Context Aware Computing for The Internet of Things

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ABOUT THE STUDY PAPER

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The survey brings an evaluation of 50 projects that represented the majority of research and solutions proposed in the context-aware computing field conducted over years 2001 and 2011.

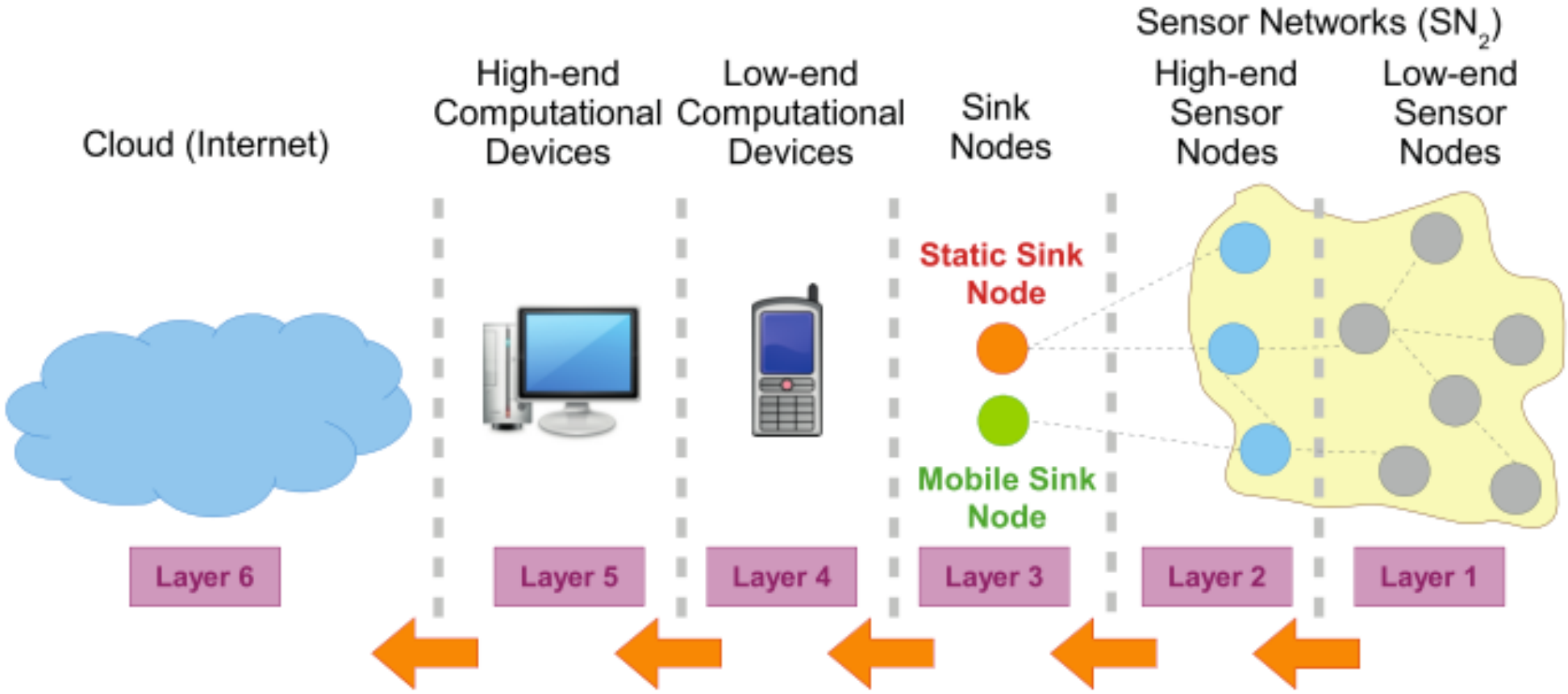
DEFINITIONS

INTERNET OF THINGS

The Internet of Things allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path/network and any service (*Vermesan et al.* [7])

DEFINITIONS

LAYERED STRUCTURE OF A SENSOR NETWORK



DEFINITIONS

WHAT IS CONTEXT? *IT IS HARD TO TELL*.

Various attempts to explain it:

- Through synonyms (*Pereira et al.* [1])
  - “Circumstance, situation, phase, position, posture, attitude, place, point; terms; regime; footing, standing, status, occasion, surroundings, environment, location, dependence.”
- Through enumeration of examples
  - location, identities of nearby people and objects, and changes to those objects (*Schilit and Theimer* [3])
  - people around the user, time of day, season, temperature (*Brown et al.* [4])
- 5 W‘s (Who, What, Where, When, Why) (*Abowd and Mynatt* [5])

DEFINITIONS

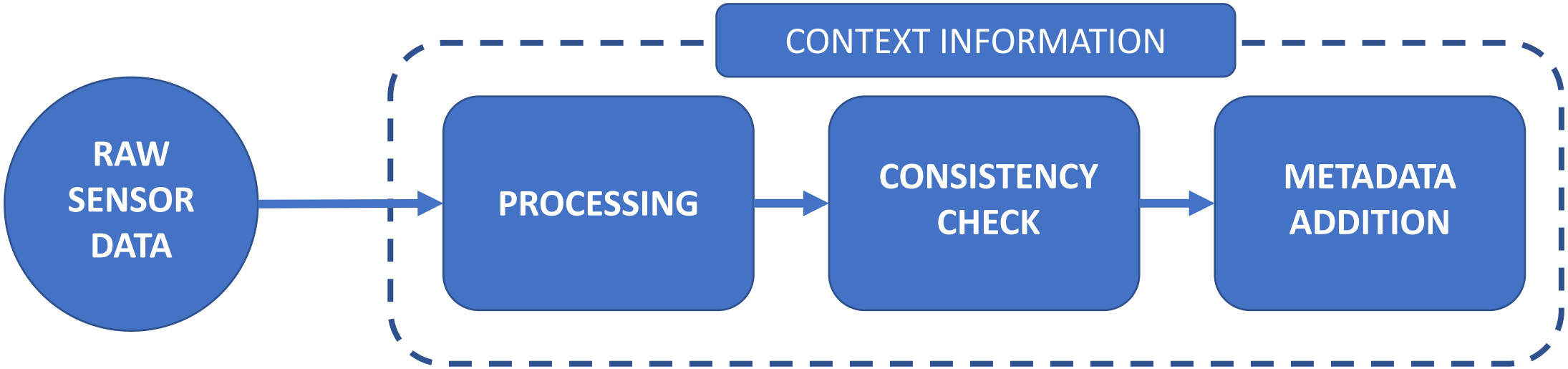
CONTEXT & ENTITY

- **Context**
  *Any **information** that can be used to **characterize the situation** of an entity (Dey et al. [2]).*

- **Entity**
  *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 et al. [2]).*

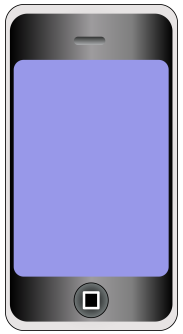
DEFINITIONS

CONTEXT INFORMATION

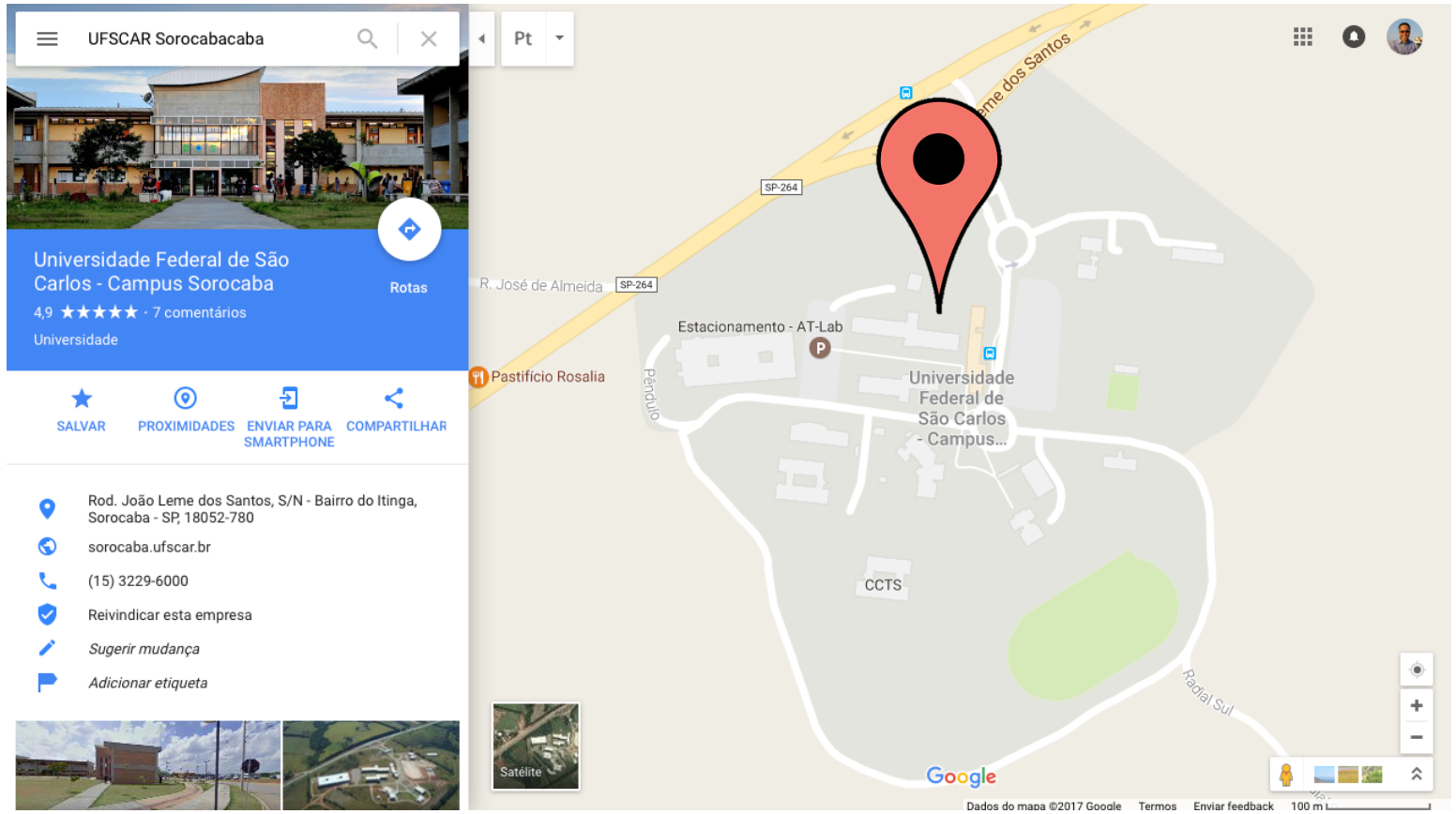


DEFINITIONS

CONTEXT & ENTITY EXAMPLE – GEO-LOCALIZATION



GPS SENSOR
(RAW DATA)



GEOGRAPHICAL LOCATION (CONTEXT INFORMATION)

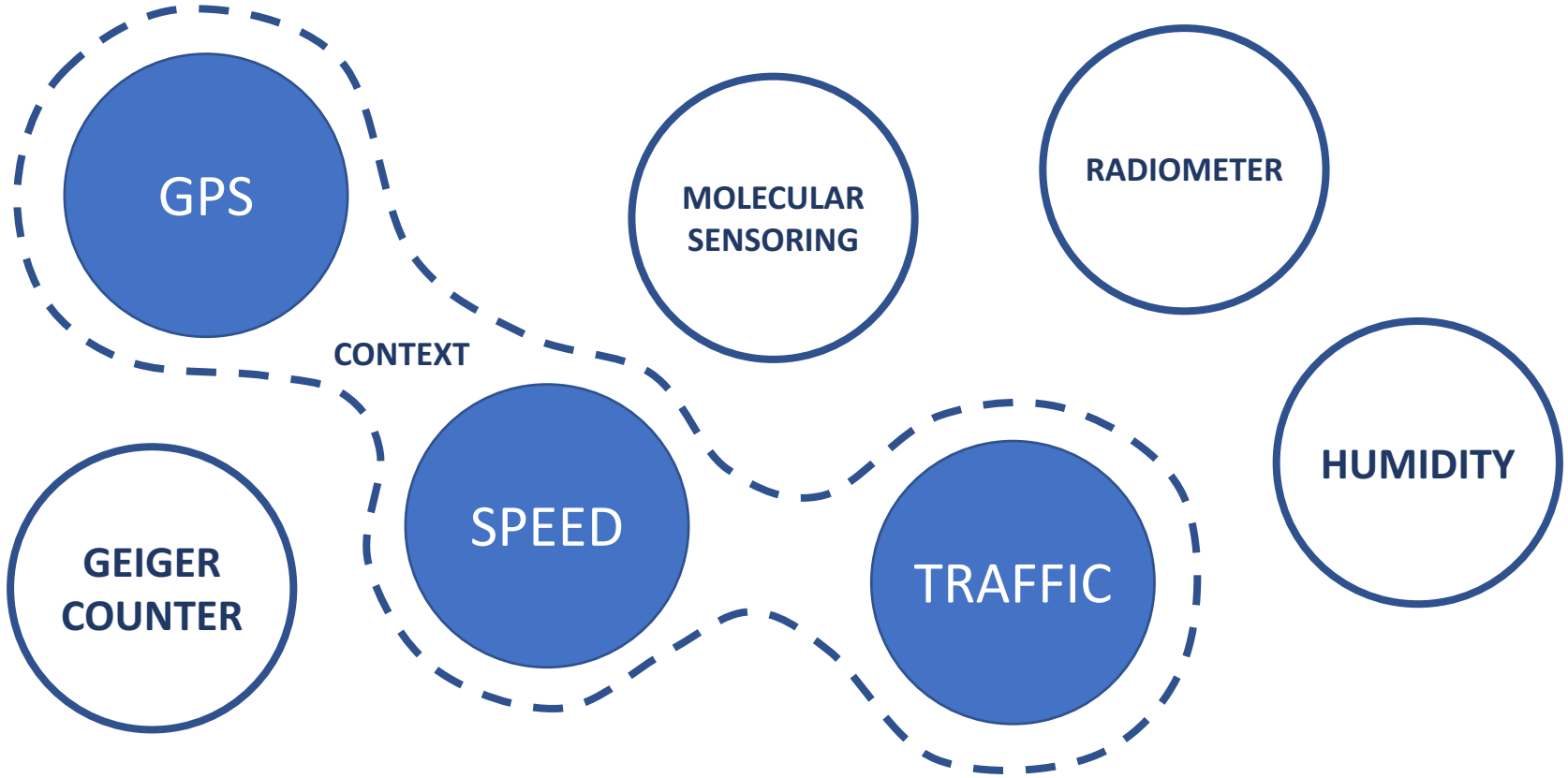
DEFINITIONS

CONTEXT AND RAW DATA

The raw data values produced by sensors can be considered as data. If this data can be used to generate context information, we identify these data as context (*Pereira et al. [1]*).

DEFINITIONS

CONTEXT AND RAW DATA EXAMPLE – GEO-LOCALIZATION



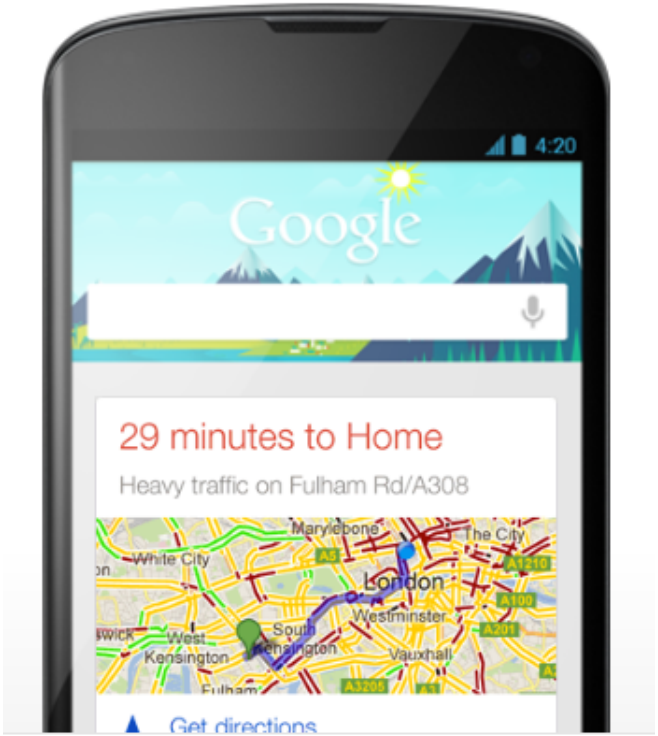
DEFINITIONS

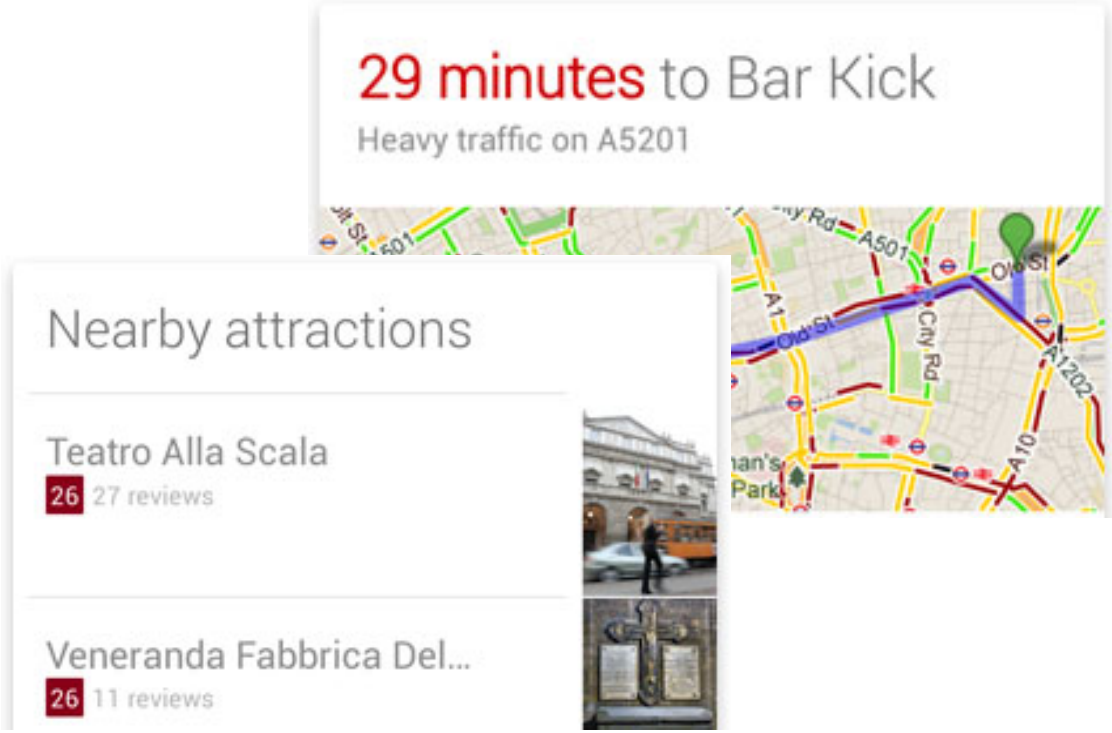
CONTEXT AWARENESS

A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task (*Pereira et al.* [1]).

DEFINITIONS

CONTEXT AWARENESS





Pictures from Google® page

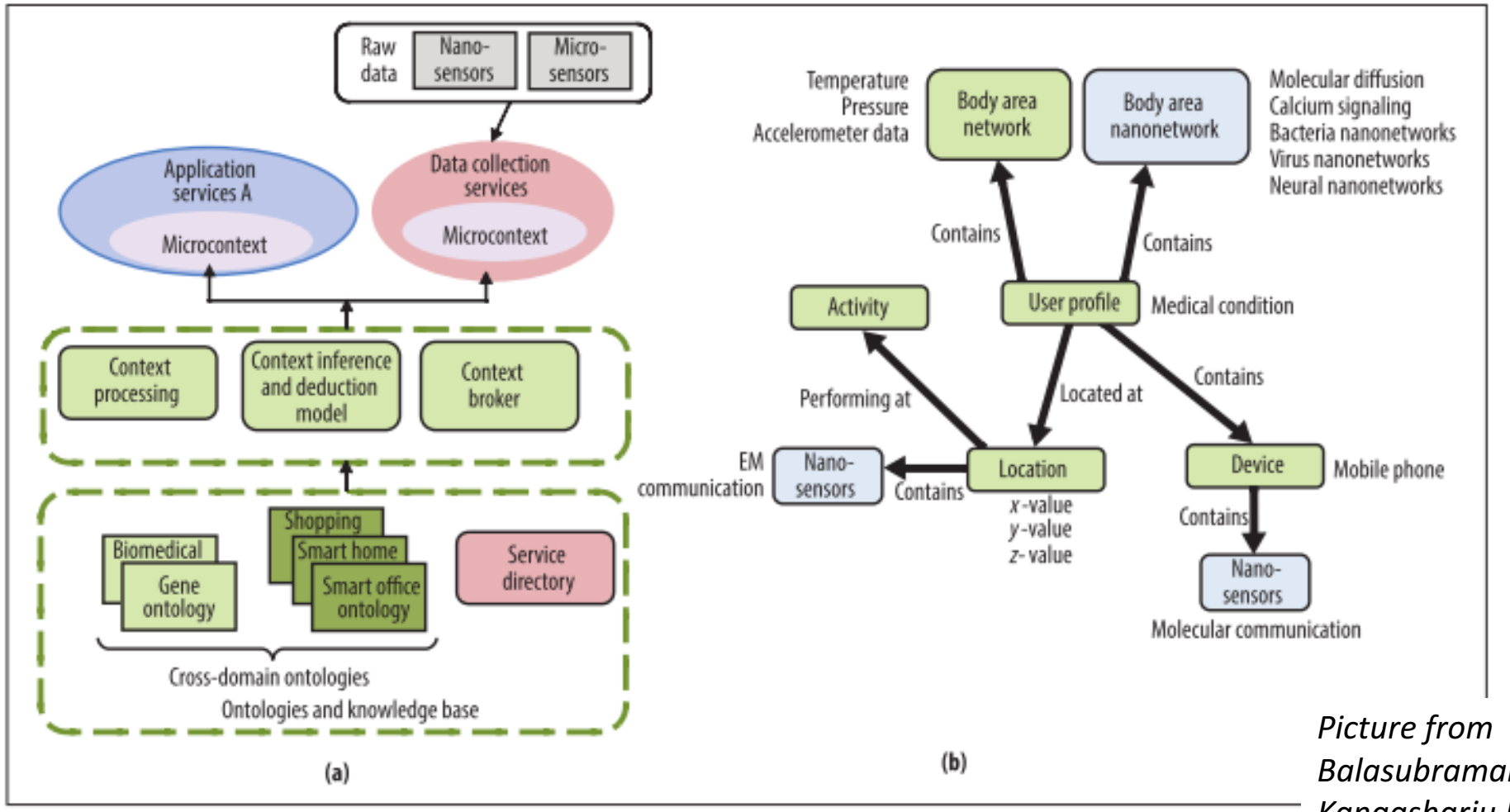
DEFINITIONS

CONTEXT MODEL

Identifies a concrete subset of the context that is realistically *obtainable* from sensors, applications and users and able to be *used* in the execution of the task (*Pereira et al.* [1]).

DEFINITIONS

CONTEXT MODEL



Picture from Balasubramaniam and Kangasharju [6]

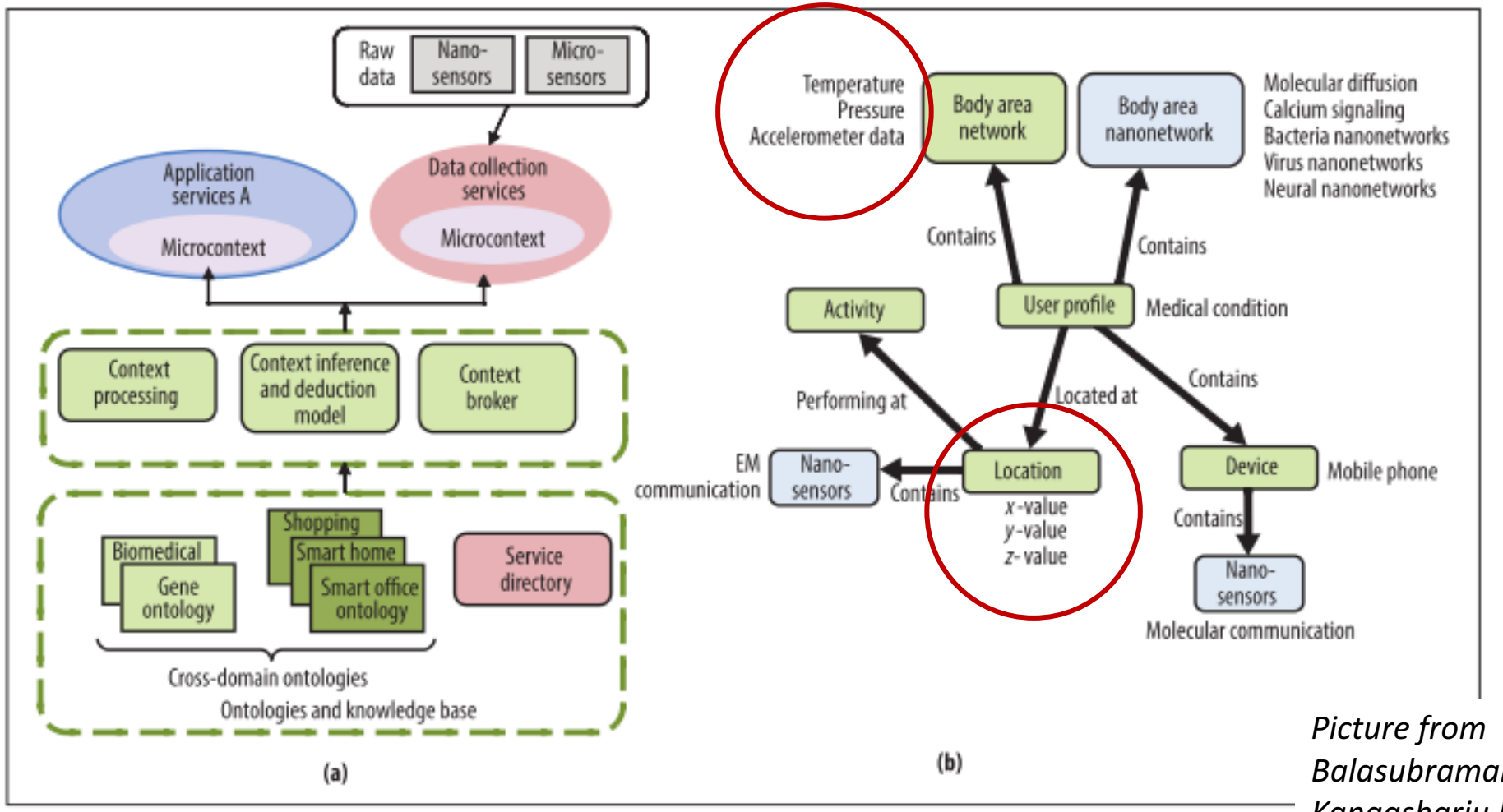
DEFINITIONS

CONTEXT ATTRIBUTE

It is an element of the context model describing the context. A context attribute has an identifier, a type and a value, and optionally a collection of properties describing specific characteristics (*Pereira et al.* [1]).

DEFINITIONS

CONTEXT ATTRIBUTE



Picture from Balasubramaniam and Kangasharju [6]

DEFINITIONS

CONTEXT-AWARE FEATURES

- **Presentation**
  Context can be used to decide what information and services need to be presented to the user (Pereira et al. [1]).
- **Execution**
  Automatic execution of services (Pereira et al. [1]).
- **Tagging**
  Context needs to be tagged together with the sensor data to be processed and understood later (Pereira et al. [1]).

DEFINITIONS

CONTEXT-AWARE FEATURES

- **Presentation**
- **Execution**
- **Tagging**

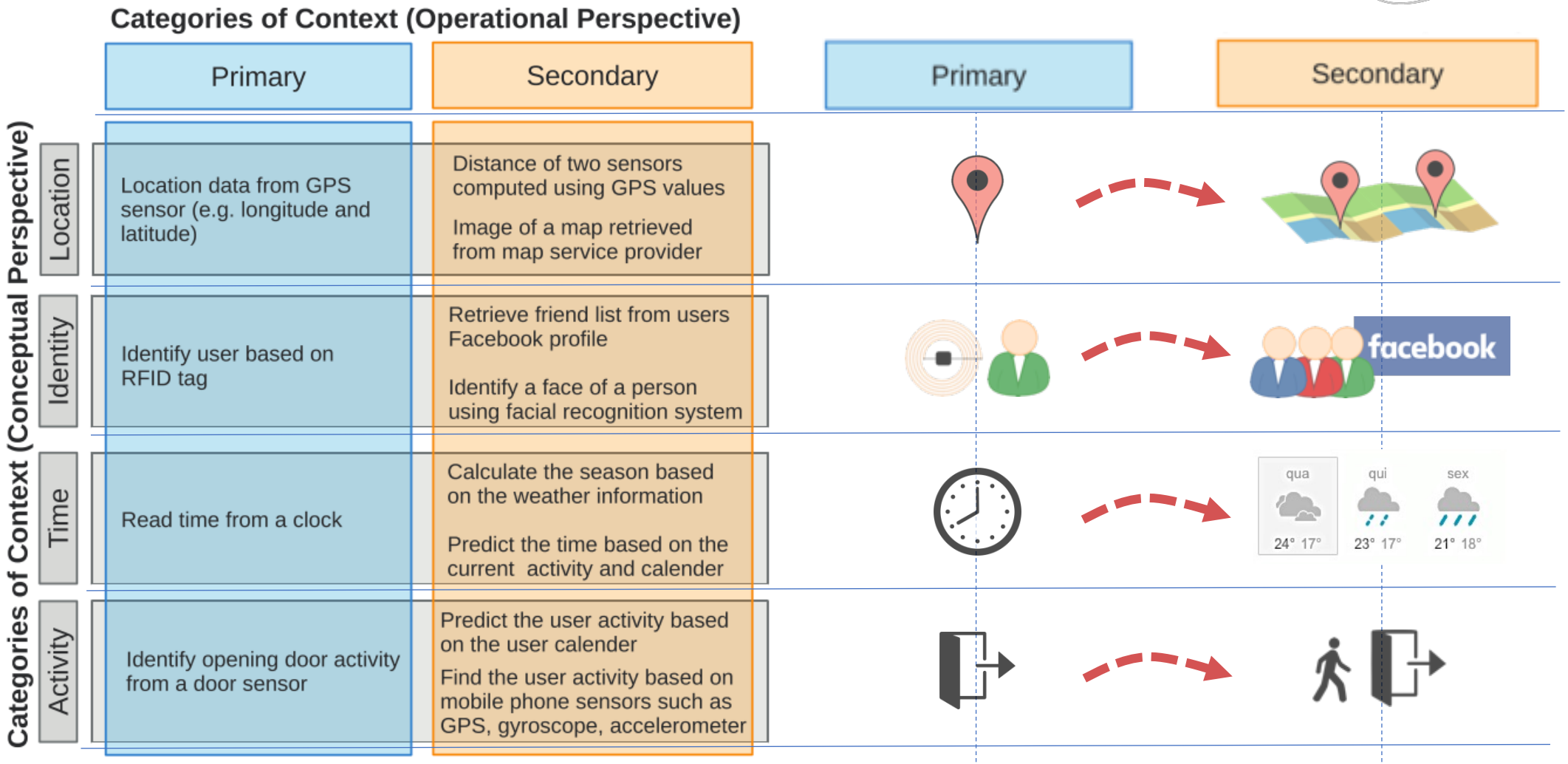
DEFINITIONS

CONTEXT CATEGORIZATION

- **Primary**
  Any information retrieved without using existing context and without performing any kind of sensor data fusion operations.
- **Secondary**
  Any information that can be computed using primary context.

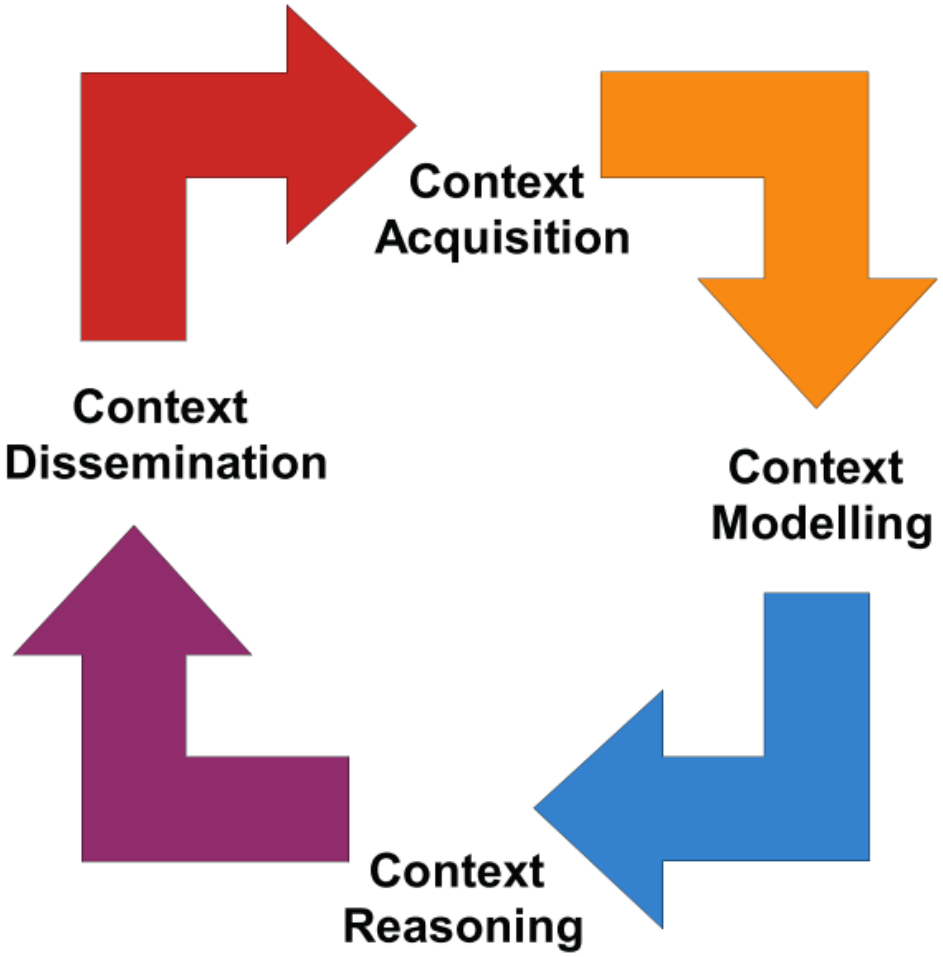
DEFINITIONS

CONTEXT CATEGORIZATION



DEFINITIONS

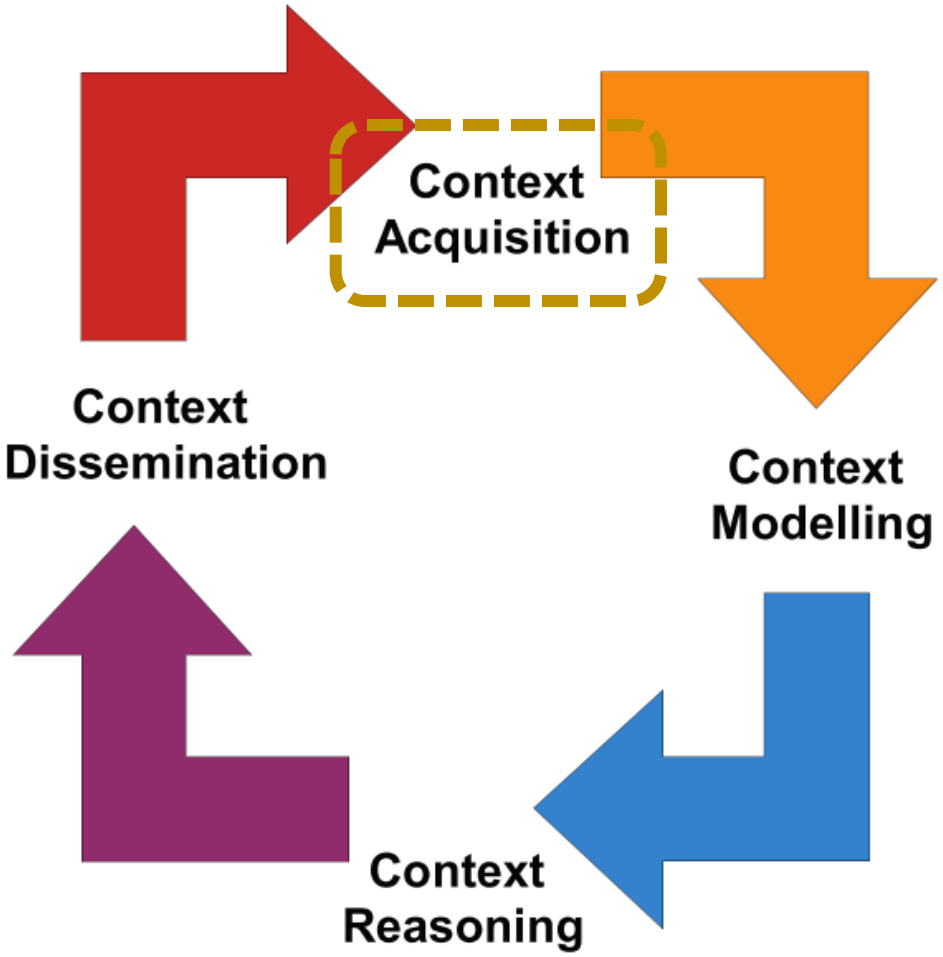
LIFE CYCLE



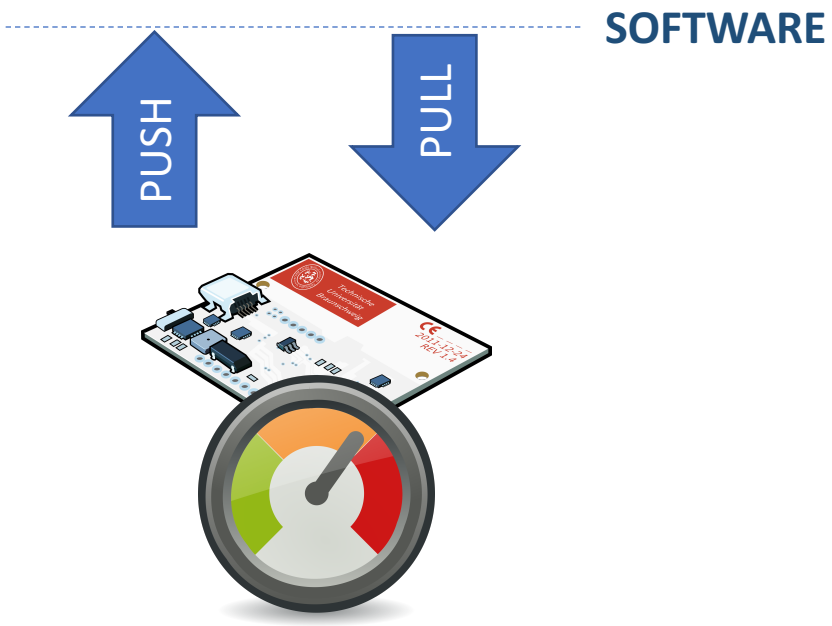
A data life cycle shows **how data moves** from **phase to phase** in software systems ...*explaining...* **where the data is generated** and **where the data is consumed**. (*Pereira et al. [1]*).

DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT ACQUISITION

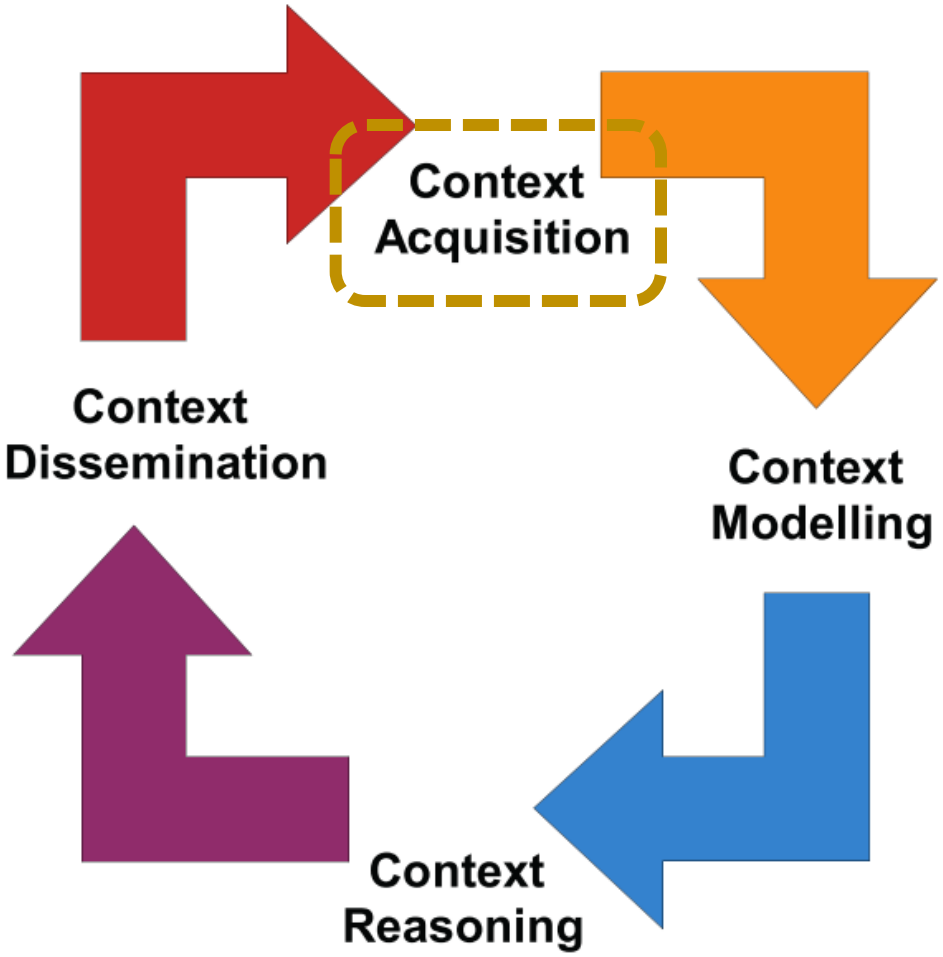


- Based on responsibility:

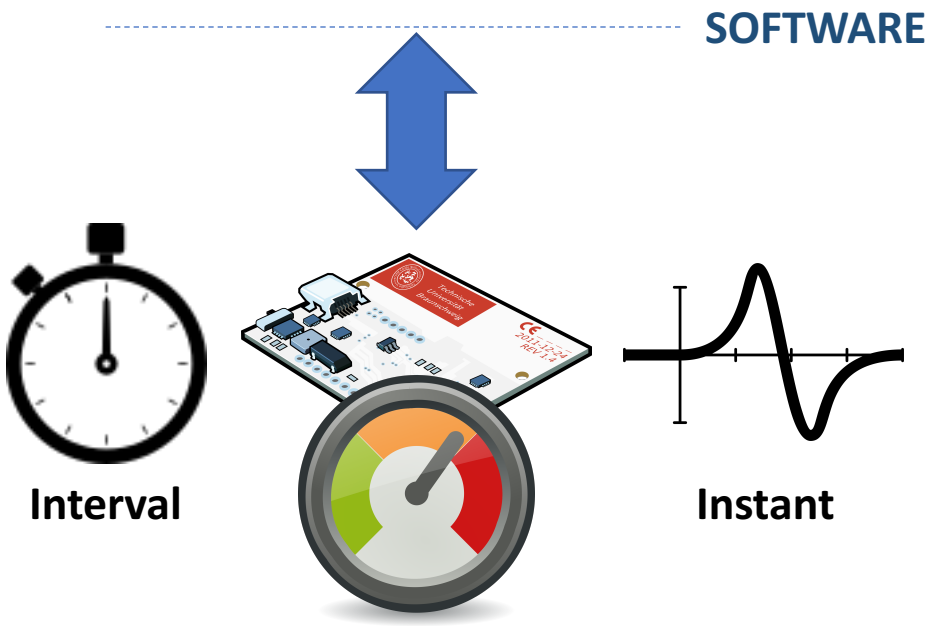


DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT ACQUISITION

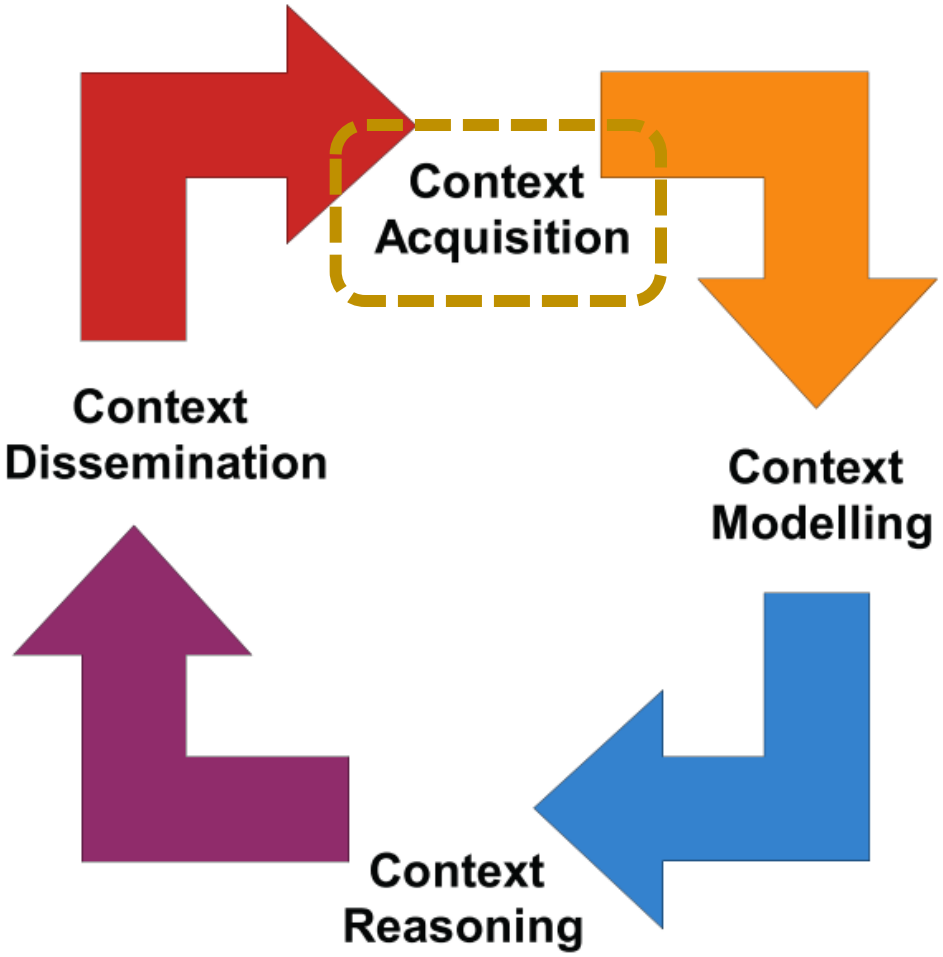


- Based on frequency:

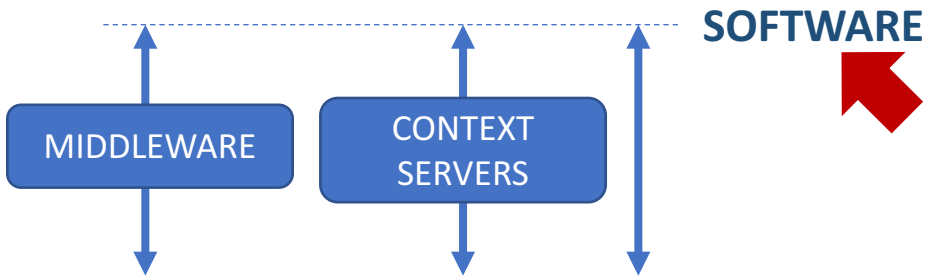


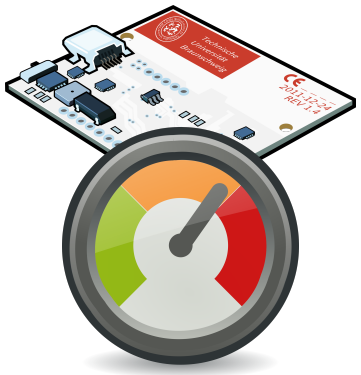
DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT ACQUISITION



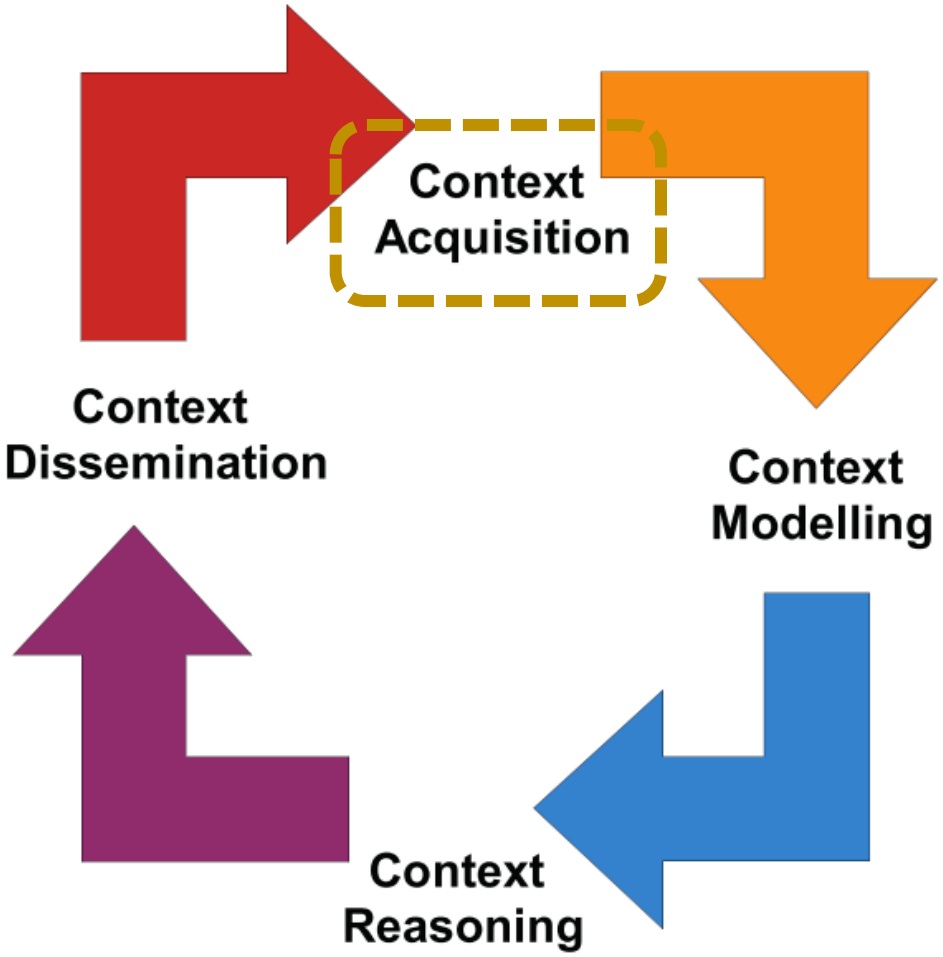
- Based on source:



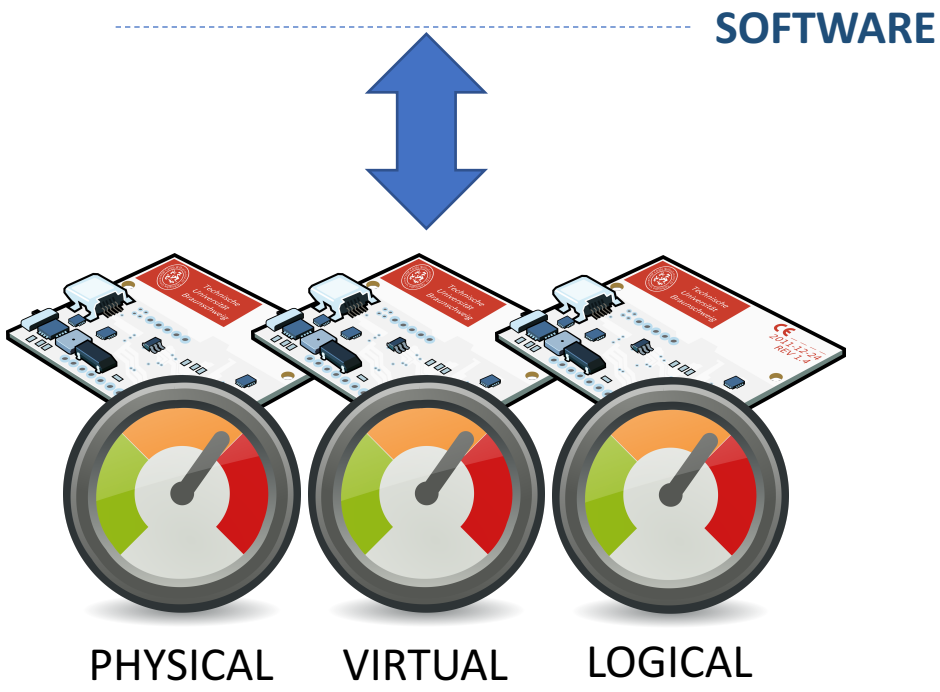


DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT ACQUISITION

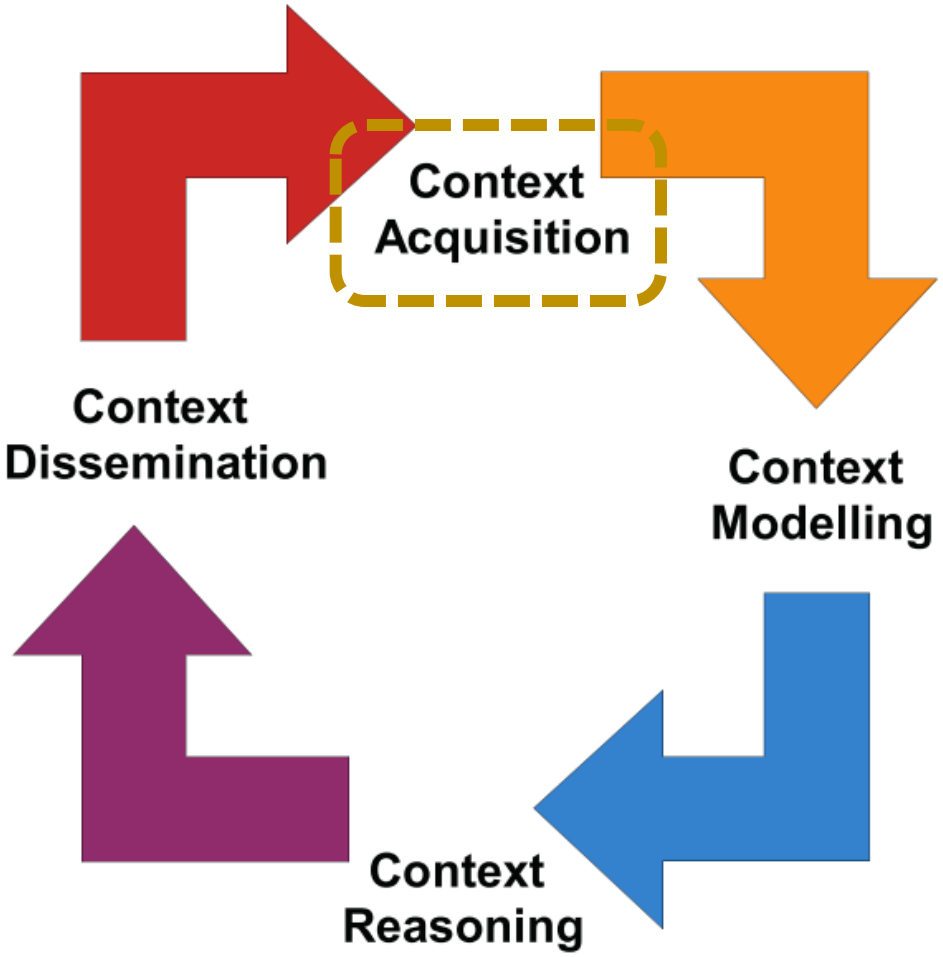


- Based on sensor type:



DEFINITIONS

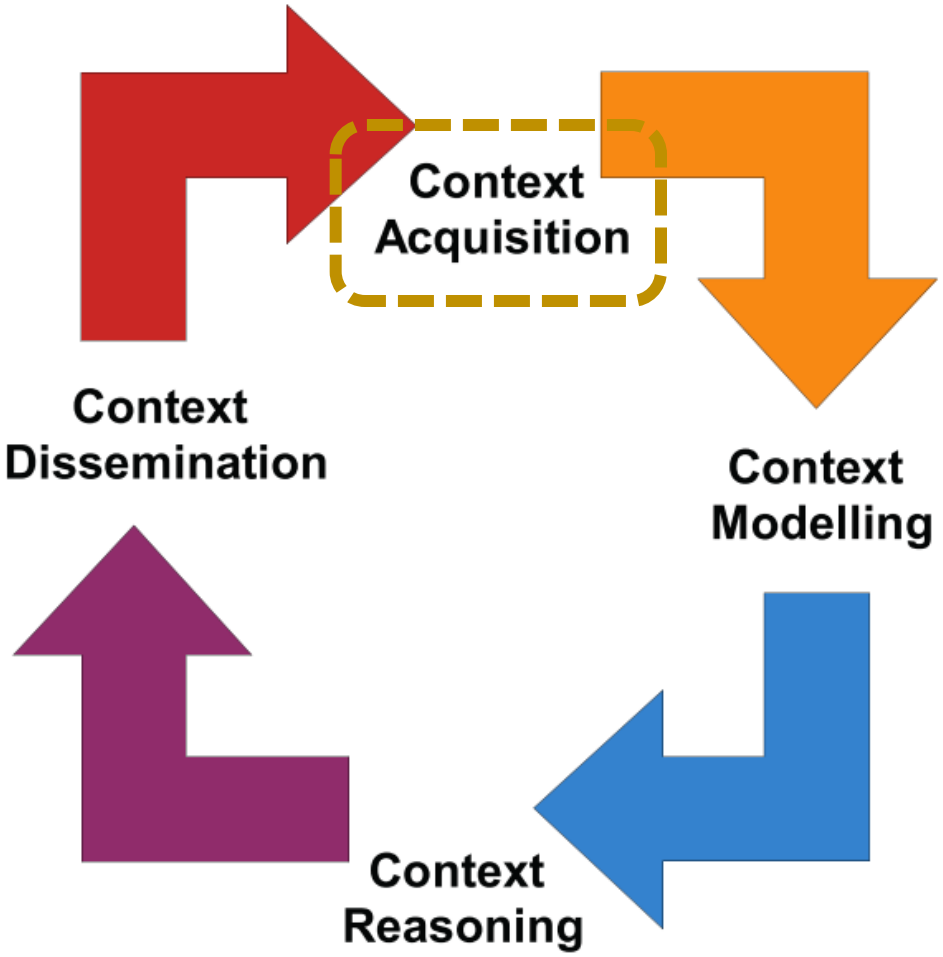
CONTEXT LIFE CYCLE – CONTEXT ACQUISITION



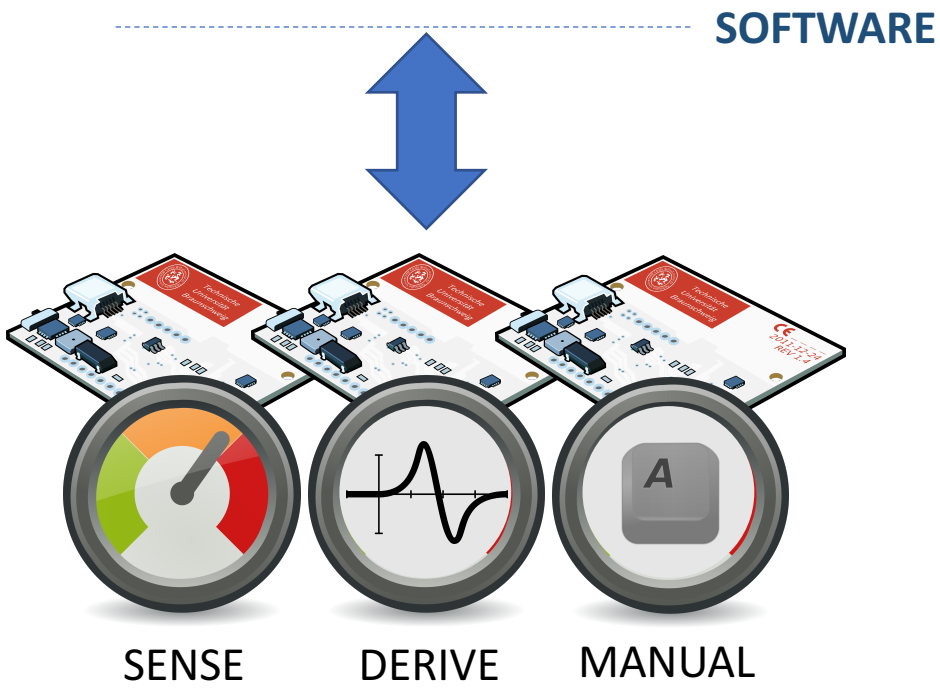
- Based on sensor type:
  - Physical
    the actual sensor
  - Virtual
    twitter statuses, calendar
  - Logical
    physical + virtual
    weather information web server (physical temperature sensor + virtual sensors such as maps, calendars,…)

DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT ACQUISITION

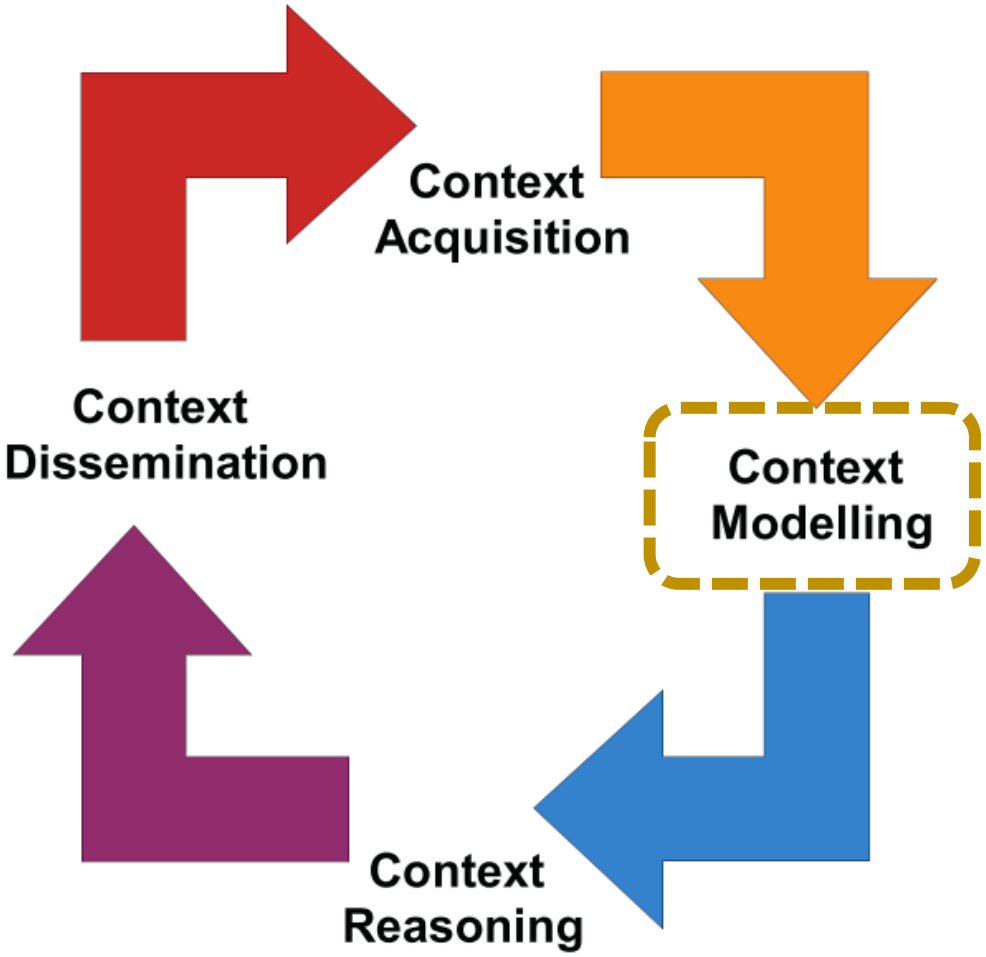


- Based on acquisition process:



DEFINITIONS

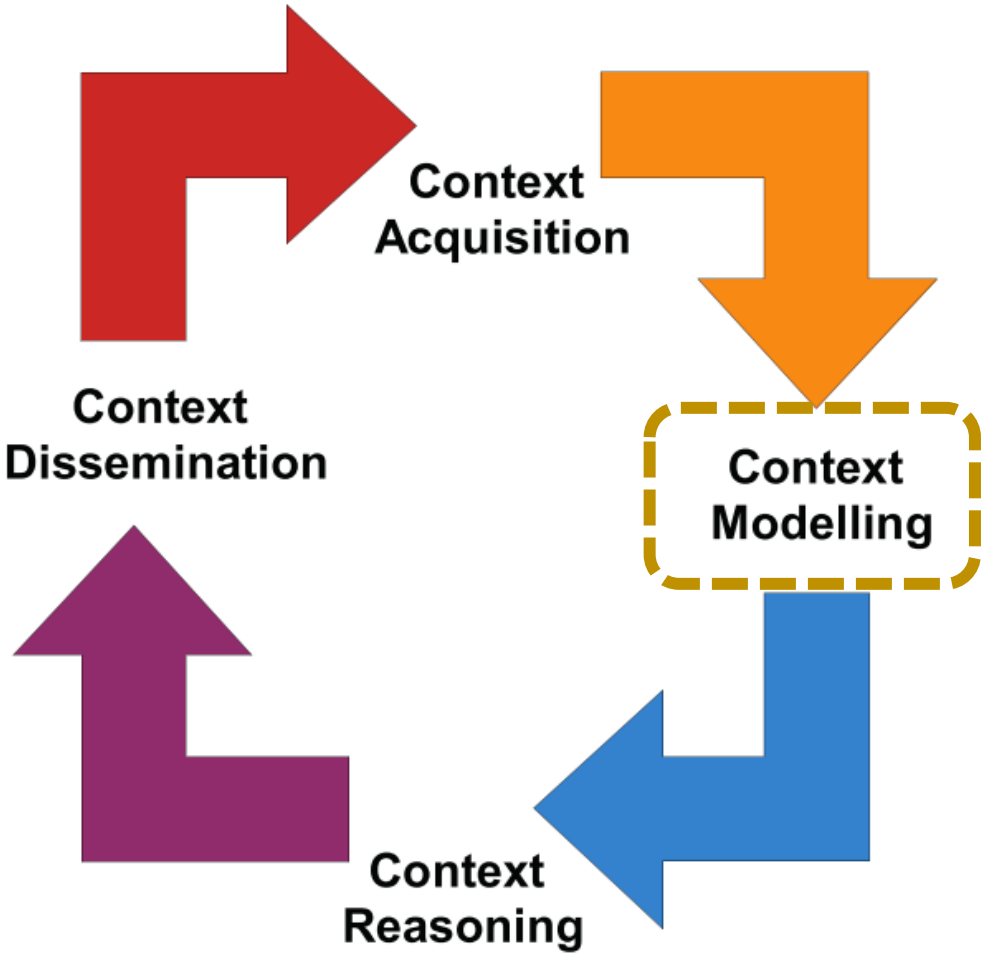
CONTEXT LIFE CYCLE – CONTEXT MODELLING



Define context information in terms of attributes, validate the attributes and then merge these attributes.

DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT MODELLING

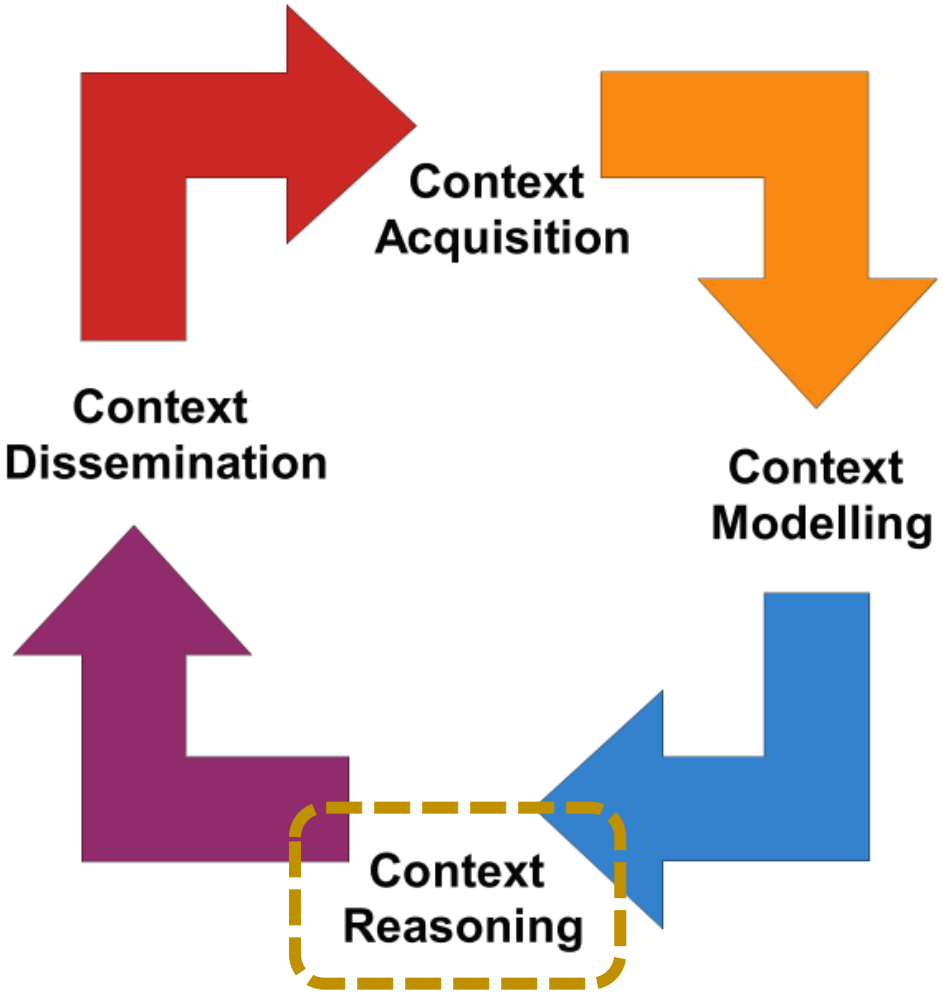


Modeling techniques:

- key-value
- markup scheme (XML)
- graphical (database)
- object based
- logic based
- ontology based

DEFINITIONS

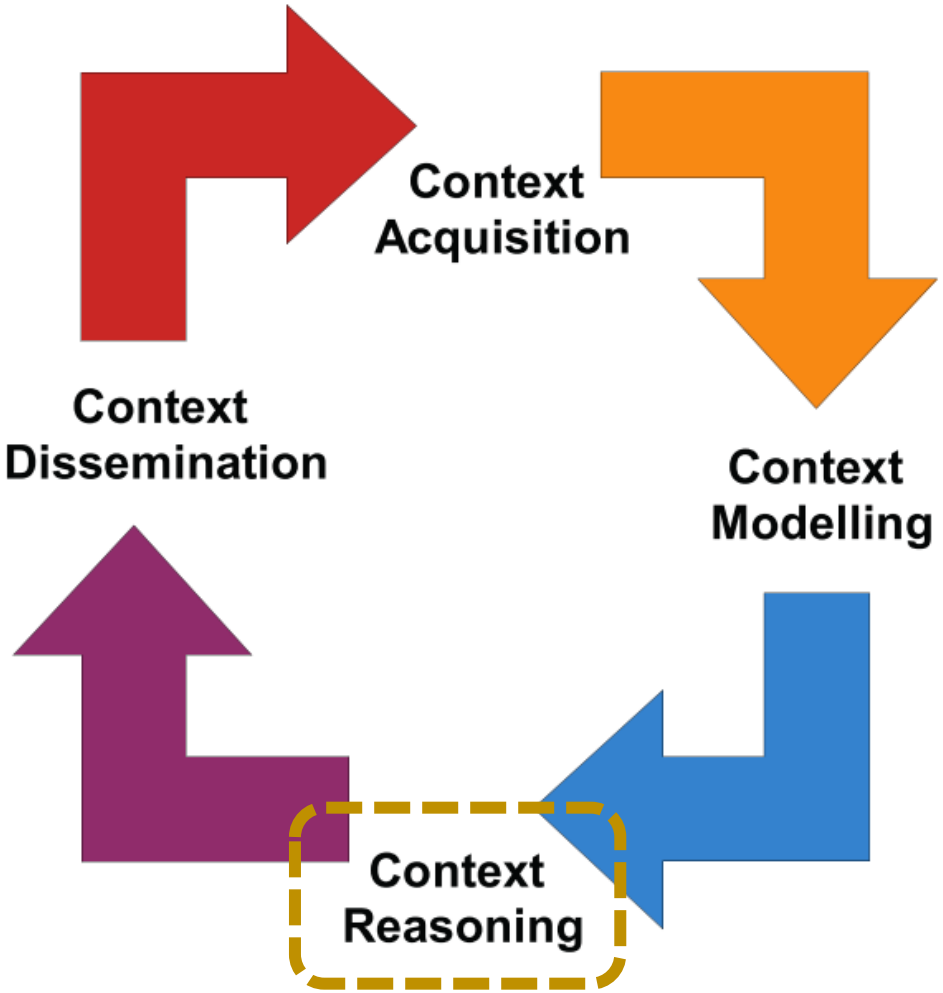
CONTEXT LIFE CYCLE – CONTEXT REASONING



Context reasoning can be defined as a method of **deducing new knowledge**, and understanding better, based on the available context (*Bikakis et al. [8]*).

DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT REASONING

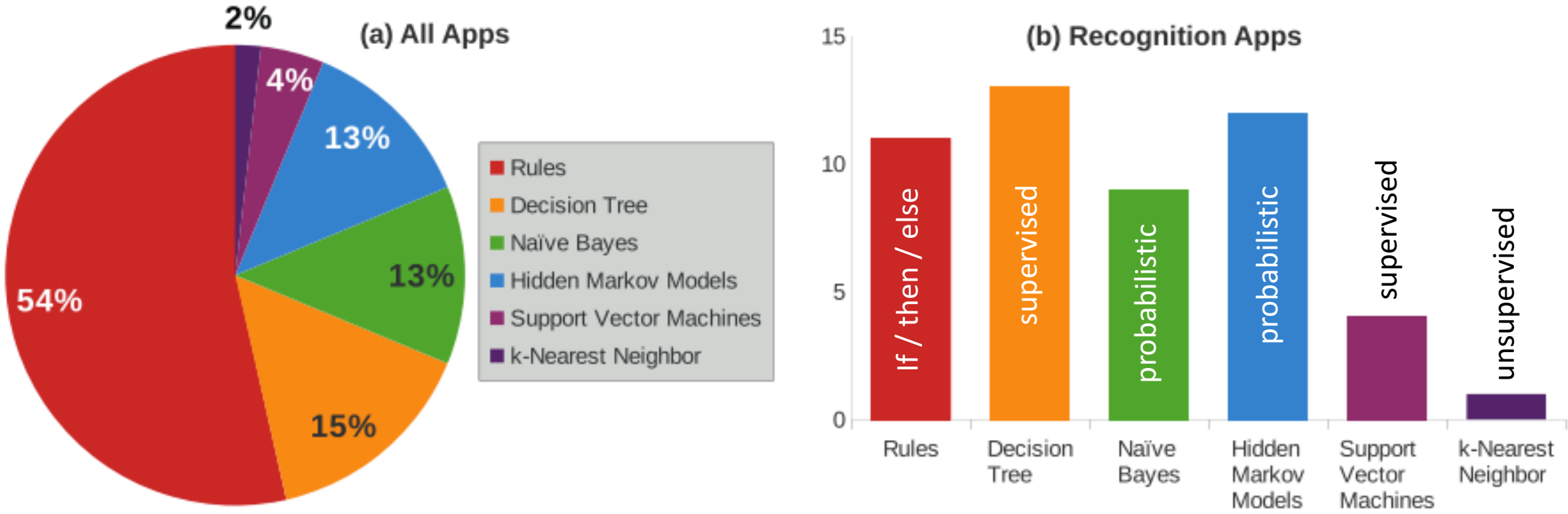


categories:

- supervised learning,
- unsupervised learning,
- rules,
- fuzzy logic,
- ontological reasoning
- probabilistic reasoning

DEFINITIONS

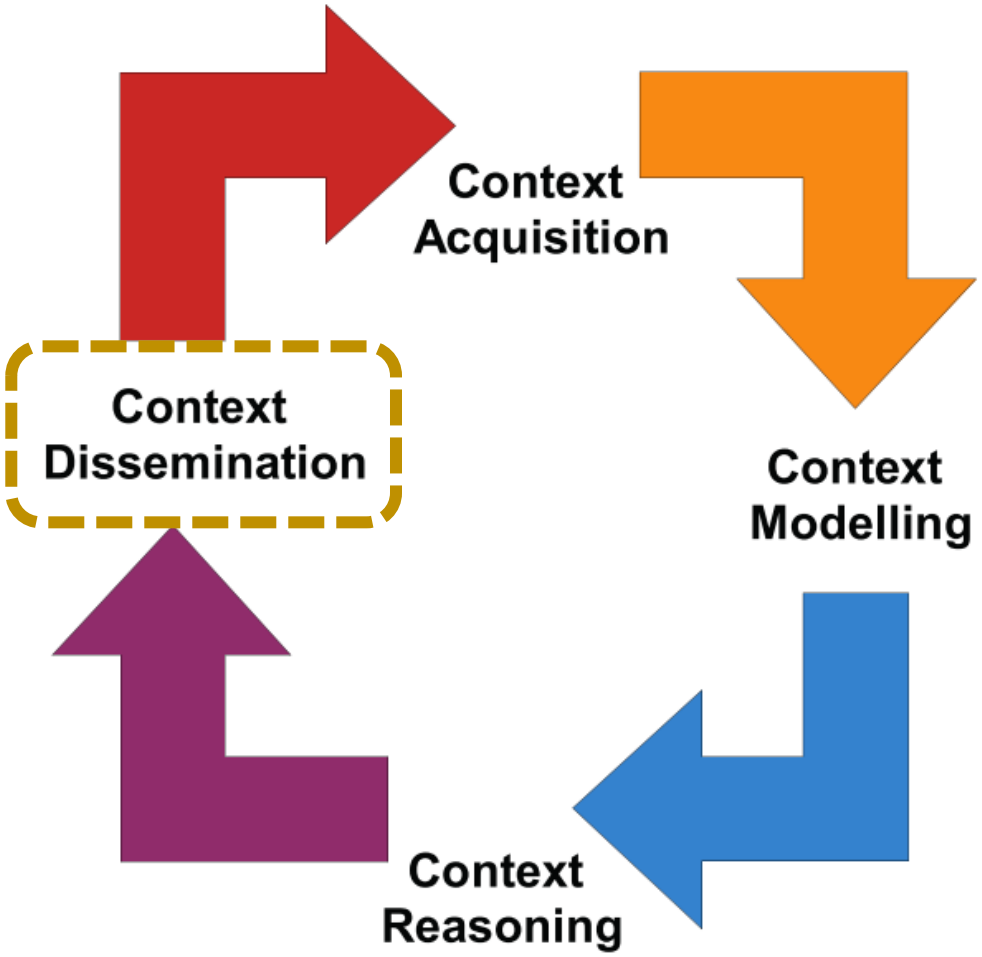
CONTEXT LIFE CYCLE – CONTEXT REASONING



(a) Counts of model types used in 109 of 114 reviewed context-aware applications and (b) counts for 50 recognition applications (*Pereira et al. [1]*).

DEFINITIONS

CONTEXT LIFE CYCLE – CONTEXT DISTRIBUTION



Commonly used methods

- Query
  Context consumer makes the request
- Subscription
  Context consumer subscribes

USE CASE #1

WANTED DRUG DEALER

Red car with license plate XXX-1234 wanted for drug dealing

USE CASE #1

WANTED DRUG DEALER

License Plate Recognition system located many times the car, but nothing was found after police inspection.

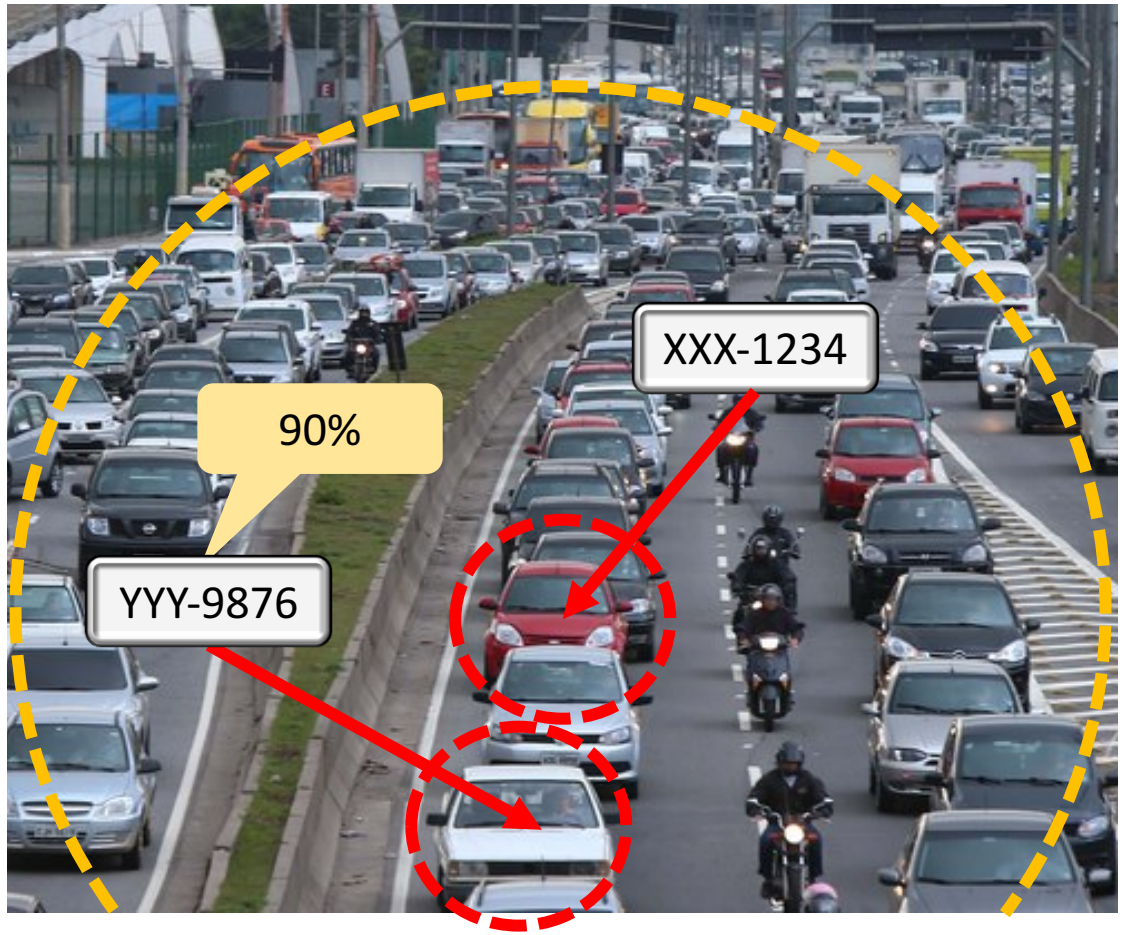
USE CASE #1

WANTED DRUG DEALER

Using context aware technologies, the system identified and stored in a database the closest cars to the one wanted.

USE CASE #1

WANTED DRUG DEALER



In 90% of the cases, a white car with license plate YYY-9876 was close to the wanted red one.

After police inspections, the white car was identified as the drug transport.

Microsoft Domain Aware System (DAS), aka Detecta in Brazil

USE CASE #2

CRIME INVESTIGATION

A woman died by asphyxiation in her apartment.

The husband was arrested for the crime.

USE CASE #2

CRIME INVESTIGATION

Police started investigations and after entering the apartment address in the system, it was found that neighbors called the gas company complaining about gas leakage several times.

USE CASE #2

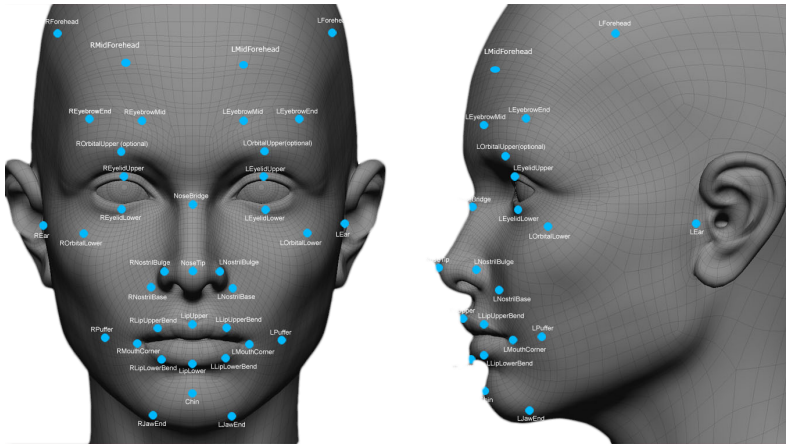
CRIME INVESTIGATION

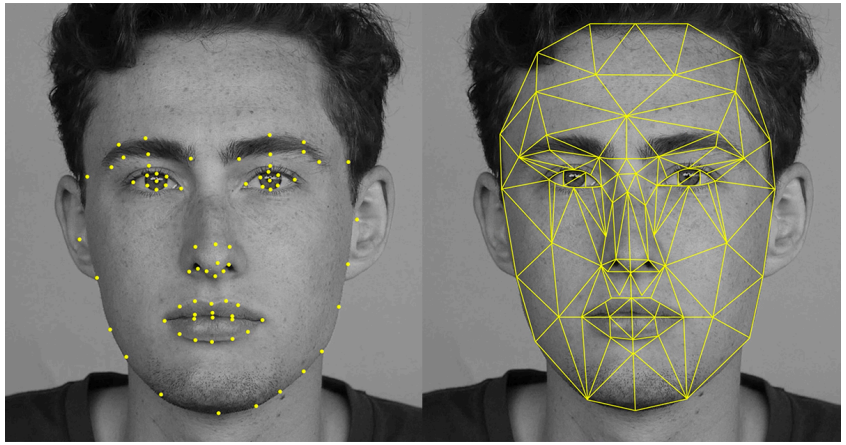
By using context aware concepts the husband was acquitted of the crime.

Microsoft Domain Aware System (DAS), aka Detecta in Brazil

USE CASE #3

FACIAL RECOGNITION



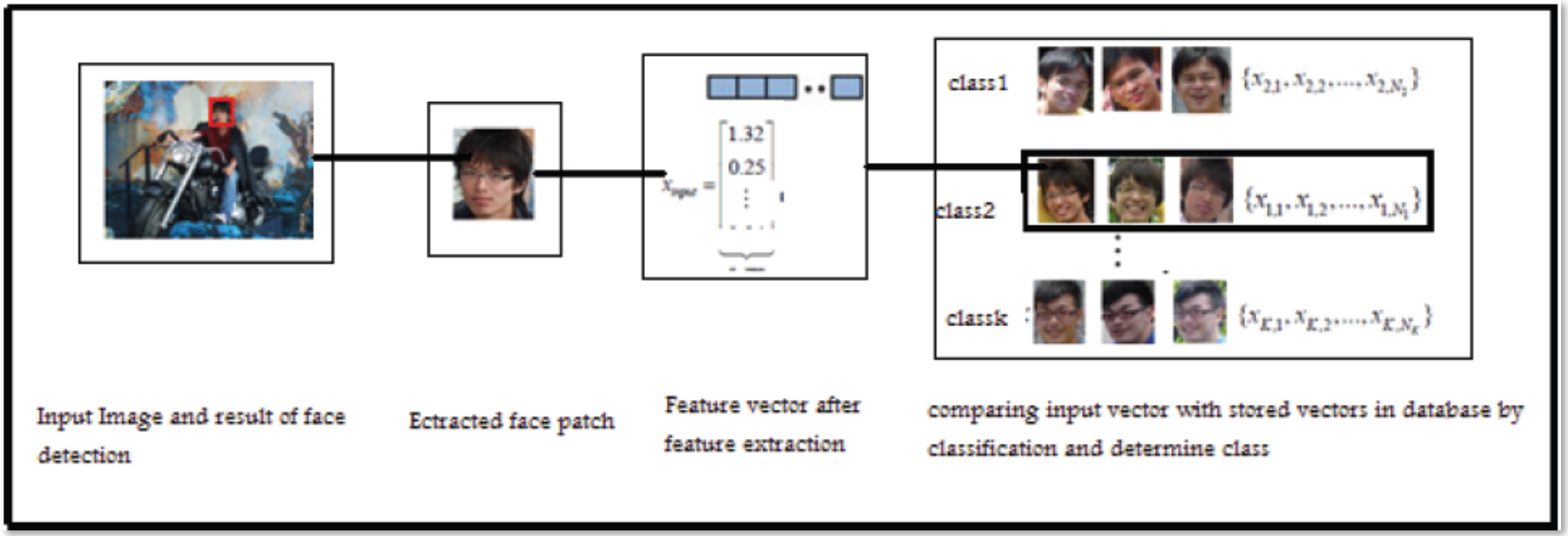


A good Facial Recognition System depends on many variables, not only the face itself, but the surrounding environment.

All these data must be considered in a context model.

USE CASE #3

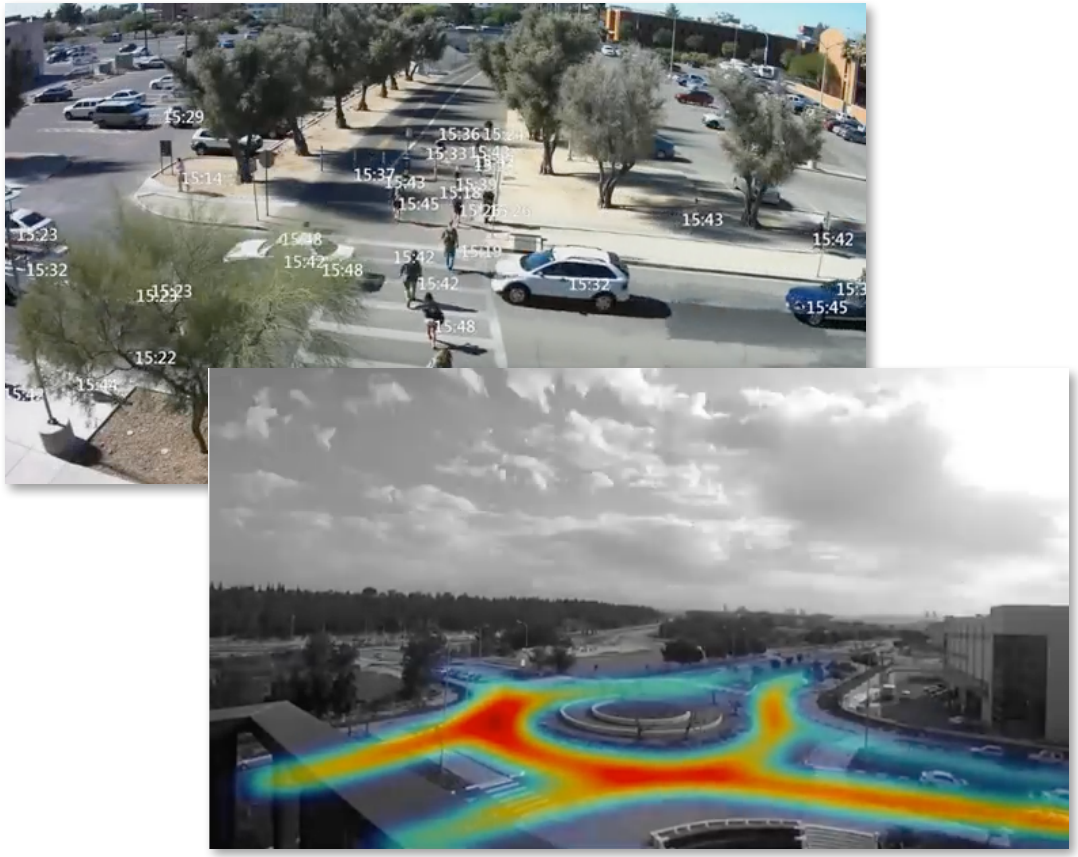
FACIAL RECOGNITION



Picture from Sundaram and Mani [9]

USE CASE #4

VIDEO ANALYSIS



- The system automatically tags a context by colors, sizes, directions, etc.
- Context presentation is implemented in order to make easier to the user to take an action.

USE CASE #4

VIDEO ANALYSIS

https://www.youtube.com/watch?v=rY1qmXda0Oo

- Entity:
  cars
- Context:
  time stamp, direction, license plate, speed,…
- Context-awareness:
  BriefCam system
- Context model:
  time stamp, direction, license plate.
- Context attribute:
  attribute id, type = license plate, value = XXX-1234

CONCLUSION

The IoT has gained significant attention over the last few years, with the advances in sensor hardware technology and cheap materials. Sensors are expected to be attached to all the objects around us with minimum human intervention. Understanding sensor data is one of the main challenges that the IoT faces. **The results clearly show the importance of context awareness in the IoT paradigm** (*Pereira et al.* [1]).

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