Clinical Decision Support Systems
An Open Source Perspective

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Agenda

• CDS Overview
• Important CDS Drivers
• CDS Examples of Interventions
• CDS Design – Components and Integration
• Quality Reporting and CDS
• Capturing Medical Knowledge
  • Rule-Based Systems
  • Information Models, Vocabularies, and Ontologies
  • Analytics, Big Data, and Machine Learning
• Important Open Source Community CDS Efforts
• An Example CDS Framework Using Open Source Tools
• Summary and Conclusion
CDS Overview

• Clinical Decision Support – Using computer systems to optimize the delivery of health care by utilizing relevant computable knowledge

• Goals of CDS
  • Provide access to relevant patient data based on conditions and context
  • Provide optimal decision support and actions to the provider or patient

• CDS Mechanisms
  • Create expert computable knowledge – generating, refining, and updating
  • Select relevant knowledge and then reason over it in light of the current patient context
  • Perform actions – usually the Then part of an If-Then rule.

• CDS Components
  • Information Model, Inference Method, Knowledge Content, Application Environment

• CDS Uses
  • Information Retrieval, Medication Management, Diagnosis, Reminders, Coordination of Care

• Many Open Source Tools and Initiatives
Important CDS Drivers

- Healthcare Costs
- Medical Errors
- EHR Adoption and Meaningful Use
- Value-based reimbursement models
- Managing Complexity and Information Overload
- Big data and analytics
- Personalized Medicine
- New Mobile Technologies
  - Smart Phones and Tablets
  - Biosensors and personal data sources
- Population-based Data Collection
# CDS Examples of Interventions

<table>
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<tr>
<th>CDS Interactions</th>
<th>Examples</th>
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<tr>
<td>Provide Information</td>
<td>Infobutton, answer questions, text search, text mining</td>
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<td>Decision Support</td>
<td>Decision Tables, Rule-based reasoning, computable clinical guidelines, statistical analytics, neural networks</td>
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<td>Monitoring</td>
<td>Reminders, alerts, CPOE, eRx, Vaccinations</td>
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<td>Workflow Coordination</td>
<td>Scheduling, Care Plans, Coordination of Care</td>
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<td>Preventive care</td>
<td>Immunization, screening, disease management guidelines for secondary prevention</td>
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<td>Diagnosis</td>
<td>Suggestions for possible diagnoses that match a patient’s symptoms and characteristics</td>
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<td>Planning or implementing treatment</td>
<td>Treatment guidelines for specific diagnoses, drug dosage recommendations, alerts for drug-drug interactions</td>
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<td>Follow-up management</td>
<td>Corollary orders, reminders for drug adverse event monitoring</td>
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<td>Hospital, provider efficiency</td>
<td>Care plans to minimize length of stay, order sets</td>
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<td>Cost reductions and improved patient convenience</td>
<td>Duplicate testing alerts, drug formulary guidelines</td>
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CDS Design – Components and Integration

• Components
  • Information model – schema for clinical data
  • Execution Engine – automated decision maker
  • Knowledge Base – contains computable rules and algorithms

• Integration

![Diagram of CDS Application and Integration]

- Clinical Users
  - Providers, Nurses, Patients, Laboratory and Pharmacy Assistants, etc.

- Medical Experts and Knowledge Engineers
  - Experts, scientists

Medical Experts and Knowledge Engineers

Medical Knowledge

Clinical Guidelines

Medical Research

Clinical Trials

Quality Measures
Relationship between Quality Reporting and CDS

- Close association between QR and CDS
- QM’s are collected \( a \) posteriori from EHRs and Applications
- CDS and QM both use the same clinical knowledge
- CDS uses clinical knowledge \( a \) priori
- QM can be used to fine tune CDS knowledge.
Capturing Medical Knowledge
Rule-Based Systems

- Production Systems - When <condition> Then <action>

Drools Example (BRMS)
rule "INR Between RangeUpperLimit and RangeUpperLimit + 1.0 rule"
salience 30
when
$patient : Patient(labs.mostRecentINRResult > $patient.anticoagulationStrategy.therapeuticRangeUpperLimit &&
labs.mostRecentINRResult <= ($patient.anticoagulationStrategy.therapeuticRangeUpperLimit + 1.0))
then
$patient.score = $patient.score + 20;
end

- Arden Syntax
- GELLO Expression Language
- Computable Guidelines
- Workflow Models

Drools Rule Engine is an open source package
Drools Guvnor is a Business Rules Management System (BRMS)

Arden2ByteCode runs on Java Virtual Machines (JVM)
and translates Arden Syntax directly to Java bytecode (JBC) executable on JVMs.

GELLO Authoring tool.

JBoss jBPM
Capturing Medical Knowledge
Information Models, Vocabularies, and Ontologies

• Information Models – usually based on UML or XML schema
  • Available Models include HL7, VHIM, FHIM, MLHIM and others
  • Model specifically developed for CDS is called vMR (HL7)
  • OS Modeling tools include Papyrus, Eclipse, Netbeans, and others

• Vocabularies and Terminologies
  • SNOMED-CT, LOINC, RxNORM, MedDRA, etc.

• Ontologies
  • Technologies include Semantic Networks and OWL
  • SNOMED-CD, RxNORM, and others have been converted to OWL
  • OS Tools include the Protégé OWL Ontology Editor, Apache JENA, Sesame
Important Open Source Community CDS Efforts

• Health eDecisions – S&I Framework Initiative
  • Advance CDS standards to enable either the routine or regular consumption of CDS interventions through a Web service or the repeated import and update of CDS artifacts into CDS systems.
  • [http://wiki.siframework.org/Health+eDecisions+Homepage](http://wiki.siframework.org/Health+eDecisions+Homepage)

• CDS Consortium (Brigham and Women’s Hospital, Harvard Medical School, and Partners HealthCare Information Systems)
  • The goal of the CDS Consortium is to assess, define, demonstrate, and evaluate best practices for knowledge management and clinical decision support in healthcare information technology at scale – across multiple ambulatory care settings and EHR technology platforms.
  • [http://www.cdsconsortium.org/default.asp](http://www.cdsconsortium.org/default.asp)

• Socratic Grid
  • Socratic Grid is a comprehensive Service Oriented Architecture (SOA) for knowledge management that ensures timely and accurate analysis of clinical data. It is designed for real-time access to clinical data, documents, diagnostic guidance, risk prediction, decision support, and planning services.
  • [http://socraticgrid.org/](http://socraticgrid.org/)

• OpenInfoButton
  • OpenInfobutton is an open source suite of Web services that enable infobutton capabilities within Electronic Health Record (EHR) systems.
  • [http://www.openinfobutton.org/](http://www.openinfobutton.org/)

• OpenCDS
  • OpenCDS is a multi-institutional, collaborative effort to develop open-source, standards-based clinical decision support (CDS) tools and resources that can be widely adopted to enable CDS at scale.
  • [http://www.opencds.org/Home.aspx](http://www.opencds.org/Home.aspx)
KAI CDS Modeling Tool
Summary and Conclusions

• CDS is a hard problem
  • Too many false positives
  • Integrating CDS systems with existing EHR’s is problematic
  • Integrating CDS into the clinical workflow is problematic
  • But this is changing
• Current EHR systems include simple alerts and reminders, orders sets, drug allergies and drug-drug interaction testing.
• CDS Drivers are producing a perfect storm for CDS adoption
• Mature open source tools do exist to construct advanced CDS systems.