ORC: an Ontology Reasoning Component for Diabetes

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Outline

1. Introduction
2. COMMODITY\textsubscript{12} personal health system
3. ORC for semantic reasoning
4. Illustrative Example
5. Conclusions
Motivation

- Availability of medical data greatly increased
  - data from different information sources and in different formats
  - mediator-based integration approaches for data translation
- Build on the existing COMMODITY\textsubscript{12} framework for diabetes management
- Complement the integration process of the mediator with ontologies and semantic reasoning support
- Improve the existing logic-based agents that provide monitoring, advice and diagnosis
Contribution

- Study how to embed a semantic reasoning at the infrastructure level
  - present SWRL rules to provide semantic reasoning on the ontology concepts
  - instantiate the ontology with individuals coming from a patient database
- Describe a diabetic patient profile using an ontology formalised in OWL
- Profiles on diabetes not previously available
Management of diabetes becomes an increasingly important problem worldwide
- diabetic patients not able to take crucial decisions related to treatment
- need to consult healthcare professionals

Advise patients with recommendations and alerts based on their data

Assist medical personnel with taking informed and timely decisions
Architecture

Deductive, hypothetical and temporal reasoning + KB

LAMA

Logical terms

XML

query processing

Translator

Mediator

Translator

Translator

Smart hub

Web interface

Doctor

Patient

Patient DB
Portavita interface

FAKE PATIENT 1112391 (Mr.)

Diabetes | GP 20987 | DM2 since 11-2011 | Hypertension, Smoking: Considers stopping

Monitor

Treatment | Problems/Complaints | Lifestyle | Phys.Exam. | Laboratory | Fundus | Feet | 24 hour blood pressure | Decision support

Consult / add treatment policy | Change memo

Diagnosis and risk factors

Type 2 diabetes mellitus
Smoking 20 units per day
General Hypertension

Outcomes and process

HbA1c 49.0  LDL 2.5  Triglyceride 3.5
Cockcroft 123  MDRD 112  Blood pressure 128/78
Annual check-up  Foot examination
Flu vaccination unknown

Memo

No memos

Treatment policy

<table>
<thead>
<tr>
<th>Date</th>
<th>Practitioner</th>
<th>Source</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-09-12</td>
<td>GP 20987</td>
<td>RC</td>
<td>sugar level too high, started with metformine 500mg, checkup in 2 weeks</td>
</tr>
<tr>
<td>23-07-12</td>
<td>Employee 512851</td>
<td>RC</td>
<td>sugar level reasonable, dietary advice given, good blood pressure</td>
</tr>
<tr>
<td>26-03-12</td>
<td>GP 20995</td>
<td>RC</td>
<td></td>
</tr>
<tr>
<td>30-12-11</td>
<td>GP 20995</td>
<td>RC</td>
<td>busy adapting lifestyle, waits with taking meds</td>
</tr>
<tr>
<td>09-12-11</td>
<td>FS</td>
<td></td>
<td>no DRP advice, yearly fundus control</td>
</tr>
<tr>
<td>14-11-11</td>
<td>GP 20995</td>
<td>AC</td>
<td>discussed stopping smoking</td>
</tr>
<tr>
<td>01-11-11</td>
<td>Employee 512851</td>
<td>RI</td>
<td>new diabetc, information diet and DCR. Please check feels for fungus</td>
</tr>
</tbody>
</table>

Medication

No medication

Treatment team

<table>
<thead>
<tr>
<th>Carried out</th>
<th>Scheduled</th>
<th>Consultation</th>
<th>Processor</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-11-2011</td>
<td></td>
<td>Annual check-up (Diabetes)</td>
<td>GP 20995</td>
<td>GP PRACTICE 1011</td>
</tr>
<tr>
<td>09-12-2011</td>
<td></td>
<td>Fundus image screening (Diabetes)</td>
<td>Employee 512851</td>
<td>GP PRACTICE 1011</td>
</tr>
<tr>
<td>01-11-2011</td>
<td></td>
<td>Risk inventory (Diabetes)</td>
<td>Employee 512851</td>
<td>GP PRACTICE 1011</td>
</tr>
<tr>
<td>25-09-2012</td>
<td></td>
<td>Routine check-up (Diabetes)</td>
<td>GP 20987</td>
<td>GP PRACTICE 1011</td>
</tr>
</tbody>
</table>
LAMA agents

- Use personal agents [Kafalı et al. 2013] as active software components to
  - manage specific characteristics of individuals in user profiles
  - identify contextual conditions about the domain by observing through sensors
  - process intelligently information by reasoning logically to support monitoring, the provision of alerts, advice, and diagnosis

- Use the agent platform GOLEM for deployment
Agent control

Body

Mind
Agent control

![Diagram showing the relationship between Body and Mind with observations pointing to Body.](image-url)
Agent control
Agent control

Observations → Body

Body → Call → Cycle step

Cycle step → Revise state

Revise state → KB

KB → Mind
Agent control

- Observations
- Cycle step
- Revise state
- Select plan

Body

Mind

KB

Call
Agent control

- Body
- Observations
- Call
- Cycle step
- KB
- Revise state
- Select plan
- Activate goal
Agent control

Body

observations → call → cycle step → revise state → select plan

Mind

KB

choose action → activate goal
Agent control

Body

observations

call

cycle step

Mind

revise state

select plan

KB

try action

choose action

activate goal
Agent control

observations → Body

Body → cycle step

cycle step → Mind

Mind → revise state

revise state → select plan

select plan → KB

KB → activate goal

activate goal → choose action

choose action → try action

try action → state

state → KB

KB → revise state

revise state → select plan
Agent control

- Body
  - observations
  - call
  - return

- Mind
  - cycle step
  - revise state
  - select plan

- KB
  - try action
  - choose action
  - activate goal

- try action
- choose action
- activate goal

- cycle step
- revise state
- select plan

- Body observes
- KB revises
- Mind selects
- Activate goal
Agent control

Diagrams:
- **Body**
  - observations
  - execute action
- **Mind**
  - cycle step
  - revise state
  - select plan
  - KB
  - try action
  - choose action
  - activate goal

Arrows:
- observations → cycle step
- cycle step → revise state
- revise state → select plan
- select plan → KB
- KB → try action
- try action → choose action
- choose action → activate goal
- activate goal → cycle step
- cycle step → return
- return → observations
COMMODITY$_{12}$ extended with $\textit{ORC}$

**Existing COMMODITY$_{12}$ system**

- Deductive, hypothetical and temporal reasoning
- LAMA
- Web interface
- Smart hub
- Patient DB
- Doctor

**Proposed extension**

- Ontology instance (individuals)
- Semantic rules (SWRL)
- Patient profile ontology (OWL)

**ORC**

- Import external ontologies
- Food
- SNOMED CT observation

$\textit{ORC}$: Ontology Reasoning for Diabetes
**Sample logic rule**

```prolog
advise_e_consultation(Patient, T) :-
    has_age(Patient, Age, T), Age < 80,
    has_no_hospital_access(Patient, T),
    \ + consulted(Patient, internist, years, 1, T),
    has_systolic_bps(Patient, [MostRecent, SecondMostRecent|Rest],
                     months, 6, T), MostRecent > 140, SecondMostRecent > 140.
```

- Rule can be improved via semantic reasoning in terms of
  - access to / inference on data:
    has_no_hospital_access(...) inferred from living place
Sample logic rule

\[
\text{advise\_e\_consultation}(\text{Patient}, T): - \\
\quad \text{has\_age}(\text{Patient}, \text{Age}, T), \text{Age} < 80, \\
\quad \text{has\_no\_hospital\_access}(\text{Patient}, T), \\
\quad \text{consulted}(\text{Patient}, \text{internist}, \text{years}, 1, T), \\
\quad \text{has\_systolic\_bps}(\text{Patient}, [\text{MostRecent}, \text{SecondMostRecent} | \text{Rest}], \\
\quad \text{months}, 6, T), \text{MostRecent} > 140, \text{SecondMostRecent} > 140.
\]

- Rule can be improved via semantic reasoning in terms of
  - access to / inference on data:
    - \text{has\_no\_hospital\_access}(\ldots) inferred from living place
  - knowledge representation / development effort:
    - \text{has\_systolic\_bps}(\ldots) parent concept from class hierarchy
Ontology classes

Class hierarchy: SystolicBloodPressureObservation

Annotations: SystolicBloodPressureObservation

SubClass Of

- hasActCode some ({8480-6, Portavita1236, Portavita714, Portavita715, Portavita716, Portavita717})
- hasValue max 1 nonNegativeInteger
- Observation

SubClass Of (Anonymous Ancestor)

- hasSubject exactly 1 Patient
- hasActCode exactly 1 ActCode
Ontology rules

Data property hierarchy:

- hasNeuropathyPresentation
- hasNeuropathyTreatment
- hasNightShifts
- hasObservationValue
- hasPeripheralVascularDiseaseType
- hasPortion
- hasRelativeCVDDiagnosisAge
- hasRelativeDiabetesDiagnosisDate
- hasRelativeDiabetesType
- hasRelativeHiperlipidaemiesDiagnosis
- hasRelativeHiperlipidaemiesPhenotypes
- hasRelativeStatus
- hasRetinopathyClass
- hasSmokesPerDay
- hasTotalCalory
- isActiveTreatment

Rules:

RuralArea(?lp) -> hasHospital(?lp, false)

PatientProfile(?p), hasLifeStyle(?lp, false) -> hasHospital(?lp, false)

Characteristics: hasObservationValue

- Functional

Description: hasObservationValue

Domains (intersection)
- Observation

Ranges
- integer

Disjoint With
### Portavita patient database

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Living Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>82319</td>
<td>73</td>
<td>Lutjebroek</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient</th>
<th>Observation</th>
<th>Date</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>82319</td>
<td>11783457</td>
<td>25-01-2013</td>
<td>8480-6</td>
<td>133</td>
</tr>
<tr>
<td>82319</td>
<td>11827346</td>
<td>15-02-2013</td>
<td>Portavita714</td>
<td>141</td>
</tr>
<tr>
<td>82319</td>
<td>12053457</td>
<td>01-04-2013</td>
<td>8480-6</td>
<td>157</td>
</tr>
</tbody>
</table>
Illustrative Example

Ontology assertions

for every patient \( p \):
   add to the ontology:
   \[
   \text{individual } p \text{.patientId with class } \text{"PatientProfile"}
   \]
   \[
   \text{individual } p \text{.livingPlace with class } \text{"LivingPlace"}
   \]
   \[
   \text{object_property } p \text{.patientId } \text{"hasLivingPlace" } p \text{.livingPlace}
   \]
   \[
   \text{object_property } p \text{.patientId } \text{"hasAge" } p \text{.age}
   \]

for every observation \( o \):
   add to the ontology:
   \[
   \text{individual } o \text{.observationId with class } o \text{.code}
   \]
   \[
   \text{data_property } o \text{.observationId } \text{"hasValue" } o \text{.value}
   \]
   \[
   \text{data_property } o \text{.observationId } \text{"hasMeasurementDate" } o \text{.date}
   \]
   \[
   \text{object_property } o \text{.patientId } \text{"hasObservation" } o \text{.observationId}
   \]
Reasoning outcome

- Get data from DB
- Apply semantic reasoning
- Translate ontology individuals into logic predicates

```prolog
has_no_hospital_access(patient_82319, 13-05-2013).
has_systolic_bp(patient_82319, 133, 25-01-2013).
has_systolic_bp(patient_82319, 141, 15-02-2013).
has_systolic_bp(patient_82319, 157, 01-04-2013).
```
Conclusions

- Present an ontology reasoning component $\textit{ORC}$ that:
  - builds upon existing personal health environment $\text{COMMODITY}_{12}$
  - support the integration and interpretation of multimodal medical information

- Future work:
  - integrate other ontologies such as for food and alcohol
  - provide generic translators based on a concept ontology
  - run experimental tests to evaluate our system