Versions and Applicability of Concept Definitions in Legal Ontologies

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OWLED 2008 DC, Gaithersburg
Outline

1 Preliminaries
   - Context
   - Versioning

2 Representation
   - Overview
   - Time
   - Concept Definitions
Legal domain
- Legislation, contracts, jurisprudence etc.

Representation of
- Norms
- Definitions (→ legal ontologies)

... for the purpose of
- Assessment, planning, simulation, harmonisation

How to deal with versions?
- Different classification of domain objects
- Reasoning results in different outcome
- Impact may be significant
Variants of concept definitions in legislation

- Ordering on objects in the world
- Conflicts
  - Specificity (\textit{lex specialis})
  - Different issuers (\textit{lex superior})
  - \textbf{Through time} (\textit{lex posterior})
- Definitions hold independently, at the same time
- Complex determination of validity of definitions
  - Applicability & Activity
Validity Intervals

Immediate

- active
- applicable

- publication
- enacted
- effective
- repealed
Validity Intervals

- **Retroactive**
  - publication
  - enacted
  - repealed

- **Active**
  - effective

- **Applicable**
Validity Intervals

Delayed validity interval

- publication
- enacted
- effective
- applicable
- active
- repealed
Ontology Evolution & Versioning

Approaches

- Evolution & Versioning
- Comparing two versions
- Time stamps (properties and classes)
  - Meta-ontology
  - Temporal Extension of KR language
  - Builtins
  - Rules

Drawbacks:

- Standard reasoning unaware of temporal information
  - Should infer conclusions that hold only at ‘current’ time
  - Relations may only hold between concepts that are both valid
- Snowball effect
- Rules may conflict with DL semantics, and lead to undecidability
- Multiple intervals?
Focus & Requirements

Versioning in Law

- Impact on classification of objects in a domain

Requirements

- General purpose representation formalism (OWL DL)
- Incremental versioning
  - New version of a concept should have *minimal impact*
- Co-existence of multiple (incompatible) versions
- Ability to switch between versions
- Reasoning on both versioned and version-independent concepts
- Validity depends on multiple intervals
Expressiveness of $SHOIN \ (\Rightarrow \text{ supported by OWL-DL}).$

Representation:

- A **dynamic concept** is a concept whose meaning changes over time.
- Each new **concept variant** is introduced as a *defined* class, subsumed by the dynamic concept class.
- Concept variants are *valid* within some combination of intervals.
- A DL reasoner classifies individuals as class members, based on the choice of a *current interval.*
Incorporating Time

Three layers:

- Timeline and current interval:
  - A finite, discrete axis,
  - undecomposable intervals + total ordering relation,
  - selection mechanism for current interval,

- Stamping individuals,

- Scoping concepts.
Timelapse

\[ \text{TimeInterval} \equiv \{ \text{interval}_1, \ldots, \text{interval}_n \} \]

for any \( \text{interval}_i \) and \( \text{interval}_j \), if \( i \leq j \) then the ABox contains:
- beforeEq(\( \text{interval}_i \), \( \text{interval}_j \))
- afterEq(\( \text{interval}_j \), \( \text{interval}_i \))

We specify the \textbf{valid time} by defining:

\[ \text{CurrentInterval} \equiv \{ \text{interval}_i \} \]

where \( i \in \{1, \ldots, n\} \)
A **timestamp** marks two temporal limits (**from** and **to**):

\[
\text{Timestamped} \equiv (\exists \text{from. TimeInterval } \sqcap \geq 1 \text{ from } \sqcap \leq 1 \text{ from}) \\
\quad \sqcap (\exists \text{to. TimeInterval } \sqcap \geq 1 \text{ to } \sqcap \leq 1 \text{ to})
\]
An individual \textbf{exists} in the current interval only if it came into existence \textbf{before or during} the interval and ceased to exist \textbf{during or after} it.

\[
\exists \text{from.}(\exists \text{beforeEq.CurrentInterval}) \land \exists \text{to.}(\exists \text{afterEq.CurrentInterval})
\]
More generally, we can specify a general temporal restriction:

\[
\text{GeneralTRestriction} \equiv \exists \text{from.}(\exists \text{beforeEq.}(\bigcap_{1 \leq i \leq m} T\text{Constraint}_i))
\]

\[
\cap \exists \text{to.}(\exists \text{afterEq.}(\bigcap_{1 \leq i \leq m} T\text{Constraint}_i))
\]

- Every \( T\text{Constraint}_i \) is a subset of time intervals.
- Every \( \text{GeneralTRestriction} \) contains at least:
  - \( T\text{Constraint}_1 \equiv \text{CurrentInterval} \)
  - \( T\text{Constraint}_2 \equiv \exists \text{afterEq.}\{\text{interval}_i\} \cap \exists \text{beforeEq.}\{\text{interval}_j\} \)

where \( 1 \leq i \leq j \leq n \)

- Two possibilities:
  - \( \text{CurrentInterval}_2^T \subseteq T\text{Constraint}_2^T \)
  - \( T\text{Constraint}_1^T \cap T\text{Constraint}_2^T = \emptyset \)
A DynamicConcept is the union of its variants:

$$\text{DynamicConcept} \equiv \text{Variant}_1 \sqcup \ldots \sqcup \text{Variant}_m$$

Each variant is an intersection of its meaning and a GeneralTRestriction:

$$\text{Variant}_k \equiv \text{Meaning}_k \sqcap \text{GeneralTRestriction}_k$$

The variants exclusively, and exhaustively cover the time axis. An individual can be classified as an instance of a variant in the current interval only if the individual exists and the variant is valid in that interval.
DynamicConcept

\[ V_1 \equiv M_1 \cap GTR_1 \]
\[ V_2 \equiv M_2 \cap GTR_2 \quad (\perp) \]
\[ V_3 \equiv M_3 \cap GTR_3 \quad (\perp) \]

individuals

\[ i_1 : M_1 \]
\[ i_2 : M_1 \cap M_2 \]
\[ i_3 : M_3 \]

current interval

time intervals
DynamicConcept

\[ V_1 = M_1 \cap GTR_1 \]
\[ V_2 = M_2 \cap GTR_2 (\perp) \]
\[ V_3 = M_3 \cap GTR_3 (\perp) \]

\[ i_1 : M_1 \]
\[ i_2 : M_1 \cap M_2 \]
\[ i_3 : M_3 \]
Walkthrough

DynamicConcept

\[ V_1 = M_1 \cap GTR_1 (\bot) \]

\[ V_2 = M_2 \cap GTR_2 \]

\[ V_3 = M_3 \cap GTR_3 (\bot) \]

\( i_1 : M_1 \)

\( i_2 : M_1 \cap M_2 \)

\( i_3 : M_3 \)

current interval

time intervals
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Versions and Applicability of Concept Definitions
A *legal* dynamic concepts, requires interaction between multiple intervals:

\[
\text{AppInterval} \equiv \exists \text{afterEq.}\{\text{interval}_i\} \cap \exists \text{beforeEq.}\{\text{interval}_j\}
\]

\[
\text{ActInterval} \equiv \exists \text{afterEq.}(\exists \text{from}^-\{\text{norm}\}) \cap \exists \text{beforeEq.}(\exists \text{to}^-\{\text{norm}\})
\]

where \text{norm} is a time-stamped individual representing some legal text.

A concept is valid for some the current interval only if it is both *applicable* and the norm that defines it is *active* within that interval.

Every \text{GeneralTRestiction} contains at least the \text{CurrentInterval} and some \text{AppInterval} and \text{ActInterval}
Representation of **definitional changes**, implementable using \textit{SHOIN}:

- supported directly by standard reasoners
- Supports incremental changes (reuse, maintenance)
- Backward compatibility (changes are handled monotonically)
- Easy access to all represented versions
- No update snowball effect
- Allows non-versioned concepts
- Space-efficient (performance cost)
Future work

- Performance gains:
  - `CurrentInterval` as individual vs. nominal (2x faster)
- Introduction of `last_interval`, to ‘close’ time scale,
- More complex interplay between intervals (retroactivity)
- Extension to jurisdiction:
  - Spatial
  - Authority