Leveraging Semantic Web Techniques to Gain Situational Awareness

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Leveraging Semantic Web techniques to gain situational awareness

Can Semantic Web techniques empower perception and comprehension in Cyber Situational Awareness?


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Thanks: Cory Henson and Sensor Data Management team (M. Perry, S. Sahoo)
1. Situational Awareness (SA)

2. SA within the Semantic Web
   - Situation Awareness (SAW) Ontology
   - Sensor Web Enablement
   - Provenance Context
   - Spatial-Temporal-Thematic Analysis
“Situation awareness is the *perception* of elements in the environment within a volume of time and space, the *comprehension* of their meaning, and the *projection* of their status in the near future.”


http://en.wikipedia.org/wiki/Situation_awareness
JDL: Data Fusion Model

A. Steinberg, et al., Rethinking the JDL Data Fusion Levels
M. Kokar, et al., Ontology-based Situation Awareness* (Modified Figure)
Situation Awareness Data Pyramid

- Sensor Data (World)
- Entity Metadata (Perception)
- Relationship Metadata (Comprehension)

Expressiveness

- Data
- Information
- Semantics/Understanding/Insight
Situation Awareness

Situation Awareness Components

- Physical World: Sensor Data
- Perception: Entity Metadata
- Comprehension: Relationship Metadata

Semantic Analysis

- How is the data represented? Sensor Web Enablement
- What are the antecedents of the event? Provenance Analysis
- Where did the event occur? Spatial Analysis
- When did the event occur? Temporal Analysis
- What is the significance of the event? Thematic Analysis
Sensor Web Enablement
OGC Mission
To lead in the development, promotion and harmonization of open spatial standards

- Consortium of 330+ companies, government agencies, and academic institutes
- Open Standards development by consensus process
- Interoperability Programs provide end-to-end implementation and testing before spec approval
- **Standard encodings**, e.g.
  - GeographyML, SensorML, Observations & Measurements, TransducerML, etc.
- Standard Web Service interfaces, e.g.
  - Web Map Service
  - Web Feature Service
  - Web Coverage Service
  - Catalog Service
  - **Sensor Web Enablement Services** (Sensor Observation Service, Sensor Alert Service, Sensor Process Service, etc.)

http://www.opengeospatial.org/projects/groups/sensorweb
Sensor Web Enablement

Constellations of heterogeneous sensors

Vast set of users and applications

- Distributed self-describing sensors and related services
- Link sensors to network and network-centric services
- Common XML encodings, information models, and metadata for sensors and observations
- Access observation data for value added processing and decision support applications
- Users on exploitation workstations, web browsers, and mobile devices

http://www.opengeospatial.org/projects/groups/sensorweb
SWE Languages and Encodings

- **Observations & Measurements (O&M)**
- **SensorML (SML)**
- **GeographyML (GML)**
- **TransducerML (TML)**

**Information Model for Observations and Sensing**

**Sensor and Processing Description Language**

**Common Model for Geography Systems and Features**

**Multiplexed, Real Time Streaming Protocol**

Semantic Sensor ML – Adding Ontological Metadata

Mike Botts, "SensorML and Sensor Web Enablement," Earth System Science Center, UAB Huntsville
Situation Awareness Ontology
Ontology

What is an Ontology?

“Ontology is about the exact description of things and their relationships.”

World Wide Web Consortium (W3C)
Situation Awareness Ontology

C. Matheus, et al., An Application of Semantic Technologies to Situation Awareness
Provenance Context
What is Provenance?

• The recording of details in a data process workflow
• Trace back to where the particular data entity originated
  • The phenomena captured by the sensor
  • The sensor characteristics associated with data
  • What processing was done on data
• Enables effective interpretation of object or event - Trust
• Evaluate whether particular data entity is relevant in current situation based on its provenance
• Enhanced situation comparison through use of provenance
Spatial, Temporal, Thematic Analysis
North Korea detonates nuclear device on October 9, 2006 near Kilchu, North Korea

Thematic Dimension: What

Temporal Dimension: When

Spatial Dimension: Where
Semantic Analytics

- Searching, analyzing and visualizing semantically meaningful connections between named entities

Significant progress with thematic data

- Semantic associations (Rho-Operator)
- Subgraph discovery
- Query languages (SPARQ2L, SPARQLeR)
- Data stores (Brahms)

Spatial and Temporal data is critical in many analytical domains

- Need to support spatial and temporal data and relationships
Current Research Towards STT Relationship Analysis

• **Modeling Spatial and Temporal data using SW standards (RDF(S))**¹
  – Upper-level ontology integrating thematic and spatial dimensions
  – Use Temporal RDF³ to encode temporal properties of relationships
  – Demonstrate expressiveness with various query operators built upon thematic contexts

• **Graph Pattern queries over spatial and temporal RDF data**²
  – Extended ORDBMS to store and query spatial and temporal RDF
  – User-defined functions for graph pattern queries involving spatial variables and spatial and temporal predicates
  – Implementation of temporal RDFS inferencing

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Upper-level Ontology modeling Theme and Space

Occurrent: Events – happen and then don’t exist

- occurred_at: Links Spatial_Occurents to their geographic locations

Continuant: Concrete and Abstract Entities – persist over time

- located_at: Links Named_Places to their geographic locations

Named_Place: Those entities with static spatial behavior (e.g. building)

Dynamic_Entity: Those entities with dynamic spatial behavior (e.g. person)

Spatial_Occurrent: Events with concrete spatial locations (e.g. a speech)

Spatial_Region: Records exact spatial location (geometry objects, coordinate system info)
Dynamic entities get spatial properties indirectly through relationships with spatial entities.
Scenario (Biochemical Threat Detection): Analysts must examine soldiers’ symptoms to detect possible biochemical attack

Query specifies

```
select a from table (spatial_eval (’(?a has_symptom ?b)
(Chemical_X induces ?b)(?a fought_in ?c)’, ?c,
’(?d member_of Enemy_Group_Y)(?d spotted_at ?e)’, ?e,
’geo_distance(distance=2 units=mile)’))
```
Utilizing Semantic Web technologies to enable perception and comprehension within Situational Awareness

**Perception**
- Leveraging current research in sensor data representation found in the Sensor Web Enablement metadata languages
- Using SWE languages to model sensors, processes, and data

**Comprehension**
- Extending the Sensor Web Enablement languages with semantic metadata to provide the ability to model relationships between entities
- Semantic relationships provide “meaning” to objects and events within a situation
- Using Situational Awareness Ontology to model situations and provide a framework for Semantic Analysis
- Provenance Context provides a historical record of relevant objects and events within a situation
- Spatial, Temporal and Thematic analysis provides the “where”, “when”, and “what” of objects and events within a situation
References

- C. Matheus, M. Kokar and K. Baclawski, *A Core Ontology for Situation Awareness*, Sixth International Conference on Information Fusion, pp.545-552, Cairns, Australia, July 2003


- M. Kokar, *Ontology Based High Level Fusion and Situation Awareness: Methods and Tools*, Presentation, Quebec, 2007

- A. Steinberg and C. Bowman, *Rethinking the JDL data fusion levels*, National Symposium on Sensor and Data Fusion, 2004

