Arden-Syntax-Server – Serviceorientierte Architektur für die klinische Entscheidungsunterstützung

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GMDS-Arbeitsgruppe „Wissensbasierte Systeme in der Medizin“, conhIT-Satellitenveranstaltung, 23. April 2012, Berlin
### Clinical decision support systems

#### Patients’ structured medical data

<table>
<thead>
<tr>
<th>Diagnostic support</th>
<th>Therapy advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>• clinical alerts, reminders, calculations</td>
<td>• drug alerts, reminders, calculations</td>
</tr>
<tr>
<td>• data interpretation, (tele)monitoring</td>
<td>- indication, contraindications, redundant medications, substitutions</td>
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<tr>
<td>• differential diagnostic consultation</td>
<td>- adverse drug events, interactions, dosage calculations, consequent orders</td>
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<td>- rare diseases, rare syndromes</td>
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<td>- further or redundant investigations</td>
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<td>- pathological signs accounted for</td>
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<tr>
<td>• consensus-criteria-based evaluation</td>
<td>• management of antimicrobial therapies</td>
</tr>
<tr>
<td>- definitions</td>
<td>• (open-loop) control systems</td>
</tr>
<tr>
<td>- classification criteria</td>
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</tbody>
</table>

#### Prognostic prediction

- illness severity scores, prediction rules
- trend detection and visualization

#### Patient management guidelines

- guideline-based reminders
- computerized clinical guidelines, protocols, SOPs
- high-level patient and hospital analytics
Arden Syntax and Health Level Seven (HL7)

- A standard language for writing situation-action rules that can trigger alerts based on abnormal clinical events detected by a clinical information system.
  

- Each module, referred to as a Medical Logic Module (MLM), contains sufficient knowledge to make a single decision.
  
  extended by packages of MLMs for complex clinical decision support

- Contraindication alerts, management suggestions, data interpretations, treatment protocols, and diagnosis scores are examples of the health knowledge that can be represented using MLMs.
  
  extended by single and differential diagnostic support, temporal monitoring, control systems, computerized processing of clinical pathways and management guidelines

- The first draft of the Arden Syntax was prepared at the Arden Homestead, New York, in 1989.

- The Health Level Seven Arden Syntax for Medical Logic Systems, Version 2.8, was approved by the American National Standards Institute (ANSI) and by Health Level Seven International (HL7) on 13 March 2012.
Arden-Syntax-based, service-oriented clinical decision support
Monitoring of healthcare-associated infections

Processing layers

- **Layer 0 (start)**
  - ICU, NICU, and microbiology patient data bases

- **Layer 1**
  - preprocessing: missing data, plausibility, ...

- **Layer 2**
  - mean values, scores, ...

- **Layer n-s-y-1**
  - abstraction:
    - rules, type-1 & type-2 fuzzy sets, temporal abstraction

- **Layer n-a-y**
  - basic concepts:
    - symptoms, signs, test results, clinical findings

- **Layer n (goal)**
  - linguistic HAI definitions

- **Y inference steps**
  - reasoning
  - symbols
  - data-to-symbol conversion
  - raw data
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, and 2.8)
  - 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

Fuzzy Arden Syntax

- extension to fuzzy sets, operators, statements, and parallel execution
Crisp sets vs. fuzzy sets

yes/no decision

\[ U = [0, 120] \]
\[ Y \subseteq U \text{ with } Y = \{ (\chi_Y(x) / x) | x \in U \} \]
\[ \chi_Y : U \rightarrow \{0, 1\} \]
\[ \chi_Y(x) = \begin{cases} 
0 & x > \text{threshold} \\
1 & x \leq \text{threshold} 
\end{cases} \quad \forall x \in U \]

gradual transition

\[ U = [0, 120] \]
\[ Y \subseteq U \text{ with } Y = \{ (\mu_Y(x) / x) | x \in U \} \]
\[ \mu_Y : U \rightarrow [0, 1] \]
\[ \mu_Y(x) = \begin{cases} 
\frac{1}{1 + (0.04x)^2} & x > \text{threshold} \\
1 & x \leq \text{threshold} \end{cases} \quad \forall x \in U \]
Regel zur Interpretation von klinisch relevanten Befunden (Regelprämisse bilden Äquivalenzklassen)

REGEL 103:

Wenn eine der folgenden 100 Kombinationen zutrifft

<table>
<thead>
<tr>
<th>HBsAg</th>
<th>anti-HBs</th>
<th>anti-HBc</th>
<th>IgM-anti-HBc</th>
<th>HBsAg</th>
<th>anti-HBe</th>
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<tbody>
<tr>
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Dann

Das gleichzeitige Auftreten von HBs-Antigen und Anti-HBs-Antikörpern ist im natürlichen Verlauf einer Hepatitis-B-Virusinfektion ein seltenes Ereignis. Diese Befundkonstellation ist entweder auf (a) zirkulierende HBsAg-anti-HBs-Immunkomplexe, (b) auf eine Koinzidenz einer Hepatitis-B-Virusinfektion mit einer Hepatitis-B-Impfung oder Injektion von HB-Hyperimmunglobulin oder (c) eine Reinfektion mit einem Hepatitis-B-Virus mit unterschiedlichem HBsAg-Subtyp zurückzuführen. Blut und Sekrete (Speichel, Sperma, Muttermilch) solcher Patienten sind als infekties anzusehen.

Interpretation von Hepatitis-Serologie-Befunden (I)
Interpretation of hepatitis serology test results (II)

**Hepaexpert/Interpretation**
Knowledge-based interpretation of hepatitis A, B, and C serology

**Input of test results**
- Hepatitis A serology
  - anti-HAV
    - positive
    - negative
    - borderline
    - not tested
  - IgM anti-HAV
    - positive
    - negative
    - not tested
  - HAV RNA
    - positive
    - negative
    - not tested

- Hepatitis B serology
  - HBsAg
    - positive
    - negative
    - not tested
  - anti-HBs
    - positive
    - negative
    - not tested
  - HBeAg
    - positive
    - negative
    - not tested
  - anti-HBe
    - positive
    - negative
    - not tested
  - IgM anti-HBc
    - positive
    - negative
    - not tested
  - anti-HBc
    - positive
    - negative
    - not tested

- Hepatitis C serology
  - anti-HCV
    - positive
    - negative
    - not tested
  - HCV RNA
    - positive
    - negative
    - not tested

**Interpretation**

**Hepatitis A serology**
- **anti-HAV**
- **IgM anti-HAV**
- **HAV RNA**

**Hepatitis B serology**
- **HBsAg**
- **anti-HBs**
- **HBeAg**
- **anti-HBe**
- **IgM anti-HBc**
- **anti-HBc**

**Hepatitis C serology**
- **anti-HCV**
- **HCV RNA**

This interpretation is based on the presence or absence of specific antibodies in the patient's serum.

**Important notice**

This interpretation is not a substitute for medical advice. Always consult a doctor for accurate diagnosis and treatment.

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Interoperability
Integration into i.s.h.med

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- Making of knowledge base
  - Arden Syntax IDE
- Production
  - Arden Syntax server
  - Quality assurance
  - Arden Syntax server
  - Production
- Web service
- Host system
  - i.s.h.med
- Applications
Production at the Vienna General Hospital

*knowledge services center
  operational:
  - Arden Syntax MLMs

*compiled MLMs

source code MLMs

ArdenCompiler

ArdenEngine

ArdenServer

SOAP

i.s.h.med

functionality
  calculations, alerts, prediction, ...

database*

administration
Development at the Medical University of Vienna

Arden Syntax server

- Arden Syntax development & test environment
- Knowledge

Data & knowledge services center

- Data & concept mining
- Results
- Data

Arden Syntax server

Inference engine

Data & knowledge services center

- Data & concept mining
- Results
- Data
GELLO/vMR—Query and expression language / accessing a virtual medical record data model
**GELLO/vMR and Health Level Seven (HL7)**

- An object-oriented (OO) query and expression language for decision support
- Originally developed as a guideline expression language for query statements and decision rules
- Based on the existing object constraint language (OCL) and HL7’s reference information model (RIM)
- The GELLO language can be used to
  - Build up queries to extract and manipulate data from medical records
  - Construct decision criteria by building up expressions to reason about particular data features/values
- Proposal to use a virtual medical record (vMR) that provides a standard interface to heterogeneous medical record systems
- Includes using of terminologies/ontologies such as SNOMED CT and LOINC
- 2005 adopted as international standard by HL7 and the American National Standards Institute (ANSI)
Innovation project “Standards-based CDS” of the Veterans Health Administration, USA

Transaction Diagram

VistA CPRS in use by: Volpp, Bryan D, MD (VISTASERVER)

Innovation Initiative # 209 - Clinical Decision Support

VistA_1

(1) Patient Lookup

VistA_2

(3) return NHN

(2) Patient DFN

MDWS

(1) Patient Lookup

(2) Patient DFN

(3) return NHN

(3) get NHN

(4) return NHN

(4) return NHN

Web User Interface

Arden Syntax

GELLO/vMR

(1) Patient Lookup

(2) Patient DFN

(3) return NHN

(3) Patient DFN

(3) get NHN

(4) return NHN

(4) return NHN
Clinical decision support with Arden Syntax and GELLO/vMR

- **CDS platforms**
  - based on Arden Syntax and Fuzzy Arden Syntax
    * with data (sometimes) and knowledge services center and extended interoperability (web-services, XML data interfaces, libraries)
- **integrated into or interconnected with**
  - CareVue and ICIP PDMSs (by Philips)
    * monitoring and reporting of ICU-acquired infections (ICUs and NICUs)
  - ICM (by Dräger)
    * ICU decision support modules (Universitätsklinikum Erlangen)
  - i.s.h.med HIS (by Siemens AG)
    * dosing of immunosuppressive drugs for kidney transplant patients
    * prediction of metastases in melanoma patients
    * standard operating procedures for chemotherapy treatment of melanoma patients
  - medico/s HIS (by Siemens AG)
    * laboratory-based clinical reminders
  - Soarian HIS (by Siemens AG) and Orbis HIS (by Agfa)
    * hepatitis serology test interpretation
  - VistA HIS (by Department of Veterans Affairs)
    * service-oriented, standards-based CDS (clinical reminders and patient report cards)
  - Teleiatros, iPhone, iPad
    * remote CDS, mHealth