Enhancing Event Processing Networks with Semantics to Enable Self-Managed SEE Federations

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Overview

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• Event Processing
• Identified Problems
• Proposed Solution
• Evaluation
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Motivation Scenarios
**Motivation Scenarios**

**Do we have events on the (Semantic) Web?**

- **Example 1: Semantic Sensor Web**

  Collecting and processing avalanches of data about the world around us while relying on the semantic technology to increase interoperability and provide contextual information for situational knowledge.

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Motivation Scenarios
Do we have events on the (Semantic) Web?

- Example 1: Semantic Sensor Web
  - Linked Sensor Data
    - Hurricane and blizzard observations in the United States
    - Department of Meteorology at the University of Utah
    - Measurements of phenomena such as temperature, visibility, precipitation, pressure, wind speed, humidity, etc

```
sens-obs:Observation_WindSpeed_3CLO3_2005_10_16_9_35_00
  a weather:WindObservation ;
om-owl:observedProperty weather:_WindSpeed ;
om-owl:procedure sens-obs:System_3CLO3 ;
om-owl:result sens-obs:MeasureData_WindSpeed_3CLO3_2005_10_16_9_35_00 ;
om-owl:samplingTime sens-obs:Instant_2005_10_16_9_35_00 .

sens-obs:MeasureData_WindSpeed_3CLO3_2005_10_16_9_35_00
  a om-owl:MeasureData ;
om-owl:floatValue "17.0"^^xsd:float ;
om-owl:uom weather:milesPerHour .

sens-obs:Instant_2005_10_16_9_35_00
  a owl-time:Instant ;
owl-time:inXSDDateTime "16-10-2005T09:35:00^^http://www.w3.org/2001/XMLSchema#dateTime" .
```

A sample data from hurricane Wilma readings (October 2005)

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Motivation Scenarios
Do we have events on the (Semantic) Web?

Example 2: Social Networking (Twitter)
- Adding structured annotations to a tweet
- A tweet can have one or more annotations.
- Annotation set is constrained by recommended types
  - webpage, place, review, song, movie, tvshow, book, product, stock, offer, topic, event.

```
"Just saw Avatar and it was amazing"
"annotations": [
  {
    'movie':
    {
      'title': 'Avatar',
      'url': 'http://www.rottentomatoes.com/m/avatar/',
      'image': '...',
      'text': 'Avatar'
    }
  }
]
```

An example of a tweet talking about Avatar movie

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7 Twitter Annotations Overview, [http://dev.twitter.com/pages/annotations_overview](http://dev.twitter.com/pages/annotations_overview)
Motivation Scenarios
Do we have events on the (Semantic) Web?

• Example 3: Internet of Things

  – **Central Nervous System for the Earth (CeNSE) Project** (HP Labs)
  – A research and development program to build a **planetwide sensing network**, using billions of "tiny, cheap, tough and exquisitely sensitive detectors."
  – Sensors detect vibrations, motion, light, temperature, barometric pressure, airflow and humidity.
  – Possible use-cases:
    • Warning about structural strains or weather conditions,
    • Monitor traffic, weather and road conditions,
    • Tracking hospital equipment,
    • Sniffing out pesticides and pathogens in food, etc.
  – HP is hoping that at that scale, sensor nodes will cost "next to nothing, yet measure everything." 9 ☺

Motivation Scenarios
Do we have events on the (Semantic) Web?

- Example 4: Semantic Web Service Execution Environment
  - Closing the knowledge based control-loop in order to make the environment more robust and adaptive according to the real-time circumstances.
Event Processing
Event Processing
How does an event look like?

• More than one approach to describe an event

Different Facets of an Event

The Event Type Definition Element

4 Opher Etzion and Peter Niblett. Event Processing in Action. Manning Publications Co., 2010
Event Processing
What is event processing?

• **What is Event Processing?**
  – Event processing consists of **processing many events** happening across all the layers of an organization, identifying the most meaningful events within the event cloud, analyzing their impact, and taking subsequent action in real time.\(^\text{10}\)
  – Operations that you can perform on events, in particular operations that take a set of one or more events as input and generate further events from them as output. \(^\text{11}\)

• **Event Processing**…
  – … usually focused on a real-world (i.e. physical) situations and problems,
  – … provides a higher level of decoupling than the traditional processing approaches (like batch processing), and
  – … exhibits certain level of abstraction.

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\(^\text{10}\) [http://en.wikipedia.org/wiki/Complex_event_processing](http://en.wikipedia.org/wiki/Complex_event_processing)

\(^\text{11}\) Opher Etzion and Peter Niblett. Event Processing in Action. Manning Publications Co., 2010
Event Processing
Common event processing tasks

- Events filtering
  - Reducing the event stream to those fulfilling the constrains
  - E.g., filter out those events which source is geo-located outside of 10 km radius.

- Events aggregation
  - Computing values across the range of events
  - E.g., calculate average value of temperature readings in the last 10 minutes.

- Events derivation
  - Generating new events.
  - E.g., after selling the last item from stock initiate an order of new merchandise.

- Events causality
  - Calculating/exploiting causality vectors.
  - E.g., Drill down the cause of a derived event which brings system into a erroneous state.

- ...
• The approach of (Complex) Event Processing as a possible solution
  – Established by David Luckham (2002) and further refined by Etzion (2010).
  – Addressing issues of real-time event processing.
  – Focusing in particular on temporal, geo-spatial, and causal event dimensions.
  – Event pattern detection as the core task.
  – Built around the notion of Event Processing Networks.

• What is Event Processing Network?
  – The concept was popularized by the Luckham’s book in 2002.
  – An Event Processing Network is a collection of event producers, consumers, event processing agents and global states which are connected by a collection of channels.
  – The network can be built recursively out of the constituent elements.
  – The definition is abstract and platform independent (at the level of Platform Independent Model - PIM).

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Problem Statement
How to process events?

An example of Event Processing Network
Identified Problems
Problem Statement
What happens when you apply EPN on the Web?

• Applying Event Processing Networks on the Semantic Web means:
  – Proper treatment of the notion of time and time dependent event relations
    • Can we expect synchronous time across the globe?
  – Events interoperability
    • Solutions may be segregated (current case with IoT applications).
    • Heterogeneity between the solutions may hinder the possibility to integrate different events.
  – Context-based event interpretation
    • An event interpretation depends on the context in which the event has been produced.
    • Context must be conveyed together with the event.
  – Event processing lifecycle matching the needs of the Web
    • Discovering and exploiting EPN elements on the Web.
    • Efficient pattern detection, events transformation and filtering over the Semantic Web events.
Expected contribution

Extension of the Event Processing Network (EPN) framework with the Semantic Web technologies:

- Efficient event pattern detection mechanisms operating on top of events described in Semantic Web languages (i.e., RDF(S), OWL) taking into account the effect of inferred knowledge together with parameter, timing, geo-spatial context.

- Models built on top of the Semantic Web (Service) technologies for describing notions of event, event producers and consumers, event processing agents and their capabilities.
Proposed Solution
Proposed Solution
Event Processing Networks (EPN)

Conceptual Model of Event Processing Networks as defined by Luckham\(^2\) and Entzion et al.\(^3\)

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Proposed Solution
Semantically-enhanced Event Processing Networks (sEPN)

• **sEPN** represents a grounding of conceptual EPN model into the Semantic Web technologies:
  – Ontological and comprehensive representation of Event concept.
  – Using ontology repositories to implement Global States and shared repositories.
  – Formal specification of Event Producer, Event consumer, Event Channel, Event Processing Agent properties, capabilities, and behavior.

• Current set of Semantic Web (Service) technologies provides a fruitful foundation to answer to some the identified gaps:
  – **SPARQL** can be used to specify behavior of EPA building blocks but it is missing general support for contexts (e.g., temporal, geo-spatial).
  – Query answering in SW data repositories is concentrating on one-time but not continuous.
  – Semantic Web Services frameworks are concentrating on request-response but not on publish/subscribe (i.e., notification) paradigm.
Srdjan Komazec and Davide Cerri. Enhancing Event Processing Networks with Semantics to Enable Self-Managed SEE Federations. 3rd International Workshop on Monitoring, Adaptation and Beyond (MONA+) colocated with ECOWS, Ayia Napa, Cyprus, 2010. Under submission
Proposed Solution
sEPN Agent Functionality Declaration – An example

COIN Enterprise Interoperability Use Case In Federated SEE Environment
Proposed Solution
Efficient Detection of Event Patterns on the Semantic Web

- sEPA building block functions can be reduced to graph pattern detection problems.

- Current approaches like C-SPARQL\(^4\) are separating the truth maintenance step (i.e., materialization of inferred knowledge over dynamically changing knowledge base) from the query answering step.

- Possible approach is to make knowledge derivation the integral part of graph pattern detection.
  - Taking RETE\(^5\) as the starting point.
  - During Beta memory construction enrich the network with additional nodes injected as outcome of the analysis of inference rules which influence graph pattern structure.

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Evaluation
Evaluation

• Study of the framework capabilities in the context of reference use-case
  – Fast flower delivery use-case by Etzion et al. (2010).
  – Expressiveness of the event pattern description language.
    • Time windowing, correlations of events, aggregation support.
  – Performance considerations.

• Event pattern detection engine performance evaluation
  – Measurements of throughput and scalability in the context of variable:
    • memory allocation,
    • frequency of arriving events, and
    • complexity of event pattern descriptions.
Evaluation

- Applying solution to the Semantic Execution Environment
  - Calculating aggregated statistics.
  - Communicating to external systems.
Future Work
Future Work

• **Enriching sEPA functional capabilities**
  – Declarative language with advanced concepts such as timing windows, geo-spatial-based event-relationships, supporting arbitrary event contexts, etc.
  – Accompanying Event Pattern Detection engine which supports those declarations.

• **Design and implementation of formal EPN model**
  – Investigating suitability and possible extensions to model EPN based on:
    • Current SOTA in Semantic Web Service frameworks.
    • Current SOTA in industrial efforts (W3C WS-Eventing, HP WS-Events).
Questions?