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Context-awareness and Context Modeling

Ubiquitous Computing Seminar 2014

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Context-awareness and context modeling

- Big topic in ubiquitous computing
  - Overlaps with other topics
- Applications using context are called context-aware
  - They promise various enhancements
- Different perspectives
  - Internet of Things
  - Human-Computer Interaction
  - User-oriented

Why make use of context?

- Applications may understand…
  - their environment
  - its user
  - the current situation
- …and react appropriately

- Improved Human-Computer Interaction
- Improve Machine-Machine Communication
- Personalization


CONTEXT-AWARE
COMPUTING
How Am I Feeling?
Who Am I With?
Why Am I Here?
What Am I Doing?
Where Am I Going?
When Do I Need To Leave?

What is Context?

- Hard to tell, even harder to define it

- Attempts to explain context:
  - Through synonyms
  - Through enumeration of examples
  - 5 W‘s (Who, What, Where, When, Why)

Characteristics of context

- Context must be abstracted to make sense
- Context may be acquired from multiple distributed and heterogeneous sources
- Context is continuously changing
- Context information is imperfect and uncertain
- Context has many alternative representations

Features of context-aware applications

- **Presentation** of information and services to a user
  - E.g. a mobile application dynamically updates a list of closest printers as its user moves through a building.
- Automatic **execution** of a service
  - E.g. the user prints a document and it is printed on the closest printer to the user.
- **Tagging** of context to information for later retrieval
  - E.g. an application records the names, the times and the related printer of the printed documents. The user can retrieve this information later to find his forgotten printouts.

Levels of context-awareness

- Personalisation
  - Allows user to set preferences, likes, and expectation manually
- Passive context-awareness
  - System constantly monitors the environment and offers appropriate options to users
- Active context-awareness
  - System continuosly and autonomously monitors situation and acts autonomously

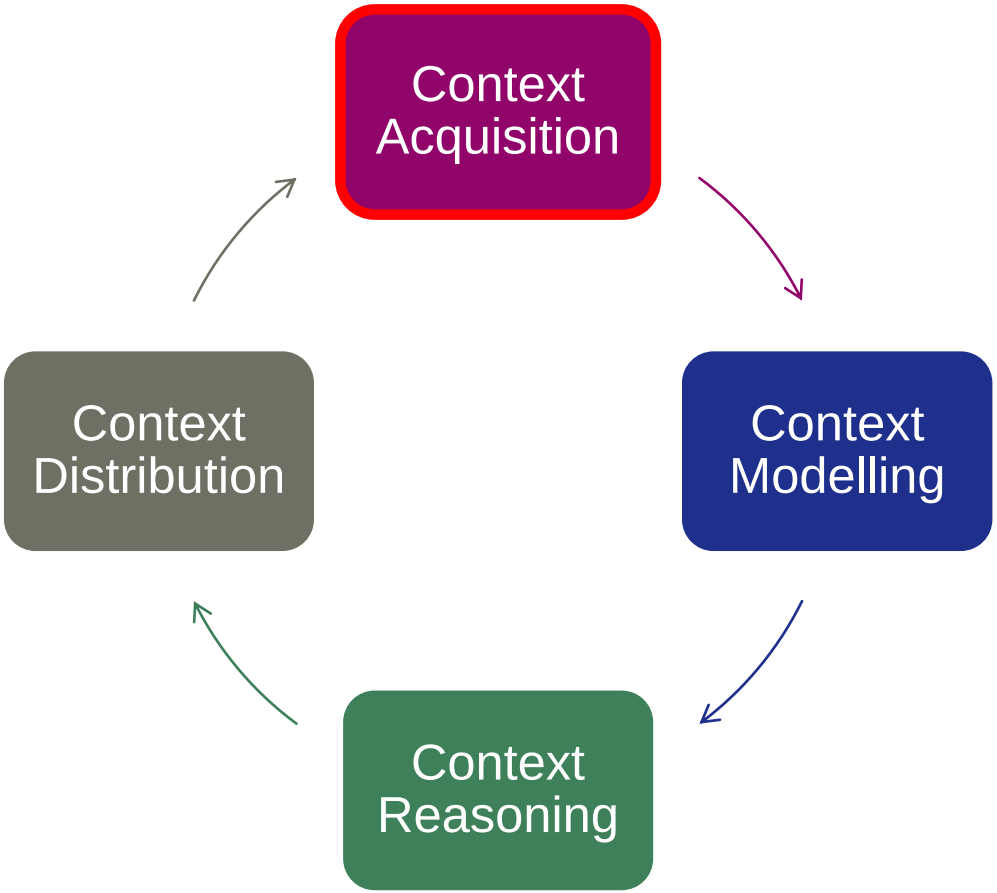
Raw context data and context information

- Distinction between raw context data and context information:
  - **Raw context data**:
    - Retrieved directly without further processing from data sources (sensors)
  - **Context information**:
    - Generated by processing raw sensor data.
    - Checked for consistency
    - Metadata is added

	Primary	Secondary
Location	Location data from GPS sensor (e.g. longitude and latitude)	Distance of two sensors computed using GPS values Image of a map retrieved from map service provider
Identity	Identify user based on RFID tag	Retrieve friend list from users Facebook profile Identify a face of a person using facial recognition system
Time	Read time from a clock	Calculate the season based on the weather information Predict the time based on the current activity and calender
Activity	Identify opening door activity from a door sensor	Predict the user activity based on the user calender Find the user activity based on mobile phone sensors such as GPS, gyroscope, accelerometer

Source: „Context Aware Computing for The Internet of Things: A Survey“

Life cycle of context in context-aware systems



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Context Acquisition: Events

- Different event types
  - Instant / threshold violation (e.g., door opened, light switched on)
  - Interval / periodically (e.g., raining, animal eating plant)

Context Acquisition: Sensors

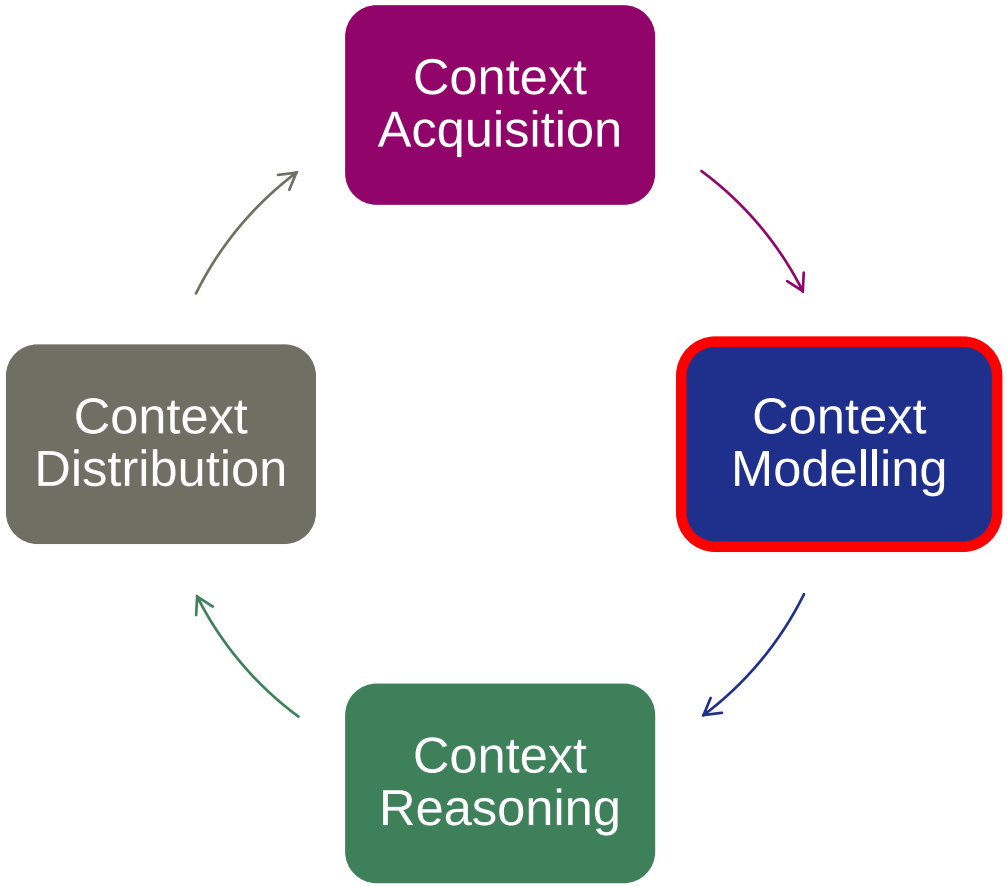
- Different types of sensors
  - Physical sensors
    - Generate data by themselves
    - Most devices used today are equipped with variety of physical sensors
  - Virtual sensors
    - Do not necessarily generate data by themselves
    - Retrieve data from many sources and publish it as sensor data
    - Do not have a physical presence
  - Logical sensors:
    - Combine physical and virtual sensors to produce more meaningful information

Source: „Context Aware Computing for The Internet of Things: A Survey“

Messuring context: Examples

What to messure	Useful sensors
Location outdoors	GPS
Location indoors	RFID, WIFI-Localization, IBeacons
Orientation	Compass, Magnetic field sensor
Temperature	Temperature sensor
Air pressure	Pressure sensor
Audio, ambient sound	Microphones
Energy consumption	Smart meter
Identity	E-Mail, social networks, RFID
Time	Synchronized clocks
Activity	Accelerometers, Video cameras, PIR motion sensor, Kinect

Life cycle of context in context-aware systems



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Context Modelling / Context Representation

- Typically involves two steps:
  - Context modelling process:
    New context information needs to be inserted into the model
  - Organize context according to model:
    Validation and merging with existing context information
- Examples of modelling techniques
  - Key-Value pairs
  - Markup schemes (e.g. XML)
  - Ontology based models

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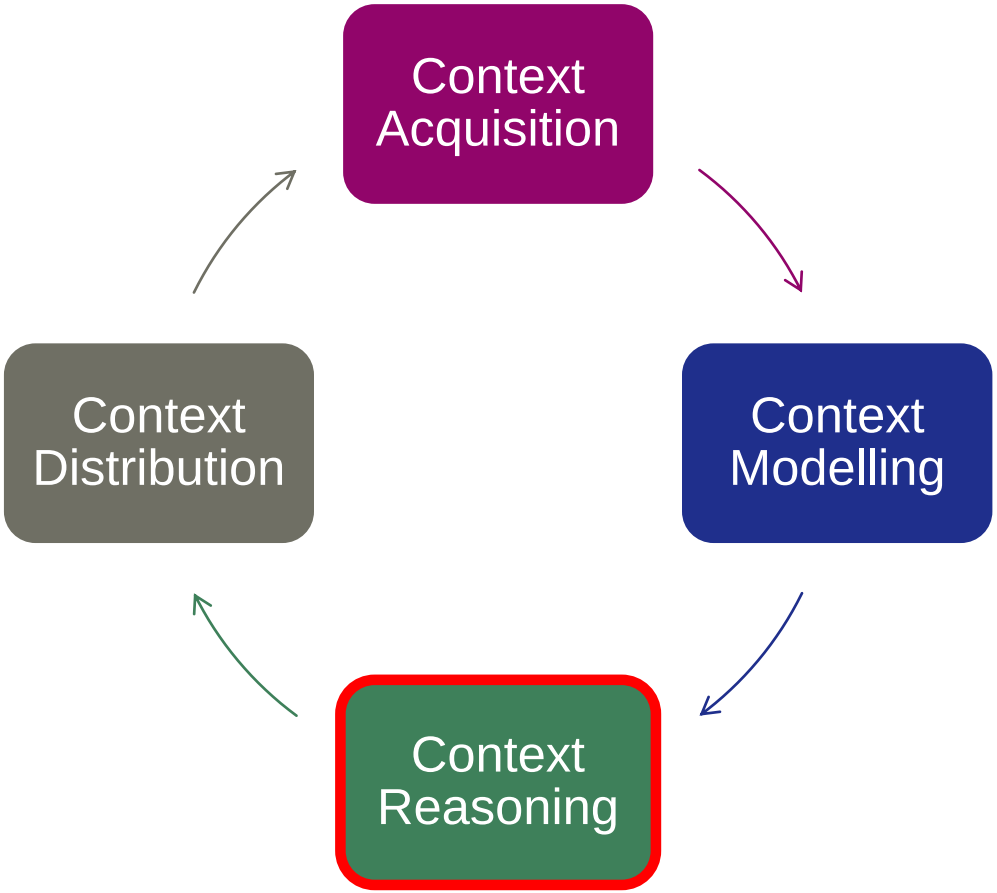
Life cycle of context in context-aware systems



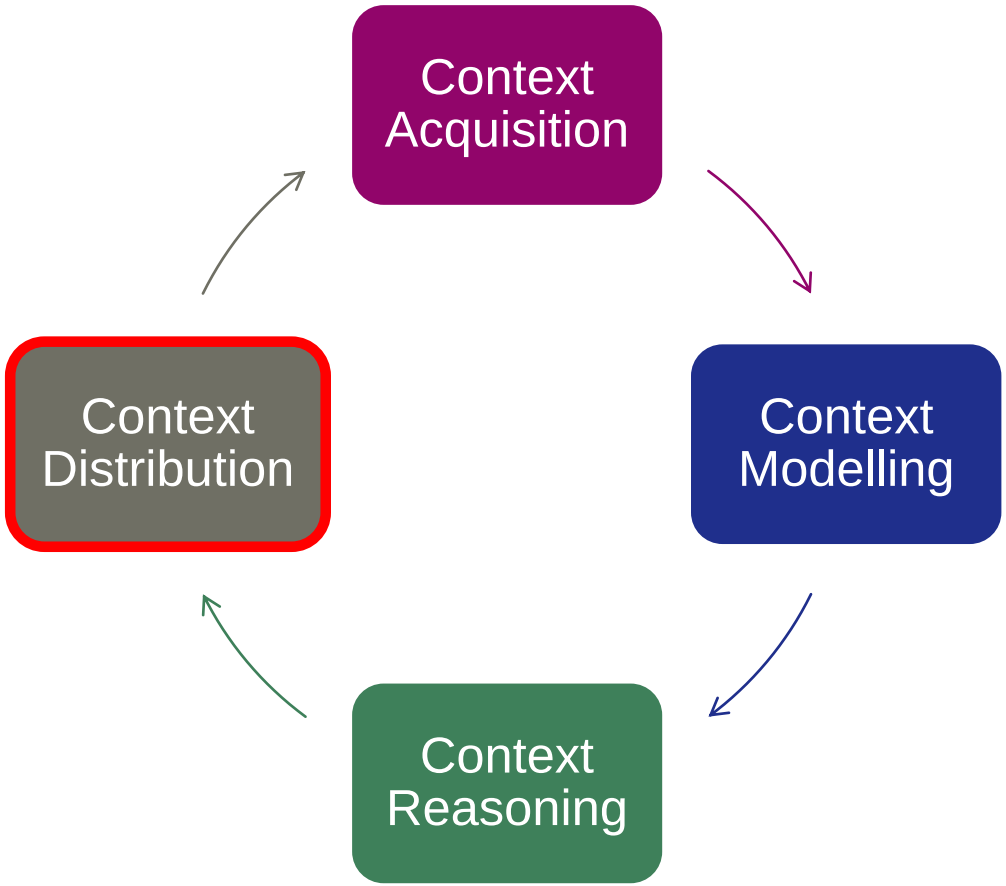
Source: „Context Aware Computing for The Internet of Things: A Survey“

Context Reasoning

- Can be divided into three steps
  - Context pre-processing:
    Cleans collected sensor data
  - Sensor data fusion:
    Combining sensor data from multiple sensors
  - Context inference:
    Generation of high-level (secondary) context information using lower-level (primary or secondary) context

Source: „Context Aware Computing for The Internet of Things: A Survey“

Life cycle of context in context-aware systems



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Context Distribution

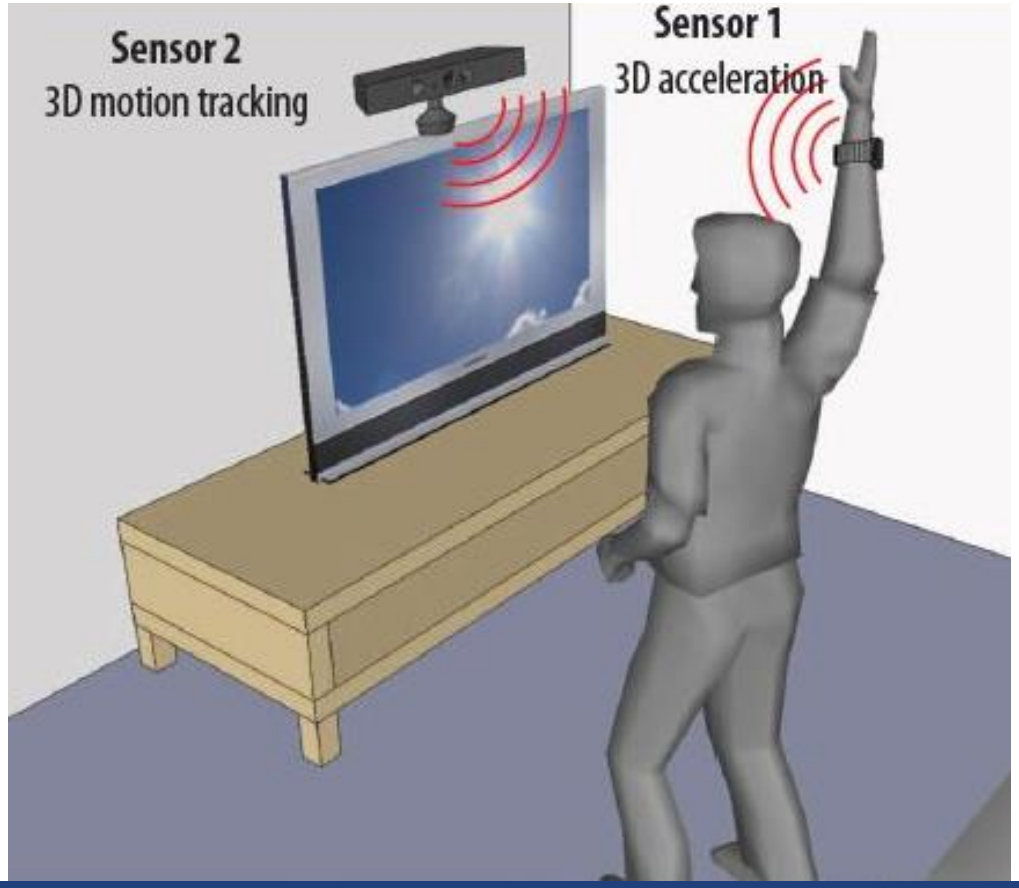
- Deliver context to the consumers
  (e.g. applications or end-users)

- Same as context acquisition from consumer perspective

- Two methods used commonly
  - Query: Context consumer makes a request

  - Subscription: Context consumer can be allowed to subscribe

Source: „Context Aware Computing for The Internet of Things: A Survey“



Research Projects

Physical Activity and Context Recognition

Physical Activity Recognition

- Important aspect in context-aware computing
- Advances in miniaturization will permit embedded accelerometers
- Naturalistic setting instead of laboratory environment (overall accuracy rate: 84%)

Physical Activity Recognition

- 20 common Activities studied
- Common misclassifications:
  - „Watching TV“ vs. „Sitting“
  - „Stretching“ vs. „Folding laundry“

Activity	Accuracy	Activity	Accuracy
Walking	89.71	Walking carrying items	82.10
Sitting & relaxing	94.78	Working on computer	97.49
Standing still	95.67	Eating or drinking	88.67
Watching TV	77.29	Reading	91.79
Running	87.68	Bicycling	96.29
Stretching	41.42	Strength-training	82.51
Scrubbing	81.09	Vacuuming	96.41
Folding laundry	95.14	Lying down & relaxing	94.96
Brushing teeth	85.27	Climbing stairs	85.61
Riding elevator	43.58	Riding escalator	70.56

L. Bao et al.: „Activity Recognition from User-Annotated Acceleration Data“

Physical Activity Recognition

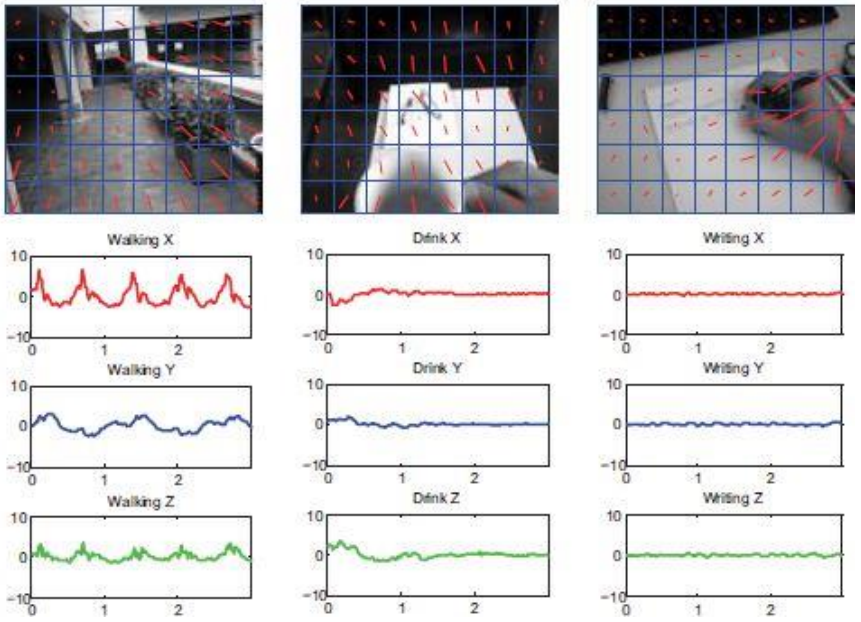
- Categorization of daily activities
  - locomotive (e.g. „walk“)
  - stationary (e.g. „watch TV“)

- Video + accelerometer („Smart Glass“) instead of only accelerometers

K. Zhan et al.: „Multi-scale Conditional Random Fields for First-Person Activity Recognition“

Physical Activity Recognition

- Overall accuracy of 90% in realistic activities of daily living



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Opportunistic Human Activity and Context Recognition

- Goal: achieve ambient intelligence
- Internet of Things now provides the necessary infrastructure
  - Transparent access to sensors
  - Standardized protocols (IPv6)

Opportunistic Human Activity and Context Recognition

- Traditional Activity Recognition Paradigm
  - Datasets collected at design time
  - Optimal sensor configurations

- Novel approach: Recognition methods dynamically adapt themselves to available sensor data

Google Now

- Personal Assistant
  - Information about Traffic
  - Remembers Meetings
  - Weather
- Makes use of context
  - Current Location
  - Location history
  - Time
  - Web search history
  - E-Mail
  - Calendar
  - Activity Recognition

Security and Privacy

- Major concern in context-aware computing

- Security and Privacy need to be handled at multiple levels
  - Hardware layer: Ensure security during collection and temporal storage
  - Communication layer: Ensure security with secure protocols
  - Application layer: Permissions and protection necessary to guarantee security and privacy

Conclusion

- There are many definitions, modelling techniques and reasoning techniques for context, but…
  - each technique has its own strengths and weakness
  - no single technique can be used to accomplish perfect results
  - Methods need to be combined to reduce weaknesses
- Security and privacy is a major concern

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Thank you for your attention