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Semantic Sensor Web

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KNO.E.SIS

COLLECTING THE DOTS | CONNECTING THE DOTS

Semantic Sensor Web

Talk at: Special SICoP Conference
Building Semantic Interoperability Solutions
for Information Sharing and Integration
Falls Church, VA, February 5, 2008

Amit Sheth
LexisNexis Ohio Eminent Scholar
Kno.e.sis Center, Wright State University

Thanks: Semantic Sensor Web team: Cory Henson, Prateek Jain, Josh Pschorr, Satya Sahoo

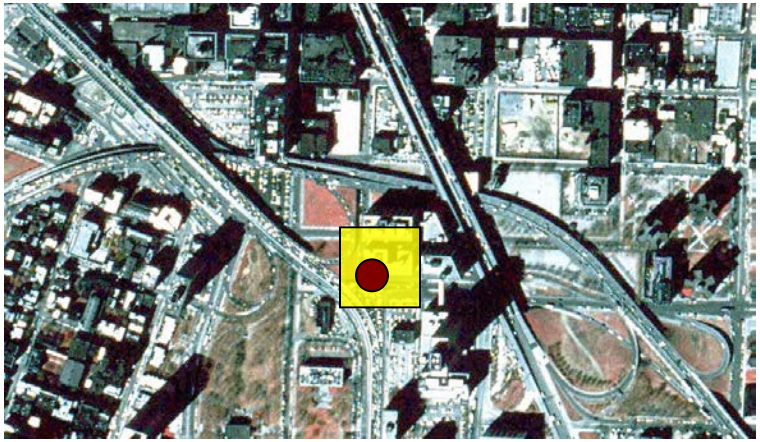
Presentation Outline

1. Motivating Scenario
2. Sensor Web Enablement
3. Semantic Sensor Web
4. Prototype Application

Motivating Scenario

High-level Sensor (S-H)

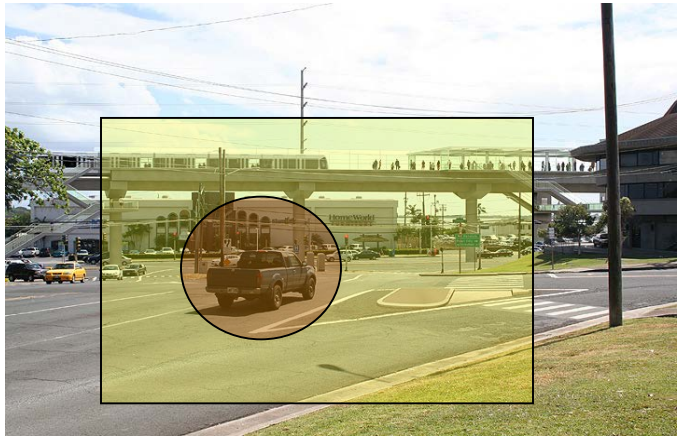
H



A-H E-H

Low-level Sensor (S-L)

L



A-L E-L

- How do we determine if A-H = A-L? (Same time? Same place?)
- How do we determine if E-H = E-L? (Same entity?)
- How do we determine if E-H or E-L constitutes a threat?

The Challenge

Collection and analysis of information from heterogeneous multi-layer sensor nodes

Why is this a Challenge?

- There is a lack of uniform operations and standard representation for sensor data.
- There exists no means for resource reallocation and resource sharing.
- Deployment and usage of resources is usually tightly coupled with the specific location, application, and devices employed.
- **Resulting in a lack of interoperability.**

Survey

Many diverse sensor data management *application* frameworks were compared, such as:

1. GSN
    - Global Sensor Network
    - Digital Enterprise Research Institute (DERI)
    - http://gsn.sourceforge.net/
2. Hourglass
    - An Infrastructure for Connecting Sensor Networks and Applications
    - Harvard
    - http://www.eecs.harvard.edu/~syrah/hourglass/
3. IrisNet
    - Internet-Scale Resource-Intensive Sensor Network Service
    - Intel & Carnegie Mellon University
    - http://www.intel-iris.net/

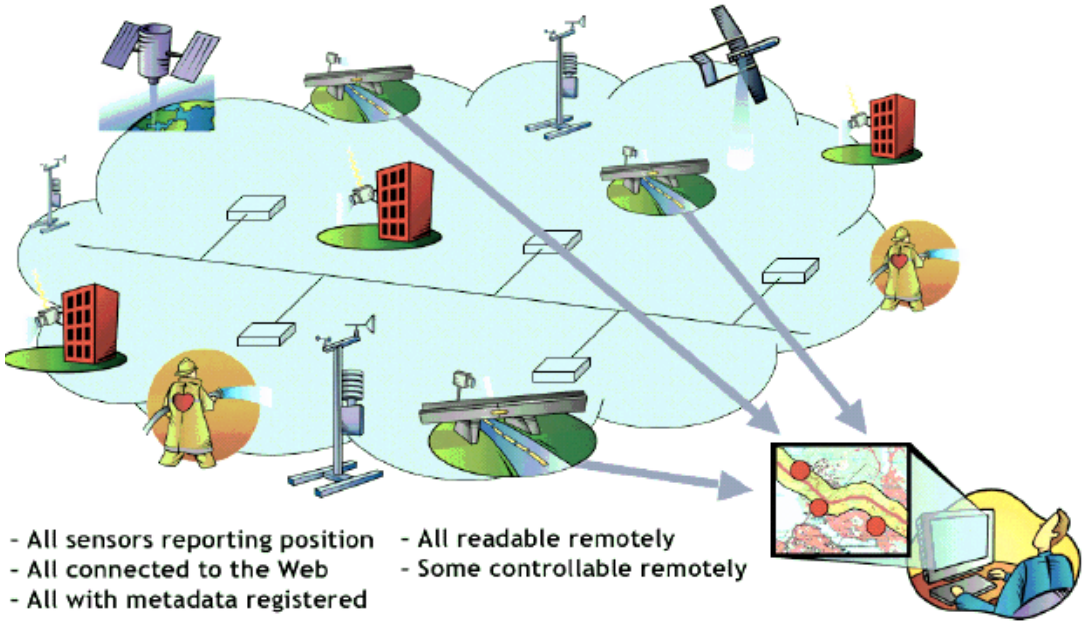
However, it soon became obvious that these application frameworks provided only localized interoperability and that a standards-based framework was necessary.

Presentation Outline

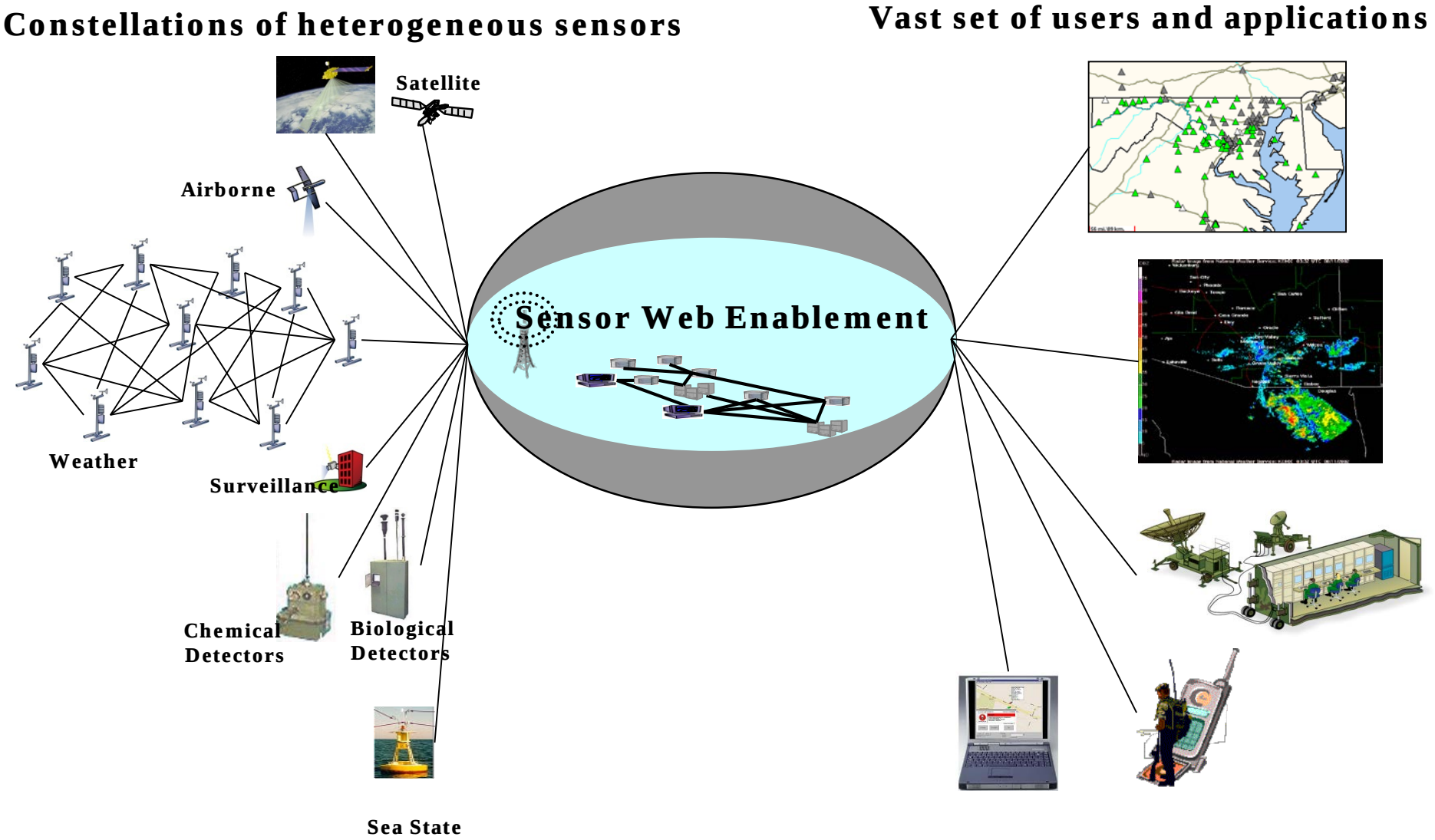
1. Motivating Scenario
2. Sensor Web Enablement
3. Sensor data evolution hierarchy
4. Prototype Application

What is Sensor Web Enablement?

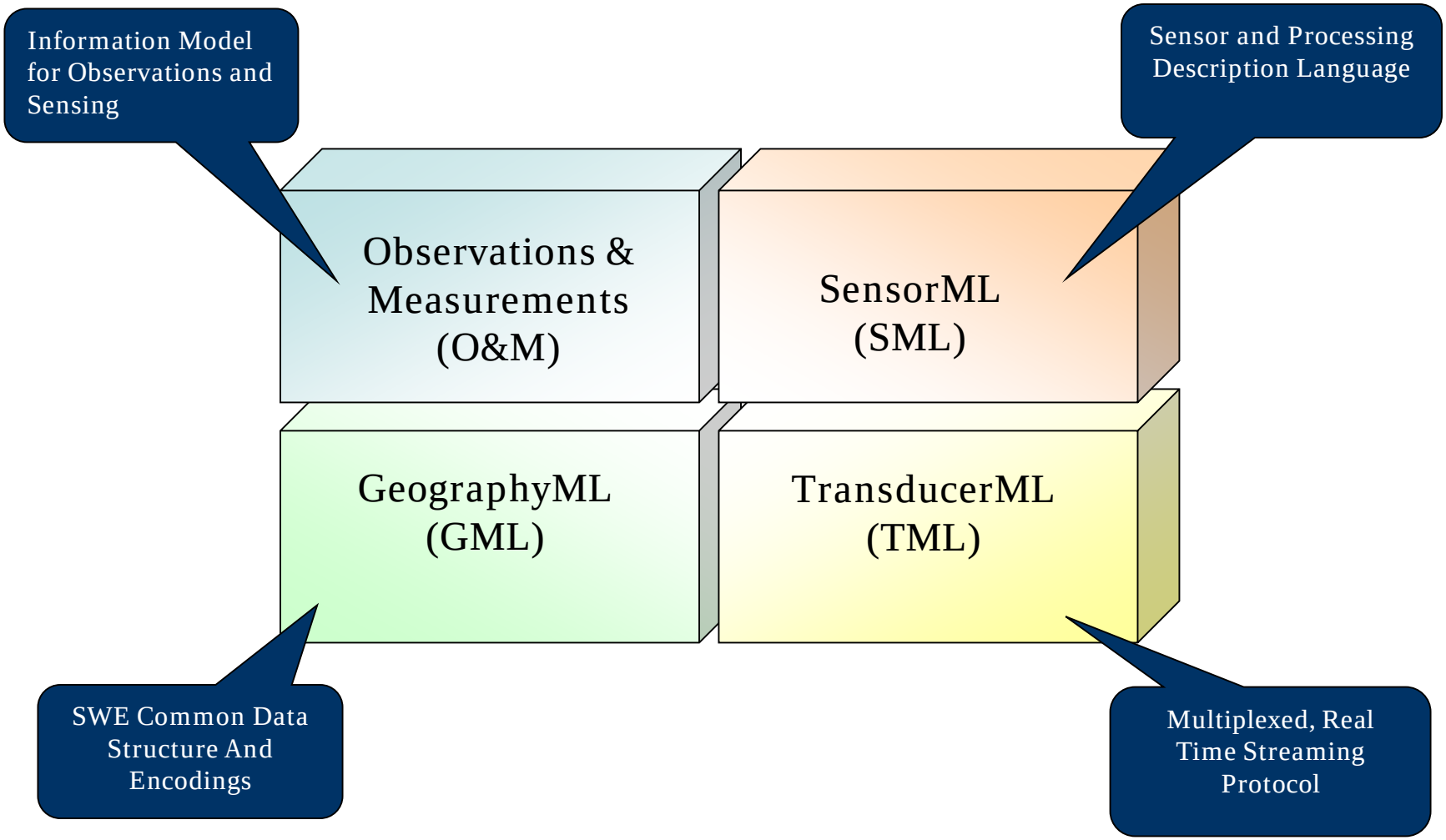
- The interoperability framework for accessing and utilizing sensors and sensor systems in a space-time context via Internet and Web protocols
- A set of web-based services may be used to maintain a registry of available sensors.
- The same web technology standard for describing the sensors' outputs, platforms, locations, and control parameters should be used all across.
- This enables the necessary interoperability.
- This standard encompasses specifications for interfaces, protocols, and encodings that enable the use of sensor data and services.



OGC Sensor Web Enablement



SWE Languages and Encodings



Sam Bacharach, "GML by OGC to AIXM 5 UGM," OGC, Feb. 27, 2007.

Presentation Outline

1. Motivating Scenario
2. Sensor Web Enablement
3. Semantic Sensor Web
4. Prototype Application

What is the Semantic Sensor Web?

- Adding semantic annotations to existing standard Sensor Web languages in order to provide semantic descriptions and enhanced access to sensor data
- This is accomplished with *model-references* to ontology concepts that provide more expressive concept descriptions
- For example, using model-references to link SML annotated sensor data with concepts within an OWL-Time ontology allows one to provide temporal semantics of sensor data, or using a model reference to annotate Sensor Device ontology* enables uniform/interoperable characterization/descriptions of sensor parameters regardless of different manufactures of the same type of sensor and their respective proprietary data representations/formats

* In the interim, SensorML can be used for describing sensor metadata

XLink

- Used for describing links between resources in XML documents.
- Several important attributes within XLink include:
  - **type**: describes the element type of the link (i.e., simple, extended)
  - **role**: semantic attribute that describes the meaning of resources within the context of a link
  - **href**: locator attribute that supplies the URI needed to find a remote resource

Other used Model Reference in Semantic Annotations

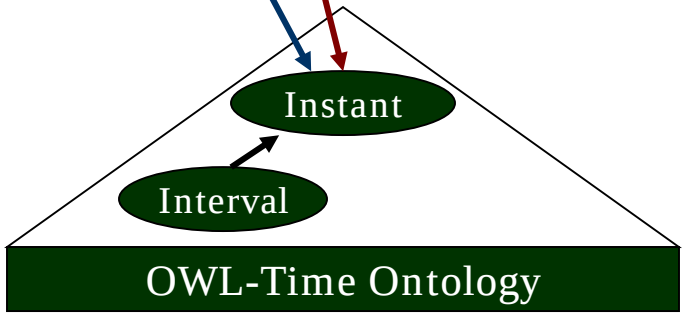
- ***SAWSDL***: Defines mechanisms to add semantic annotations to WSDL and XML-Schema components (*W3C Recommendation*)
- ***SA-REST***: Defines mechanisms to add semantic annotations to REST-based Web services.

W3C, XML Linking Language, http://www.w3.org/TR/xlink

Model Reference (SensorML)

```
<swe:definition>
    <swe:dataComponents name="video-provenance">
        <swe:DataGroup>
            <swe:component name="start-time"
                           xlink:type="simple"
                           xlink:role="time:Instant"
                           xlink:href="http://knoesis.wright.edu/projects/sensorweb/ontology/video-time.owl#instant_6HvMHPjDYZM_begin">
                <swe:Time definition="urn:ogc:def:phenomenon:time"
                          referenceTime="1970-01-01T00:00:00Z"
                          uom="urn:ogc:def:unit:date-time"/>
            </swe:component>
            <swe:component name="end-time"
                           xlink:type="simple"
                           xlink:role="time:Instant"
                           xlink:href="http://knoesis.wright.edu/projects/sensorweb/ontology/video-time.owl#instant_6HvMHPjDYZM_end">
                <swe:Time definition="urn:ogc:def:phenomenon:time"
                          referenceTime="1970-01-01T00:00:00Z"
                          uom="urn:ogc:
            </swe:component>
            <swe:component name="latitude">
                <swe:Quantity definition="urn:ogc:def:phenomenon:angle"
                              uom="urn:ogc:def:unit:degree"/>
            </swe:component>
            <swe:component name="longitude">
                <swe:Quantity definition="urn:ogc:def:phenomenon:angle"
                              uom="urn:ogc:def:unit:degree"/>
            </swe:component>
        </swe:DataGroup>
    </swe:dataComponents>
    <swe:encoding>
        <swe:AsciiBlock decimalSeparator="."
                        tokenSeparator=","
                        tupleSeparator=" "/>
    </swe:encoding>
</swe:definition>
<swe:value name="video-provenance">
    2002-11-10T015:31:00.00,2002-11-10T015:34:31.00,39.779535,-84.063821
</swe:value>
```

Semantic Annotations (model-references) to temporal ontology



Timestamp: start time

Timestamp: end time

Lat/Long coordinates

Semantic Temporal Query

- Model-references from SML to OWL-Time ontology concepts provides the ability to perform semantic temporal queries
- Supported semantic query operators include:
  - **contains**: user-specified interval falls wholly within a sensor reading interval (also called *inside*)
  - **within**: sensor reading interval falls wholly within the user-specified interval (inverse of *contains* or *inside*)
  - **overlaps**: user-specified interval overlaps the sensor reading interval
- Example SPARQL query defining the temporal operator 'within'

```
SELECT ?interval
WHERE {
  ?interval time-entry:begins ?b .
  ?interval time-entry:ends   ?e .
  ?b time-entry:inXSDDateTime ?b_datetime .
  ?e time-entry:inXSDDateTime ?e_datetime .

  FILTER (
    xsd:dateTime("2005-11-10T01:00:00.00") < xsd:dateTime(?b_datetime) &&
    xsd:dateTime("2008-11-10T01:00:00.00") > xsd:dateTime(?e_datetime)
  ) .
}
ORDER BY ASC(?b_datetime)
```

Sensor Data Architecture

Knowledge

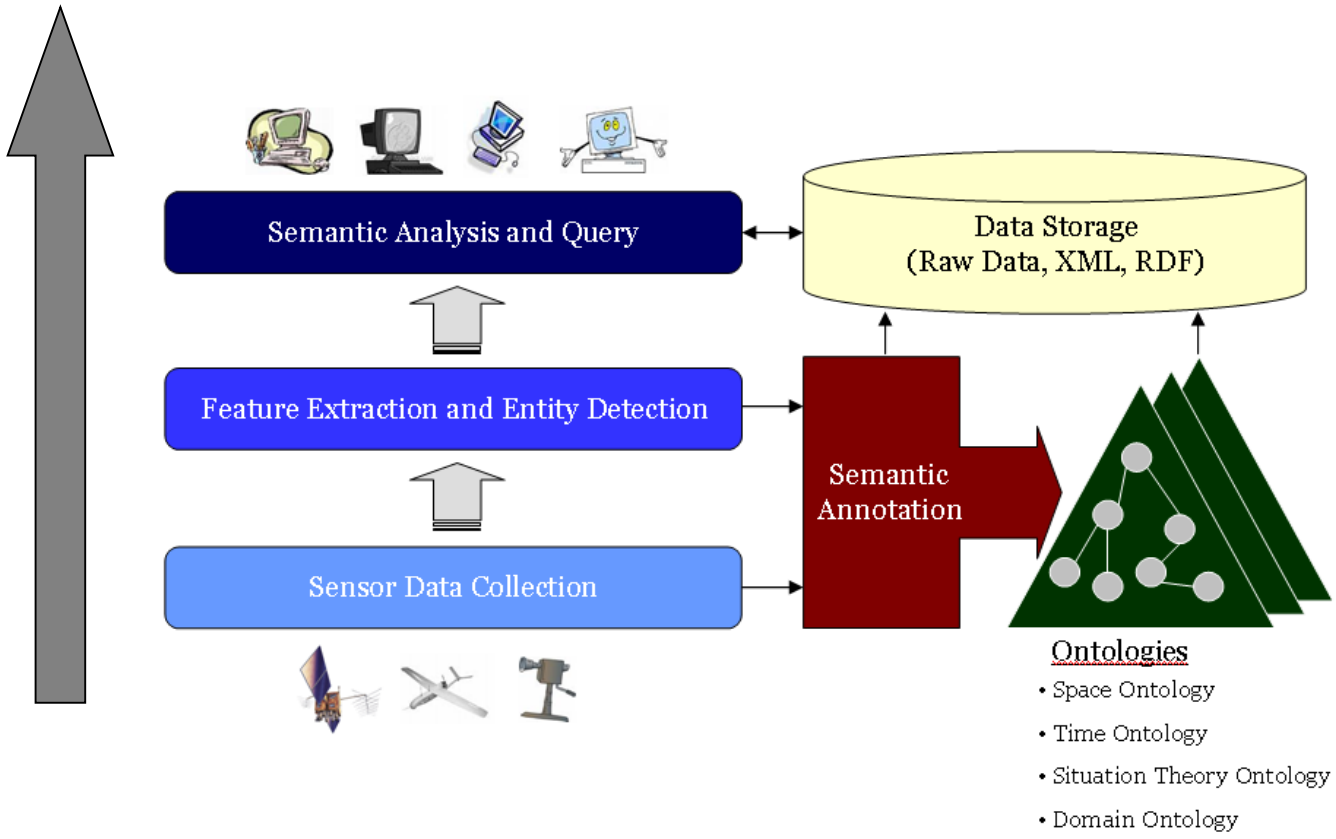
- Object-Event Relations
- Spatiotemporal Associations
- Provenance Pathways

Information

- Entity Metadata
- Feature Metadata

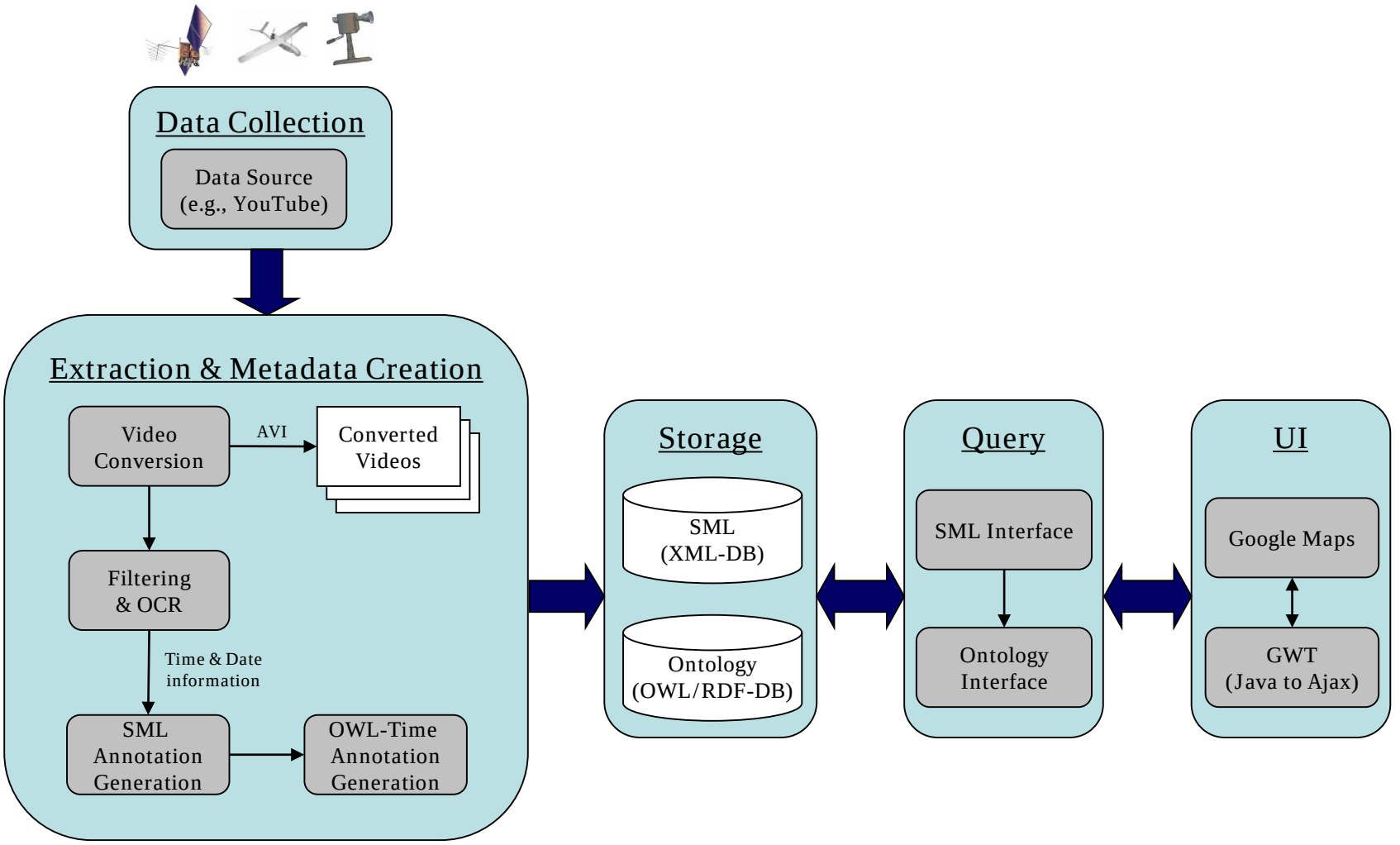
Data

- Raw Phenomenological Data



Prototyping the Semantic Sensor Web

Prototype Architecture

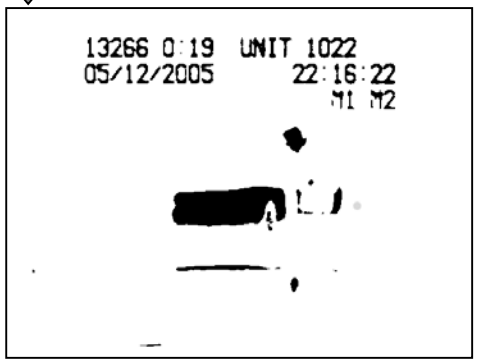


Temporal Data Extraction

Channel Minimal Suppression [1]
8-neighbor median for 'bad' pixels [1]

Temporal Minimal Suppression [2]

Binarization via adaptive threshold [1]



Tesseract OCR engine

```
13266 0:18 UNIT 1022
05/12/2005 22:16:22
M1 M2
Q
11-*
```

Regular Expression parsing
SensorML output

```
<swe:value name="video-provenance">
    2005-05-12T022:16:22.00,2005-05-12T022:24:08.00,39.779535,-84.063821
</swe:value>
```


1. https://research.microsoft.com/~xshua/publications/pdf/2002_ISCAS_TimeStampOCR.pdf
2. http://www.informedia.cs.cmu.edu/documents/vocr_ieee98.pdf

Prototype Application

http://knoesis.wright.edu/library/demos/ssw/prototype.htm

Future Work

- Incorporation of spatial ontology in order to include spatial analytics and query (perhaps with OGC GML Ontology or ontology developed by W3C Geospatial Incubator Group - GeoXG)*
- Explore new datasets, including Buckeyetraffic.org
- Extension of SPARQL with enhanced spatiotemporal query and analytics (including semantic associations)
- Integration of framework with emergent applications, including video on mobile devices running Android OS
- Monitor Semantic Sensor Web page for further progress http://knoesis.wright.edu/projects/sensorweb/

* Kno.e.sis/Wright State Univ. is a member of W3C and it's research led to the development of SAWSDL

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- W3C, Geospatial Incubator Group, http://www.w3.org/2005/Incubator/geo/
- W3C, Semantic Annotations for WSDL and XML Schema, http://www.w3.org/TR/sawsdl/
- W3C, XML Linking Language, http://www.w3.org/TR/xlink/
- Google Code, Tesseract, http://code.google.com/p/tesseract-ocr/