Towards processing and reasoning streams of events in knowledge-driven manufacturing execution systems

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Title of the paper: Towards processing and reasoning streams of events in knowledge-driven manufacturing execution systems

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Towards processing and reasoning streams of events in knowledge-driven manufacturing execution systems

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Outline

• Background and motivation
• Technology timeline
• 2010…?
• Industrial automation knowledge-driven solutions
• SPARQL languages for reasoning streams of events
• An EP-SPARQL application in manufacturing systems
• Potentials
• Conclusions
• Further work
Background

• Large investment on information communication technologies implementation during last decades for optimizing processes in manufacturing systems due to market demands

• This caused the implementation of paradigms as service-oriented and event-driven architectures in factories, used for wide data integration

• On the other hand, the use of knowledge representation permitted the description of system status in knowledge bases, which can be queried and updated at runtime.
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Technology timeline (2/2)

60s:
- Teletype
- ARPANET

70s:
- Graphics terminals
- Unix
- PC

80s:
- GUI
- Ethernet

90s:
- Smartphone
- the Internet

00s:
- Cloud computing (Platforms)
- Web standards

- Cloud computing
- Technology-agnostic
- PC
- server
- dumb terminal
- printer
- cluster controller

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2010... ?

- **Standards and best practices** for knowledge-driven, data-intensive systems.

**SPARQL**

<table>
<thead>
<tr>
<th>Paradigm</th>
<th>Query language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>W3C</td>
</tr>
<tr>
<td>First appeared</td>
<td>2008; 7 years ago</td>
</tr>
<tr>
<td>Stable release</td>
<td>1.1 / March 21, 2013; 2 years ago</td>
</tr>
<tr>
<td>Website</td>
<td><a href="http://www.w3.org/TR/sparql11-query">www.w3.org/TR/sparql11-query</a></td>
</tr>
</tbody>
</table>

**Major implementations**

- Jena[^1]
- OpenLink Virtuoso[^1]

**CEP monitor functional architecture**

source:wikipedia.org

source:Jorge Garcia, “A complex event processing system for monitoring of manufacturing systems”

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Motivation

• Several research works describe how to combine the concepts of CEP and querying KB systems for processing and reasoning streams of events in the Semantic Web

• SPARQL language extensions allow bridging the gap between the background knowledge enriched with analysis of event streams and reasoning tasks

• As recent manufacturing systems use these technologies, it is possible to integrate for processing and reasoning on streams of events during system run-time
Complex event processing (1/2)

- Event processing usually is defined on three levels: Event Stream Processing, Simple and Complex Event Processing (CEP)
- In CEP several streams of events are analyzed both as individual events and as event patterns, employing complex relationships between events
- Application of CEP in the domain of industrial automation is becoming particularly important in heterogeneous distributed automation systems
Complex event processing (2/2)

• Although CEP provide significant benefits for automation domain, most important obstacles are:
  – Dissimilarity of messages available currently in the system events
  – Reasoning over the simple messages limits the scope of data descriptions to value(s)/time comparisons, not allowing deeper correlation of data
Industrial automation knowledge-driven solutions

- The amount of data available for manufacturing systems is continuously growing and due to advance in ICT and CPS is expected to become even bigger.
- The Knowledge-Driven approach aims to include this aspect of industrial automation systems in the solution.

http://www.escop-project.eu

- In the Knowledge-Driven system the problem of persistence and manipulation of information about the system is being addressed by the use of Knowledge Representation.
SPARQL languages for reasoning streams of events

- Novel SPARQL extension languages can be used for continuous queries over streams of RDF data.
- Continuous SPARQL (C-SPARQL) and Event Processing SPARQL (EP-SPARQL) allow bridging the gap between knowledge of systems and streams of events processing.
- The main novelty of C-SPARQL and EP-SPARQL is the addition of RDF streams to the standard data types that are supported by SPARQL.
- This allows the evaluation of temporal RDF graphs during system execution.

D. F. Barbieri et. al., “An execution environment for C-SPARQL queries”, 2010
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Monitoring the evolution of system model over time

• Processing and reasoning streams of events allow monitoring ontological models evolution over time
• Starting and finishing timestamps of a RDF triple are represented in temporal triples: \( (s, p, o)[t_1, t_4] \)
An EP-SPARQL application in manufacturing systems (1/4)

• Actual industrial automation systems are forced to manage a large amount of events that occur at different points of the activities and organization hierarchies.

• For example, MES operations include complex tasks that require scheduling and monitoring the introduction of pallets in transport systems of assembly lines.
An EP-SPARQL application in manufacturing systems (2/4)

• Containers are placed in a central transport system that brings pallets to different manufacturing cells, which processes the parts transported by pallets.

• MES orders the introduction of a new pallet in the system when the transport system can handle more containers.

• Orders are sent after processing SELECT SPARQL queries that retrieve a list of pallets flowing in the production line. Then, processing the query results, the decision of pallet addition is made.
An EP-SPARQL application in manufacturing systems (3/4)

• Alternative: CEP + EP-SPARQL, assuming that:
  1. MES can handle busy events generated by cells that cannot accept a part transported by a container and
  2. Three busy events in less than 10 minutes must stop the introduction of new pallets

PREFIX mso: <http://www.tut.fi/FAST/mso#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
ASK {?Cell mso:Status mso:busy}
SEQ {?Cell mso:Status mso:busy}
SEQ {?Cell mso:Status mso:busy}
FILTER (getDURATION()"PT10M0S"^^xsd:duration)

• Dynamically states if new pallets can be inserted or not in the system
An EP-SPARQL application in manufacturing systems (4/4)

• Going through the boundaries of “different” systems. Checking if all the components where integrated to the product and the shipping is ready to start shipping of the product.

```
PREFIX mso: <http://www.tut.fi/FAST/mso#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

ASK {?
  ?product mso:hasComponent mso:comp_A
  ?product mso:hasComponent mso:comp_B
  ?product mso:hasComponent mso:comp_C
  ?shipping mso:hasStatus "ready"
}
```
Potentials

• Promising research area that can support a dynamic evolution of manufacturing system knowledge models
• Monitoring the evolution of system model over time can be taken into account for KPI calculation
• Continuous control for maintenance of industrial equipment
• Hence, EP-SPARQL or C-SPARQL can reduce the complexity, improve the efficiency and support the maintainability of systems
Conclusions and further work

• Recent SPARQL extension languages can be used for processing and reasoning streams of events in knowledge-driven manufacturing execution systems

• Addition of another degree of reasoning in actual knowledge-based systems, achieved by the consideration of time
Further work

• Implementation and test the concept in a larger scale industrial scenario
• Comparison between SPARQL language extensions/engines performance
• Developing ‘query templates’ for common manufacturing problems/cases – problem-oriented reasoning patterns
The research leading to these results has received funding from the ARTEMIS Joint Undertaking under grant agreement n° 332946 and from the Finnish Funding Agency for Technology and Innovation (TEKES), correspondent to the project shortly entitled eScop, Embedded systems for service-based control of open manufacturing and process automation (http://www.escop-project.eu/)
THANK YOU!
Any questions?

http://www.youtube.com/user/fastlaboratory

https://www.facebook.com/fast.laboratory

http://www.slideshare.net/fastlaboratory