Applying Context-Awareness to Service-Oriented Architecture

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Context-Aware and Ambient Applications, 2007
Outline

1 Motivation

2 Context Management
   - A Proposed Layered Reference Architecture
   - Sensing
   - Context Data Representation in the Context Repository
   - Context Querying and Reasoning
   - Context Provider (Aggregation and Delivery)

3 Selected Systems Applying Context-Awareness and Service-Oriented Architecture
   - Service-Oriented Context-Aware Middleware (SOCAM)
   - Context-Sensitive Service Discovery System (CSDS)
Context-Aware Applications.

- **Mobile Devices**
  - Good computing power, memory, networking
  - User experience limited by interaction with small displays and keyboards

- **Context-Awareness**
  - Minimizes amount of interaction user ↔ device
  - Enables provision of situation-dependent services
  - ⇒ augmented reality
Context-Aware Applications.

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Service-Oriented Architecture

- Recent paradigm in Software Engineering
- Services
  - Loosely coupled
  - Distributed
  - Fulfill specific functionality according to a service contract
  - Functionality implemented and deployed once only
- Create applications by composing services
- Typical roles
  - Client
  - Service repository
  - Service provider
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Figure: Roles and interactions in an SOA
Mutual influences between context-awareness and service-oriented architecture

- Context-aware applications
  - Context-aware middleware solutions based on SOA paradigm
  - Use composition to integrate partial contexts

- SOA
  - Context-aware service discovery
  - Context-aware service usage
Context-Awareness and Service-Oriented Architecture

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- Context-aware applications
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Context-Awareness and Service-Oriented Architecture

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General Concepts of Context Management

- Context is managed at different levels of abstraction
- Contextual information
  - Single scalar value, e.g. temperature
  - Vector, e.g. location (latitude, longitude)
  - Abstract situation, e.g. waiting for the bus, lunch break, in a meeting
- Processed by different components/layers according to level of abstraction
- Multiplicity higher layer to lower layer: 1 - *
A Proposed Layered Reference Architecture

Figure: A proposed layered reference architecture for context management systems
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Sensing

- Sensor hardware provides raw data
- Data tuples represent the state of an observed entity
- Typical examples
  - Temperature
  - Location
  - Movement
  - Proximity of other entities
- Sensing layer
  - Abstracts from underlying hardware
  - Translates between physical and virtual domain
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Context repository

- Stores lower-lever contextual information acquired by sensors
- Data structures according to a formal context-model
- Goal: semantic model that machines can reason about
Context Models

- Key-value
- Markup-based (hierarchical)
- Logic-based
- Ontology-based
Ontologies

- In Philosophy: The study of *being or existence*
- Concepts
- Attributes
- Interrelationships
**OWL – The Web Ontology Language**

- Part of the Semantic Web activity
- Semantic content to be interpreted by machines
- Core elements:
  - Classes
  - Properties
  - Instances
- Identified uniquely by URIs
- Relationships between classes in terms of Boolean operators
- Properties define valid domain, range and cardinality
Listing 1: An excerpt of an OWL-described food ontology [1]

```
<owl:Class rdf:ID="PotableLiquid">
  <rdfs:subClassOf rdf:resource="#ConsumableThing" />
  <owl:disjointWith rdf:resource="#EdibleThing" />
</owl:Class>

<owl:Class rdf:ID="Juice">
  <rdfs:subClassOf rdf:resource="#PotableLiquid" />
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#madeFromFruit" />
      <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:minCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```
CoOL – ASC model

- Context Ontology-Language [3] defined on top of OWL
- Based on formal context model: ASC
  - Entity
  - Aspect
  - Context Information
  - Scale
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Context Querying and Reasoning

- **Querying**
  - For the state of another entity (or self)
  - For entities whose contexts satisfy certain criteria

- **Reasoning**
  - Inferring high-level contextual information from low-level information in repository
  - Existing reasoning engines can be used on ontology-based models
  - Ontologies, repository state, set of rules

- **Query languages depend on context data representation**
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Context Provider (Aggregation and Delivery)

- Provides contextual information to external client
- Interaction modes
  - Poll (query)
  - Notify (filter)
  - Transparent (trigger)
- Facade that hides intrinsic details of context management
- Potentially composite structure
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Service-Oriented Context-Aware Middleware

- Introduced by Gu, Pung and Zhang [4]
- Concepts from reference architecture realized as independent services
- Open architecture
- Context provider services
- Context interpreter services
  - Context knowledge-base
  - Context reasoner
  - Uses OWL as representation
  - Generalized context ontology and domain-specific ontologies
  - Notify or trigger actions on clients upon satisfaction of FOL statement
- Service location services
  - OWL-like query language
SOCAM
Service-Oriented Context-Aware Middleware

Figure: Overview of the SOCAM architecture [4]
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CSDS
Context-Sensitive Service Discovery System

- Introduced by Kuck et al. [5, 6]
- Formalized service-discovery model
- Uses concepts from information retrieval
  - Term-based context model
  - Query matched against a collection of services
  - Relevance of service according to ranking function
- User context matched against service context
- Static service context derived from WSDL
- Dynamic context derived from user feedback
CSDS
Context-Sensitive Service Discovery System

User Context

- **Person**
  - gender
  - date of birth
  - languages
  - ...

- **Situation**
  - location
  - date & time
  - weather
  - ...

- **Information World**
  - documents
  - emails
  - webpages
  - ...

**Figure:** Context of a mobile user [5]
Service Context

**WSDL**
- purpose
- provider
- language
- cost
- ...

**Feedback**
- user contexts
- queries
- popularity
- hits
- ...

**static features**

**dynamic features**

**Figure:** An example service context model [5]

CSDS
Context-Sensitive Service Discovery System
Summary

- **Context-Awareness** and **SOA** can mutually take advantage of each other.
- **Service-Oriented Architectures** help building powerful distributed **Context-Management Systems**.
- **Ontology-based context models** help inferring higher-level understanding of situation.
For Further Reading I

W3C:
Food ontology.
Web resource Available online at http://www.w3.org/TR/owl-guide/food.rdf;
visited on May 24th 2007.

Strang, T., Linnhoff-Popien, C.:
A context modeling survey.
In: Workshop on Advanced Context Modelling, Reasoning and Management as part of UbiComp 2004 - The Sixth International Conference on Ubiquitous Computing, Nottingham, England (September 2004)