Policy-based Adaptation of Context Provisioning in Ambient Intelligence

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Outline

1. Introduction
   - Context Provisioning
   - Research Objectives
2. CONSERT Middleware
   - Architecture
   - Context Provisioning Policy Definition
   - Provisioning Protocols and Policy Execution
3. Conclusions and Future Work

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Introduction: Context Provisioning

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Definition

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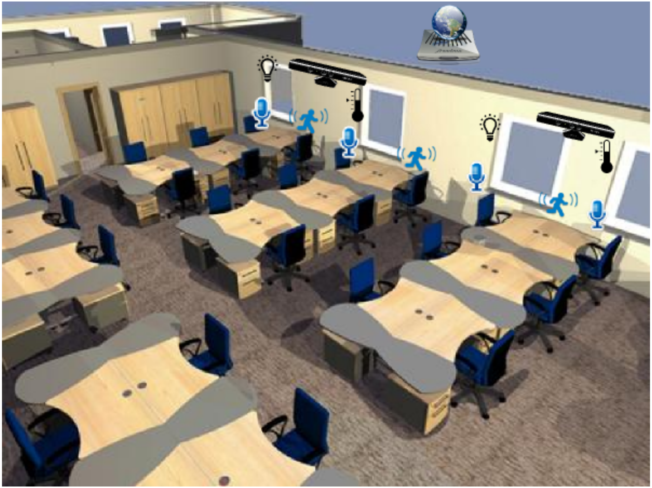
- Main Life Cycle
  - Context Acquisition
  - Context Modeling / Reasoning / Coordination
  - Context Dissemination

- Complementary Functionality
  - Context Producer Discovery
  - Mobility Management (e.g. interaction session, handovers)
  - Context Access Management
  - Provisioning Adaptability (structural, functional)
  - ...

Introduction: Example Scenario



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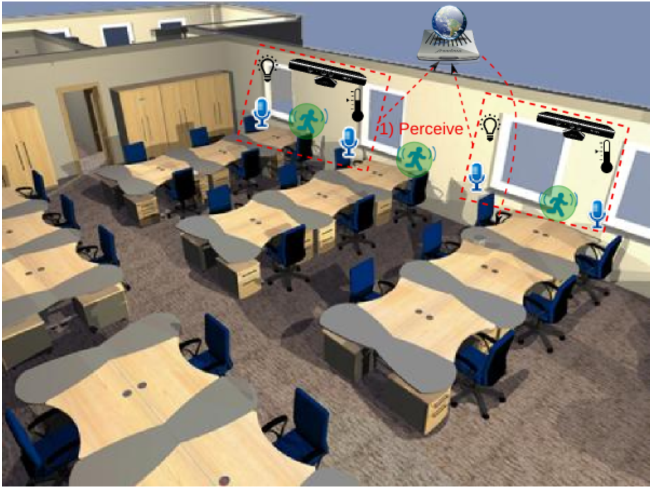

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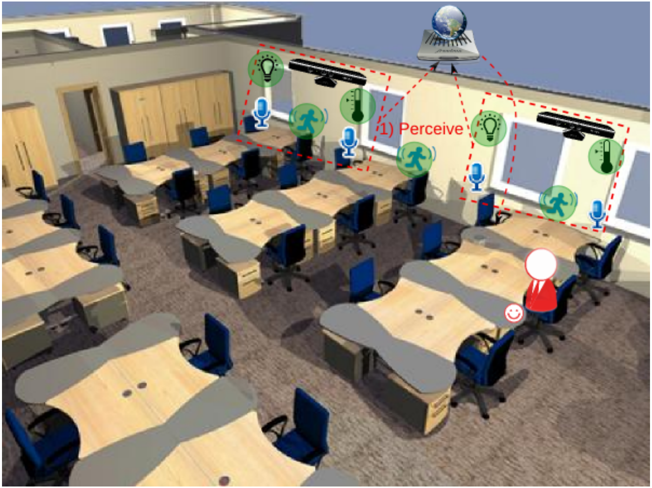

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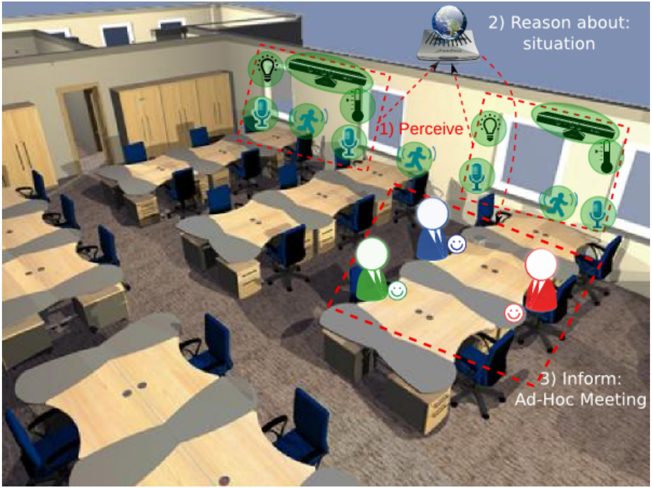

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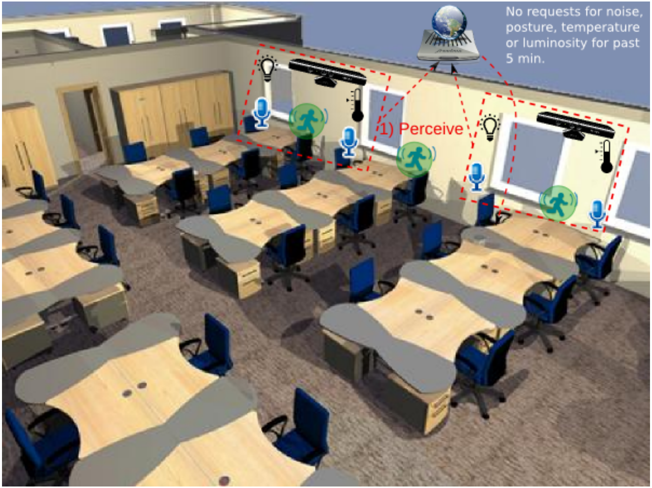

No requests for noise, posture, temperature or luminosity for past 5 min.

Introduction: Context Provisioning Issues

- What is a good abstraction for the fundamental units of context management?

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- What is a good mechanism to engineer the adaptability of the context provisioning process?
- How to support application development by ensuring flexibility and ease of use of the adaptation mechanism?

Introduction: Main Goals

- Develop a Context Management Middleware (CMM) based on design principles from the **Multi-Agent Systems**, **Semantic Web** and **Software Service Component** domains.
    - **Agents**: units of **control encapsulation** for each provisioning aspect with **potential for increased autonomy**.
    - Guide and adapt agent provisioning behavior through **declarative policies**.

- Why these objectives?

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CONSERT Middleware Architecture

- CONSERT = CONtext asSERTion [Sorici et al., 2015b]
- **Multi-Agent Based Architecture**: use **MAS design principles** as a **good fit** for this **engineering problem**

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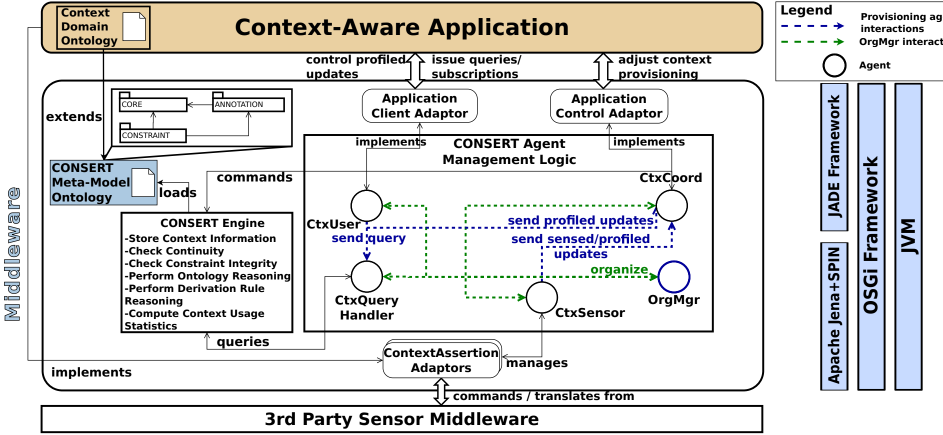
- **Multi-Agent Based Architecture**: use **MAS design principles** as a **good fit** for this **engineering problem**
- **Why Agents?**
  - Conceive the provisioning units as: **autonomous, reactive, proactive** and **socially interacting** entities
  - Exploit research into message-based, communicative-act centric interaction protocols to address communication infrastructure concerns

  ⇒

  - **Good encapsulation** of the logic for each provisioning aspects with **potential for increased provisioning autonomy**
  - **Message based communication** with complete handling of success and failure cases

CONSERT Middleware Architecture


Context Domain Ontology
Context-Aware Application
control profiled updates
issue queries/ subscriptions
adjust context provisioning
Legend
Provisioning ag
interactions
OrgMgr interact
Agent
extends
CORE
ANNOTATION
CONSTRAINT
Application Client Adaptor
Application Control Adaptor
implements
implements
CONSERT Agent Management Logic
CONSERT Meta-Model Ontology
loads
commands
CtxCoord
CtxUser
send query
send profiled updates
send sensed/profiled updates
organize
CONSERT Engine
-Store Context Information
-Check Continuity
-Check Constraint Integrity
-Perform Ontology Reasoning
-Perform Derivation Rule Reasoning
-Compute Context Usage Statistics
CtxQuery Handler
CtxSensor
OrgMgr
Middleware
queries
ContextAssertion Adaptors
manages
implements
commands / translates from
3rd Party Sensor Middleware
JADE Framework
Apache Jena+SPIN
OSGi Framework
JVM

CONSERT Middleware Agents

Multi-Agent Based Architecture: 4 provisioning agents + 1 management agent

Provisioning Agents

- **CtxSensor Agent**: manage interactions with sensors (based on sensing policies), communicate with CtxCoord to send updates and receive provisioning tasking commands
- **CtxCoord Agent**: coordinate processing of context information
  - Create and control CONSERT Engine
  - Use coordination policies to determine *what* sensor updates and inferences are active and *how* (e.g. with which frequency) updates must be sent

CONSERT Middleware Agents

Provisioning Agents

- **CtxQueryHandler Agent**: disseminate context information, answer to queries and subscriptions. Can work in local or federated mode.
- **CtxUser Agent**: connection with application logic
  - Send queries and subscriptions
  - Act as prosumer: provide *static* or *profiled* ContextAssertions

Management Agent

- **OrgMgr Agent**:
  - Control deployment and life cycle of provisioning agents (i.e. create, start, stop, destroy provisioning agents)
  - Maintain overview of distributed deployment (if the case) + manage query/updates routing

Context Provisioning Policies

- Guide the behavior of provisioning agents (especially CtxCoord and CtxSensor)
- Consist of a set of **parameters** (key-value attributes) and a set of **control rules** (developer defined)
- **Implemented using Semantic Web Technologies**
  - Ontology-based parameter vocabulary
  - SPARQL-based rule definition

Context Sensing Policies

- Specify initial settings for **how** sensed context information is updated
- 2 parameters: **update-rate**, **update-mode** (change-based, time-based)

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```
:presenceSensingPolicy
    a  sensorconf:SensingPolicy ;
    coordconf:forContextAssertion
        ex:sensesBluetoothAddress ;
    sensorconf:hasUpdateMode
        coordconf:time-based ;
    sensorconf:hasUpdateRate  2 .
```

```
:luminositySensingPolicy
    a  sensorconf:SensingPolicy ;
    coordconf:forContextAssertion
        ex:sensesLuminosity ;
    sensorconf:hasUpdateMode
        coordconf:change-based ;
    sensorconf:hasUpdateRate  0 .
```

Context Coordination Policies

- Define the adjustable aspects of the context provisioning process
- Allow for a rule-based mechanism for controlling the adjustment (adaptation)

- **Control Parameters**: Setup the CONSERT Engine, specify enabled updates and update modes
- **Control Rules**: alter control parameters according to **dynamic use of context information**

Provisioning Control Parameters

- Parameters may be *general* or *context information type specific*

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Parameter	Values	Role
assertion enabling	true/false	Specify if assertion updates are enabled by default.
ont. reasoning interval	number in seconds	Time span between calls to ontology reasoner.
TTL	number in seconds	Time to live for any *ContextAssertion* in the runtime storage
integrity constraint resolution	String in enumeration	Identifier of the service handling integrity constraint resolutions
uniqueness constraint resolution	String in enumeration	Identifier of the service handling uniqueness constraint resolutions
observation_window	number in seconds	Length of time window over which context usage statistics are computed
inference scheduling service	String in enumeration	Identifier of service providing priority scheduling for *ContextDerivationRules*

Provisioning Control Rules

- Make use of *context knowledge base snapshots* and *CONSERT Engine usage statistics* to express conditions for altering of provisioning control parameters
- Implemented as SPARQL Query Templates (using SPIN[1])

[1] http://spinrdf.org

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- Implemented as SPARQL Query Templates (using SPIN[1])

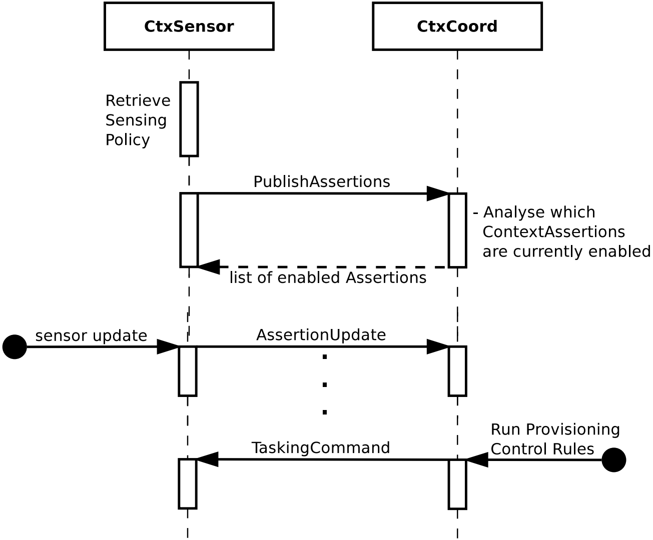
```
CONSTRUCT {
  _:b0 a :StopAssertionCommand.
  _:b0 :forContextAssertion ?assertion.
}
WHERE {
  ?stat a :AssertionSpecificStatistic.
  ?stat :forContextAssertion ?assertion.
  ?stat :isDerivedAssertion true.
  ?stat :nrSubscriptions 0.
  ?stat :timeSinceLastQuery ?time.
  FILTER (?time > ?elapsedThreshold).
}
```

```
coord:ControlPolicy
  coord:hasStopAssertionCommand [
    a   :QueryAbsenceAssertionCancellation;
    arg:contextAssertion ami:sensesLuminosity;
    arg:elapsedTimeThreshold 300;
  ];
```

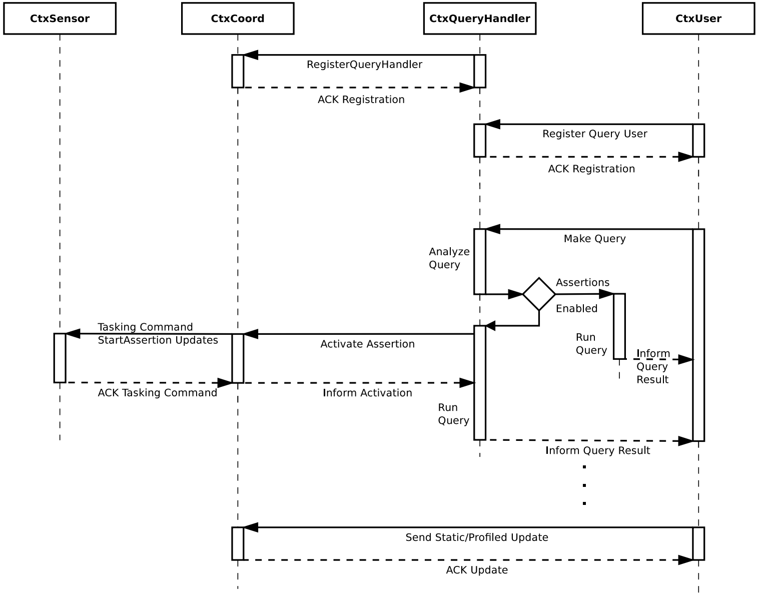
Figure : SPARQL expression of derivation cancellation rule template (left) and control rule assignment (right)

[1] http://spinrdf.org

Context Provisioning Protocols - Sensing Chain



Context Provisioning Protocols - Request Chain



Context Provisioning Policy Execution

- CtxCoord agent uses control parameters to set up the CONSERT Engine and the default active CtxSensor agents
- CtxCoord agent runs control rules every *observation_window* seconds

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- CtxCoord agent runs control rules every *observation_window* seconds
- CtxCoord agent requests *snapshot of context knowledge* base and *context usage statistics* from CONSERT Engine
- Control rules are partitioned into *execution groups*
  - *Execution groups* are run in a *developer-specified order*
  - Rule outcomes from later groups *overwrite* contradictory outcomes from rules in previous groups ⇒ ensure *control rule output consistency*.

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- Exploit multi-agent potential for autonomy by introducing Context Level Agreements (CLAs)
  - CtxCoord, CtxSensor agents have individual goals (e.g. reduce workload, save energy) which are valued against request characteristics (e.g. required accuracy, needed freshness) from a CtxUser
  - Control of CLA establishment needs to be integrated in provisioning policies
    - Increase *specificity level* of control rules to *individual* context providers
    - Use *observed Quality-of-Context* to enhance expressiveness of control rule conditions

References I

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THANK YOU!

Questions?