provide searchable, contextualized clinician-consumable knowledge through APIs to multiple applications and business partners. Measure use and impact and cycle feedback to knowledge curation.

• **Deliver knowledge enriched data:** Build out the data pipeline to standardize, normalize, enrich and contextualize clinical data.
The role of BPM+

- **Facilitate knowledge curation:** BPM+ provides a way to faithfully represent clinical knowledge that is both human- and computer-readable. (“from SME to screen”)

- **Know what we know:** Standard metadata based on controlled vocabularies provide transparency into the knowledge assets.

- **Deliver curated knowledge:** A single, model-driven technical solution can deliver knowledge across all specialties and care settings. And a single model can be applied in many ways.

- **Deliver knowledge enriched data:** Defining input data is a mechanism for defining and labeling the data enrichments needed.
Current Application of DMN

• Data Enrichment Logic
• Scoring Tool Logic
• Recommendation Logic
• Human decision-making models for advanced cognitive support
Data Enrichment Logic

Abnormal Renal Function (HAS BLED)

- On Dialysis
- Prior Kidney Transplant
- Most Recent Creatinine

On Hemodialysis
On Peritoneal Dialysis

<table>
<thead>
<tr>
<th>U</th>
<th>On Dialysis</th>
<th>Prior Kidney Transplant</th>
<th>Most Recent Creatinine</th>
<th>Abnormal Renal Function HAS BLED</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>true</td>
<td>-</td>
<td>-</td>
<td>true</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>true</td>
<td>-</td>
<td>true</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>&gt;2.26</td>
<td>true</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>false</td>
<td>false</td>
<td>&lt;=2.26</td>
<td>false</td>
<td></td>
</tr>
</tbody>
</table>
Scoring Tool Logic

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>true</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>true</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>“&lt;55”</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>“65-74”</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
<td>“65-74”</td>
<td>true</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>true</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>true</td>
<td>true</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>“female”</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>
Recommendation Decision Model
## Recommendation Logic

<p>| | | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Inputs
- **Age**: Number
- **Recent LDL Value**: Number
- **Has Clinical or Subclinical Atherosclerotic Cardiovascular Disease**: Boolean
- **Has Very High Risk for ASCVD or Has Very High Risk for Future ASCVD Events**: Boolean
- **Has Diabetes**: Boolean
- **Current ASCVD Risk Score Value**: Condition
- **Most Recent Coronary Artery Calcium Value**: Number
- **Family History of Premature Atherosclerotic Disease**: Condition

### Outputs
- **Management of Cholesterol**: Number
  - 1: High Intensity Statin, LDL < 70, no escalation
  - 2: Moderate Intensity Statin or Continue High Intensity, Goal LDL Reduction 30-49%, no escalation
  - 3: High Intensity Statin, LDL < 70, Ezetimibe and PCSK9
  - 4: High Intensity Statin, LDL < 100, Ezetimibe and PCSK9
  - 5: Moderate Intensity Statin, LDL Reduction 30-49%, If high dose, reduce to moderate
  - 6: Lifestyle Changes

### Annotations
- **Description**
Advanced Cognitive Support: What it is

- Enable better decision making by combining synthesis of the patient record with codified clinical knowledge
- Applying what we know about medicine (knowledge) to what we know about the patient (data)
- A reflection of how physicians think about a case
Advanced Cognitive Support: How it works

SMART on FHIR application
  *driven by*
BPM+ Models
  *which are stored in a*
Knowledge Repository
  *and which interpret information from*
Patient Data and Knowledge Resources
  *All tied together by*
A variety of services

*Platform:* Repository, KnowledgeBase, Language, Glossary

*Application:* Application UI, Application Gateway
Using the Models to Power the Application

- Navigation
- Display of patient data
- Display of content
- Actions
(Cognitive) Care Process Models
Decision Tasks = Navigation
Decision Models = Data Grouping

- Decision fragment annotations drive the UI and application behavior

### Decision Types

<table>
<thead>
<tr>
<th>Purpose of the Decision</th>
<th>Actionable</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>How the Decision is Made</td>
<td>Computable</td>
<td>Naturalistic</td>
</tr>
<tr>
<td>Whether to Display</td>
<td>Implicit</td>
<td></td>
</tr>
<tr>
<td>Type of Answer</td>
<td>Choice</td>
<td></td>
</tr>
<tr>
<td>How the Inputs are Displayed</td>
<td>Aggregation</td>
<td>Temporal Correlation</td>
</tr>
<tr>
<td>Decision-maker</td>
<td>Shared</td>
<td></td>
</tr>
</tbody>
</table>
Decision Types

Aggregating Decision

Shared Decision

Choice Decision

Temporal Correlating Decision
Knowledge Sources = Relevant Content

Rate control

- Rate easily controlled with medications (negative chronotropic agents for rate control and antithrombotic agents)
- Minimal or no symptoms with atrial fibrillation
- Multiple trials of rhythm control unsuccessful

Rhythm control: Consider cardioversion and/or antiarrhythmic medications

- First episode of atrial fibrillation warrants attempt at restoration of normal sinus rhythm
- Symptomatic atrial fibrillation
  - In patients with recurrent episodes of atrial fibrillation, rate versus rhythm control is dependent on:
    - Symptoms associated with atrial fibrillation
    - Previous success with rhythm control and history of use of antiarrhythmic therapies

It is important to rule out reversible causes of atrial fibrillation as well as to determine whether or not there are any treatable exacerbating factors.

Patients who remain symptomatic while in atrial fibrillation often warrant aggressive rhythm control to prevent loss of mechanical atrial contraction. Cardiology consultation should be considered.
Decision Inputs = Patient Data

Current Cardiac Status

Relevant Tests
- Most Recent Echocardiogram
  - EF 65%
  - Valve Disease Not Found
- Most Recent QRS Interval
- Most Recent Corrected QT Interval

Relevant Imaging
- Most Recent Chest X-Ray
- Most Recent Cardiac Cath

Relevant Procedures
- Most Recent Electrocardiogram
  - QTc 410 ms/c
  - QRS 90 ms/c

Result Summary
Making the models “semantic”

• Each input is annotated with a clinical concept
• Each concept has an “operational definition”
• Each concept has a data type definition

On Anticoagulants
Clinical Situational Concept

MedicationStatement?patient={{Patient ID}}&code_in=http://terms.mayo.edu/kmd/valueset/2.16.840.1.113883.3.2.11.5.26&status=active

Operational Definition

FHIR Medication Statement

Data Definition
Clinical Situational Ontology

- Patient Intervention Ever
  - Patient Intervention Now
    - Has Biventricular Pacemaker
    - Has Implantable Cardioverter Defibrillator
    - Has Intra-aortic Balloon Pump
    - Has Left Ventricular Assist Device
    - On Dialysis
      - On Hemodialysis
      - On Peritoneal Dialysis
      - On Oxygen Therapy

<table>
<thead>
<tr>
<th>Labels and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>preferred label:</td>
</tr>
<tr>
<td>notation:</td>
</tr>
<tr>
<td>type:</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>broader concept:</td>
</tr>
<tr>
<td>narrower concept:</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifier:</td>
</tr>
<tr>
<td>isDefinedBy:</td>
</tr>
</tbody>
</table>
Creating Operational Definitions
The Benefits of BPM+

- Visibility of knowledge
- Availability of editing and execution tools
- Sharability of knowledge with partners, customers, and ourselves
- Flexibility of models to different business needs
- Community of practice
Questions/Discussion