Contexts in Medical Decision Making
Overview of Talk

• Presenter Information
• This Talk in Pat Hayes’ Context Formalism
• Understanding Databases as Ontologies
• Medical Decision Making Use Cases
• Clinical Decision Support Software
• Summary
Presenter Information

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Ontolog-Forum, IEEE-SUO, ResearchCyc, Common Logic, MELD, SUMO, COSMO

Medical Informaticist 1982-Present

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This Talk in Pat Hayes’ Context Formalism - Linguistic

- **External Language Context** used to apply structure/context to text of Clinical Notes
- **Referential connection of Natural Language to physical context** refers to medical or clinical events of world
- **Contextual meaning of discourse over sentences** recorded in Electronic Health Record
- **Rare Disambiguation of Lexical Items** (indexicals or anaphora) or **content disambiguation** in internal form
- **Topic Context** enhanced by associating a note title to a hierarchical note title taxonomy
- **Temporal Context** established by Events recorded as Encounter records
This Talk in Pat Hayes’ Context Formalism (Internal Code)

• **Data definition** and **input constraints** provide context for syntactic validations for database fields

• Extension of data records using **deductive Inferencing**

• Implicit meaning of **database fields** made explicit through formal ontology

• **Notes and data** framed within a **data use context**

• **Ground data**, treated as Logical axioms, support useful inferences as well as actionable findings

• **Inference Rules** establish needed context for particular decision making, using context of applicability of rules.
This talk in Pat Hayes Context Formalism (Conceptual Context)

• All “contents” share same “container”
• Medical Data is inherently relational and hierarchical
• Body Parts are “parts” of Functional Systems
  • E.g. The Heart is part of the Circulatory System
  • Right Arm is instance of Arm, and of Right Side
• An Appointment is associated with Patient and Clinic
  • Sam’s Appointment is an Event part of both Sam and the Eye Clinic
• “no show” flag is part of Appointment of a Patient
  • All entries subfile/dependant table share same patient context
  • Appointment as Metaphoric Container defines context for the “no show” flag field.
Pat Hayes’ Context Formalism

- Topic of Conversation or Narrative
- Indices for Recording Fine Conceptual Distinctions
- Physical Setting of Conversation or Narrative
- Temporary Group of deductive assumptions
Understanding Databases as Ontologies (Overview)

• Metaphors for Data Properties
• Classification Definitions
• Database or Data Set mapping to Logical Forms
• Rules Interoperability, Representation, and Transmission
• Standard Terminology for Medical Classification
Metaphors for Data Properties

Using “sight as understanding” metaphor to classify kinds of data stored in a computer and methods of processing.

• **Transparent** – data stored in fields, each well defined in value range, data type, synactic form, inter-field constraints. Includes text entry where input is limited by “templates” or boilerplate that must be filled in by human

• **Translucent** – data stored as Natural Language text, sometimes organized as an outline or with named paragraphs. Fields holding data may have grammar rules or human enforced constraints on semantics of fields. Includes OCR results of Opaque data.

• **Opaque** – Image data, text data saved as an image, fax capture, marked x-y graphs, observation data as a chart (EKG, EEG, Telemetry, ICU Monitored Data)
Classification Definitions

Groups are also called Classes, Categories, and Collections. This is using Container Image Schema with concepts/terms as contents.

- **Vocabulary** is a set of terms, no groups
- **Terminology** has terms organized into a groups
- **Taxonomy** has a group of terms in an “isa” or “genls” relation organized as a hierarchy
- **Ontology** has a group of terms in multiple hierarchies adding relations such as “part-of” or “stuff-of” to the “isa” and “genls” relations

Each of these should have defining conditions for inclusion in groups, sometimes explicitly stated.
Database or Data Set mapping to Logical Forms

A Logical Sentence corresponds to the combination of:

- **Predicate** name maps to Data Field (column) name possibly including the File (table) name

- **Arguments** each of which might be:
  - Data Field values such as Number, Free Text, Set of Codes
  - ROWID (Internal Entry Number) identification values
  - Computed fields values are given a formula or program call

Hierarchical Data (subfiles and subfields)

- are mapped to predicates whose arity increases for n-levels deep data

- **Subfiles** or **Dependent Tables** map to sentences with extra arguments dependent on depth

- **Pointers** (Foreign Keys) may imbed related fields as args
Sentences (logical combination of elements connected with AND OR NOT THEREEXISTS FORALL etc...) can be used to control inferencing.

Predicate (arg1, arg2, etc... )
Relation (arg1, arg2, arg3, arg4, etc... )
Function(arg, etc...)

Each argument may be a constant or function call or variable or evaluated expression or reference to database element or field

Clinical Reminders uses a **database entry** for control such as:

<table>
<thead>
<tr>
<th>REMINDER DEFINITION</th>
<th>ROWID</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>COMPLICATED OUTCOMES</td>
</tr>
<tr>
<td>LOGIC</td>
<td>(TODAY-ADMIT_DATE(1,4)-TODAY) &lt; MAX_LEN_STAY(17)</td>
</tr>
<tr>
<td>USAGE</td>
<td>Reminder Reports, Reminder Order Checks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>USE IN PATIENT COHORT LOGIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION FINDING TERM (subfile/Dependent Table)</td>
</tr>
<tr>
<td>FUNCTION</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>MIN_LEN_STAY</td>
</tr>
<tr>
<td>ADMIT_DATE</td>
</tr>
</tbody>
</table>
Mapping from Table to Logical Form

<table>
<thead>
<tr>
<th>ROWID or IEN</th>
<th>Name</th>
<th>Gender</th>
<th>Date of Birth or DOB</th>
<th>AGE</th>
<th>Appointment (Subfile/Dependent Table)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TEST, JOE</td>
<td>MALE</td>
<td>4-JULY-1976</td>
<td>Calculate</td>
<td>...</td>
</tr>
<tr>
<td>23</td>
<td>EXAMPLE, PAT</td>
<td>UNKNOWN</td>
<td>25-DEC-2000</td>
<td>Calculate</td>
<td>...</td>
</tr>
<tr>
<td>56</td>
<td>SAMPLE, SUE</td>
<td>FEMALE</td>
<td>31-OCT-1999</td>
<td>Calculate</td>
<td>...</td>
</tr>
</tbody>
</table>

| COLUMN Name (rowid,value) |

- ROWID(1,”PatientTable”)  
- ROWID(23,”PatientTable”)  
- ROWID(56,”PatientTable”)  
- Name(1,”TEST,JOE”)  
- Name(23,”EXAMPLE,PAT”)  
- Name(56,”SAMPLE,SUE”)  
- Gender(1,”MALE”)  
- Gender(24,”UNKNOWN”)  
- Gender(56,”FEMALE”)  
- DOB(1,”TEST,JOE”)  
- DOB(23,”EXAMPLE,PAT”)  
- DOB(56,”SAMPLE,SUE”)  

Age = CALCULATE(Date of Birth – TODAY)  

Spreadsheet Data Sets or SQL Tables will map to 2 argument logical forms.

COLUMN name(rowid,value)
## Mapping from Table to Logical Form

<table>
<thead>
<tr>
<th>Patient Table/File</th>
<th>Appointment (Subfile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROWID or IEN</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Appointment (Subfile/Dependent Table) of Patient Table/Files</th>
<th>Clinic</th>
<th>No Show Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent ROWID or IEN</td>
<td>ROWID or IEN</td>
<td>Appt Start Date&amp; Time</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>5-June-2012</td>
</tr>
<tr>
<td>1</td>
<td>27</td>
<td>18-May-2017</td>
</tr>
<tr>
<td>1</td>
<td>1094</td>
<td>20-Sep-2019</td>
</tr>
</tbody>
</table>

- a cell/field in the Parent may encompass an entire subfile or dependent table - use 3 args
- Clinic(56,9,”Dental”) NoShowFlag(141094,”UNK”)
Medical Decision Making
common contexts for Rules

• The current patient.
  • In Clinical Reminders, there is an implicit loop through all the patients in the system or through a cohort.

• A particular time and date
  • If current time and day then Today or Now
  • Admission date of patient, Discharge Date
  • Date of Birth, Current year’s birthdate, Date of Death
  • Date of Disease onset, Date of significant disease treatments

• The local place (the absolute physical location, subjective kind of room, closest nurse’s station)

• The organizational locality (particular clinic, particular medical division, treatment facility type)
Rules Interoperability, Representation, and Transmission

- **Rules** may be expressed in an **ontology** using logical sentences, or in a **rule set** or other **specification**.
- **Specifications** may include **resources** used by the system in collecting data from end-users.
- **Rules** can have **dependencies** on:
  - The **syntax of sentences** (and particular version)
  - the **software** (and particular version) that provides **inference**
  - locally installed **source code and data structures** implicitly or explicitly used by the **expressions in the specification**.
- **Specification packaging** may be **formatted** as:
  - **PRD** (Packed Reminder/Dialog) from Clinical Reminders
  - **RIF** (Rule Interchange Format) from W3C
  - **SWRL** (Semantic Web Rule Language) from Protege
  - **DRL** (Drools Rule File)
Medical Industry Standard Classification Systems

- **CPT** (Current Procedural Terminology) from AMA (American Medical Association)
- **FMA** (Foundational Model of Anatomy Ontology) from University of Washington
- **ICD-0, ICD-9, ICD-10** (International Classification of Diseases)
- **LOINC** (Logical Observation Identifiers Names and Codes) from Regenstrief Institute
- **RXNORM** (normalized names for clinical drugs) from NLM (U.S. National Library of Medicine)
- **SNOMED CT** (Systematized Nomenclature of Medicine -- Clinical Terms) from the College of American Pathologists
- **UMLS** (Unified Medical Language System) from NLM
- **GALEN** Common Reference Model
Medical Decision Making Use Cases

• Reminders of Best Practices in care
• Checking Validity of Orders
• “Due Lists” reminding of activities needed in Treatment Planning for the patient.
• Notifications of relevant events and changes to the patient between encounters
• Simulation of non-visible Processes
• Policy-compliant Documentation of Care
• Creating subsets of patients for Studies
• Classification and Standardization of Terms
• Ontologies used for Auditing/Accounting
Clinical Decision Support Software

Logical systems are commonly implemented within a larger program used by clinicians for their needs. This means the software and data are not easily visible from user interfaces.

• Classification Support with OpenGALEN
• GALEN expert system
• Parsing Clinical Care Notes with Apache cTAKES
  • clinical Text Analysis Knowledge Extraction System
• Drug Interactions in First Databank and VistA E.H.R. (MOCHA, OCX)
• Clinical Reminders (PXRM) in VistA E.H.R.
Classification Support with OpenGALEN

• OpenGALEN is an system to create Classifications suitable for use by Description Logic. Generally, these Classifications have consisted of clinical terminology

• GRAIL (GALEN Representation and Integration Language) developed at University of Manchester and used to create clinical models and for indexing knowledge bases.

A website exists for OpenGALEN but I (David Whitten) have not professionally encountered it to date.
• GALEN is an expert system language based upon nonmonotonic logic and sorted higher-order quantificational logic

• Originally designed to permit the composition of expert systems for computerized electrocardiographic diagnosis

• Associated facilities for natural language handling, handling coding systems

• Code and experience of implementors expanded into a specialized Accounting/Auditing expert system

• The availability of this source code is undetermined
Parsing Clinical Care Notes with Apache cTAKES

Apache cTAKES is a natural language processing system for extraction of information from electronic medical record clinical free-text.

- Standard medical codable entities
- Temporal events
- Properties and Relations.
- Converts Translucent Text to Transparent
- UIMA Analysis compatible with Watson
- A demo system is available on the Internet
input text:
The patient arrived via ambulance to Memorial Hospital at two pm on April 31, 2017. Tom Thumb presents as a 45 year old man with diabetes and evidence of weak pulmonary function.

results:

sentence: the patient arrived via ambulance to memorial hospital

DT NN VBD IN NN IN JJ NN

at two pm on April 31, 2017.

IN CD NN IN NNP

cTAKES does recognize a variety of parts of speech but will need to include recognition for Names and Locations. It recognizes a date as a Noun Phrase but not as a date phrase. Number words are recognized but actual numbers are ignored. Common patterns like “age is” would help too.
cTAKES RESULTS: (cont)

SENTENCE: Tom Thumb presents as a 45 year old man with diabetes

and evidence of weak pulmonary function.

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cTAKES does recognize certain diseases and anatomy words, and provides a match to a code in a standard coding Scheme which is the US variant of SNOMED CT.
Drug Interactions in First Databank and VistA E.H.R.

• **DIF** (Drug Interaction Framework) subroutine library and data from First Databank

• **MOCHA** – VistA E.H.R. transmits data as XML to external system which uses First Databank

• **Latte (OCX)** – VistA E.H.R. internal expert system used to validate Orders from Users can also be used to find drug interactions
Drug Interactions

A Drug Interaction may be an allergy or more generally, as an Adverse Reaction. Recognizing an occurrence of a drug interaction is a particularly important use-context for Medical Decision Support Systems.

Interactions come from

• Evidence based data from medical journals
• Pharmacy manufacturers
• Reports from daily practice at a wide range of health management and care organizations
• Academic research from pharmacy educators

Checking Drug Interactions significantly lowers errors in prescribing, ordering, dispensing, and administration.
Kinds of Drug Interactions

- Drug – Drug Interactions
- Drug – Drug Class Interactions
- Drug – Drug Ingredients Interactions
- Drug – Food Interactions
- Drug – Disease Interactions
- Drug Dose Toxicity and Maximum Daily dosing as well as weight/height restrictions
- High Risk and Teratogenic Identification (for pregnancy or cancer monitoring)
Clinical Reminders (PXRM)

The VA Clinical Reminders system allows caregivers to track and improve preventive healthcare and disease treatment for patients and to ensure that timely care actions are taken.

When rules are evaluated, the context includes

- Current Patient, and Demographics
- Age, Age Range, Date of Birth, Date of Death
- Current Vital Signs Weight, Height
- Current Admission, Transfer, and Discharge Dates
- Encounter Diagnosis, Purpose of Visit, Provider
- Existence of Patient behavior change encounters
Clinical Reminders (PXRM)  
Rule Processing

When using a rule, it must be established that it is applicable. This is a logical sentence providing a form of context evaluation.

Rules can also have the following as a form of context:

- counts of occurrences, Priorities, disambiguation ranking,
- minimum dates and maximum dates to be able to include the occurrence,
- Sex specific rules,
- how frequently the rule should be run
- whether it should be used to calculate other rules,
- whether it can be used to build the resolution cohort of patients,
Clinical Reminders (PXRM)

Findings used in rules

A Finding is a piece of information that the reminder searches for in the computer. Some findings are ephemeral (available only when the rule is tested). There are also computed findings that can be extended with locally code and definitions. Findings are used to determine:

• Who needs an intervention (cohort)
• What resolves the reminder (whether it is due)

Findings include individual or groups of Labs, Patient Education Topics, Taxonomies of codes (ICD9, ICD0, CPT), Exams, Measurements, Health Factors, Medications, Progress Note Titles, Computed Findings, etc…
Clinical Reminders (PXRM)
Common Functional Findings

These are built-in functions which can be applied to any data finding, computed or stored.

• **MRD – (Most Recent Date)** given a list of findings this function returns the finding date
• **DUR – (Duration)** given a single finding, returns the number of days between the start and stop date of the finding. If only one date exists, returns the number of days between the first occurrence and last occurrence in the Occurrence Count
• **DIFF_DATE, MAX_DATE, MIN_DATE** – date value handling functions
• This is extensible with local software
Summary

Medical Decision Support systems are a direct result of standardizing the practice of clinical and medical care as well as continued research into pedagogy of medical and clinical education.

Concepts in care are still being refined, but the expected workload and expected accuracy in care suggests that support systems are needed and appreciated.

The formalization of reasoning requires explicit recognition of contexts to make medical decision making a tractable task.

This is an exciting time to be practicing medical informatics.
Questions?

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