Ontology-Based Context Modeling

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Background

Digital Enterprise Research Institute

- Applying semantics to Web services to achieve (semi-) automatic discovery, composition, …
- Non-functional and dynamic aspects of service descriptions and goals/tasks to execute
- Middleware for ‚Internet of Services': semantic tuplespaces
  - Management tasks / Non-functional properties
  - Self-Representation
  - Reflection, scalability trade-offs

Overview

1. *Ontologies: Some Basic Facts*
2. *Modeling Criteria*
3. *The Survey*
4. *Challenges & Problems*

Ontologies
Some Basic Facts

Ontologies

Ontologies are

„explicit formal specifications of the terms in a domain and the relations among them"

Modeling characteristics

- semi-structured with clear model semantics (not OO)
- modeling facilities for concepts and properties (not Logic)

Projecting real-life entities onto machine-understandable data constructs

Benefits

- Interoperability
  - high-level, explicit specification (understanding)
  - reusability, applicability (speed of implementation)
  - data and system integration (in the large)
- Validity and compatability checking, formal constraints
- Reasoning
  - validation of models and instances
  - derivation of instances & relations (implicit knowledge)
    - the system can infer more about the big picture
  - knowledge interpretation and evaluation

Ontology Languages

- Two branches of languages
  - **First-Order Logic (FOL)**
    - Description Logics (DL; e.g. OWL-DL) subsets of FOL
  - **Logic Programming (LP)**

- FOL, DL
  - open world, no unique name assumption
  - subsumption reasoning, consistency checking, classification
- LP
  - closed world, unique name assumption
  - query answering, consequence finding (rules systems)

    ? – child(?x) AND gender(?x,male).

Success factors for context modeling ontologies

Modeling Criteria: Context (1)

- Comparability of data values
  - heterogeneity of coding systems, units and values
- Traceability
  - provenance (trust)
  - computational source for derived context
- Logging, history
  - decisions based on the past
  - monitoring (detecting unlikely changes)

Modeling Criteria: Context (2)

- Quality
  - e.g. mean error, standard deviation
- Satisfiability (constraint modeling)
  - restrictions and constraints on acceptable values
- Inference, derivation
  - high-order context (situations, activities…)
    - inWater, moving → swimming
  - new contextual types based on primitive values
    - show the relationship of speed with distance and time

Modeling Criteria: Ontology (3)

- Reusability
  - simple and small ontologies (DC, FOAF)
  - genericity: domain independent (upper ontologies)
- Consistency
  - no contradictions (neither implicit nor explicit)
- Completeness, redundancy
  - cover the whole domain
  - but do not redefine explicit/implicit knowledge

Modeling Criteria: Ontology (4)

- Readability
  - humans develop ontologies, humans choose ontologies
  - understandable, intuitive relations and terms
  - not important for machines, but...
  - **very relevant factor for reuse, and adaptation'**

- Language, formalism
  - choose the right language for the problem
  - choose the right reasoning support for the problem
    - compatability of formalism
    - decidability (FOL + LP!!!)

The Survey

Survey: Ontologies

MobiLife	Classification-based situational reasoning for task-oriented mobile service discovery
ConOnto	Negotiation Context Information in Context-Aware Systems
SCAFOS / SCALA	A first-order logic model for context-awareness in distributed sensor-driven systems
CONON / ULCO	Ontology-Based Context Modeling and Reasoning using OWL;
Metamodel for Context	A Metamodel Approach to Context Information
CAPNET	RDF based Model for Context aware Reasoning in Rich Service Environments
CARE	Loosly Coupling Ontological Reasoning with an Efficient Middleware for Context-awareness
SOUPA	SOUPA: Standard Ontology for Ubiquitous and Pervasive Computing
MAS / mySAM	Representing Context in an Agent Architecture for Context-Based Decision Making
CDF	Context Description Framework for the Semantic Web
CAMidO	CAMidO, A Context-Aware Middleware Based on Ontology Meta-Model
GAIA	An infrastructure for context-awareness based on first order logic
CC Quality Model	A resource and context model for mobile middleware
VTT Finland	Managing Context Information in Mobile Devices
COBRA-ONT	An ontology for context-aware pervasive computing environments
CoOL / ASC	CoOL: A Context Ontology Language to enable Contextual Interoperability
DOLCE-DnS	Understanding the Semantic Web through Descriptions and Situations
CoDAMoS	Towards an extensible context ontology for Ambient Intelligence
GAS	GAS ontology: an ontology for collaboration among ubiquitous computing devices
CWI-Context	Modeling Adaptation in Web Services Execution using Context Ontologies

UbiComp, Pervasive, PerCom (CoMoRea), CONTEXT, CAPS,
PUC, IEEE Pervasive...

Survey: Introduction

- Aims to show
  - the state of the art
  - deployed features and factors that lack support
  - examples of work done and work to be done
- Definitively not a complete list of efforts
  - new examples monthly...
- Difficult to find complete information about models
  - ontologies not publicly available
  - lack of complete descriptions

Survey: Observations (1)

- Genericity:
  - abstract vocabularies to describe context values
    - ConOnto (ContextView, ContextFeature),
    - ASC (Aspects, Scales, ContextInformation)
  - upper ontologies to model entities involved in context-aware systems: Person, Location, Environment, Application, Device…
    - SOUPA, CONON, CoDAMoS (user, service, platform,…)
- **Context information is not (only) profiles**
  - profiles with values (formalized) in ontologies
  - key-value approaches with (formalized) values

Survey: Observations (2)

- Comparability
  - seldom explicitly integrated (values not at the core)
  - how to compare non-countable values?
  - counter-example ASC: focus on the values

- Traceability
  - VTT Finland framework attaches attribute source
    - no further modeling of sources
  - CONON tags values with type of source
    - sensed, derived, aggregated, deduced

Survey: Observations (3)

- Logging, history
  - often done by use of timestamps
  - GAIA: integrates relational database for temporal queries (values regularly stored in RDBMS)

- Quality
  - Most clearly recognized meta-context
    - probability, confidence, meanError
    - baysien reasoning, fuzzy logic
    - quality ontologies

Survey: Observations (4)

- Satisfiability
  - logical expressions (rules)
  - external services (application and Web service bindings)
  - again: of particular interest for non-countable values

- Derivation, inference
  - integration of derivation rules, axiomatic expressions
    - activity(sleeping) <- location(inBed) AND eyes(closed)
  - inter/intra operations of ASC
    - Speed = Interoperation(Distance, Time)

Survey: Observations (5)

- Most models rely on FOL (in fact OWL-DL)
  - subsumption reasoning, entity hierarchies, model checking

- LP is chosen for inclusion of context rules

```
forall X suggestion(X,drink) <-
        X:human[activity->running] and
        T:temperature[value->V, unit->Celsius] and V > 20 .
```

- Few combined solutions for schema and value modeling (FOL) and the integration of derivation and user rules (LP)

- Interesting: CDF extension to RDF
  - trueInContext, contextProbability properties

Survey: Conclusions

- Quality and timestamps recognized as important
- Provenance needs more attention
  - yet more important in large-scale distributed settings
  - also a prerequisite for trust measures
- Interoperability crucial
  - solid ontology modeling
  - comparability, constraints modeling (satisfiability)
  - especially in open pervasive environments and the "Internet of Services"

Challenges & Problems

Challenges and Problems

- Top-down creation
  - the applications determine the models
  - resulting ontology on a per case basis. Reusability?
- Applications become globally reachable
  - not some tiny tool on a mobile device
  - need for standardization, or integration, mapping
- Accessibility
  - Reuse of ontologies requires that they are available
  - Lack of publicly available ontologies: a **human-caused problem**

Challenges and Problems

- Open topic in the Semantic Web community
  - combination of FOL and LP
    - causes undecidability, ongoing research
      - Description Logic Programs
      - SWRL (OWL + RuleML), RIF (W3C WG)
      - WSML-Full
  - scalability, performance of reasoners
  - distributed querying and reasoning

- Future: “Internet of Services”?
  - context-aware discovery, composition, negotiation
  - combination of functional and non-functional aspects

Thank you.

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