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IoT Systems

Ubiquitous Computing and Context Aware Systems

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Some concepts

- **Ubiquitous computing:** the purpose of a computer is to help you do something else. The computer should then extend your unconscius. Ubicomp is the collective use of computers available in the physical environment. (Weiser, 1991)
- **Pervasive computing:** merging mobile computing and computers static in the environment
- **Autonomic computing:** systems that self-heal, self-configure, self-monitor, self-communicate. Self-* (Horn 2001)
- **Ambient Intelligence:** smart interfaces which react to the presence of users in everyday environments (Marzano and Aarts, 2003)

Context

- **Context** is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves. (Dey and Abowd, 1999)
- **Context-aware systems** adapt themselves to the environment of the user, such as location, neighbors, time, physical condition, illness.

Practically context can be

- Location data
- Proximity to people, things, places, events
- Environment data such as temperature, humidity, traffic
- Device status
- User activity, such as walking, sleeping, driving
- Illnesses
- … and many more!

Examples

- Temperature is high so switch on cooling system
- Traffic ahead, hence change road
- I’m in Milan, so if look up for ”Pizzeria” the system should show first ”Pizzeria” in Milan
- No one is at home, so switch on the alarm system

Use cases

- **Users side:** Emergency services, shopping, tracking services, Entertainment, Billing, …

- **Industry:** fleet management, Workforce management, Billing, Security, automation

Context aware systems: business

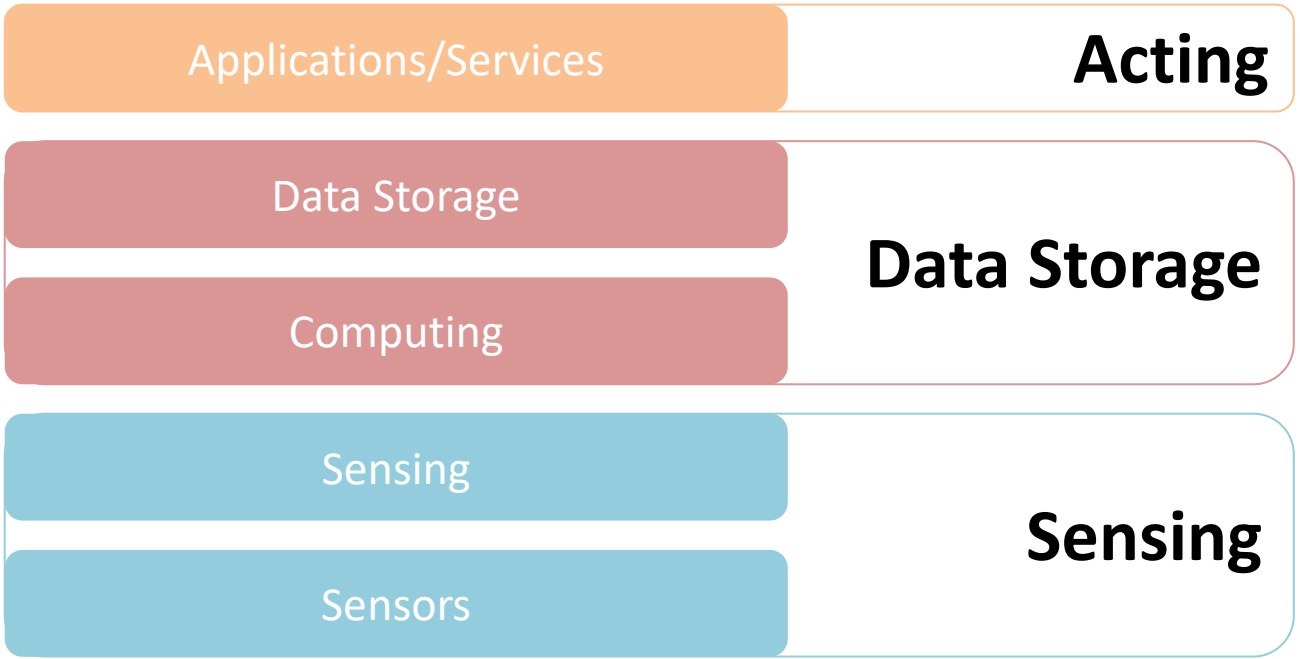
- Technology vendors
- Devices
- Mobile operators, network providers
- Fog/Cloud providers
- Application developers
- …

A context aware system

- Can be seen as having 3 main functionalities
  - Sensing data
  - Computing (thinking)
  - Taking decisions

- Different challenges
  - How to get raw data to provide context awareness?
  - How to infer context from data?
  - How and what data to share to third party apps?
  - How to model data?

Overview of a context aware system



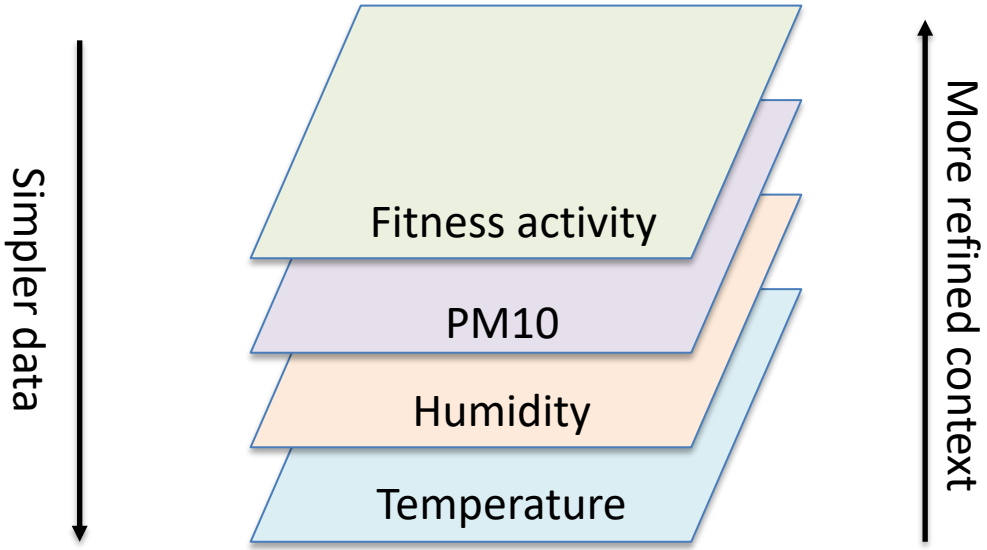
Get the data

- Data is typically obtained by sensors, which can be of a multitude of different types
- There are however many challenges, related to:
  - Sampling frequency
  - How to communicate data to others
  - Battery efficiency
  - Privacy
  - Data processing

Infer context

- To provide complex personalized services data has to be aggregated with other data
- Context can be inferred using 1 to n different data
- Algorithms ~~can~~ should be built accounting for data availability
  - If temperature is lower than 28 degrees go running
  - If temperature is lower than 28 degrees and humidity is lower than 80% go running
  - If temperature is lower than 28 degrees and humidity is lower than 80% and PM10 is low go running
  - If temperature is lower than 28 degrees and humidity is lower than 80% and PM10 is low and last run was more than 2 days ago go running

Infer context - layers



Infer context

- Through Machine Learning models
  - Obtain a dataset, train a model on the available data, with context definition as output
    - Method used for instance in activity recognition with smartphones

- Through a set of rules
  - If speed > 50 km/h then user is either in a car or in a train

Data sharing

- Once data is obtained and context is inferred, how should be able to access it?
- Here privacy problems arise:
  - Context: alone at your place. Would you share it?
  - Context: driving. Would you share it?
- Not only privacy issues:
  - Sharing may be expensive in terms of communication, battery
  - Sharing may also be necessary due to space and performance constraints

Data modeling

- When merging data together, things may be difficult
- Assume you have a sensor reporting temperature, and you want to average the temperature of your city
- Aggregate other temperature data
  - Is it in Celsius or Fahrenheit?
  - Is the data trusted?
  - Will the data be available tomorrow?
  - Is it referring to outdoor or indoor temperature?
  - Is the data fresh enough?

Four dimensions of context

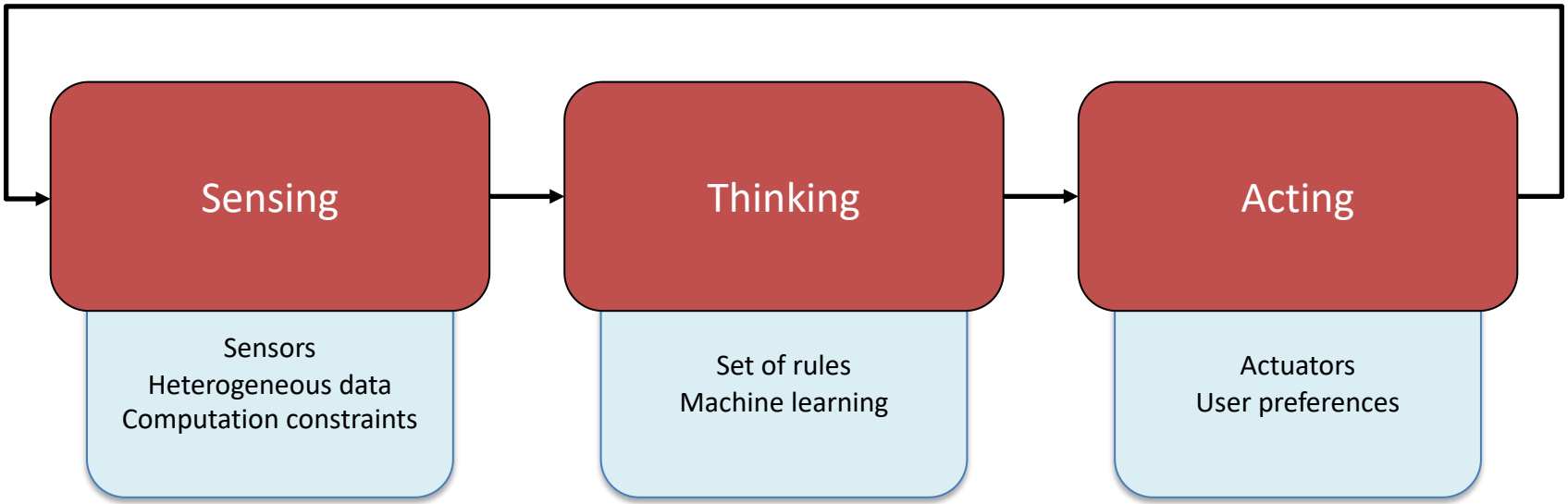
Scenario	Environmental	Computing	User Preference
• Calendar • Location • Time	• Temperature • Noise • Humidity • Proximity	• Network technology and performance • Network battery costs • Bandwidth • Network devices	• Configuration • Behavior • Neighbors

Active or Passive Context

- Active Context Awareness: inferred context changes the behavior of the application
  - Examples: change road due to traffic jam, switch on air conditioning if temeprature is greater than 28 degrees

- Passive Context Awareness: inferred context enriches the user experience
  - Examples: displays traffic information, notifications, displays sensed data

Recap


Sensing
Thinking
Acting
Sensors
Heterogeneous data
Computation constraints
Set of rules
Machine learning
Actuators
User preferences

Challenges

- How to save, manage and represent context
- Algorithms to infer context
- Context refresh
- Determining needed sensors and infrastructure
- Fallback when no context or limited context is available