Arden-Syntax-based genuine technology platform for clinical decision support (CDS)

I: Web services for MLM calling and for data transfer
II: Web services for MLM calling and server/database connector for data access
III: Data warehouse + Arden Syntax server = autonomous CDS system
Integration into i.s.h.med at the Vienna General Hospital

SOP checking in melanoma patients receiving chemotherapy
## University of Colorado Health—with Epic EHR

### Heart failure readmission risk score (HFRRS)

**Input:**
- vital signs
- lab data
- demographics
- ATD info
- ICD codes

<table>
<thead>
<tr>
<th>Arden - Cardiac ICU (7 Patients)</th>
<th>Room/Bed</th>
<th>Patient Name/Age</th>
<th>Readmit Score</th>
<th>Service</th>
<th>Braden Score</th>
<th>CHADS</th>
<th>Acuity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>37</td>
<td>Cardiology Heart Failure</td>
<td>21</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21</td>
<td>Cardiology Heart Failure</td>
<td>17</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13</td>
<td>Cardiology 3</td>
<td>22</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>Cardiology 2</td>
<td>19</td>
<td>2.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>Cardiology 3</td>
<td>17</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Cardiology 2</td>
<td>20</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

© 2014 Epic Systems Corporation. Used with permission.

**Example of e-mail from HFRRS MLM to HF nurse practitioners:**

Message: [Redacted] | [Redacted] | Heart Failure Readmission Risk Score = 21 - scores > 20 indicate the patient is at risk for readmission. | Service: Hospitalist-HMS1 | Provider: [Redacted] | MD [Redacted]
linguistic HAI definitions

basic concepts:
symptoms, signs, test results, clinical findings

intermediate concepts:
pathophysiological states

abstraction:
rules, type-1 & type-2 fuzzy sets, temporal abstraction

feature extraction:
mean values, scores, …

preprocessing:
missing data, plausibility, …

ICU, NICU, and microbiology patient data bases

reasoning

symbols

data-to-symbol conversion

raw data

patient-specific cockpit
legal reporting
quality benchmarking
Moni-ICU cockpit
Fuzzy Arden Syntax: Modelling uncertainty in medicine

- **linguistic uncertainty**
  - due to the unsharpness (fuzziness) of boundaries of linguistic concepts; gradual transition from one concept to another
  - modeled by fuzzy sets (e.g., fever, increased glucose level, hypoxemia)

- **propositional uncertainty**
  - due to the incompleteness of medical conclusions; uncertainty in definitional, causal, statistical, and heuristic relationships
  - *here*: modeled by truth values between zero and one (e.g., 0.6, 0.9)
Arden Syntax server and software components

- Arden Syntax integrated development and test environment (IDE) including
  - Medical logic module (MLM) editor and authoring tool
  - Arden Syntax compiler (syntax versions 2.1, 2.5, 2.6, 2.7, 2.8, 2.9, and 2.10)
  - Arden Syntax engine
  - MLM test environment
  - MLM export component
- command-line Arden Syntax compiler

- web-services-based Arden Syntax server including
  - Arden Syntax engine
  - MLM manager
  - XML-protocol-based interfaces, e.g., SOAP, REST, and HL7
  - a project-specific data and knowledge services center may be hosted
- Java libraries
  - Arden Syntax compiler
  - Arden Syntax engine
Automated interpretation of hepatitis serology test results

• includes frequent, rare, as well as inconsistent combinations

• complete coverage of the problem domains

• e.g., hepatitis B serology: about 150 rules in 3 layers for more than 61,000 possible combinations
To summarize

- **Arden Syntax software**: versatile, scalable, data- and knowledge-processing software for CDS and quality measures
- High integratability through web services and database connectors
- Cockpit monitoring of and dashboard analytics for adverse events
- Reporting and quality benchmarking of adverse events
- **Users**: patient-care institutions, healthcare and research institutions, health IT companies, and consumers