Context Management in Ambient Intelligence using Semantic Complex Event Processing

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Outline

1) Ambient Intelligence
   1) Intro
   2) Scenarios

2) Context Management in AmI
   1) Objective and Challenges
   2) Context Representation and Reasoning

3) Semantic Complex Event Processing
   1) Definition and Uses
   2) CEP Principles
   3) ETALIS

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Ambient Intelligence

What is Ambient Intelligence (AmI)?

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*In an **AmI** world, **devices work in concert to support people** in carrying out their **everyday life activities, tasks and rituals** in an easy, natural way using **information and intelligence seamlessly emerging from the interaction of the devices**.* (Adapted from Wikipedia)

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Features of AmI:

- **Sensitivity, Responsiveness, Adaptability**
- **Transparency, Ubiquitousness**
- **Intelligence**

- **Decentralized Control**
- **Distributed Information**
- **Openness**

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Ambient Intelligence

Applications of AmI

Ambient Intelligence

Applications of AmI

- Smart Houses :-)
- Smart Workplaces
  - Universities, office buildings, co-work spaces
- Smart Leisure Venues
  - Museums, Bars, Exposition Venues
- Smart Cities

Ambient Intelligence

Applications of AmI (a holistic experience)

ISTAG Maria Scenario [Ducatel et al., 2001]

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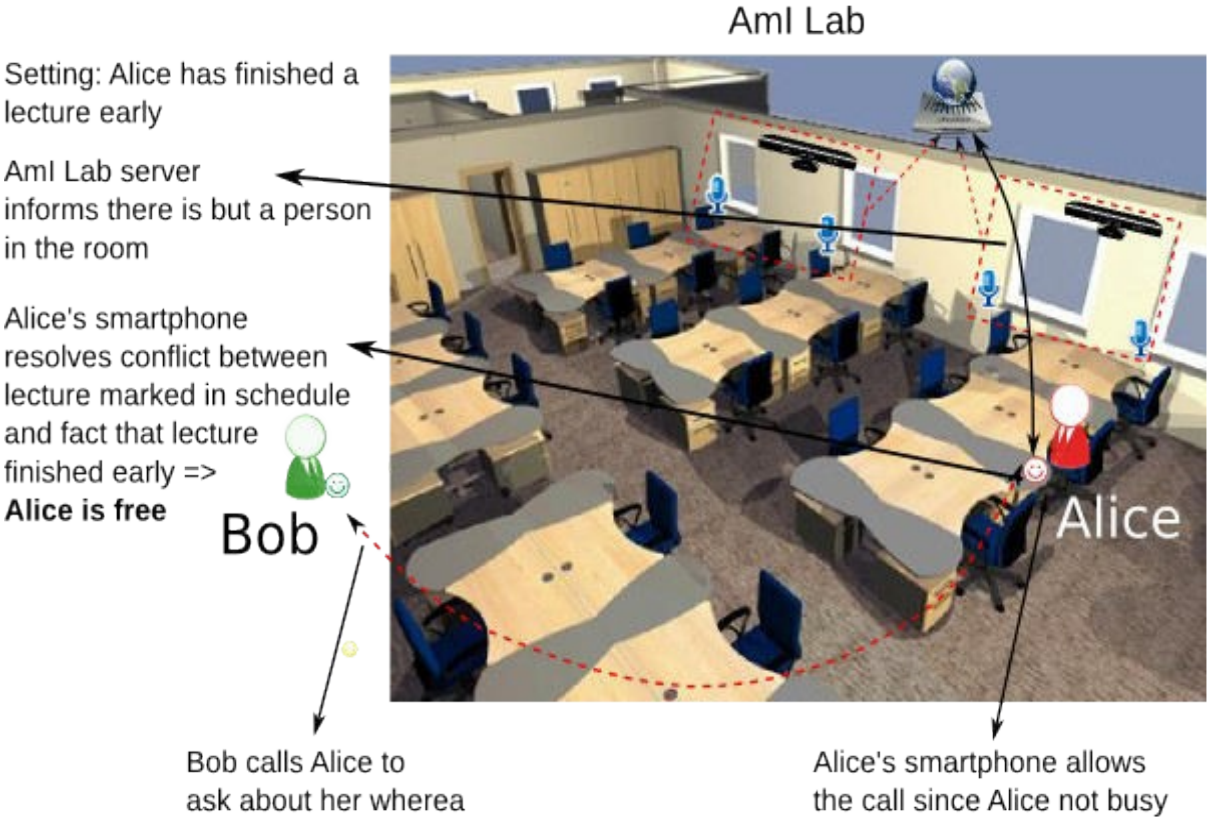
Ambient Intelligence

Applications of AmI

Smart University Lab [Sorici et al., 2015]



Ambient Intelligence

Applications of AmI

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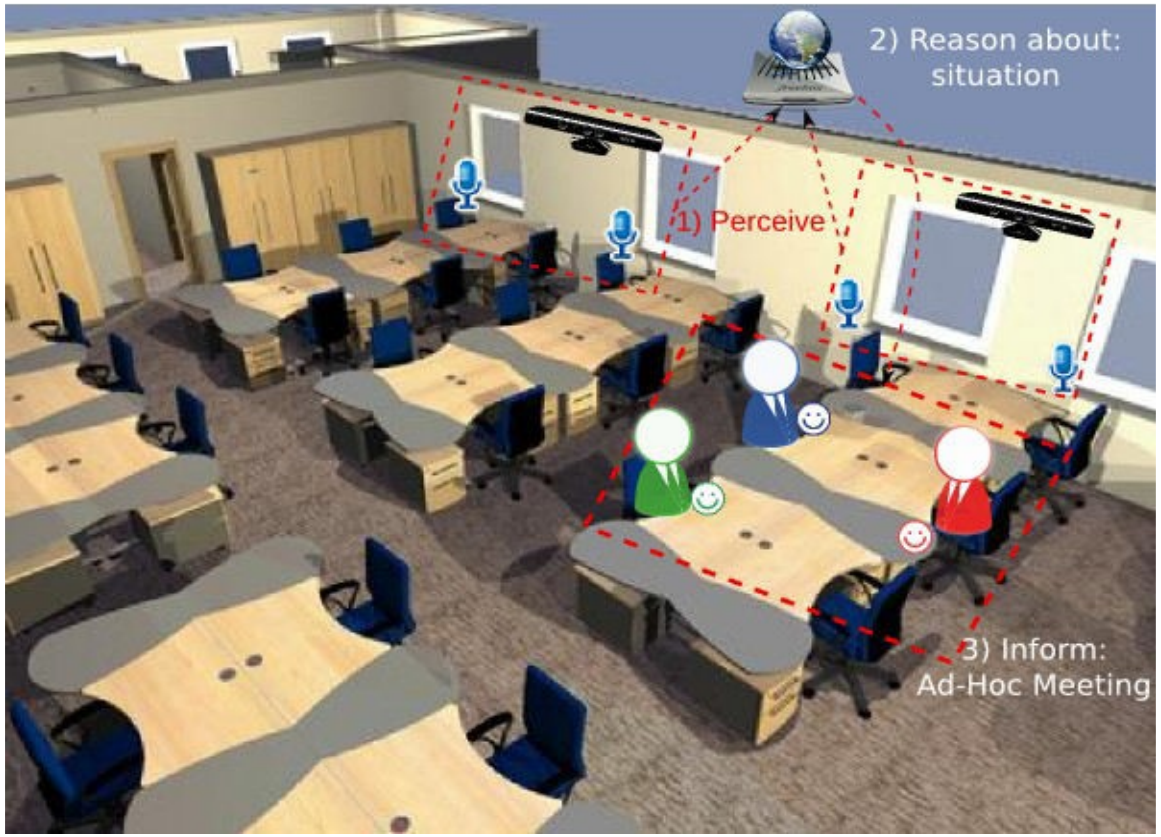

Ambient Intelligence

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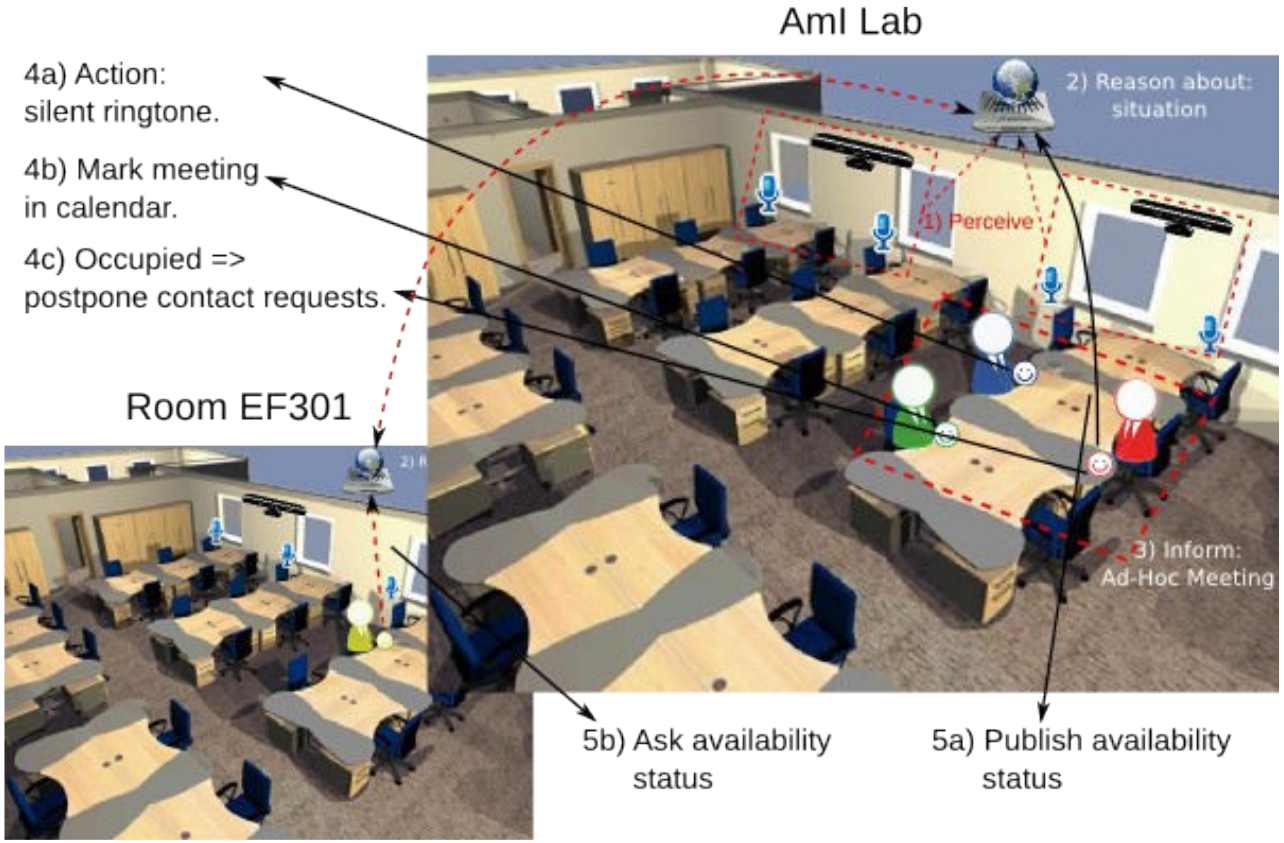

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Context Management in AmI

What is Context Management?

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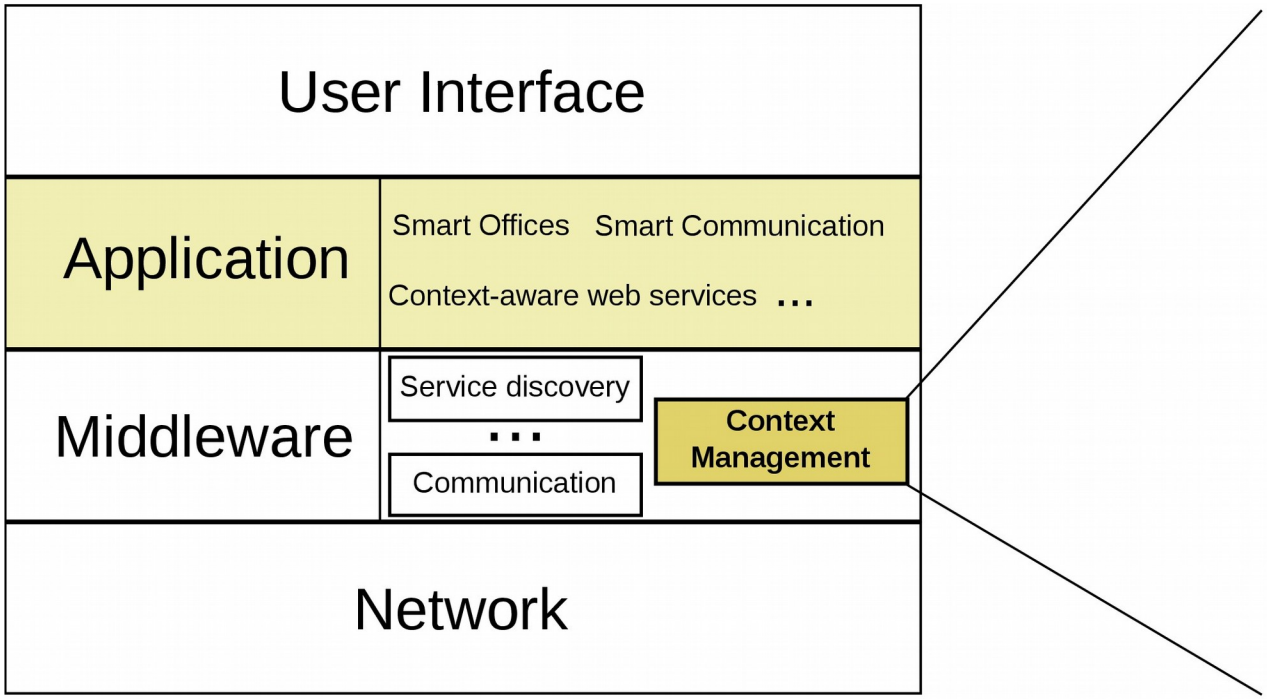


Definition of Context (Dey, 2001)

Any information that can be used to characterize the situation of entities (whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves.

Context Management

Context Representation and Reasoning

Context Provisioning:
acquisition, coordination, dissemination, usage

Context Management Solution Deployment

Context Management in AmI

What is Context Management?

1. **Context Modeling:** representation and reasoning about context information
2. **Context Provisioning:** functionality of **context processing units** + information/command flow they enable
3. **Context Provisioning Deployment**: configuration and physical deployment of context processing units within an AmI application

Context Management in AmI

Objectives / Challenges in Context Modeling

Context Management in AmI

Objectives / Challenges in Context Modeling

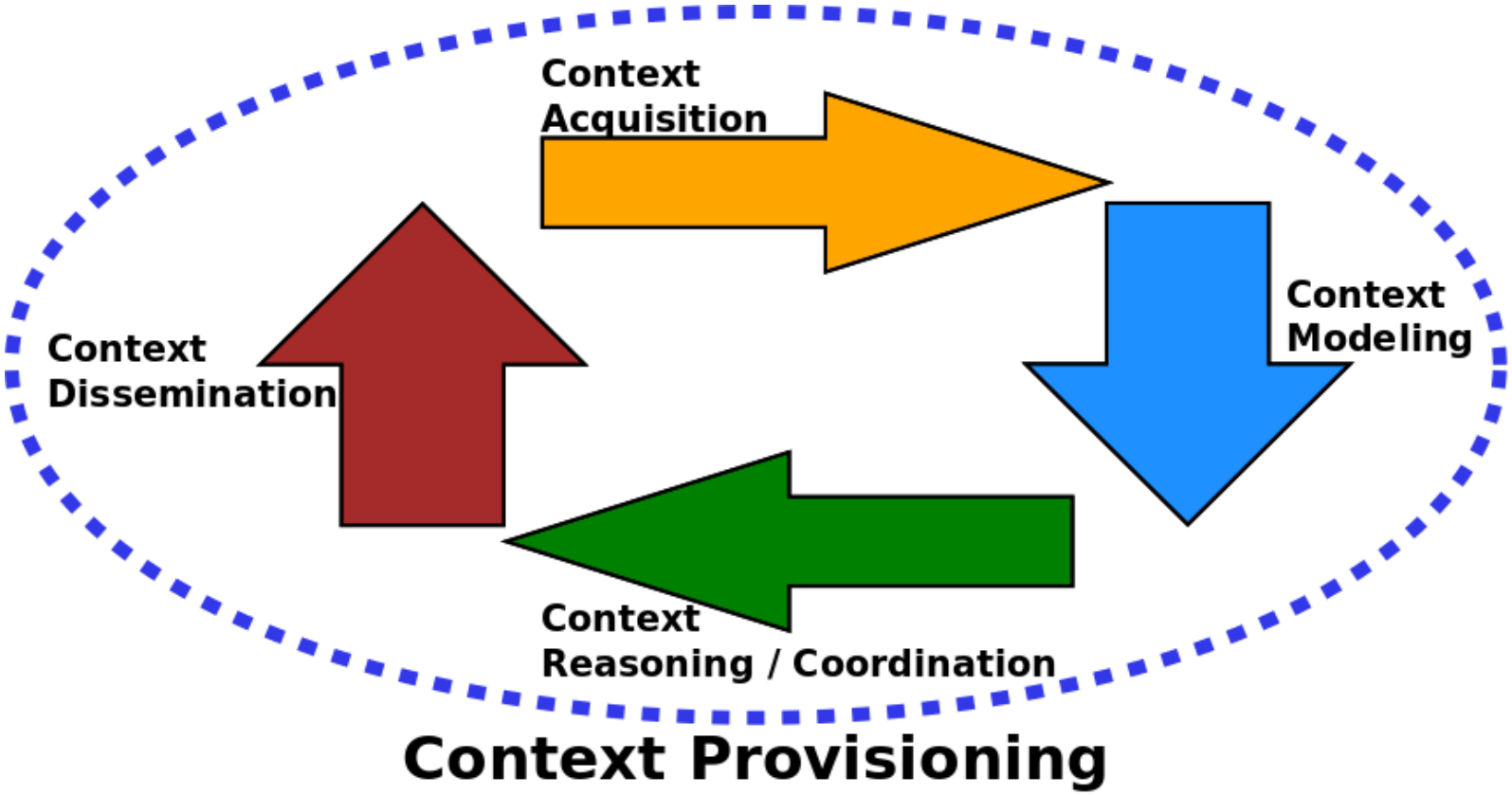
- Creating a **flexible** model
- **Heterogeneity** of information sources
- Specifying context information **dependencies** (e.g. constraints, derivations)
- Ability to handle **temporal aspects** (**context history**)
- Ability to handle **incomplete/ambiguous information**
- Adequate support for **complex reasoning** (inference and consistency management)
- **Usability** of the Model

Context Management in AmI

Objectives / Challenges in Context Provisioning

Context Management in AmI

Objectives / Challenges in Context Provisioning



Context Management in AmI

Objectives / Challenges in Context Provisioning

- Main Lifecycle
  - Context Acquisition (physical or virtual sensors)
  - Context Coordination (reasoning, flow management)
  - Context Dissemination (direct queries, content-based subscriptions)

- Complementary Functionality
  - Context Producer Discovery
  - Mobility Management (registration and handover in distributed architectures)
  - Access Management (system and user defined policies)
  - Application Adaptability

Context Management in AmI

Challenges of Context Provisioning

- **Requirements**
  - Openness / Heterogeneity
  - Mobility support
  - Scalability
  - Traceability and control + History
  - Support for privacy and security
  - Fault tolerance + robustness
  - Ease of deployment / configuration

Context Management in AmI

Objectives / Challenges of Context Provisioning Deployment

Context Management in AmI

Objectives / Challenges of Context Provisioning Deployment

- Manage the life cycle of context provisioning units (install, start, stop, uninstall)
- Support centralized and distributed coordination
- Context-aware application structuring

- How to **package** context-aware application configs?
- How to easily **switch between** different **provisioning unit sets** depending on service requirements?

Context Management in AmI

Context-aware application examples

- Adaptive Video Streaming
- Driving Assistance
- Location-aware recommendations (Siri, Google Now, Cortana)

- Lots of Google Products :-)
  - Google Nest (smart thermostat)
  - Google Now (on Tap)
  - Google Home
  - Google Awareness API (time, location – symbolic and coordinates – activity, battery, weather, earphones plugged in/not)

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Context Representation & Reasoning

Context Model

A concrete subset of the context that is realistically attainable from sensors, applications and users and able to be exploited in the execution of the task. (Henrickson, 2003)

Context Attribute

An *element* of the context model describing the context.

- has an identifier, a type and a value
- (optionally) meta-properties (temporal validity, QoC, access information)

Context Representation & Reasoning

Context Modeling Categories [Fuchs et al., 2005]

- **Individuality**
  - Sensors and the information they provide
  - User profiles, Hardware/Software platform capabilities / status
- **Space**
  - GPS coordinates, symbolic localization
- **Time**
  - Time of day, week season
- **Activity**
  - Scheduled tasks, physical activity
- **Relations**
  - Organizational (employer-employee), compositional (part-of)

Context Representation & Reasoning

Context Models in Applications

- **No context model:** Context life cycle operations within the application boundaries

- **Implicit Context Model:** Context life cycle operations in libraries, frameworks, and toolkits
  - Still hard bound to specific application

- **Explicit Context Model:** Context life cycle operations lie outside application boundaries. Part of middleware solution
  - separation of concerns between *main application functionality* and *context management and context-aware adaptation*

Context Representation & Reasoning

Context Model Example

- What is context for the Smart University Lab?

Context Representation & Reasoning

Context Model Example

- What is context for the Smart University Lab?
  - **Space:**
    - Laboratory, desk

Context Representation & Reasoning

Context Model Example

- What is context for the Smart University Lab?
  - **Space:**
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  - **Activity:**
    - Sitting, Talking, Ad-hoc meeting

Context Representation & Reasoning

Context Model Example

- What is context for the Smart University Lab?
  - **Space:**
    - Laboratory, desk
  - **Activity:**
    - Sitting, Talking, Ad-hoc meeting
  - **Individuality**
    - User availability status: busy / free
    - Smartphone ringtone status
    - Sensors:
      - Estimote Beacon signal
      - Kinect camera skeleton position
      - Microphone noise level

Context Representation & Reasoning

Context Model Example

- What is context for the Smart University Lab?
  - **Meta-properties**
    - Temporal validity of sitting activity, ad-hoc meeting
    - Confidence in:
      - Microphone loudness level
      - Kinect camera pose detection
    - Access Rights for availability status

Context Representation & Reasoning

Context Representation Techniques

- **Key-Value**
- **Markup Scheme based**
- **Graphical**
- **Object Oriented**
- **Logic based**
- **Ontology based**

Context Representation & Reasoning

Context Reasoning

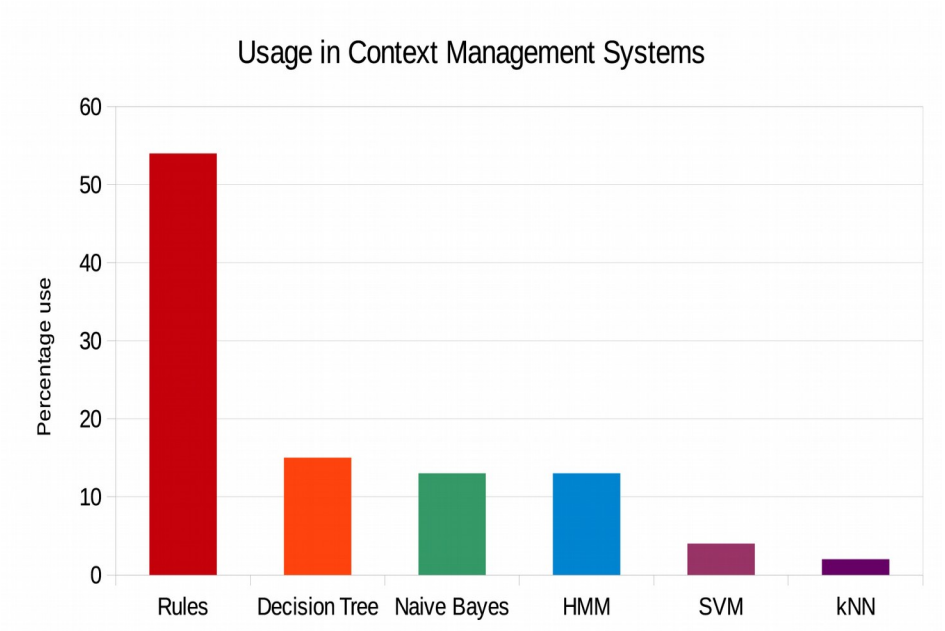
- **Pre-processing**:
  - clean collected sensor data – fill missing values, remove outliers, validate context via multiple sources
- **Data Fusion / Inference**:
  - combine data from multiple sources, produce more accurate, complete and dependable information
- **Consistency Management:**
  - (value, uniqueness, general) Constraint detection and resolution, context information TTL management

Context Representation & Reasoning

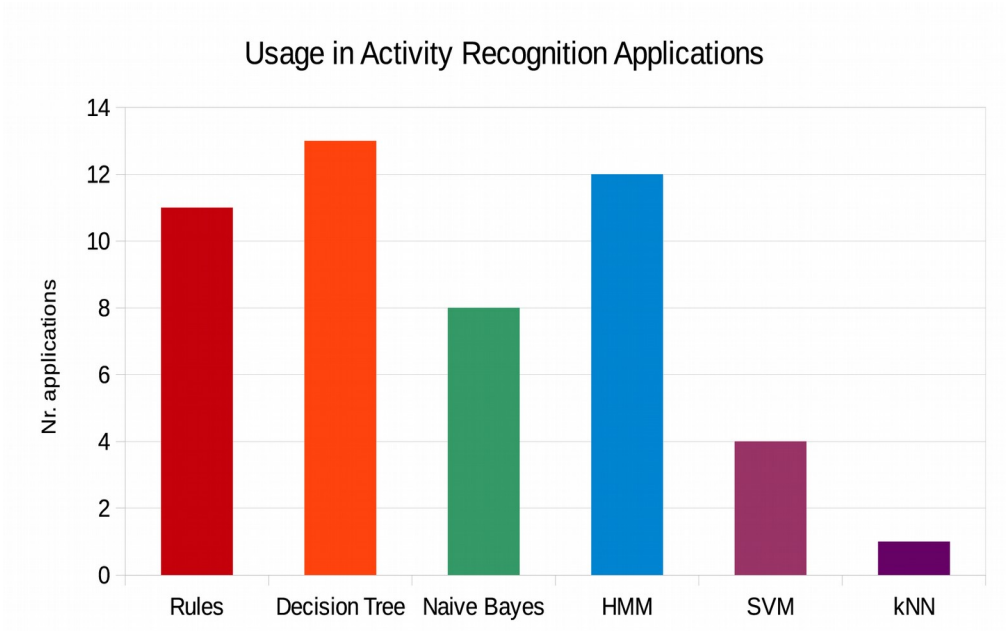
Context Reasoning Techniques

- Supervised Learning (NN, Bayesian Learning, Decision Trees, SVMs)
- Unsupervised Learning (clustering, kNN)
- Rules
- Fuzzy Logic
- Ontology based (FOPL)
- Probabilistic Logic (e.g. Dempster-Shafer)

Context Representation & Reasoning



Counts of reasoning techniques used in 109 context-aware applications [Lim and Dey, 2010]



Counts of activity recognition techniques used in 50 reviewed applications [Lim and Dey, 2010]

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Semantic Complex Event Processing

What is Event Processing?

- **Event:** an occurrence within a particular system or domain. It is something that has happened, or is contemplated as having happened in that domain [Etzion and Niblett, EPIA'10]

- **Event Processing:** computing that performs operations on events. Common processing operations include *reading, creating, transforming* and *deleting events* [Etzion and Niblett, EPIA'10]

Semantic Complex Event Processing

What is *Complex* Event Processing (CEP)?

- Event Processing that combines data from **multiple sources** to **infer events or patterns** for complicated situations.
- Identify **meaningful events** and respond/react to them quickly and appropiately.

Semantic Complex Event Processing

What is *Semantic* Complex Event Processing (SCEP)?

- Formalism to express **both** *complex event patterns* and ***background information***
- Examples of background information:
  - Well defined event schema (type information)
  - Sub-class / sub-property relations
  - Event constraints / inter-dependencies

Semantic Complex Event Processing

Uses of CEP

- Business Activity Monitoring (observation)
  - Exception detection
  - Fraud detection
  - Alert notification (banking, risk assessment, quantitative trading)
  - Trigger actions

- Rule-based routing
  - Content and Context-based routing (network traffic, vehicle traffic)

- Spatio-Temporal Event Detection Service
  - Traffic and navigation
  - Intelligent driving
  - Emergency and safety systems

Semantic Complex Event Processing

Uses of CEP in AmI

- Wherever a rule-based approach is possible
  - Activity Recognition
    - Detecting Activities of Daily Living (e.g. cooking, watching TV, sleeping)
  - Application Service Adaptation
    - e.g. Video / Audio Streaming depending on network latency, connectivity type (e.g. WiFi, GSM, wired), billing plan
    - Interface adaptation
  - Ambient Assisted Living
    - Health Measurement Anomaly Detection

Semantic Complex Event Processing

Players in CEP

- Big Guns:
  - IBM Websphere, TIBCO Streambase, SAP ESP
  - Esper, Drools Fusion
- Open Source Frameworks
- RDF Stream Processors
  - C-SPARQL
  - CQELS
  - SPARQLstream
  - INSTANS
  - EP-SPARQL and **ETALIS**

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CEP Principles

Typical *Event Processing Agents* (Operations) [Etzion and Niblett, 2010]

- Filtering
- Pattern Detection
- Transformation
  - Translate
    - Enrich
    - Project
  - Aggregate
  - Split
  - Compose

CEP Principles

- Windowed computation
  - Event operations are considered over a window in the event stream
- In memory processing
  - For low latency and high availability
- Use of event consumption policies
  - Chronologically, most recent, custom

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ETALIS

- Event TrAnsaction Logic Inference System
- Research-oriented, commercial grade CEP Logic Programming system
- Implemented in Prolog

ETALIS

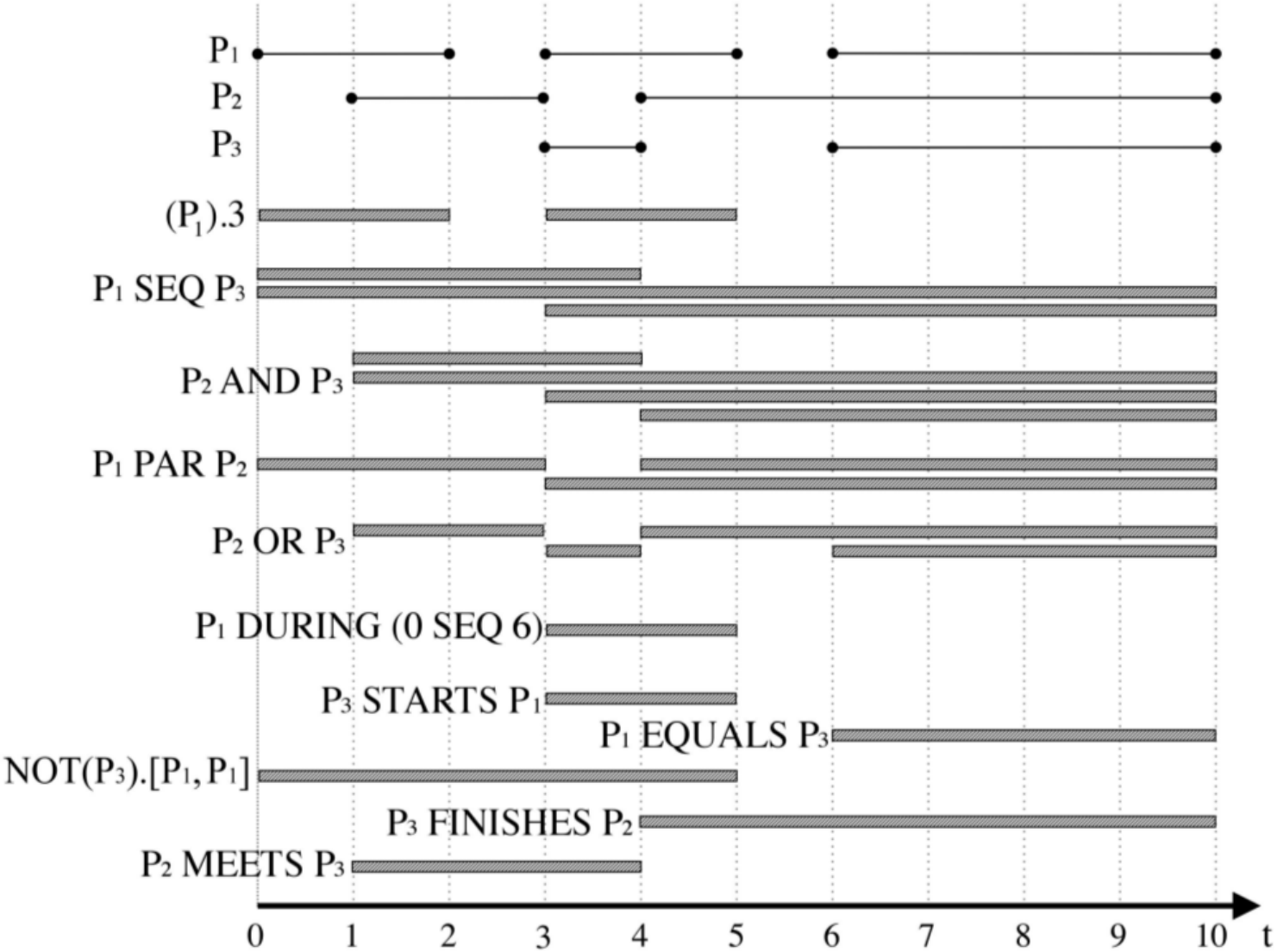
- Logic Programming (LP) in ETALIS enables:
  - Formal declarative semantics
  - Reasoning about events *and knowledge* (=> semantics)
    - Contradicting events / situations
    - Detect not yet fulfilled complex patterns
    - Event retraction and out-of-order events
  - Justifications: why did an event occur? Why didn’t it occur?
  - On-the-fly adaptation
    - Rule patterns can be inserted / deleted just like data

ETALIS

- Other features in ETALIS
  - Support for **atomic-events** and **interval-events**
    - Classic event operators (e.g., sequence, concurrent conjunction, disjunction, negation)
    - All operators Allen's interval algebra (e.g., during, meets, starts, finishes);
  - Different garbage collection policies:
    - Global
    - Per rule pattern
  - Efficient aggregation functions (sum, max, min, count)

ETALIS

Interval based Semantics



ETALIS

Modeling Smart Laboratory Example

Events:

- locatedAt(Person, Desk).
- hasPosture(Person, Posture).
- loudnessLevel(Desk, Level).

Rules:

- personSittingAtDesk(Person, Desk)
- inAdHocMeeting(Person, Desk)

ETALIS

Modeling Smart Laboratory Example

```
r_person_at_desk 'rule:'
personSittingAtDesk(Person, Desk) ←
   locatedAt(Person, Desk) 'and'
   hasPosture(Person, sitting).

event_rule_property(r_person_at_desk,window,300).
event_rule_property(r_person_at_desk,window_step,5).
```

ETALIS

Modeling Smart Laboratory Example

```
r_num_sitting 'rule:'
nrPeopleAtDesk(D, Nr) ←
   personSittingAtDesk(Person, Desk) 'seq'
   aggregate(count, personSittingAtDesk(P, D), Nr).

event_rule_property(r_num_sitting,window,300).
event_rule_property(r_num_sitting,window_step,5).
```

ETALIS

Modeling Smart Laboratory Example

```
r_avg_loudness 'rule:'
avgLoudnessAtDesk(Desk, AvgL) ←
   loudnessLevel(Desk, Lvl) 'seq'
   aggregate(avg(Lvl), loudnessLevel(Desk, Lvl), AvgL).

event_rule_property(r_num_sitting,window,300).
event_rule_property(r_num_sitting,window_step,5).
```

ETALIS

Modeling Smart Laboratory Example

```
r_adhoc_meeting 'rule:'
inAdHocMeeting(Person, Desk) ←
   nrPeopleAtDesk(Desk, Nr) 'and'
   averageLoudness(Desk, AvgL) 'intersect'
   personSittingAtDesk(Peson, Desk) 'where' (
      Nr >= 3, AvgL >= 60
   ).


event_rule_property(r_adhoc_meeting, window, 300).
event_rule_property(r_adhoc_meeting, window_step, 5).
```

References

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THANK YOU :-)