Ontology based Context Modeling

Hitesh Maidasani
CMSC818G Spring 2014
An ontology for context-aware pervasive computing environments

Harry Chen, Tim Finin, and Anupam Joshi
What is an ontology?

- a formal representation of knowledge as a set of concepts and relationships between those concepts within a domain
Why use ontologies?

- a common ontology enables knowledge sharing in open and dynamic systems
- better reasoning of context
- allow devices and agents to work together
- Define Context FORMALLY
CoBrA

- Context Broker Architecture
- a collection of ontologies called COBRA-ONT for modelling the context in an intelligent meeting-room environment
Context broker architecture

- central intelligent agent called the context broker
- maintain a shared model of context
- community of agents and devices in the space
- protect the privacy of users
Pros/Cons of Broker

● Pros
  ○ supports resource-limited mobile computing devices
  ○ addresses the concerns for user privacy

● Cons
  ○ can create a “bottleneck” in large scale space
  ○ Solution: multiple brokers are grouped together to form a broker federation
COBRA-ONT

- ontologies expressed in the Web Ontology Language OWL
  - expressive “ontology language” by W3C
  - classes and properties
  - based on XML
An example

- a sensor detects Bluetooth cellphone in Rm 210
- sends event using COBRA-ONT to broker
- broker has identity of device
- Rm 210 is in CS building on campus
- broker concludes the person is in school today

= context
<table>
<thead>
<tr>
<th>CoBrA Ontology Classes</th>
<th>CoBrA Ontology Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>“Place” Related</strong></td>
<td><strong>“Place” Related</strong></td>
</tr>
<tr>
<td>Place</td>
<td>latitude</td>
</tr>
<tr>
<td>AtomicPlace</td>
<td>longitude</td>
</tr>
<tr>
<td>CompoundPlace</td>
<td>isSpatiallySubsumedBy</td>
</tr>
<tr>
<td>Campus</td>
<td>spatiallySubsumes</td>
</tr>
<tr>
<td>Building</td>
<td>accessRestrictedToGender</td>
</tr>
<tr>
<td>AtomicPlaceInBuilding</td>
<td>lotNumber</td>
</tr>
<tr>
<td>Room</td>
<td>locatedIn</td>
</tr>
<tr>
<td>Hallway</td>
<td>locatedInAtomicPlace</td>
</tr>
<tr>
<td>Stairway</td>
<td>locatedInRoom</td>
</tr>
<tr>
<td>OtherPlaceInBuilding</td>
<td>locatedInRestroom</td>
</tr>
<tr>
<td>Restroom</td>
<td>locatedInParkingLot</td>
</tr>
<tr>
<td>MensRoom</td>
<td>locatedInCompoundPlace</td>
</tr>
<tr>
<td>ParkingLot</td>
<td>locatedInBuilding</td>
</tr>
<tr>
<td></td>
<td>locatedInCampus</td>
</tr>
<tr>
<td><strong>“Agent” Related</strong></td>
<td><strong>Agent’s Location Context</strong></td>
</tr>
<tr>
<td>Agent</td>
<td>locatedIn</td>
</tr>
<tr>
<td>Person</td>
<td>locatedInAtomicPlace</td>
</tr>
<tr>
<td>SoftwareAgent</td>
<td>locatedInRoom</td>
</tr>
<tr>
<td>Role</td>
<td>locatedInRestroom</td>
</tr>
<tr>
<td>SpeakerRole</td>
<td>locatedInParkingLot</td>
</tr>
<tr>
<td>AudienceRole</td>
<td>locatedInCompoundPlace</td>
</tr>
<tr>
<td>ActionFoundInPresentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>locatedInBuilding</td>
</tr>
<tr>
<td></td>
<td>locatedInCampus</td>
</tr>
<tr>
<td><strong>Agent’s Activity Context</strong></td>
<td></td>
</tr>
<tr>
<td>PresentationSchedule</td>
<td>participatesIn</td>
</tr>
<tr>
<td>Event</td>
<td></td>
</tr>
<tr>
<td>EventHappeningNow</td>
<td></td>
</tr>
<tr>
<td>RoomHasPresentationHappeningNow</td>
<td></td>
</tr>
<tr>
<td>ParticipantOfPresentationHappeningNow</td>
<td></td>
</tr>
<tr>
<td>SpeakerOfPresentationHappeningNow</td>
<td></td>
</tr>
<tr>
<td>AudienceOfPresentationHappeningNow</td>
<td></td>
</tr>
<tr>
<td>PersonFillsRoleInPresentation</td>
<td></td>
</tr>
<tr>
<td>PersonFillsSpeakerRole</td>
<td></td>
</tr>
<tr>
<td>PersonFillsAudienceRole</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Place (class)

● properties
  ○ longitude, latitude, name

● subclasses
  ○ AtomicPlace and CompoundPlace
  ○ CompoundPlace subsumes AtomicPlace
  ○ Ex. Campus -> Building -> Room
<owl:Class rdf:ID="Place">
    <owl:unionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#AtomicPlace"/>
        <owl:Class rdf:about="#CompoundPlace"/>
    </owl:unionOf>
    ...
</owl:Class>

<owl:Class rdf:ID="AtomicPlace">
    <rdfs:subClassOf rdf:resource="#Place"/>
    <rdfs:subClassOf>
        ...
    </rdfs:subClassOf>
</owl:Class>
Agents

- Person, SoftwareAgent
- properties
  - name
  - Role
    - SpeakerRole and AudienceRole
Context of Agents

1. No agent can be physically present in two different atomic places during the same time interval.
2. An agent can be physically present in two different compound places during the same time interval just in case one spatially subsumes the other.
Event

- Presentation
  - invitedSpeaker and expectedAudience
  - RoomHasPresentationEventHappeningNow
COBRA-ONT

- just for meeting room domain
- need to be generalized for smart spaces
SOUPA: Standard Ontology for Ubiquitous and Pervasive Applications

Harry Chen, Filip Perich, Tim Finin, and Anupam Joshi
SOUPA Ontologies

- based on COBRA-ONT and many others
- intended to standardize ontologies
- two set of ontologies
  - SOUPA Core -> generic, universal
  - SOUPA Extension -> using core; specific
SOUPA Core

- person
- agent
- belief-desire-intention (BDI)
- action
- policy
- time
- space
- event
Person

● contact information and the profile of a person

```xml
<per:Person>
  <per:firstName
    rdf:datatype="&xsd;string">Harry</per:firstName>
  <per:lastName
    rdf:datatype="&xsd;string">Chen</per:lastName>
  <per:gender rdf:resource="&per;Male"/>
  <per:birthDate
    rdf:datatype="&xsd;date">1976-12-26</per:birthDate>
...
```
Policy

- set of rules that is specified by a user or a computing entity to restrict or guide the execution of actions
- Security and Privacy
Action

Policies permit or forbid actions
Agent & BDI

- Computing entities and humans
- BDI (beliefs, desires, intentions) of agent can give “mental state”
- `agt:believes`, `agt:desires`, and `agt:intends`
Time

- `tme:TimeInstant` and `tme:TimeInterval` classes

```xml
<tme:TimeInterval>
  <tme:from>
    <tme:TimeInstant>
      <tme:at rdf:datatype="xsd:dateTime">2004-02-01T12:01:01</tme:at>
    </tme:TimeInstant>
  </tme:from>
  <tme:to>
    <tme:TimeInstant>
    </tme:TimeInstant>
  </tme:to>
</tme:TimeInterval>
```

- Other properties: before, after, etc.
Space

- spc:GeographicalSpace
- spc:GeographicalRegion
- spc:FixedStructure
- spc:FixedStructure
- properties
  - coordinates, subsumes
Event

- Spatial and Temporal extensions
- Activities, schedules, sensing events

```
<owl:Class rdf:ID="DetectedBluetoothDev">
  <rdfs:subClassOf
    rdf:resource="#TemporalSpatialEvent"/>
</owl:Class>

<owl:ObjectProperty rdf:ID="foundDevice">
  <rdfs:domain
    rdf:resource="#DetectedBluetoothDev"/>
</owl:ObjectProperty>

<DetectedBluetoothDev>
  <spc:hasCoordinates>
    <geo:LocationCoordinates>
      <geo:longitude rdf:datatype="...">
```
SOUPA Extension

- define an extended set of ontologies to support specific domains
- demonstrate how to define new ontologies using SOUPA Core
SOUPA can be generalized

- Able to use/generalize SOUPA ontologies on CoBrA in a smart meeting room
Conclusions

- Ontologies are key for formalizing context
- SOUPA standardizes ontologies for context aware systems