A Description Logics Approach to Clinical Guidelines and Protocols

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Formalization of CGP

- Up until now:
  CGPs are treated as plans: actions, states, transition functions. Methodologies from the AI Planning & OR Scheduling community

- New Approach:
  Formal Ontology methodology can be used to represent (at least, selected) aspects of CGPs in order to support consistency, fusion, and modularization of CGPs
Our Proposal

- Ontological analysis of CGPs
  - Introduce basic categories
  - Classification of domain entities
  - Axiomatize foundational relations
  - Study interrelations between domain entities

- Choose a logic framework for the formalization of the ontology
  - Representation: Description Logics (FOL subset)
  - Reasoning: Powerful Taxonomic Classifiers (e.g., FaCT, RACER)
### Fundamental Distinctions

<table>
<thead>
<tr>
<th>Continuants</th>
<th>vs.</th>
<th>Occurrents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Objects,</td>
<td></td>
<td>Processes, Events, Actions, Courses of Diseases, Treatment</td>
</tr>
<tr>
<td>Substances,</td>
<td></td>
<td>Episodes</td>
</tr>
<tr>
<td>Organisms,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Parts</td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Individuals</th>
<th>vs.</th>
<th>Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>my left Hand, Paul’s</td>
<td></td>
<td>Hand, Diabetes, Appendectomy</td>
</tr>
<tr>
<td>Diabetes,</td>
<td></td>
<td>Appendectomy of Patient #230997</td>
</tr>
<tr>
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<td></td>
<td></td>
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</table>

How do CGPs fit into this framework?
Guidelines and Occurrents

- Proposal: A Guideline $G$ can be mapped to a set of classes of occurrents:
  $$E = \{E_1, E_2, ..., E_n\}$$
- The elements of $E$ correspond to all allowed paths through a Guideline $G$
- Each element of $E$ represents - as a conceptual abstraction – a class of individual clinical occurrences
Simplified Chronic Cough Guideline

E1 = (CC, AN, PE, SM, CS, NC)
E2 = (CC, AN, PE, SM, CS, CO, CX)
E3 = (CC, AN, PE, NS, CX)
E4 = (CC, PE, AN, SM, CS, NC)
E5 = (CC, PE, AN, SM, CS, CO, CX)
E6 = (CC, PE, AN, NS, CX)

Temporal sequence of clinical occurrents
Simplified Chronic Cough Guideline

E1 = (CC, AN, PE, SM, CS, NC)
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Temporal sequence of clinical occurrences

Clinical occurrence
Simplified Chronic Cough Guideline

**Chronic Cough [CC]**

- **Phys. Exam [PE]**
- **Anamnesis [AN]**

**Smoking [SM]**
- **Cessation of Smoking [CS]**
- **No Cough [NC]**
- **Cough [CO]**

**Non Smoking [NS]**
- **Chest X-Ray [CX]**

Temporal sequence of clinical occurrences:

- $E1 = (CC, AN, PE, SM, CS, NC)$
- $E2 = (CC, AN, PE, SM, CS, CO, CX)$
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Basic Relations

Taxonomic Order (is-a) relates classes of specific occurrences to classes of general ones:

\[ \text{is-a}(\text{CX}, \text{XR}) \rightarrow_{\text{def}} \forall x: \text{CX}(x) \rightarrow \text{XR}(x) \]
Basic Relations

Taxonomic Order (is-a)
relates classes of specific occurrences to classes of general ones:
\[ \text{is-a}(CX, XR) \rightarrow \text{def } \forall x: CX(x) \rightarrow XR(x) \]

Mereologic Order (has-part)
relates classes of occurrences to classes of sub-occurrences:
\[ \forall x: PE(x) \rightarrow \exists y: HA(y) \land \text{has-part}(x,y) \]
Basic Relations

**Taxonomic Order (is-a)**
relates classes of specific occurrences to classes of general ones:
\[ \text{is-a}(CX, XR) \rightarrow_{\text{def}} \forall x: CX(x) \rightarrow XR(x) \]

**Mereologic Order (has-part)**
relates classes of occurrences to classes of sub-occurrences
\[ \forall x: PE(x) \rightarrow \exists y: HA(y) \land has-part(x,y) \]

**Temporal Order (follows / precedes)**
relates classes of occurrences in terms of temporal succession
Modelling Pattern

\[ K \quad L \quad T \quad S \]

*occurrent concepts*

<table>
<thead>
<tr>
<th>transitive relations</th>
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<tr>
<td>( \exists \text{ has-part} )</td>
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<tr>
<td>( \exists \text{ precedes} )</td>
</tr>
<tr>
<td>( \text{is-a} )</td>
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Modelling Pattern

\[ K \quad L \quad T \quad S \]

\[ K_U \quad L_U \quad U \quad T \quad S \]

*occurrence* concepts
definition of U

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Modelling Pattern

\[ \exists \text{ has-part} \]
\[ \exists \text{ precedes} \]
\[ \text{is-a} \]
Modelling Pattern

\[ \exists \text{ has-part} \]
\[ \exists \text{ precedes} \]
\[ \text{is-a} \]

transitive relations

\(_K \) \_R \_L \_T \_S

\(_K_U \) \_L_U \_U \_E

\(_U_E \) \_S_E

occurrent concepts
definition of \( U \)
definition of \( E \)
\( U_E \) inherits properties of \( U \)
Modelling Pattern

\[ U \text{ has-part } \exists \text{ precedes } \exists \text{ inherits properties of } U \]

\[ \text{definition of } U \]

\[ \text{definition of } E \]

\[ U_E \text{ inherits properties of } U \]

\[ \text{definition of } F \text{ as a subconcept of } E \]

\[ \text{transitive relations} \]

\[ \exists \text{ has-part} \]

\[ \exists \text{ precedes} \]

\[ \text{is-a} \]
Modelling Pattern

**transitive relations**
- $\exists \text{ has-part}$ (green arrow)
- $\exists \text{ precedes}$ (red arrow)
- is-a (blue arrow)

- $\exists$ concepts
- definition of $U$
- definition of $E$
- $U_E$ inherits properties of $U$
- definition of $F$ as a subconcept of $E$
- $F$ inherits properties of $E$
Modelling Pattern

occurrent concepts
definition of U
definition of E
$U_E$ inherits properties of U
definition of F as a subconcept of E
F inherits properties of E
F, additionally, has a T which occurs between U and S

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Modelling Pattern

\[ \begin{align*}
\exists \text{ has-part} & \quad \text{green} \\
\exists \text{ precedes} & \quad \text{red} \\
\text{is-a} & \quad \text{blue}
\end{align*} \]

**transitive relations**

- \( \exists \text{ has-part} \)
- \( \exists \text{ precedes} \)
- is-a

**occurrent concepts**
- definition of U
- definition of E
- \( U_E \) inherits properties of U
- definition of F as a subconcept of E
- F inherits properties of E
- F, additionally, has a T which occurs between U and S
- inferences / constraints (formalization see paper)
Modelling Pattern


\[\begin{align*}
\text{K} & \rightarrow \text{L} \\
\text{K}_U & \rightarrow \text{U} \\
\text{K}_U & \rightarrow \text{U}_E \\
\text{L}_U & \rightarrow \text{U}_E \\
\text{L}_U & \rightarrow \text{S}_E \\
\text{U} & \rightarrow \text{T} \\
\text{U}_E & \rightarrow \text{T} \\
\text{U}_E & \rightarrow \text{F} \\
\text{S}_E & \rightarrow \text{F} \\
\end{align*}\]

\textit{occurrence} concepts

definition of U

\text{U}_E \text{ inherits properties of U}

definition of E

\text{F} \text{ inherits properties of E}

\text{F, additionally, has a T which}

occurs between U and S

\text{inferences / constraints}

(formalization see paper)

\text{transitive relations}

\exists \text{ has-part}

\exists \text{ precedes}

\text{is-a}
Benefits

- Description Logics implementations allow taxonomic classification and instance recognition.
  - Checking of logical integrity in the management, cooperative development and fusion of CGPs
  - Detecting redundancies and inconsistencies, e.g., conflicting orders when applying several CGPs simultaneously to one clinical case
  - Auditing of concrete instances (cases) from the Electronic Patient Record in terms of cross-checking against applicable CGPs (quality assurance, epicritic assessment)
Discussion

- First sketch of ongoing research
- Based on Description Logics $\mathcal{ALCN}$
- Up until now, not all (temporal) inferencing capabilities are supported
- Needs to be validated under real conditions
- Recommended for further investigation
  - Tool: OilED Knowledge editor (oiled.man.ac.uk) with built-in FaCT classifier
  - Theory: Baader et al (eds.) The Description Logics Handbook