Leveraging Semantic Web Techniques to Gain Situational Awareness

Amit P. Sheth
Wright State University - Main Campus, amit.sheth@wright.edu

Follow this and additional works at: https://corescholar.libraries.wright.edu/knoesis
Part of the Bioinformatics Commons, Communication Technology and New Media Commons, Databases and Information Systems Commons, OS and Networks Commons, and the Science and Technology Studies Commons

Repository Citation
Leveraging Semantic Web techniques to gain situational awareness

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


Amit Sheth
LexisNexis Ohio Eminent Scholar
Kno.e.sis Center
Wright State University
http://knoesis.wright.edu

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.”

A. Steinberg, et al., Rethinking the JDL Data Fusion Levels
Endsley’s Model w/ Semantics

**Semantic Analysis**
- thematic
- Spatio-Temporal
- trust

**Provenance**
- Relate Situation Entities
- Identify Situation Entities
- Collect Relevant Data

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 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
Open Geospatial Consortium

- 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.)

OGC Mission

To lead in the development, promotion and harmonization of open spatial standards

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)
  - Information Model for Observations and Sensing
- SensorML (SML)
  - Sensor and Processing Description Language
- GeographyML (GML)
  - Common Model for Geography Systems and Features
- TransducerML (TML)
  - 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
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
Three Dimensions of Information

Thematic Dimension: What
North Korea detonates nuclear device on October 9, 2006 near Kilchu, North Korea

Temporal Dimension: When
October 9, 2006

Spatial Dimension: Where
near Kilchu, North Korea
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

---


Upper-level Ontology modeling Theme and Space

Occurrent: Events – happen and then don’t exist
Continuant: Concrete and Abstract Entities – persist over time
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)
Located at: Links Named Places to their geographic locations
Occurred at: Links Spatial Occurrents to their geographic locations
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

```sql
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)'));
```
Using SW to enable perception and comprehension

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

