Motivations and Effects of Different Guideline Representations on the Example of the HL7 RIM.

Computerized Guidelines and Protocols EuroMISE 2004, Praha

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Regenstrief Institute

- Health System Research and Medical Informatics
  - McDonald CM, Tierney W, Overhage JM, Dexter P
- Regenstrief Medical Record System
  - 30 years of patient data, county and university hospitals, outpatient centers
  - Indiana Network of Patient Care covering 90% of emergency and primary care visits in central Indiana
  - structured data, documents
- CARE reminders (per encounter forms)
- Gopher CPOE system, G-Care rules
  - defaults, calculations, pick lists, fill in the blanks, consequent orders, blocking orders, reminders.
What is HL7?

- ANSI accredited Standard Development Organization (SDO) to provide standards for
  - the exchange, management and integration of
- data that support
  - clinical patient care and the
  - management, delivery and evaluation of healthcare services. Specifically, to
- create flexible, cost effective
  - approaches, standards, guidelines, methodologies, and related services for
- interoperability between healthcare information systems.
What HL7 Specifications Exist?

- HL7 version 2 messaging standards for:
  - Patient administration,
  - Results Reporting,
  - Order Entry, ...

- HL7 version 3 specifications for:
  - all of the above, plus
  - Reference Information Model (RIM)
  - Data Type Specification
  - XML Data Representations
  - Clinical Document Architecture
  - Controlled Vocabulary

- Others (by acquisition):
  - Arden Syntax Medical Logic Modules
  - C-COW (clinical desktop integration)
What’s it got to do with CGP?

• We’ve been doing it all along (since ~1990), i.e. prescriptions
  • Amoxicillin 500 mg 3/d for 10 days.
  • Azithromycin 500 mg now then 4 doses 250 mg 1/d 2h PC.
  • Coumadine 5 mg p.o. Mon + Wed.

• Patient care plans
  • “critical pathways”

• Clinical trial protocols
1997 HL7 Information Model

In search of the order.

Gunther Schadow
A simple, flexible model?

In search of the order.
Entity-Attribute-Value “Model”

- **Entity**
  - id
  - attributeId
  - value
HL7 RIM Backbone (UML)

Entity
classCode : CS
determinerCode : CS
id : SET<II>
code : CE
quantity : SET<PQ>
name : BAG<EN>
desc : ED
statusCode : SET<CS>
existenceTime : IVL<TS>
... 
telem : BAG<TEL>
riskCode : CE
handlingCode : CE

Role

classCode : CS
d : SET<II>
code : CE
negationInd : BL
addr : BAG<AD>
telem : BAG<TEL>
statusCode : SET<CS>
effectiveTime : IVL<TS>
certificateText : ED
time : IVL<TS>
modeCode : CE

Participation

typeCode : CS
functionCode : CD
contextControlCode : CS...
sequenceNumber : INT
negationInd : BL
noteText : ED
time : IVL<TS>
modeCode : CE

Act

classCode : CS
moodCode : CS
id : SET<II>
code : CD

negationInd : BL
derivationExpr : ST
text : ED
title : ST
statusCode : SET<CS>
effectiveTime : GTS
activityTime : GTS
availabilityTime : TS

inboundRelationship

0..n

ActRelationship

typeCode : CS
inversionInd : BL
contextControlCode : CS
contextConductionInd : BL
priorityNumber : INT
pauseQuantity : PQ
checkpointCode : CS
splitCode : CS
joinCode : CS

seperableInd : BL

localVariableName : ST

0..n

target

0..n

source

0..n
HL7 Data in XML

<act classCode="ACT" moodCode="...">
  <id root="1.3.6.1.4.1.12009.3" extension="A1234"/>
  <code code="..." codeSystem="2.16.840.1.113883.6.1"/>
  <participant typeCode="...">
    <participant classCode="ROL">
      <id root="1.3.6.1.4.1.12009.4" extension="1234567-8"/>
      <code code="..." codeSystem="2.16.840.1.113883.6.21"/>
      <playingEntity classCode="ENT">
        <name>...</name>
      </playingEntity>
      <scopingEntity classCode="ENT">
        <name>...</name>
      </scopingEntity>
    </participant>
  </participant>
  <sourceOf typeCode="REL">
    <target classCode="ACT">
      <id root="1.3.6.1.4.1.12009.3" extension="A1235"/>
    </target>
  </sourceOf>
</act>
Guideline Document vs. Logic

• Most practice guidelines are narrative
  • and most are not computer actionable
• Guideline document systems
  • initially used for retrieval, library
• Increasingly internal logic recovered
  • Shiffman: GEM, GEM cutter
  • Růžička&Svátek: Stepper mark-up
  • Shahar: DeGeL דגל
• Similarity to EHR views as document vs. structured data.
Ontology (Heller&Herre)

- Urelement
  - Individual
    - Endurant
      - Physical Structure
      - Configuration
    - Ocurrent
      - Event
      - Process
  - Abstract
    - Universal
      - Concept
      - Type
  - Space/Time Entity
    - Chronoid
    - Topoid
Desiderata for CGP Ontologies

• Problem: it is difficult to compare guideline conceptualizations if everything about is different
  • Entropy: “different consensus groups come up with different consensus”

• Diversity is life and life is good … but, please:
  • Clarify the purpose of the chosen ontology structure
  • Recognize that there are other ways to set it up
  • Clarify the relation to other guideline ontologies
  • Justify (=speak to) your differences

• Need to map and relate to each others concepts!
  • Rather than just always restating our private axioms …
  • … or creating new ones isolated by themselves
Ontology (Heller&Herre)
In the mood?

- Mood (2) etymology: alteration of mode. (lat: modus verbi)
- “Distinction of form [...] of a verb to express whether the action [...] it denotes is conceived as
  - fact, or in some other manner (as
  - command,
  - possibility,
  - or wish)
Speaking of which ...

• The RIM as a Language
  • Verbal Phrase: Act
    • Tense and other moods: moodCode
  • Nominal Phrase: Entity in Role
    • determiner: determinerCode
    • casus, preposition, particle: Participation.type

• Act Event = Statement (Rector & Nolan)

• Langue et Parole (Language and Speech)

• Speech Acts
  • how to do things with words? (Austin)
  • Pragmatics! (in every sense of the word)
  • Vizenor&Smith: The Ontological Nexus between Speech Acts and Medical Records (right next door)
Guidelines + EMR Integration

- Correndo, Terenziani: Integration of Guidelines with Medical Ontologies and Medical Information Systems
- HL7: YEAH! AMEN!
- Mapping, see also Tu (SAGE), Peleg (GLIF): VMR (loosely) based on (i.e. mapped to) the HL7 RIM.
  - effect: use same vocabulary for clinical observations, actions, etc.
- Sure, but ... Electronic Medical Record Data has the same form as Guidelines!
  - Guidelines should have a recognizable relationship with care plans, order sets
  - Orders should have a recognizable relationship to EMR data
  - The HL7 RIM is one uniform model for both individuals and universals
Guidelines as Action Plans

• Terenziani & Correndo: GLARE “limited set of clear representative primitives”

• Actions: Work, Query, Decision, Conclusion -- What we like:
  • Actions composite or primitive – defined based on the presence of components (has-part relations to other acts)
    • supporting top-down refinement
    • encompasses sequence, alternative, etc.

• Miksch: Asbru “skeletal plan”
Action Group ("Battery")

Observation code: *E'lytes-Battery*

- has-component
  - Observation code: *Sodium*
  - Observation code: *Potassium*
  - Observation code: *Chloride*
  - Observation code: *pH*
  - Observation code: *Bicarbonate*
  - Observation code: *Calcium (free)*
Act Decomposition

Act code: laparoscopic cholecystectomy

- has-component
  - seqNum = 1
  - Act code: incisions & insertion of trocars & laparoscope

- has-component
  - seqNum = 2
  - Act code: preparation of gall-bladder

- has-component
  - seqNum = 3
  - Act code: ligature of vessels

- has-component
  - seqNum = 4
  - Act code: excision & extraction of gall bladder

- has-component
  - seqNum = 5
  - Act code: retraction of laparoscope

- has-component
  - seqNum = 6
  - Act code: sutures & bandages

- has-component
  - seqNum = 1
  - Act code: ligature of ductus cysticus

- has-component
  - seqNum = 2
  - Act code: ligature of A. cystica
Act Decomposition

Component = 1
Act code: ligature of ductus cysticus

Component = 2
Act code: ligature of A. cystica

has-component
seqNum = 1
Act code: clamp prox.

has-component
seqNum = 2
Act code: clamp dist.

has-component
seqNum = 3
Act code: cut
Act Decomposition

- has-component seqNum = 1
  - Act code: clamp prox.
- has-component seqNum = 2
  - Act code: clamp dist.
- has-component seqNum = 3
  - Act code: cut
- has-component seqNum = 1
  - Act code: open clamp
- has-component seqNum = 2
  - Act code: set clamp
- has-component seqNum = 3
  - Act code: close clamp
“robotic arm discussion”

- to grasp object:
  - locate object
  - find \( \frac{3}{4} \) distance
  - calculate move
  - move arm \( \frac{3}{4} \) closer
  - relocate object
  - Repeat process until close enough to grasp

“Acts are Fractal!”
Care Provision Acts

Patient Care Provision

Inpatient encounter

Referral

Visit
Preadmit
Inpatient stay
Readmission

Visit

Visit

Procedures

Procedures

Results

Results
Block structured language

```python
activity() {
    while(loopCondition()) {
        step1();
        step2();
        if(condition1()) step31();
        else if(condition2()) step32();
        else step33();
        step4();
    }
}
```
Block structured, graphical

Diagram shows a block structured, graphical model with nodes labeled A1, A2, A3.1, A3.2, A3.3, and A4. The diagram includes arrows indicating connections and labels "split" and "join."
RIM “Programming” Constructs

- statement – act
- if/switch – split-code exclusive
- fork – split-code inclusive
- join – join-codes wait, kill, detach
- loop – repeat-number
- preconditions, post-conditions
After measuring baseline serum glucose, patient drinks 100 g glucose with water. Serum glucose is measured after 10, 30, and 60 minutes.
Guidelines as Action Plans

- Terenziani & Correndo: GLARE “limited set of clear representative primitives”
- Actions: Work, Query, Decision, Conclusion – What else we do like
  - Query satisfied by prompt or database (not a prompt action)
  - ProForma Keystones: Action, Plan, Enquiry, Decision
  - Workflow as data-flow (and vice versa.)
Goals vs. Intentions

• Fox: Goal ontology (see also Asbru)
  • Knowledge goals
    • acquire information
      • isn’t that the “enquiry keystone”?
    • decide between alternatives
      • isn’t that “decision keystone”?
  • Action goals
    • achieve some state of the world
    • enact tasks (e.g. arrange service)

• Difference between intentions and goals
  • intensions: what do I intend to do (=intent).
  • goals proper: what I want to accomplish.
HL7: Intents vs. Goals

• **Intents**
  • plan (what I make for my and mine)
  • recommendation (what I offer you)
  • request (what I ask you to do)

• **Goals**
  • **goal** as what I set for my patient
    • “required future state”
    • mood of an act, kind of predicate
  • **objective** of an action
    • **final objective** (stop when reached)
    • **maintenance objective** (keep on doing it)
Of starting and stopping ...

- Asbru (Miksch, Shahar 1996)
  - filter-precondition
  - setup-precondition
  - complete-condition
  - intention: overall-state
  - intention: intermediate-state
  - suspend-condition
  - restart-condition
  - abort-condition
  - effect

- HL7 RIM
  - precondition
  - trigger
  - postcondition ("outcome")
  - final objective
  - maintenance objective
  - neg. through-precondition
  - final or maint. objective
  - risk (adverse effect)
  - has-manifestation
Act states and transitions

- **Normal Path**
  - new
  - activate
  - active
  - complete

- **Exceptional Termination**
  - nullified
  - obsolete

- **Temporary Interruption**
  - held
  - suspended
  - cancelled
  - aborted

- Actions:
  - hold
  - cancel
  - activate
  - abort
  - reactivate
  - release
  - suspend
  - resume
  - complete
  - nullify
  - obsolete

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Time and Timing

- Kaiser&Miksch: TimeWrap, Asbru
  - interval-based
  - cyclical plan
    - frequency as period duration
      - HL7: period
    - “starting shift”, “finishing shift”
      - HL7: phase
    - number of occurrences restriction?
      - HL7: repeatNumber: 1=single >1=cyclical
Time and Timing in HL7

• Elapsed time: 10 min, 30 s, etc.
  • a Physical Quantity (like any other)
• Point in time: 19870605043210.001
• Interval of time: 19870605..19870613
• Periodic interval of time
  • period = 7d, phase = [19870605;19870606]
• Arbitrary Set of Time
• Event related interval of time:
  • e.g., 1h AC, CC, HS
Periodic Time

- Frequency \( f = 3/d \), same as
- **Period** \( T = 8 \) h
- **Phase** \( \varphi \) (\( \sim \Delta t \)) can address any point in period.
- If phase is a range, we get periodic time intervals.
Arbitrary Sets of Time

- Composed by set-operations
- Example: Every other day from Monday to Friday 8:00 AM to 10:00 AM for six consecutive times.
Dear Samson ...

• Tu: EON, SAGE
  • “opportunities for decision support”
  • e.g., CPOE

• Problem with clinical protocols
  • there is no “program counter”

• CPOE Alert & Reminder Systems
  • are proven effective
  • single evidence-based decision support requires little context
Example: Arden MLM

maintenance:
title: Check creatinine for gentamicin orders;;
knowledge:
type: data_driven;;
data: genta_order := event {'o132';};
      (crea_value) := read last {'e44'; 'o44'};
      output := destination {'alert_channel'};;
evoke: genta_order;;
logic: if time of crea_value is > 3 days
       conclude true;;
action: write "need to check serum creatinine"
       at output ;;
Same rule in the RIM

**SubstanceAdministrationEventCriterion**
- `classCode`: `SBADM`
- `moodCode`: `E VN.CRT`
- `code`: `CD CWE [0..1] <= GentamicinTreatment`

**InformDefinition**
- `classCode`: `INFRM`
- `moodCode`: `DEF`
- `text`: ST [0..1] "need to check serum creatinine"
- `title`: ST [0..1] "Check creatinine for gentamicin orders"

**ObservationEventCriterion**
- `classCode`: `OBS`
- `moodCode`: `E VN.CRT`
- `code`: `CE CWE [0..1] <= SerumCreatinine`

**Trigger**
- `typeCode`: `TRIG`

**Precondition**
- `typeCode`: `PRCN`
- `pauseQuantity`: PQ [0..1] "< 3 d"
Underlying knowledge

**SubstanceAdministrationDefinition**
- classCode*: <= SBADM
- moodCode*: <= DEF
- code: CD CWE [0..1] <= GentamicinTreatment

**precondition**
- typeCode*: <= PRCN
- pauseQuantity: PQ [0..1] "< 3 d"

**ObservationDefinition**
- classCode*: <= OBS
- moodCode*: <= DEF
- code: CE CWE [0..1] <= SerumCreatinine
Workflow Plan

**SubstanceAdministrationDefinition**
- classCode *: <= SBADM
- moodCode *: <= DEF
- code: CD CWE [0..1] <= GentamicinTreatmentProtocol

**ObservationDefinition**
- classCode *: <= OBS
- moodCode *: <= DEF
- code: CE CWE [0..1] <= SerumCreatinine

**Component**
- typeCode*: <= COMP
- sequenceNumber: INT [0..1] "1"

**Component1**
- typeCode*: <= COMP
- sequenceNumber: INT [0..1] "2"

0..* observationDefinition

0..* substanceAdministration
Purpose of rule: dose check

SubstanceAdministrationDefinition
- classCode: <= SBADM
- moodCode: <= DEF
- code: CD CWE [0..1] <= GentamicinTreatment
- derivationExpr: ST [0..1]
  "doseQuantity.lessThan(m.dividedBy(crea).times(PQ(1, mg2/kg/dL)))"

ObservationDefinition
- classCode: <= OBS
- moodCode: <= DEF
- code: CE CWE [0..1] <= SerumCreatinine

ObservationDefinition
- classCode: <= OBS
- moodCode: <= DEF
- code: CE CWE [0..1] <= BodyMass

0..* inputObservationDefinition
- derivedFrom1
  - typeCode: <= DRIV
  - sequenceNumber: INT [0..1] "1"
  - localVariableName: ST [0..1] "crea"

0..* inputObservationDefinition
- derivedFrom
  - typeCode: <= DRIV
  - sequenceNumber: INT [0..1] "1"
  - localVariableName: ST [0..1] "m"
Which Is Best?

- **Arden-like approach**
  - says what the system does
  - i.e. show alert message

- **Precondition dependency relations**
  - says what you have to do first
  - but doesn’t say why

- **Workflow plan**
  - says what steps you have to do
  - but what if you have already done them?

- **Parameter dependency relation**
  - says what the use of the antecedent is
  - transformed into business rule depending on the receiving system
Benefits of HL7 RIM Approach

- Knowledge concepts can be modeled, in the same language used to model patient data.
  - Facilitates Integration
- RIM allows for different guideline conceptualizations
- Information and Knowledge have essentially the same form!
  - Direct systematic comparability
- Rooted in practical use cases and applications
- Broad Cross-Domain Consensus
thank you