Handling time in RDF

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Outline

• Introducing time into RDF
• Temporal RDF Graphs
• Semantics of Temporal RDF Graphs
• Syntax for Temporal Graphs
• Querying Time in RDF
Introducing time into RDF

Student

Grad

M.Sc

John

UnderGrad

Grad $\text{subC}$ Student

M.Sc $\text{subC}$ Grad

John $\text{type}$ UnderGrad

Time in RDF – p. 3/15
Introducing time into RDF

The diagram illustrates a hierarchy of educational levels and degrees:

- **Student**
  - **Grad**
    - **Ph.D**
    - **M.Sc**
  - **UnderGrad**

The relationships are represented as follows:

- **Student** is a parent of **Grad** and **UnderGrad**.
- **Grad** is a parent of **Ph.D** and **M.Sc**.
- **UnderGrad** is a parent of **M.Sc**.
- John is a child of **M.Sc**.

The edges are labeled with the following properties:

- **subC**
- **type**
Introducing time into RDF
General Issues

• Versioning versus Labeling
  – Label elements subject to change
  – Maintain a snapshot of each state of the graph
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• Time Points versus Time Intervals.

\[[4, 31] = [4] \cup [5] \cup \cdots \cup [30] \cup [31]\]
General Issues

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  – Label elements subject to change
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• Temporal Query Language
  – Point based (variables refer to point times)
  – Interval based (variables refer to intervals)
RDF Intrinsic Issues

• Notion of temporal Entailment $\models_\tau$
RDF Intrinsic Issues

- Notion of temporal Entailment $\models_\tau$

- Treatment of temporal Blank Nodes:
RDF Intrinsic Issues

- Notion of temporal Entailment $\models_\tau$

- Treatment of temporal Blank Nodes:

- Vocabulary for temporal labeling
Definitions

Temporal Triple: an RDF triple with a temporal label, e.g. \((a, b, c)[t]\)

Temporal Graph: set of temporal triples

Snapshot of graph \(G\) at time \(t\):

\[ G(t) = \{(a, b, c) : (a, b, c)[t] \in G\} \]

Notion of temporal entailment \(G_1 \models_{\tau} G_2\)
Semantics

Ground Case:

\[ G_1 \models_\tau G_2 \text{ if for each } t, \ G_1(t) \models G_2(t) \]
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Non Ground Case:

\[ G_1 \models_{\tau} G_2 \text{ if there are ground instances } \mu_1(G_1) \text{ and } \mu_2(G_2) \text{ such that for each } t: \]

\[ \mu_1(G_1)(t) \models_{\tau} \mu_2(G_2)(t) \]
Semantics

Ground Case:

\[ G_1 \models \tau G_2 \quad \text{if for each } t, \quad G_1(t) \models G_2(t) \]

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\[ G_1 \models \tau G_2 \quad \text{if there are ground instances } \mu_1(G_1) \text{ and } \mu_2(G_2) \text{ such that for each } t: \]

\[ \mu_1(G_1)(t) \models \tau \mu_2(G_2)(t) \]

**Proposition.** For ground graphs, \( G_1 \models \tau G_2 \) implies \( G_1(t) \models G_2(t) \) for all times \( t \).
Semantics (cont.)

The **temporal closure** $tcl(G)$ is a maximal set of temporal triples $G'$ such that:
- $G'$ contains $G$
- $G$ is equivalent to $G'$

**Proposition.**
$G_1 \models_{\tau} G_2$ iff $tcl(G_1) \models_{\tau} G_2$

**Proposition.** Deciding if $G'$ is the closure of $G$ is DP-complete.
Syntax for \((a, b, c)[4, 5]\)

- Point version

\[
\begin{align*}
\text{Y1} & \quad \text{Instant} \quad 4 \\
\text{Y2} & \quad \text{Instant} \quad 5 \\
\end{align*}
\]
Syntax for \((a, b, c)[4, 5]\)

- **Point version**

- **Interval version**
Syntax (cont.): rules

Rule 1-2: Equivalence between point and interval versions

Rule 3: Normalization of point-version:
Syntax (cont.): rules

Rule 1-2: Equivalence between point and interval versions

Rule 3: Normalization of point-version:
Syntax works well

\((a, b, c)[m, n]\)
Syntax works well (cont.)

*Theorem.*

1. \( G_1 \models_{\tau} G_2 \) implies \((G_1)^* \models (G_2)^*\)
2. \( G_2 \models G_2 \) implies \((G_1)_* \models_{\tau} (G_2)_*\)
3. \((G_*)_* = G\) and \( G \models (G_*)^*\)

*Theorem.* Let \( \vdash \) be the deductive system formed by RDFS rules plus Temporal rules. Then:
\( G_1 \models_{\tau} G_2 \) iff \((G_1)^* \vdash (G_2)^*\)
Querying Temporal RDF

Proposal: Conjunctive fragment with
- interval and point variables
- aggregate functions
- constructor of graphs for answers
Querying Temporal RDF

**Proposal:** Conjunctive fragment with
- interval and point variables
- aggregate functions
- constructor of graphs for answers

- Students who have taken a Master course between year 2000
- Students taking Ph.D courses together and the time when this occurred
- Time intervals when the IT Master program was offered
- Students applying for jobs at time $t$ after finishing their Ph.D program in no more than 4 years
What we have:

1. Semantics for Temporal RDF graphs
2. Syntax to incorporate the framework into standard RDF
3. Sound and complete inference rules for temporal graphs
4. Complexity bounds showing temporal RDF preserves complexity of RDF
5. Sketch of Temporal RDF query language