Understanding Group Activities from Movement Sensor Data

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Smart Buildings

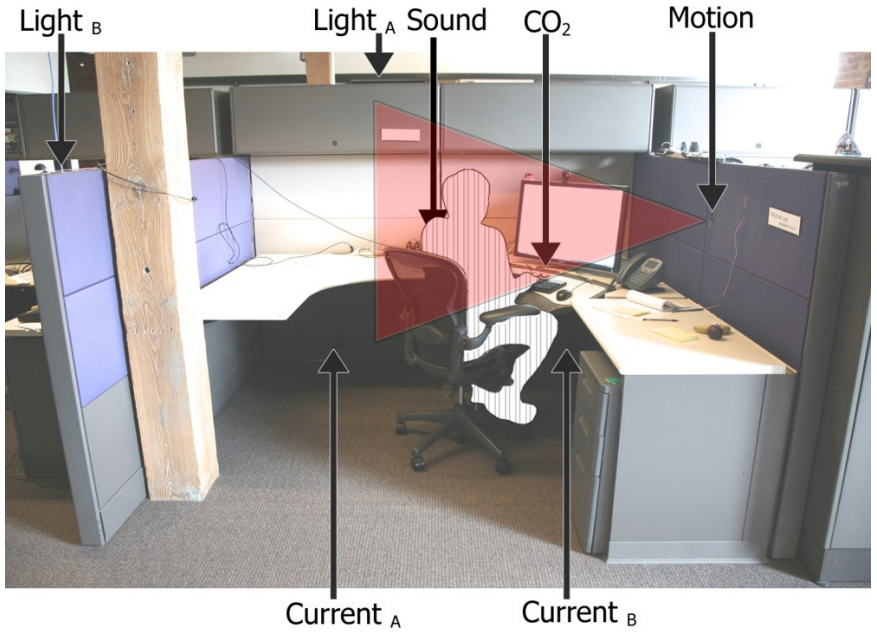
Smart buildings
and
energy efficiency

Based on human activity adjust heat and light in building

Raw Sensor Signals

Collecting raw sensor data is easy

- Lots of small compute nodes stream various raw sensor signals (e.g. audio, temperature, light)
- "Raw" signals: each sensor measures one thing
  - Heterogeneous: each sensor has its own format and its own "signal"

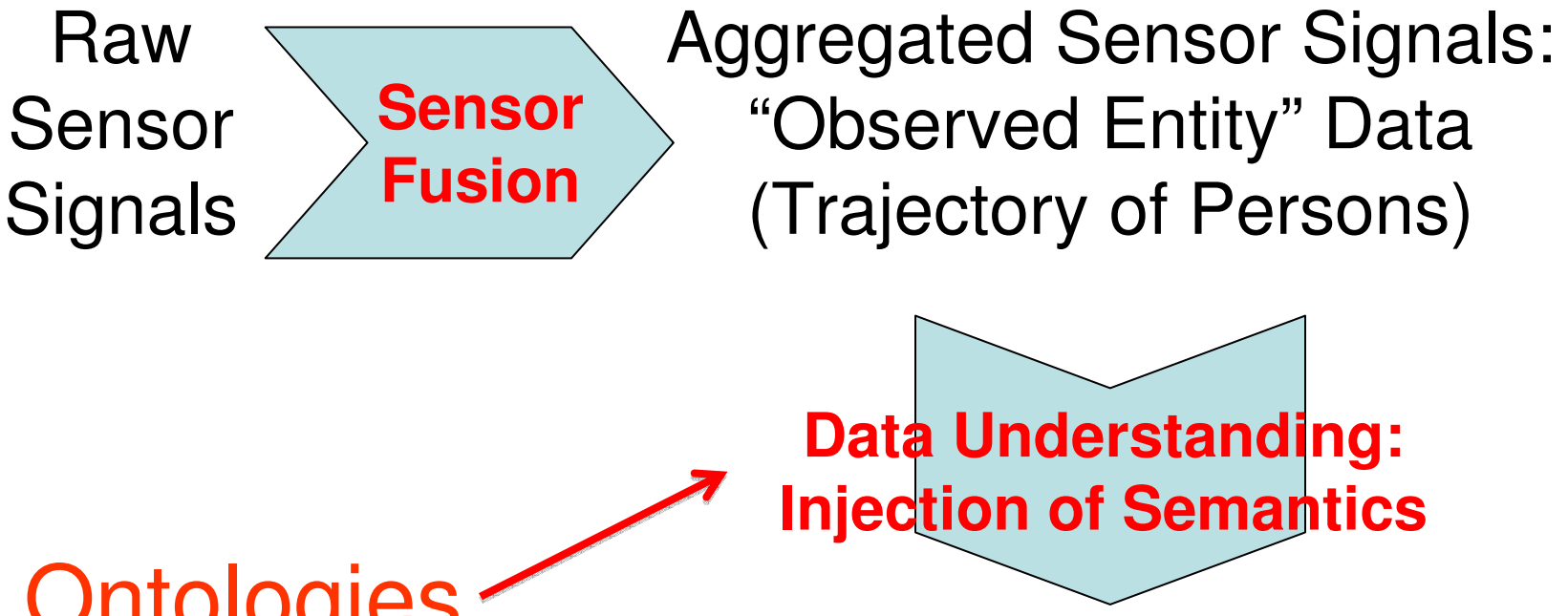


- E.g. "when is the light on and off?" is different from "when does someone speak?" in a cubicle but both might indicate the presence of a person

Raw Sensor Signals vs. “Entity Signals”

- Challenge: How to extract knowledge from the raw sensor data?
  - understand “big picture” of what is happing
  - understand complex processes and events and their interactions that cannot be captured by a single signal alone
- ➔ Several *layers* of signals to understand
  - Layer 1: Raw sensor signals (e.g. light)
  - Layer 2: “Observed entity signals” (indoor trajectory)
  - Layer 3: Activities of observed entities (e.g. meetings)

Raw Sensor Data to Knowledge



Kind of Ontology Needed

- **Role:** Describe background knowledge about the things that we would like to know from the sensor data
- Ontology very focused on (and limited to!) the particular application domain
  - Limited to the kind of higher level knowledge we want to extract and to how it relates to the raw or aggregated data

Our Hypothesis

- Limited and focused ontologies ("vocabulary") can be a very powerful tool to automate *understanding* of low-level signals collected in heterogeneous wireless sensor networks
- The ontology captures the type of limited universe of information we are interested in. It can be stepwise refined to understand more details.

Our Case Study

- Use pre-aggregated ('fused') sensor data about human movements in an office building
- Identify different types of *group activities*, such as meetings
- Sensor data:
  - Observed entities: simple trajectories of humans: **Who was in which room at which time?**
  - Series of location updates of individuals currently stored in database, would also work with data streams
    - (needs different aggregation algorithms)

Approach

1. **Define "meeting" *ontology* (as part of "group activity" ontology)**
   - Define concept of a meeting
   - Define types of meetings
2. **Write SQL queries to aggregate trajectory data into**
   - Collocation events: two people in the same room at the same time
   - Classify collocation events into meetings based on the semantics specified in the ontology

Higher-Level Ontological Concepts We Want to Extract: “Meetings"

- **What are meetings (and what not)?**
  - Necessary condition:
    - 2 people in the same room at the same time
  - Not sufficient:
    - 2 people in the washroom → location-dependent
    - 2 people together for a brief moment → time-dependent
- **What different kinds of meetings are there?**
  - Supervisory meetings, departmental meetings, project or team meetings, spontaneous desk meetings, …
- **How to distinguish types of meetings?**

Higher-Level Concepts We Want to Extract: “Meetings"

- **How to distinguish types of meetings?**
  - **Dependent on location:** in a dedicated meeting room, at a desk, in an office, in the kitchen or lunch room, ...
    - Usually not meetings: two people getting coffee at the same time, two people in the reception area, in the washroom
  - **Dependent on time:**
    - Duration, Presence behaviour (many people arrive/leave at the same time vs. people dropping in, leaving early, come and go, ...), start/end conditions
  - **Dependent on participants:** everybody from the same department, an employee and their supervisor, managers from different dept., only members of a specific project

Role of the Ontology in the Use Case

- **Describe different classes of meetings and basic knowledge about them**
  - Location restrictions: Where?
  - Time restrictions: When? How long?
  - Participation restrictions: Who must/may participate?
- **Describe background knowledge:**
  - Rooms, room purpose, room equipment, …
  - Employees: office/desk, departments, projects, relationships between them, …