Fakultät für Informatik
Facoltà di Scienze e Tecnologie informatiche
Faculty of Computer Science

A Framework for Temporal Ontology-based Data Access: a Proposal

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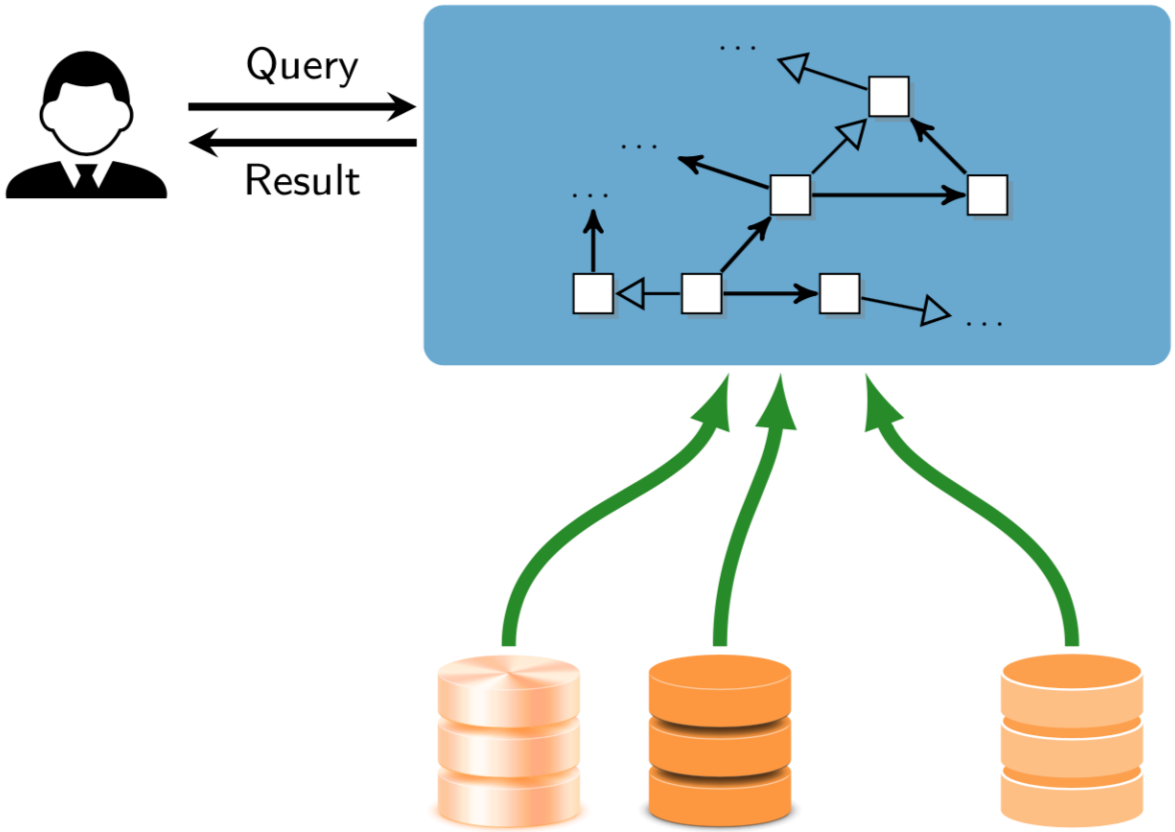
September 24, 2017

- Ontology-based Data Access
- A Framework of Temporal OBDA
- Practical Considerations
- Conclusion and Future Work

Outline



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provides global vocabulary and conceptual view

Mappings
how to populate the ontology from the data

Data Sources
external and heterogeneous

Logical transparency in accessing data:

- does not know where and how the data is stored.
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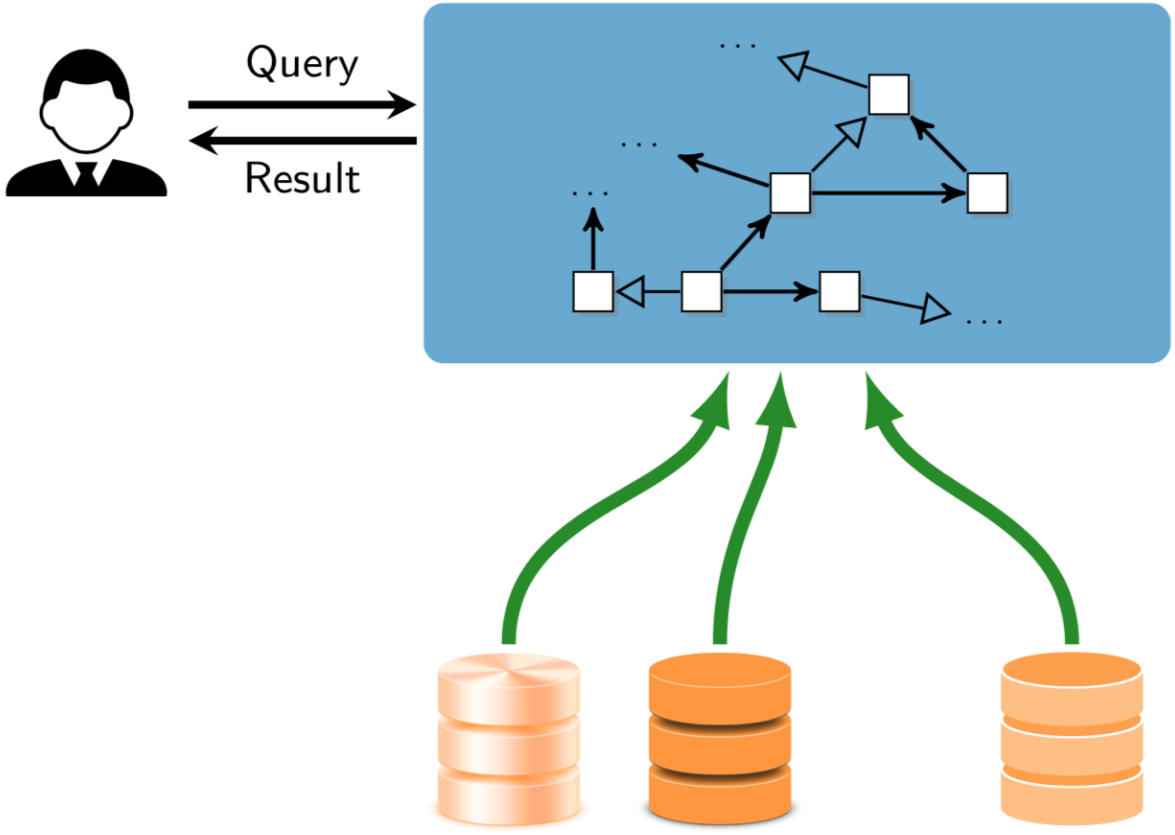

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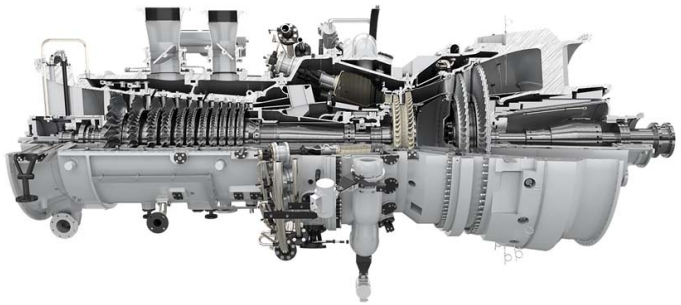
Most of the existing works in OBDA uses only on static data, or only supported limited temporal reasoning capabilities.

Siemens Use Case

Monitoring gas and steam turbines

Collects data from 50 remote diagnostic centres

Centres are linked to a **common DB centre**



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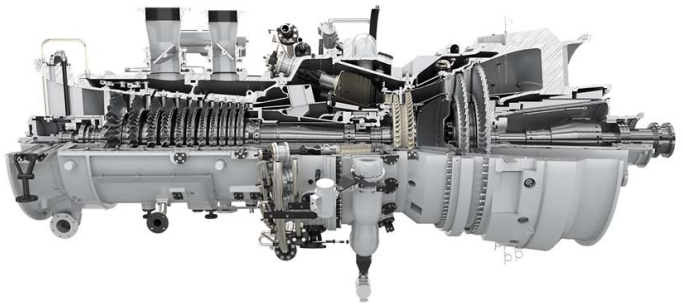

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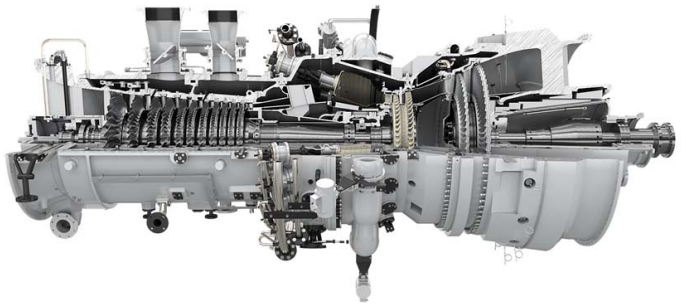

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'find the **gas turbines** deployed in the train with the ID *T001* and **time periods** of their **accomplished purgings**'.

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Proposed Temporal OBDA Framework

A traditional *OBDA* ***specification*** is a **triple** $\mathfrak{S} = \langle \mathcal{O}, \mathfrak{M}, \mathcal{S} \rangle$.

- $\mathcal{O}$ is an ontology,
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Our temporal OBDA ***specification*** is a **tuple**

$$\mathfrak{S} = \langle \Sigma_s, \Sigma_t, \mathfrak{M}_s, \mathfrak{M}_t, \mathcal{O}, \mathcal{R}, \mathcal{T}, \mathcal{S} \rangle,$$

- where Σ_s (Σ_t) is a **static** (respectively, **temporal**) vocabulary,
- $\mathfrak{M}_s$ ($\mathfrak{M}_t$) a set of **static** (respectively, **temporal**) mapping assertions,
- $\mathcal{O}$ an **ontology**,
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Static Ontology

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An **ontology** for modeling the **static knowledge** about

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$$\begin{aligned}
\mathsf{GasTurbine} &\sqsubseteq \mathsf{Turbine}, & \exists \mathsf{isMonitoredBy} &\sqsubseteq \mathsf{TurbinePart},\\
\mathsf{SteamTurbine} &\sqsubseteq \mathsf{Turbine}, & \exists \mathsf{isMonitoredBy}^- &\sqsubseteq \mathsf{Sensor},\\
\mathsf{RotationSpeedSensor} &\sqsubseteq \mathsf{Sensor}, & \exists \mathsf{isPartOf} &\equiv \mathsf{TurbinePart},\\
\mathsf{TemperatureSensor} &\sqsubseteq \mathsf{Sensor}, & \exists \mathsf{isPartOf}^- &\sqsubseteq \mathsf{Turbine},\\
\mathsf{PowerTurbine} &\sqsubseteq \mathsf{TurbinePart}, & \exists \mathsf{isDeployedIn} &\sqsubseteq \mathsf{Turbine},\\
\mathsf{Burner} &\sqsubseteq \mathsf{TurbinePart}, & \exists \mathsf{isDeployedIn}^- &\sqsubseteq \mathsf{Train}.
\end{aligned}$$

We use *DL-Lite*$_{\mathcal{R}}$ (OWL 2 QL) as our static ontology language.

Static Rules

However, ***DL-Lite***$_{\mathcal{R}}$ is not able to capture all the **static knowledge** required in the **Siemens** use case.
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Turbine parts monitored by different co-located sensors (e.g. temperature, rotation speed).

$$\begin{aligned}\text{ColocSensors}(tb, ts, rs) \leftarrow\ & \text{isMonitoredBy}(pt, ts), \text{TemperatureSensor}(ts),\\ & \text{isMonitoredBy}(pt, rs), \text{RotationSpeedSensor}(rs),\\ & \text{isPartOf}(pt, tb), \text{Turbine}(tb).\end{aligned}$$

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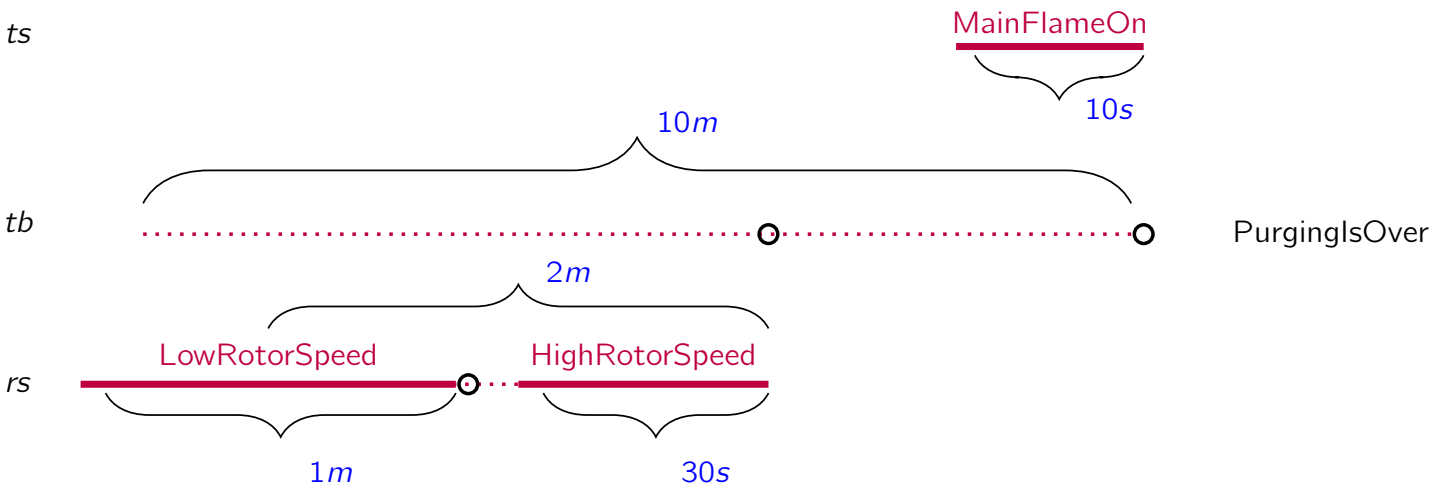

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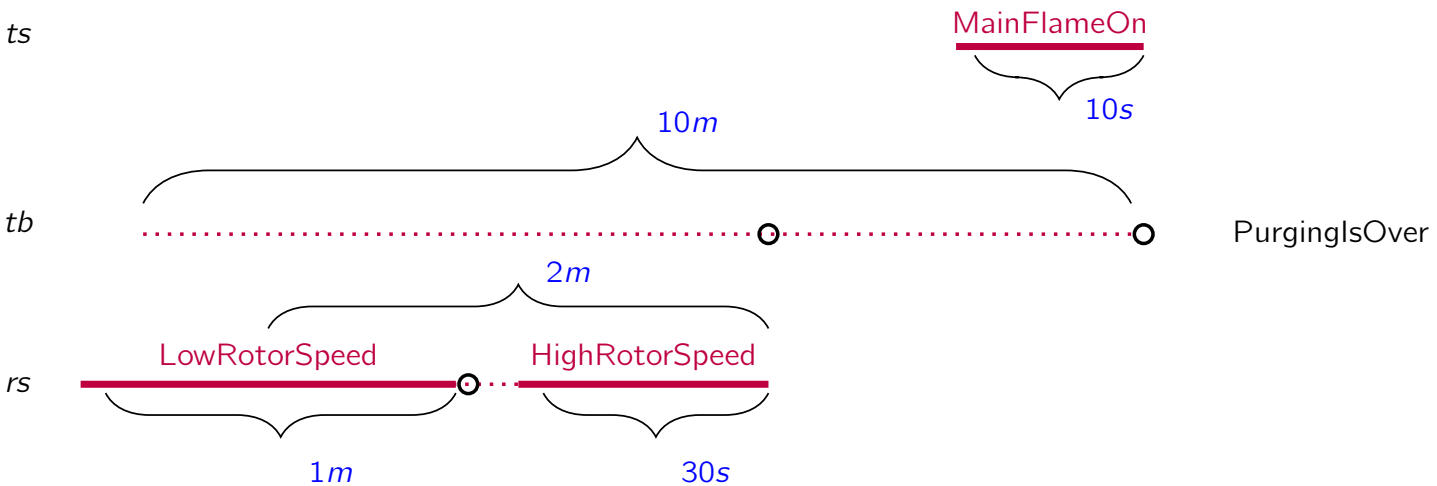

$$\text{PurgingIsOver}(tb) \leftarrow \boxminus_{[0s,10s]} \text{MainFlameOn}(ts),$$
$$\diamondminus_{(0,10m]}\big[\boxminus_{(0,30s]} \text{HighRotorSpeed}(rs), \diamondminus_{(0,2m]} \boxminus_{(0,1m]} \text{LowRotorSpeed}(rs)\big],$$
$$\text{ColocTempRotSensors}(tb, ts, rs).$$
$$\text{HighRotorSpeed}(tb) \leftarrow \text{rotorSpeed}(tb, v), v > 1260.$$
$$\text{LowRotorSpeed}(tb) \leftarrow \text{rotorSpeed}(tb, v), v < 1000.$$

A Quick Recap of datalogMTL

datalogMTL is a Horn fragment of **Metric Temporal Logic (MTL)**.

A **datalogMTL** *program* is a finite set of ***rules*** of the form

$$A^+ \leftarrow A_1 \wedge \cdots \wedge A_k \quad \text{or} \quad \bot \leftarrow A_1 \wedge \cdots \wedge A_k,$$

where $k \geq 1$, each A_i is either a comparison expression (e.g. $\tau \neq \tau'$, $\tau \leq \tau'$) or defined by the grammar

$$A \ ::= \ P(\tau_1, \ldots, \tau_m) \ \mid \ \boxplus_\varrho A \ \mid \ \boxminus_\varrho A \ \mid \ \diamondplus_\varrho A \ \mid \ \diamondminus_\varrho A$$

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$$\boxminus_{[0,3h]}\mathsf{Blizzard}(v) \leftarrow \boxminus_{[0,3h]}\mathsf{StrongWind}(v) \wedge \boxminus_{[0,3h]}\mathsf{LowVisibility}(v) \wedge \boxminus_{[0,3h]}\mathsf{Snow}(v)$$

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- **Data complexity** of query answering with **datalog$_{nr}$MTL** is AC^0.
- query answering with **datalog$_{nr}$MTL** can be reduced to SQL
- Suitable as a temporal rule language for OBDA

Schema and Data

An example data schema $\mathcal{S}$ for the Siemens data, including sensor measurements and deployment details:

$$\text{tb\_measurement}(\underline{\text{timestamp}}, \underline{\text{sensor\_id}}, \text{value}),$$
$$\text{tb\_sensors}(\underline{\text{sensor\_id}}, \text{sensor\_type}, \text{mnted\_part}, \text{mnted\_tb}),$$
$$\text{tb\_deployment}(\underline{\text{turbine\_id}}, \text{turbine\_type}, \text{deployed\_in}),$$
$$\text{tb\_components}(\underline{\text{turbine\_id}}, \underline{\text{component\_id}}, \text{component\_type}).$$

tb_measurement		
timestamp	sensor_id	value
2017-06-06 12:20:00	rs01	570
2017-06-06 12:21:00	rs01	680
2017-06-06 12:21:30	rs01	920
2017-06-06 12:22:50	rs01	1278
2017-06-06 12:23:40	rs01	1310
	...	
2017-06-06 12:32:30	mf01	2.3
2017-06-06 12:32:50	mf01	1.8
2017-06-06 12:33:40	mf01	0.9
	...	

tb_sensors			
sensor_id	sensor_type	mnted_part	mnted_tb
rs01	0	pt01	tb01
mf01	1	b01	tb01
	...	...	

tb_components		
turbine_id	component_id	component_type
tb01	pt01	0
tb01	b01	1
	...	

Static Mapping Assertions

Static mapping assertions: $\phi(\vec{x}) \rightsquigarrow \psi(\vec{x})$

where $\phi(\vec{x})$ is a **query** over the **schema** $\mathcal{S}$,

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$$\texttt{SELECT sensor\_id AS X FROM tb\_sensors WHERE sensor\_type} = 1 \rightsquigarrow \text{TemperatureSensor}(\texttt{X})$$

$$\texttt{SELECT component\_id AS X FROM tb\_components WHERE component\_type} = 1 \rightsquigarrow \text{Burner}(\texttt{X})$$

$$\texttt{SELECT mnted\_part AS X, sensor\_id AS Y FROM tb\_sensors} \rightsquigarrow \text{isMonitoredBy}(\texttt{X}, \texttt{Y})$$

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We retrieve the following **facts**:

Burner(b01), TemperatureSensor(mf01),

isMonitoredBy(pt01, rs01), isMonitoredBy(b01, mf01).

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$\mathfrak{M}_s$ is the set of ***static*** mapping assertions.

Temporal Mapping Assertions

Temporal mapping assertions:

$$\phi(\vec{x}, \texttt{begin}, \texttt{end}) \rightsquigarrow \psi(\vec{x})@\langle t_{\texttt{begin}}, t_{\texttt{end}} \rangle$$

`begin` and `end` are mapped to values of the **date/time** format

'$\langle$' is either '(' or '[', (and similarly for '$\rangle$').

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```
SELECT * FROM (
    SELECT sensor_id, value,timestamp AS begin, LEAD(timestamp, 1) OVER W AS end
    FROM tb_measurement, tb_sensors
    WINDOW W AS (PARTITION BY sensor_id ORDER BY timestamp)
    WHERE tb_measurement.sensor_id = tb_sensors.sensor_id AND sensor_type = 0
) SUBQ WHERE value > 1260
```

$\rightsquigarrow$ HighRotorSpeed(sensor_id)@[begin, end)

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$\rightsquigarrow$ HighRotorSpeed(`sensor_id`)@[`begin`, `end`)

We retrieve **temporal facts** from the database:

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We denote **sets** of such mapping assertions by $\mathfrak{M}_t$.

Temporal OBDA Specification (Recap)

A Temporal OBDA ***specification*** is the tuple

$$\mathfrak{S} = \langle \Sigma_s, \Sigma_t, \mathfrak{M}_s, \mathfrak{M}_t, \mathcal{O}, \mathcal{R}, \mathcal{T}, \mathcal{S} \rangle,$$

- where Σ_s (Σ_t) is a **static** (respectively, **temporal**) vocabulary,
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Temporal OBDA Instance

A temporal OBDA ***instance*** $\mathfrak{I}$ is a pair $\langle \mathfrak{S}, D \rangle$

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We advocate the use **RDF Datasets**, following the model proposed by the W3C **RSP Community Group**.

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The **temporal fact**

$$\text{HighRotorSpeed}(\texttt{rs01})@[\text{2017-06-06 12:22:50, 2017-06-06 12:23:40})$$

is modeled as the **named graph**

$$\text{GRAPH } g_0 \ \{(\texttt{rs01}, a, \text{HighRotorSpeed})\}$$

and the following set of triples in the **default graph**:

$(g_0, a, \text{time:Interval})$,
$(g_0, \text{time:isBeginningInclusive}, \text{true}), (g_0, \text{time:isEndInclusive}, \text{false})$,
$(g_0, \text{time:hasBeginning}, b_0), (b_0, \text{time:inXSDDateTimeStamp}, \text{'2017-06-06 12:22:50'})$,
$(g_0, \text{time:hasEnd}, e_0), (e_0, \text{time:inXSDDateTimeStamp}, \text{'2017-06-06 12:23:40'})$.

Query Answering

'find the **gas turbines** deployed in the **train** with the ID *T001* and **time periods** of their **accomplished purgings**'.

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We ask for the query $Q(tb)@\iota$, where $Q(tb)$ is defined as

$$\begin{aligned} \mathsf{Q}(tb) \leftarrow\ & \mathsf{Train}(\text{“}T001\text{”}), \mathsf{GasTurbine}(tb), \\ & \mathsf{isDeployedIn}(\mathsf{tb}, \text{“}T001\text{”}), \mathsf{PurgingIsOver}(tb). \end{aligned}$$

Outline

Concrete Syntax

component	defines predicates in	in terms of predicates in	language
$\mathfrak{M}_s$	Σ_s	$\mathcal{S}$	R2RML
$\mathfrak{M}_t$	Σ_t	$\mathcal{S}$	R2RML
$\mathcal{O}$	Σ_s	Σ_s	*DL-Lite*$_\mathcal{R}$ / OWL 2 QL
$\mathcal{R}$	Σ_s	Σ_s	non-recursive datalog
$\mathcal{T}$	Σ_t	$\Sigma_s \cup \Sigma_t$	datalog$_{nr}$MTL

Ontop Mapping Syntax

```
[PrefixDeclaration]
st:             http://siemens.com/temporal/ns#
xsd:    http://www.w3.org/2001/XMLSchema#
obda:   https://w3id.org/obda/vocabulary#

[MappingDeclaration] @collection [[
mappingId   mappingRSA1260
target      st:HighRotorSpeed/{sensor_id} obda:hasStatus st:HighRotorSpeed.
interval    [ {begin}^^xsd:dateTimeStamp, {end}^^xsd:dateTimeStamp )
source      SELECT sensor_id, begin, end FROM (
    SELECT sensor_id, value, timestamp AS begin,
    LEAD(timestamp, 1) OVER W AS end
    FROM MEASUREMENT
    WINDOW W AS (PARTITION BY sensor_id ORDER BY timestamp)) SUBQ
    WHERE value > 1260
]]
```

Query Language

'find the **gas turbines** deployed in the **train** with the ID ***T001*** and **time periods** of their **accomplished purgings**'.

```
PREFIX ss: <http://siemens.com/ns#>
PREFIX st: <http://siemens.com/temporal/ns#>
PREFIX obda: <https://w3id.org/obda/vocabulary#>

SELECT ?tb ?left_edge ?begin ?end ?right_edge WHERE {
?tb a ss:GasTurbine ; ss:isDeployedIn ss:train_T001 .

{?tb a st:PurgingIsOver}@<?left_edge,?begin,?end,?right_edge>
}
```

Equivalent SPARQL Query

```
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX time: <http://www.w3.org/2006/time#>
PREFIX ss: <http://siemens.com/ns#>
PREFIX st: <http://siemens.com/temporal/ns#>
PREFIX obda: <https://w3id.org/obda/vocabulary#>

SELECT ?tb ?left_edge ?begin ?end ?right_edge WHERE {
  ?tb a ss:GasTurbine ; ss:isDeployedIn ss:train_T001 .

  GRAPH ?g { ?tb a st:PurgingIsOver.}

  ?g a time:Interval ;
     time:isBeginningInclusive ?left_edge  ;
     time:hasBeginning [ time:inXSDDateTimeStamp ?begin ] ;
     time:hasEnd [ time:inXSDDateTimeStamp ?end ] ;
     time:isEndInclusive ?right_edge .
}
```

Outline

Future Work

- Query rewriting algorithm
- Implementation as an extension of Ontop
- Experiments with **real world** data (hopefully in Siemens)
- Extend the framework for **streaming** data

THANKS