MONASH University

Information Technology

FIT5183: Mobile and Distributed Computing Systems (MDCS)

Lecture 10A
Ubiquitous Computing and Context-Awareness

Outline

- ❑ Pervasive/Ubiquitous Computing
- ❑ Context Aware Computing
- ❑ Situation Aware Computing

Pervasive/Ubiquitous Computing

Pervasive/Ubiquitous Computing

- A term coined by" Mark Weiser around 1988
- This generation of computing will see computers so pervasive, we will likely see no computers at all
- **'invisible'** sensing and processing devices are so **embedded in our environment,** so natural, so friendly we use them without even noticing
- Enables **'anytime, anywhere'** computing

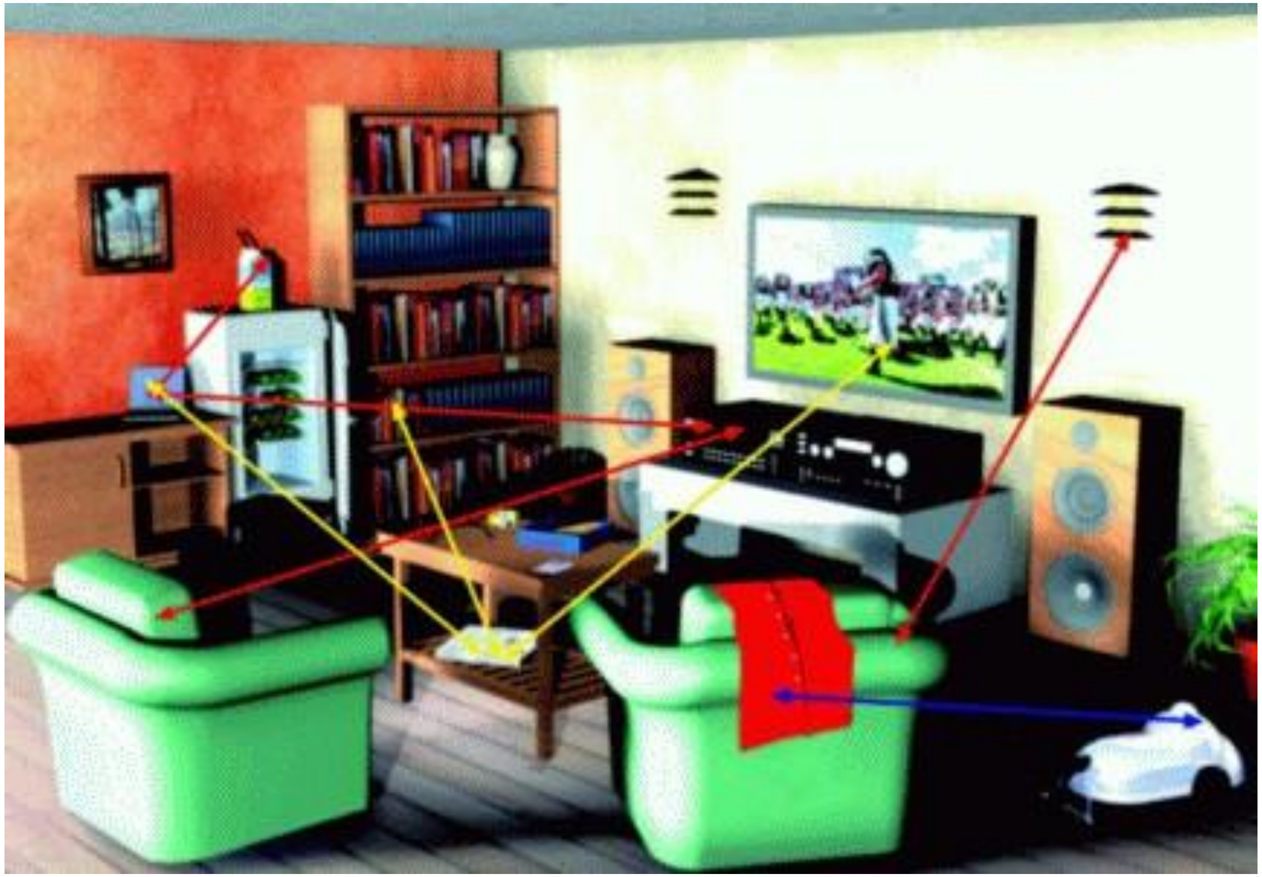
Pervasive Computing

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are undistinguishable from it."

Mark Weiser
Chief Scientist at Xerox PARC

An Example

In our homes, objects communicate with one another



Pervasive Computing - Characteristics

- In practice:
  - Lots of inexpensive and intelligent devices interacting with each other
- Usually consisting of:
  - Computers, laptops, tablets, mobile phones, watches, …
  - Sensors and actuators
  - Reasoning and processing elements
  - Wireless communication technologies

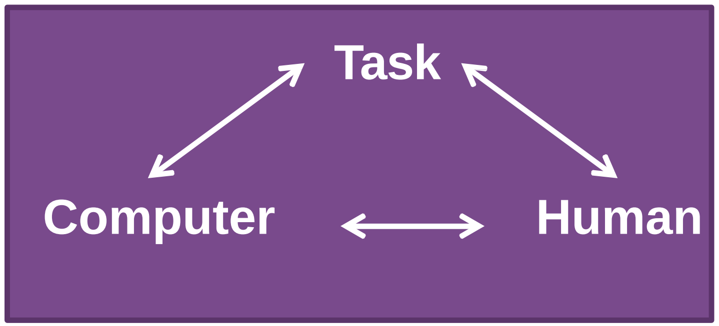
Different Aspects to Consider

- ❑ Sensing technologies and wearables
- ❑ Data stream mining and machine learning
- ❑ Big data analytics
- ❑ Cloud computing and fog computing
- ❑ On-board device (local) computing
- ❑ Interconnection and integration
- ❑ Interoperability
- ❑ Personalisation and user-centred applications
- ❑ Smart and proactive applications
- ❑ Human-computer interaction (HCI)

HCI (Human-computer Interaction)

- HCI deals with the interactions between *humans* and *computers*, where certain tasks are performed
- The User Interface includes the methods and devices to enable the interaction
  - GUI allows user interactions with computing devices through graphical icons and visual objects
- In HCI, the aim is to improve the *usability* of computer interfaces

  "the quality of an interactive computer system with respect to ease of learning, ease of use, and user satisfaction" (Rosson & Carroll 2002)



HCI in Pervasive Computing

- ❑ Conventional HCI based on interactions with stationary devices (e.g. keyboard, mouse) in a pre-defined manner
- ❑ In ubiquitous computing, devices are pervasive, embedded and invisible in our environment
- ❑ Different/new forms of computing input and output required

Input devices

- ❑ Keyboard
- ❑ mouse, trackballs, joysticks
- ❑ Direct and indirect Pointing Devices
- ❑ Touchscreens
- ❑ Stylus Pen/touch
- ❑ Voice/speech
- ❑ Motion, proximity, hand gestures
- ❑ Automated capture through sensors






Considerations with Input Devices

- Environment/context (a hospital environment different from a classroom)
  - In the context, where users need to use their hands to perform other tasks

- Multi-user systems e.g. ATM different from single user applications
- Speed of interaction (games)
- Size of the screen
- Speed of learning
- Complexity of the system (touch screen unsuitable for complex tasks)
- Audience (disability, language skills)
- Level of danger (i.e. controlled robots for disarming bombs)

Other Input Sources

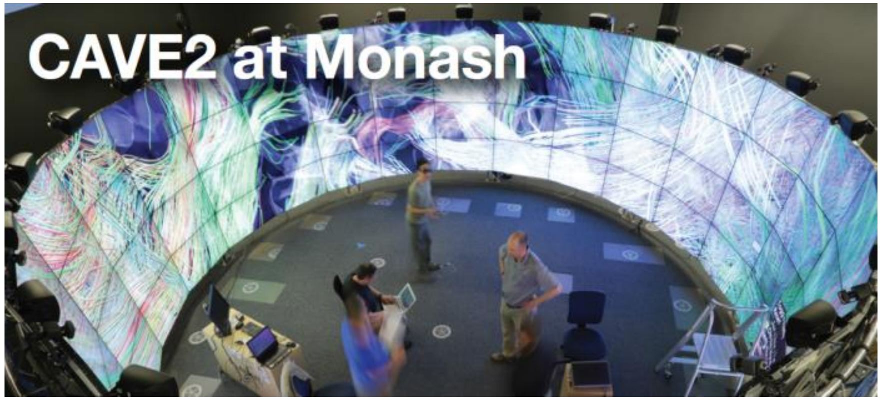
In ubiquitous and IoT environments, input data can be captured also:

- Implicitly by the device such as date and time
- GPS location
- Automatically captured from sensors and wearables
- Facial expressions and behavioural cues
- Inputs from other biophysical sources (eye tracking, skin conductance, heart rate, EEG brainwaves..)

A video: Daptly Mirror

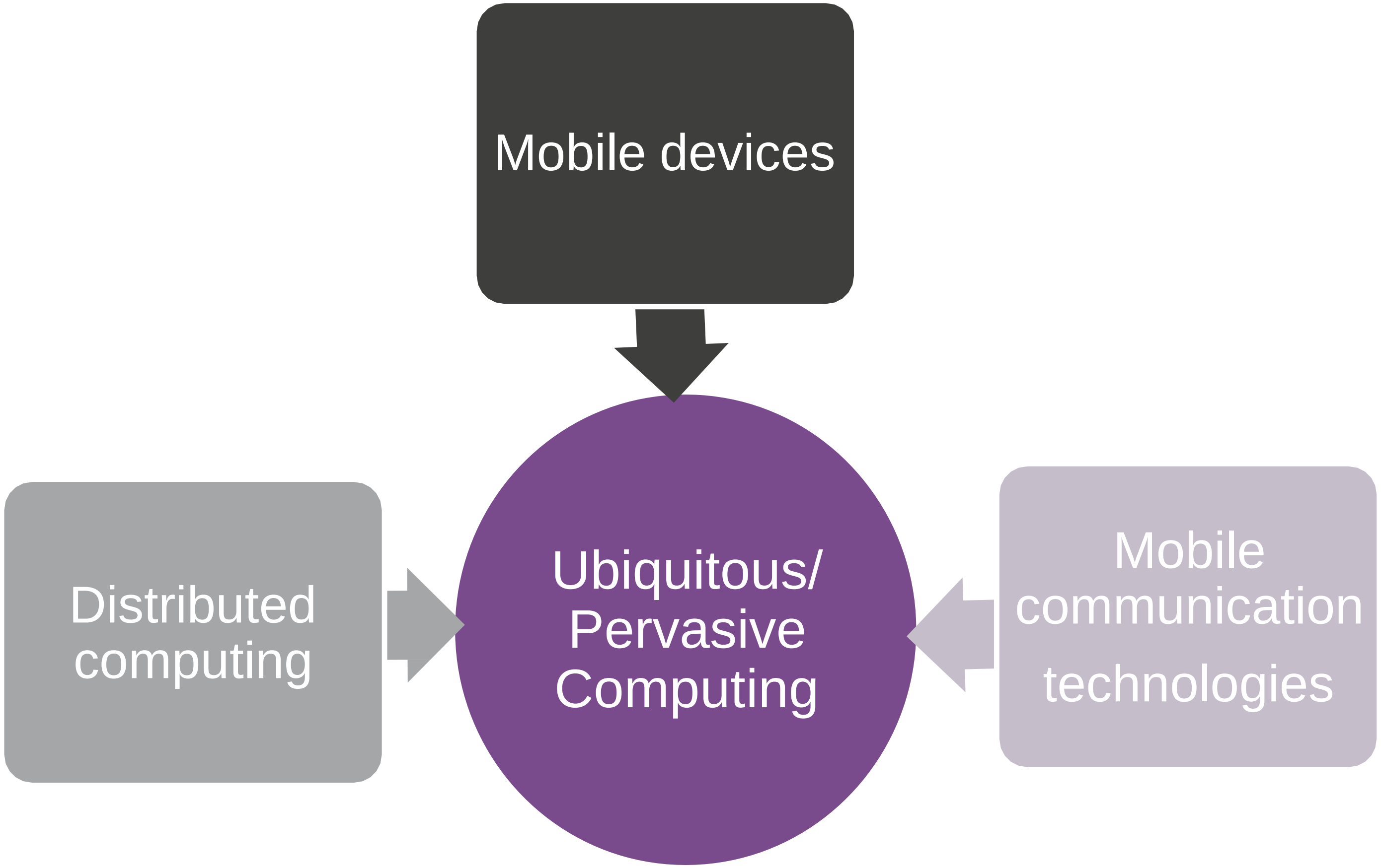
Output devices

- Voice/speech
- Small-size to wall-sized (touch) screens
- 3D printer
- 3D visualisation
- Hologram
- Virtual reality and Augmented reality



Ray Kurzweil speaking to a conference as a hologram in 2006
https://www.theguardian.com/science/2009/feb/03/nasa-google-futurology-kurzweil-singularity

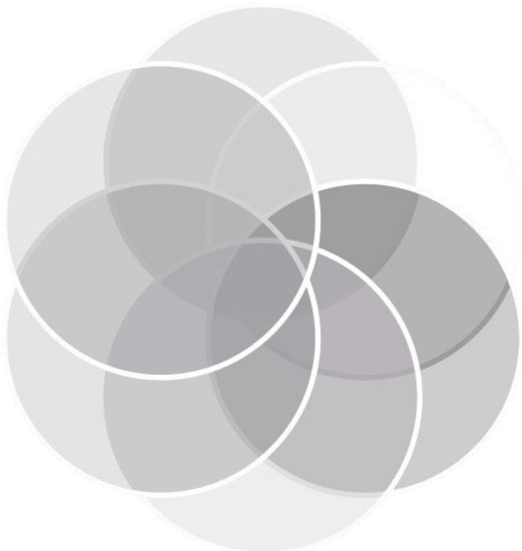
Motivation



Mobile devices
Distributed computing
Ubiquitous/ Pervasive Computing
Mobile communication technologies

Emerging Fields

Context/Situation-Aware Computing



Smart Cities

Activity Recognition

Internet of Things (IoT)

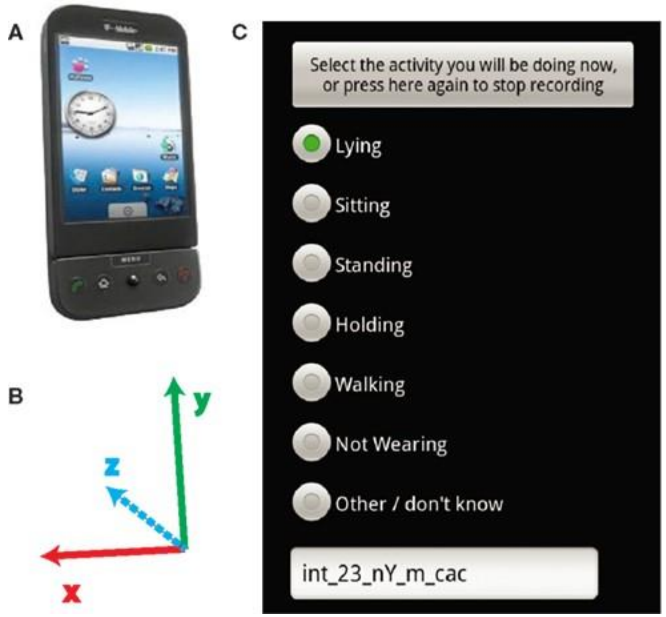
(Mobile) Crowdsensing

Integrated Robotics

M2M

Activity Recognition

- ❑ Identifying user activities based on analysing sensory data from:
  - – External accelerometers or built-in sensors in phones
- ❑ Usually supervised learning is used:
  - – Decision Trees (J48), K-Nearest Neighbor, Naive Bayes and Support Vector Machines (SVM)
- ❑ Classification methods:
  - – Data is collected and labelled first
  - – The labelled data is used to train the classifier model
  - – After the model is built, it can be used to process real time sensory data



Context/Situation Aware Computing

Context-Awareness

- ❑ Context-awareness is considered a key component of ubiquitous computing system
- ❑ It enables the application to be:
  - Adaptive to dynamic changes
  - user-centric and personalised
  - Intelligent and pro-active (anticipating user needs)
  - cost-efficient

What is Context?

- Context is a very broad term that encompasses different aspects and characteristics
- Context is any useful information related to a network, application, environment, process, user or device
- Contextual information can be sensed, derived, reasoned, computed, learned, inferred or explicitly entered by users

Context Definition

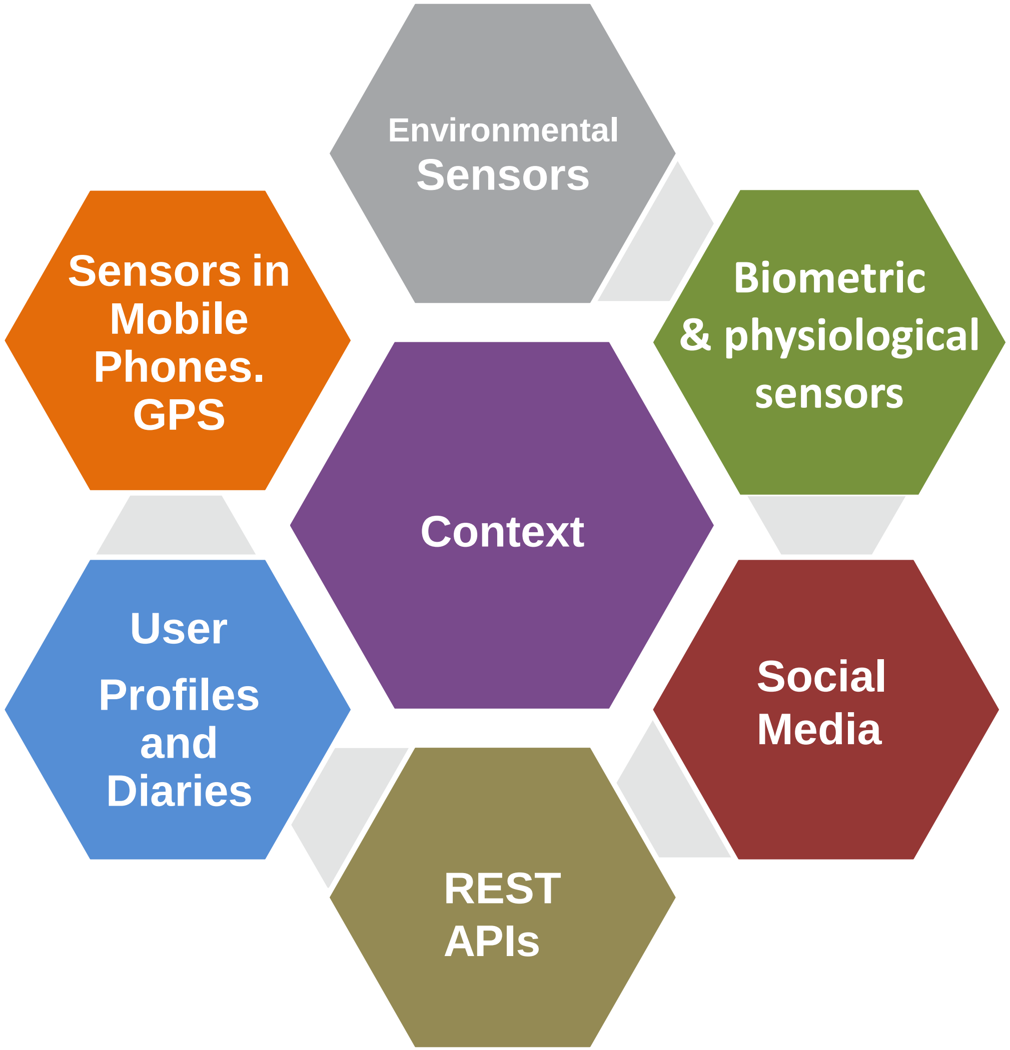
"Any information that can be used to characterize the situation of an entity" (Dey, 1999)

- Examples:
  - Identity (Who)
  - Activity (What)
  - Time (When)
  - Location (Where)
- Devices and systems anticipate user needs and make tailored recommendations (notably in retail)

Types of Context

- ❑ Dynamic vs. static Context
- ❑ Continuous data streams (sensory data)
- ❑ Metadata and Quality of Context (QoC)
- ❑ Spatial Context
- ❑ Computational resources (battery level, memory , CPU)
- ❑ Network context
- ❑ User Context – e.g. human activity or behaviour patterns (use in law enforcement, security and anti-terrorism)
- ❑ Information about physical environment
- ❑ Emotions and feelings
- ❑ Situations (high level context that is reasoned from multiple context (e.g. there is a ‘meeting’ in H7.39)

Sources of Context



What is Context-Aware Computing

- A context-aware system **is aware** of the current context (state, surroundings, location, etc.) and **uses** this information **to adapt its behaviour or operations** accordingly

Context-Aware Computing Definition

- The context-aware computing term was first used by Schilit and Theimer in 1994 to describe

  *Applications that "**adapt** according to its **location of use**, the collection of **nearby people and objects**, as well as the **changes to those objects** over time".*

- Ryan et al. (1997) describes context-awareness as the ability of applications to sense and react to contextual information about environment, location, time, or user

First Context-Aware System

- ❑ First Location Aware System was **Active Badge** system at Cambridge AT&T Lab

- ❑ Location/Context-Aware Digital Assistant from **PARCTab**
  - To know where each PARCTab was (worn by personnel)
  - Infrared communication
  - One of 3 components in an integrated experimental environment (cm scale *tabs*, decimetre scale *pads* and meter scale *boards*).

Context-Aware Computing

- Context-aware energy management
- Context-aware healthcare?
- Context-aware advertising?
- Context-aware e-Learning?
- Context-aware data comms or transfer?
- Context-aware data stream mining?
- Context-aware networking?
- Context-aware security?
- Context-aware remote sensing?
- Context-aware recommender systems?

E.g. Flower Lamp

Context Modelling

- Representation of context that describes the properties and structure of context in **a standard and consistent manner**
- Using a generic context model can provide applications with the benefits of **context sharing and interoperability**

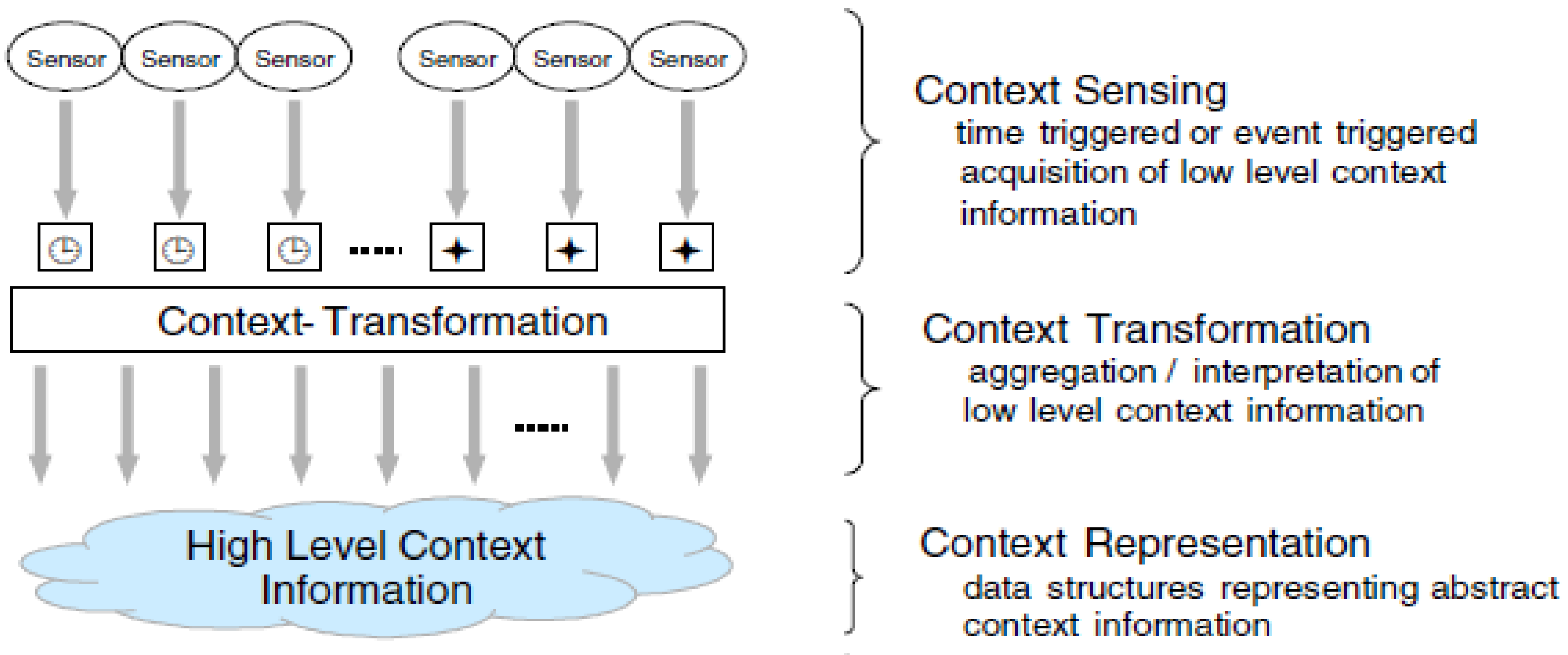
Key and Value

- Key characterise environment variables and values represent the actual context data
- Adopted in the Proximate Chooser (by PARCTAB) and in the active map service (AMS) to publish location information of objects in a region

Situation Aware Computing

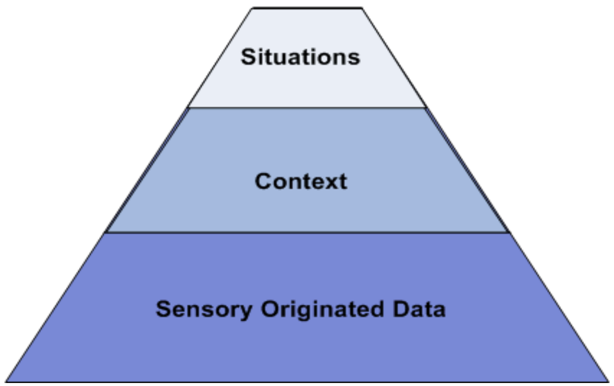
High level context

- Situations: higher level of knowledge and context
- Situations may be inferred through reasoning and inference methods.
- Dey (2001) defines a situation as “a description of the states of relevant entities”

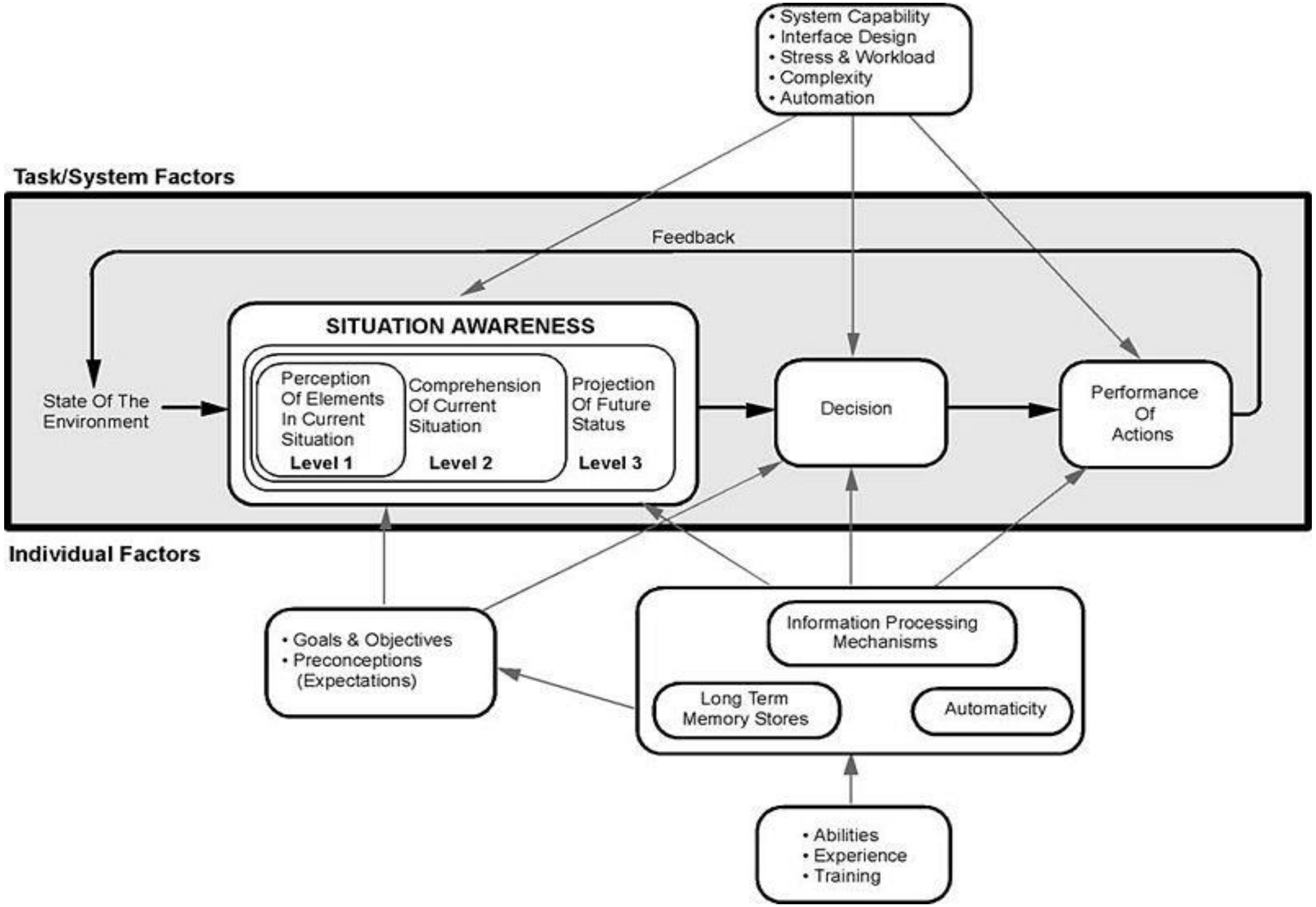


Situation Awareness

- ❑ Representing real-life situations of interest
  - for a health monitoring application: hypertension, healthy
  - for a fire monitoring application: fire-threat, safe, fire
- ❑ In context-aware computing, the focus is on an individual context
- ❑ In situation-aware computing, multiple sensory data are aggregated (e.g. humidity, wind speed and temperature)
- ❑ A need for **context/situation modelling and reasoning methods** to represent and infer occurring situations from low level context (sensory data)
  - E.g. Fuzzy Situation Inference (FSI)



Situation Awareness – in Human Factors



[Endsley 1995]

Context vs Situations - examples

- For a health monitoring application:
  - Context: heart rate, blood pressure, body temperature
  - Situations: healthy, hypertension, hypotension, heat stroke
- For a fire monitoring application:
  - Context: wind speed, temperature, light
  - Situations: fire, fire-threat, safe
- For Air Traffic Control:
  - Context: aircraft heading, altitude, flight plans
  - Situations: violation of horizontal or vertical separation limits
- For monitoring offices:
  - Context: noise, light, motion
  - Situations: meeting, presentation, vacant

Challenges

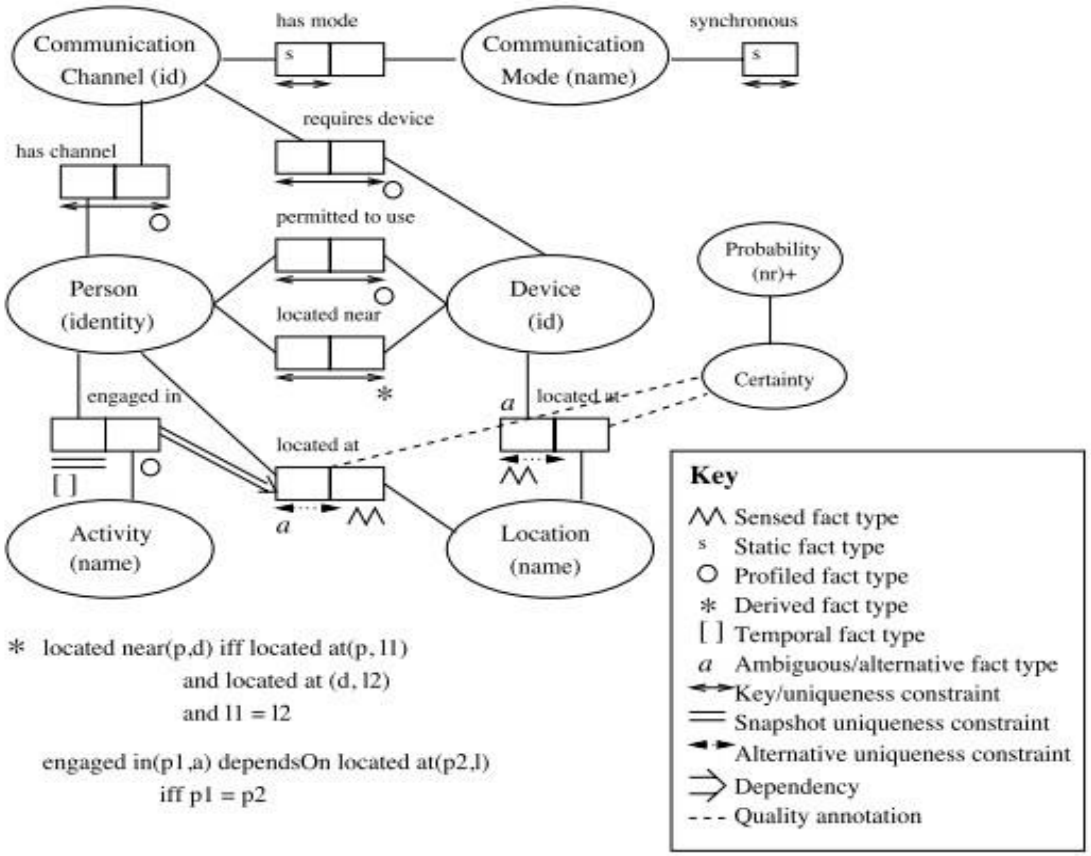
- ❑ Inherent inaccuracy of sensors
- ❑ Insufficient data to infer context
- ❑ Cost-efficiency issue in mobile environments
- ❑ Context collection and pre-processing
- ❑ Context fusion and aggregation
- ❑ Accuracy of context/situation reasoning methods

Context/Situation Modelling

- Representation of context that describes the properties and structure of context in a standard and consistent manner
- Using a generic context model can provide applications with the benefits of context sharing and interoperability
- Enables performing context/situation reasoning

Graphical Modelling

- Uses a graphical notation to represent concepts
- Context Modelling Language (CML) *(Henricksen, Indulska & McFadden, 2005)*



Context/Situation Reasoning

- Context/situation reasoning methods produce high level contextual information by aggregating and performing reasoning on low level context
- Situation reasoning requires sensor fusion to aggregate multiple sensory data sources
- Different approaches – active areas for research:
  - Simple Logic
  - Fuzzy logic
  - Ontology based
  - Machine learning methods
    - Naïve Bayes
    - Bayesian Networks
    - Hidden Markov Models
    - Decision Trees
    - Neural Networks/Deep Learning

Rule-based Reasoning

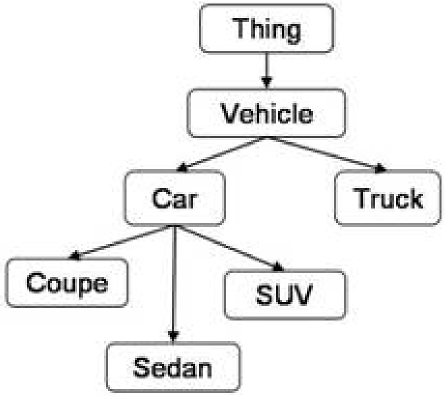
- A logic defines the conditions on which a concluding expression or fact may be derived from a set of other expressions or fact
- Use of static rules

  - although there are machine learning methods that could be used obtain these automatically (e.g. Ripper algorithm based on C4.5 classifier)
- Generally requires inputs from domain (subject matter) experts
  - If heart rate>100 then send an alert

Ontology-Based Modelling: Example

- Modelling

```
<owl:Class rdf:about='#Vehicle'>
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty rdf:resource='#numberOfWheels' />
<owl:minCardinality rdf:datatype='&xsd;nonNegativeInteger'>
</owl:minCardinality>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>
```



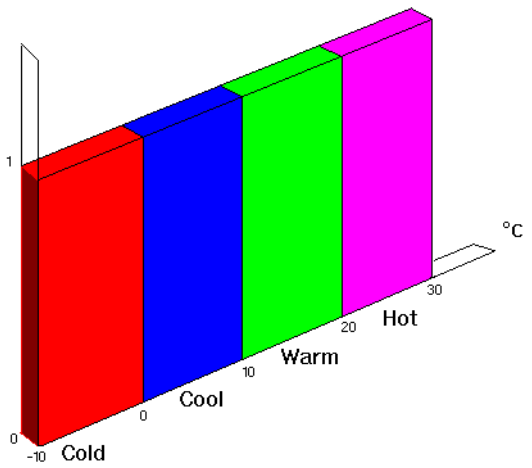
- Reasoning

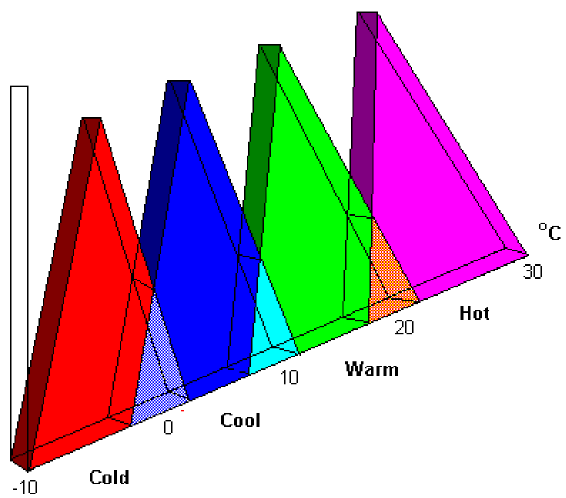
BusinessMeeting $ Activity # ≥ 2 hasActor #∀ hasActor.Employee #∃ hasLocation.(ConfRoom # CompanyBuilding)

Fuzzy Logic Based Situation Inference

- ❑ Fuzzy Situation Inference (FSI)
  (Delir Haghighi et al. 2008, 2009, 2010)

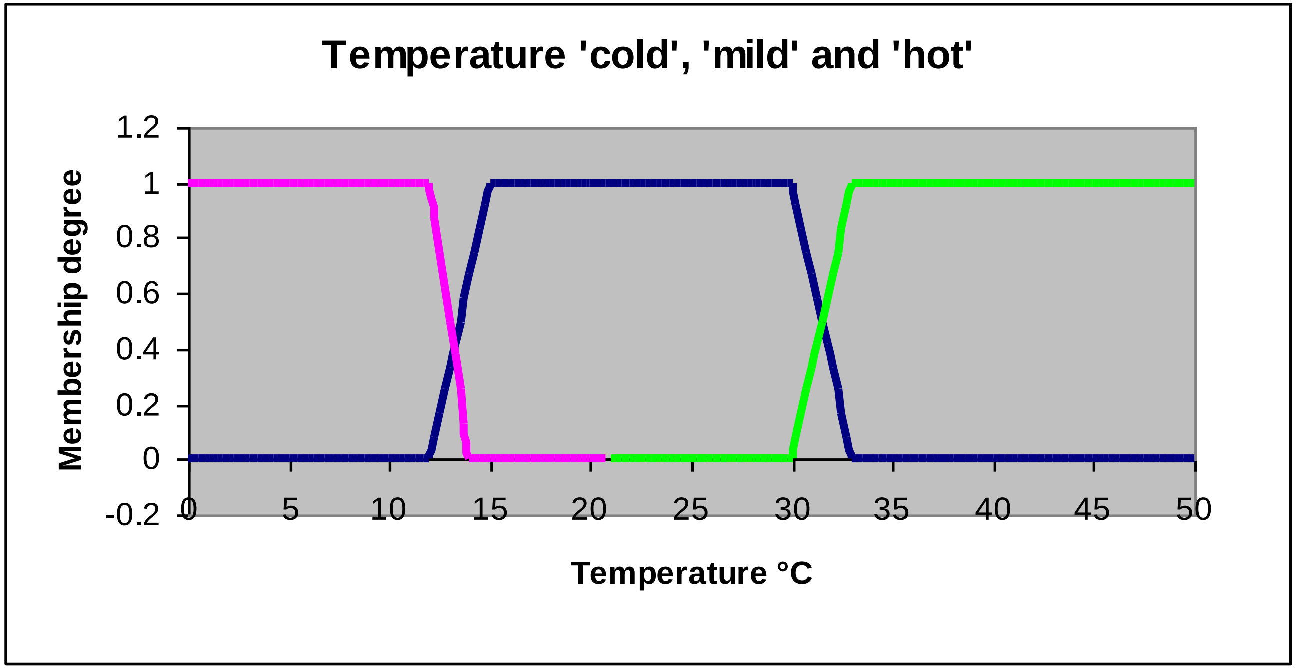
- ❑ Conventional Sets vs Fuzzy Sets:





Trapezoidal MF

$$trapmf(x; a, b, c, d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$



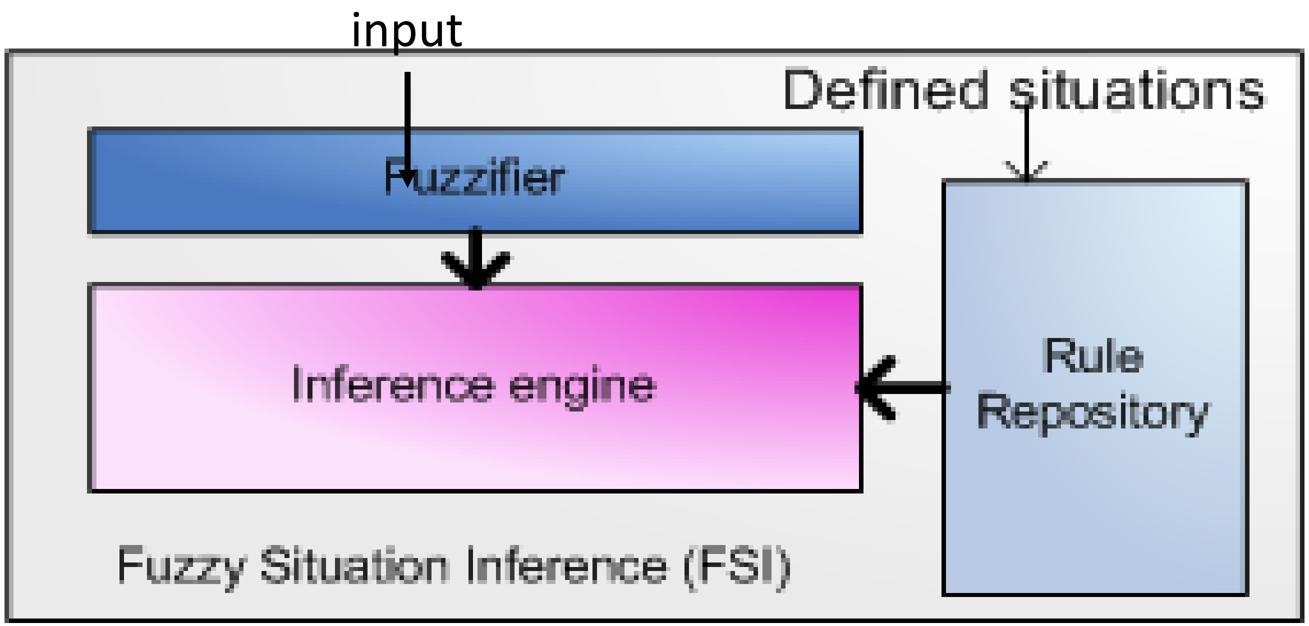
Defining Situations in FSI

- Based on Fuzzy Logic:
  - Linguistic variables
  - Fuzzy sets
  - Membership function
  - Fuzzification

Situation	Linguistic variable	Terms/fuzzy sets*	Weight
Hypertension	SBP	High	0.35
	DBP	High	0.4
	HR	Fast	0.25
FSI rule: IF SBP is 'high' AND DBP is 'high' AND heart_rate is 'fast' THEN situation is 'hypertension'			

FSI Components

- Three main components: Fuzzifier, Rule repository and Inference Engine



FSI Inference Technique 1

$$Confidence = \sum_{i=1}^{n} w_i \mu(x_i)$$

weights

relative importance of each linguistic variable(0-1), adds up to 1

membership degree μ

represents membership degree of each element

The confidence value of an inferred situation indicates the level of confidence in the occurrence of the situation

Fuzzy Situation Inference: Example

if SBP is 'high' and DBP is 'high' and HR is 'fast' then situation is 'hypertension'

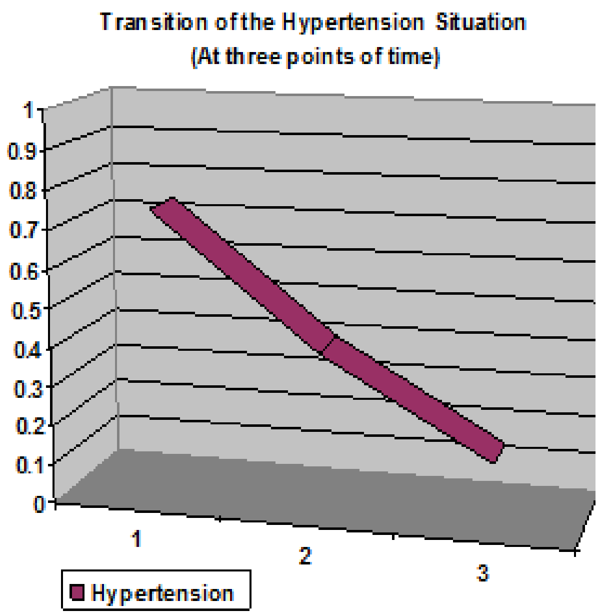
$$Confidence = \sum_{i=1}^{n} w_i \mu(x_i)$$

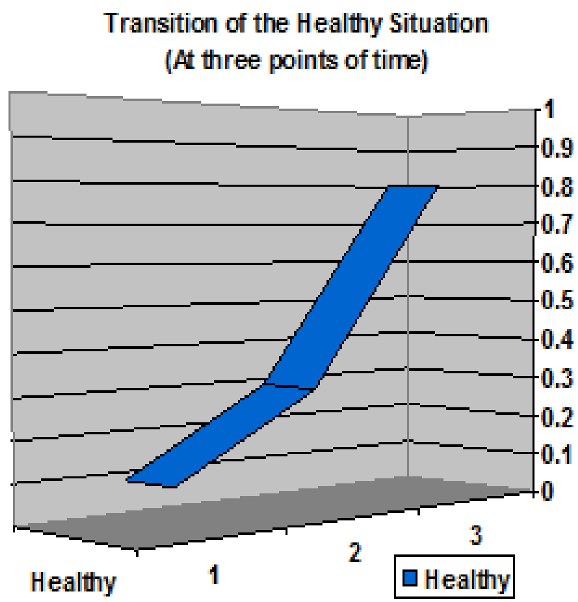
Antecedent	Input crisp Value	Weight	Weighted Membership Degree
1: SBP is 'high'	129 mm Hg	0.35	0.9*0.35=0.315
2: DBP is 'high''	93 mm Hg	0.4	0.8*0.4=0.32
3: HR is 'fast'	102 bpm	0.25	1*0.25=0.25
Confidence= 0.315+0.32+0.25=0.885			

$\mu_{s_i}(x) \geq \varepsilon$ threshold (a value between 0 and 1)

Situation *Transition* in FSI

Confidence values at first point of time	Confidence values at second point of time	Confidence values at third point of time	Transition direction
Hypertension = 0.74 Pre-hypertension= 0.6 Normal= 0.1	Hypertension = 0.4 Pre-hypertension= 0.8 Normal= 0.3	Hypertension = 0.15 Pre-hypertension= 0.4 Normal= 0.8	Hypertension moving towards normal





Context and Situation Aware Computing examples (more short videos!)

- ❑ Take a Seat Video
- ❑ Context-aware computing examples (Ryerson DMZ)
- ❑ IBM context aware stream computing
- ❑ Context aware hospital bed (Denmark)
- ❑ Hospital surgery using Augmented Reality glasses
- ❑ Context aware security guard
- ❑ An Intelligent Mirror

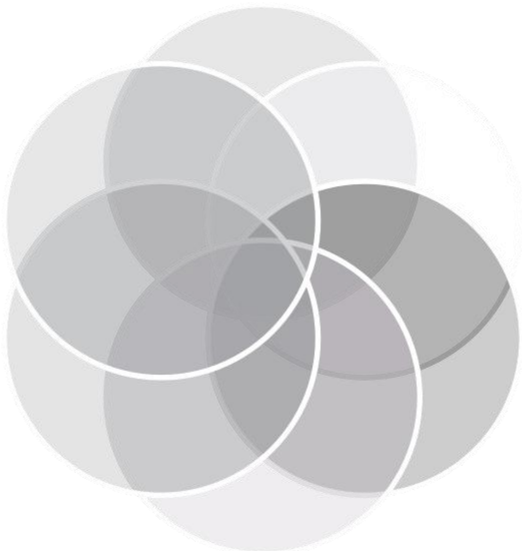
➢ Many more examples available – this field is still in it's infancy!

Emerging Fields

Context/Situation-
Aware Computing

Activity
Recognition

Smart Cities



Internet of Things
(IoT)

(Mobile)
Crowdsensing

Integrated
Robotics

M2M

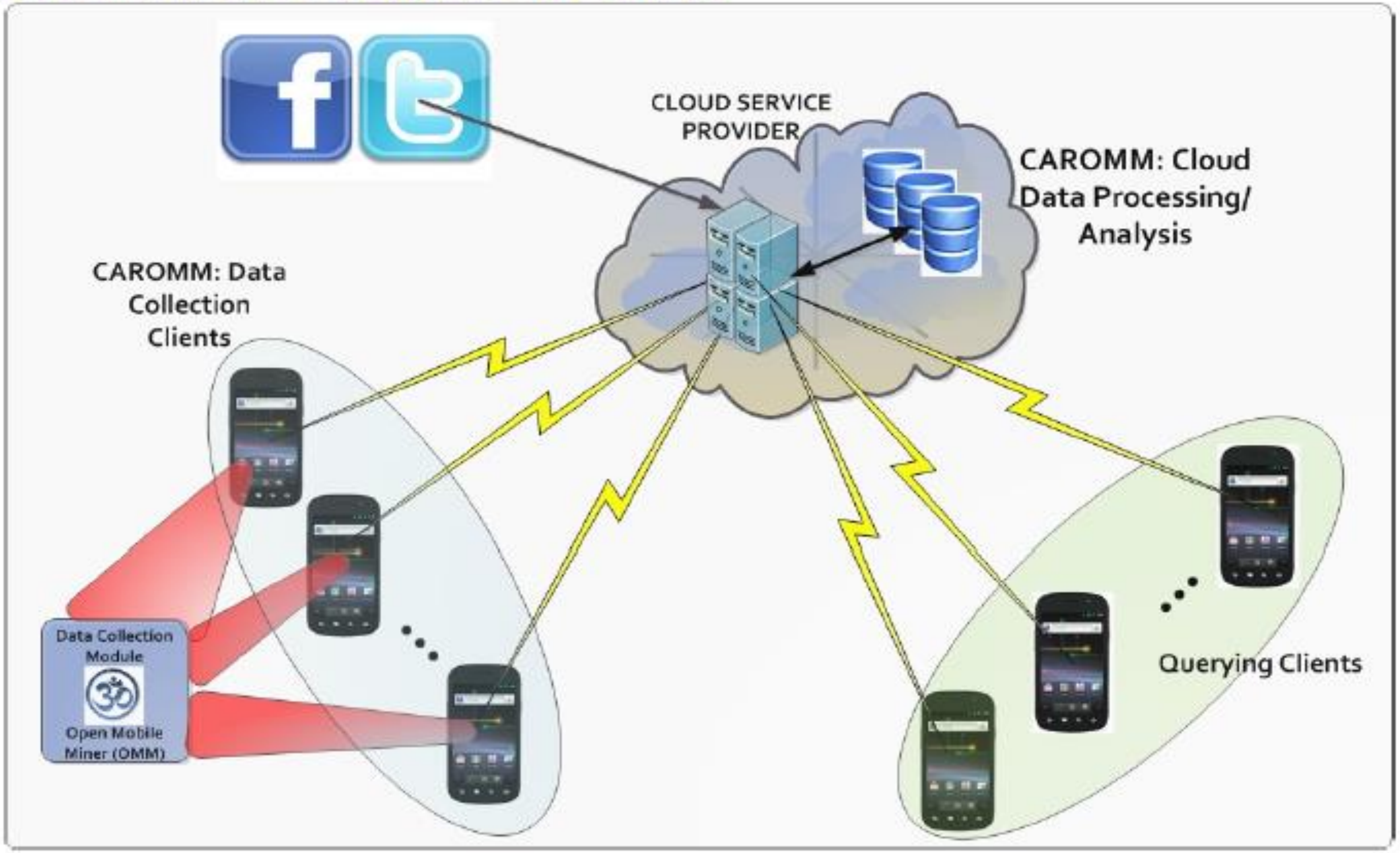
Mobile Crowdsensing

- The term “crowdsensing” refers to using the power of the crowd to collect information regarding phenomena of interest with the use of available sensors in the mobile and wearable devices
- MCS applications remotely collect data about the environment and physical world
- It relies on mobile and sensing devices, and cloud computing
- The key contextual information: location and accelerometer
- Privacy is a main issue

Participatory and Opportunistic Sensing

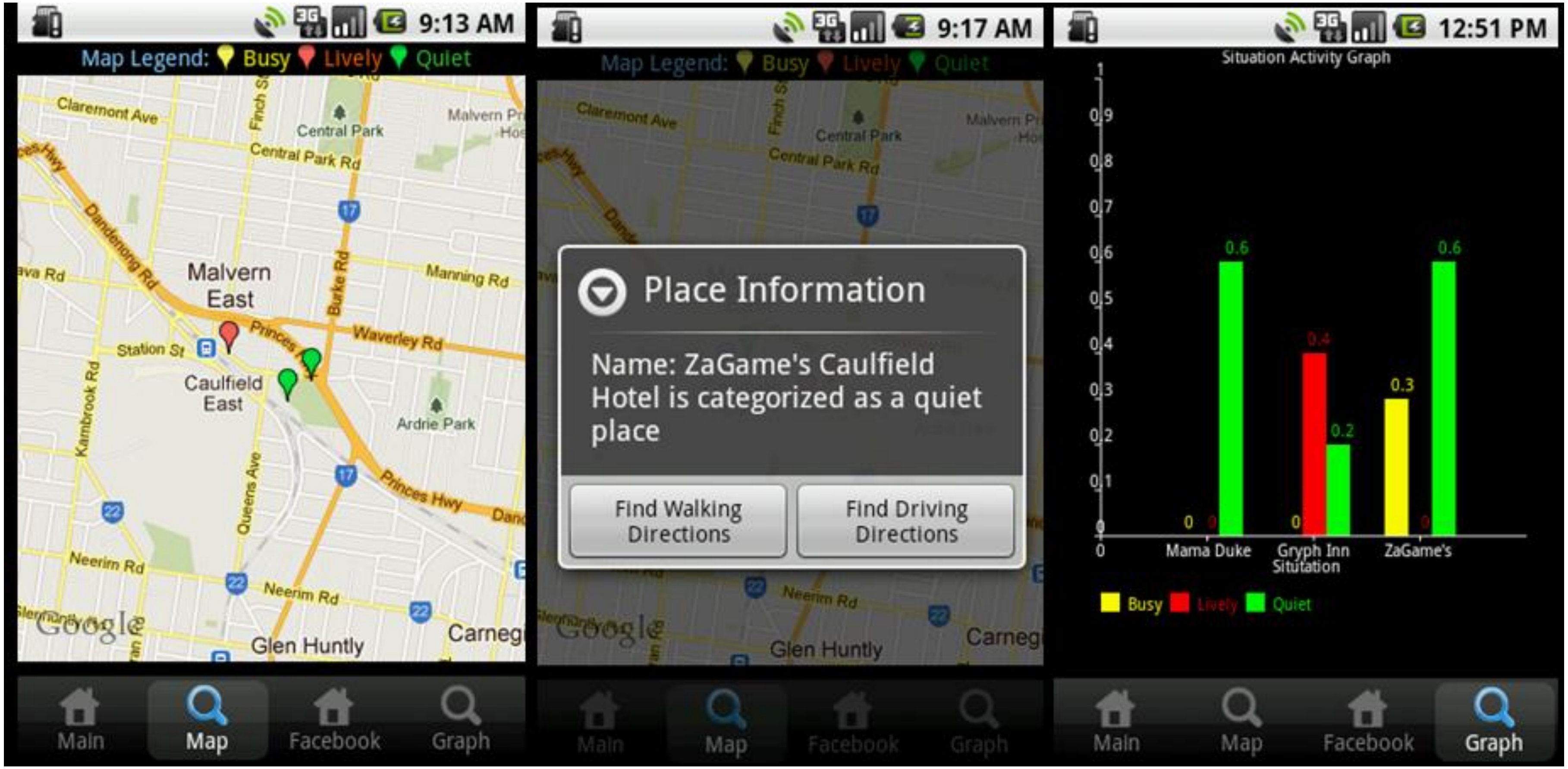
- Based on the level of user's involvement in the sensing task, there are two types of crowdsensing
- *Participatory sensing*
  - Users are directly involved in the data collection process
- *Opportunistic sensing*
  - Users are not directly involved in the data collection process (minimal involvement)
  - Sensing tasks happen in the background
  - Mobile devices decide when and how they should participate in a sensing task

CAROMM Framework



Wanita Sherchan, Prem Jayaraman, Shonali Krishnaswamyy, Arkady Zaslavsky, Seng Loke and Abhijat Sinha, "Using On-the-move Mining for Mobile Crowdsensing", International Conference on Mobile Data Management 2012, July 23 - 26, 2012, Bangalore, India

P. P. Jayaraman and A. Sinha, W. Sherchan, S. Krishnaswamy, A.Zaslavsky, P. Delir Haghighi, S. Loke, M. Thang Do "Here-n-Now: A Framework for Context-Aware Mobile Crowdsensing", Pervasive, 2012, Newcastle Upon Tyne, UK, 18-22 June, 2012


9:13 AM
Map Legend: Busy Lively Quiet
Malvern East
Caulfield East
Glen Huntly
Main
Map
Facebook
Graph
9:17 AM
Place Information
Name: ZaGame's Caulfield Hotel is categorized as a quiet place
Find Walking Directions
Find Driving Directions
12:51 PM
Situation Activity Graph
Mama Duke
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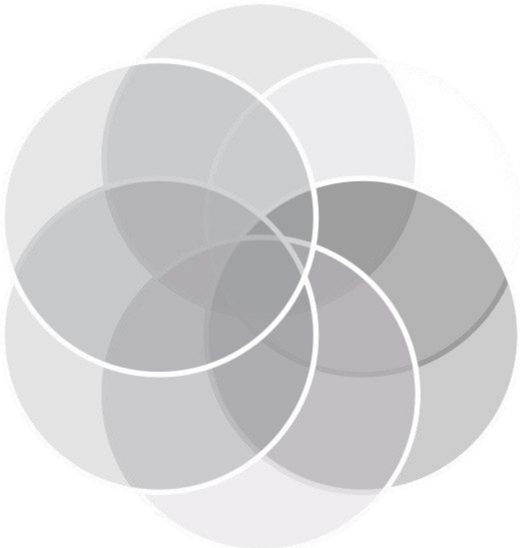


**Internet of Things
(IoT)**

(Mobile)
Crowdsensing

Integrated
Robotics

M2M

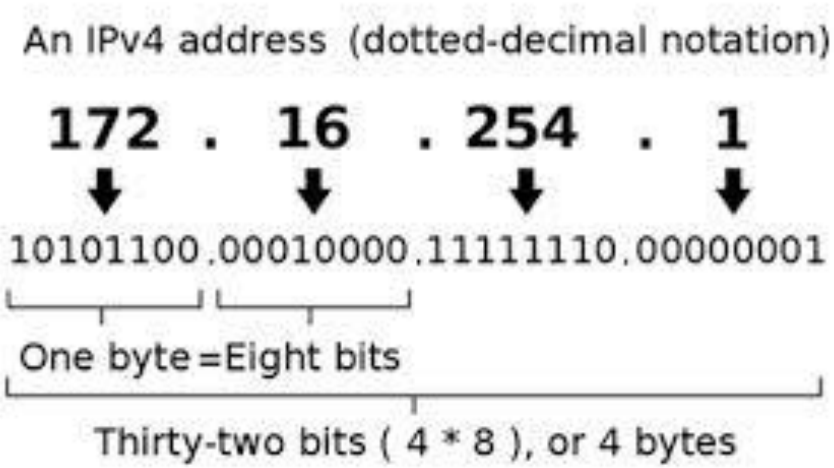
Internet of Things (IoT)

(Some videos shown in Week 9)

- ❑ Coined by Kevin Ashton from MIT
- ❑ A new era of ubiquity
- ❑ A network of everyday objects (smart *things*)
- ❑ All objects and people equipped with identifiers can connect
- ❑ Communication between devices to exchange useful information
- ❑ **IPv6 makes it possible**

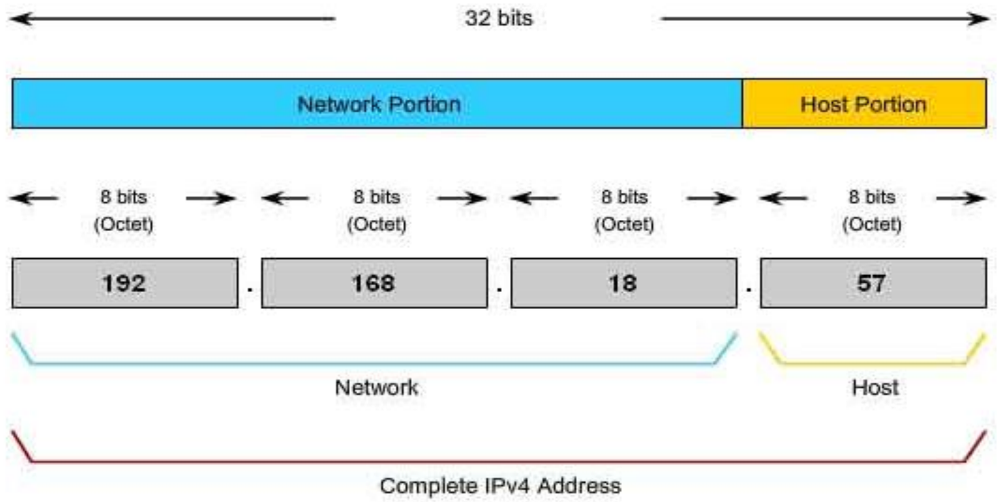
IPv4 (Internet Protocol version 4)

- Every device on the Internet must be assigned an IP address in order to communicate with other devices
- A global IP address is a unique identifier
- IP address is 32 bit (4 bytes) in length
- Only 4,294,967,296 (232) possible unique addresses (global ones)
- Dot Notation, 4 decimal numbers, each ranging from 0 to 255



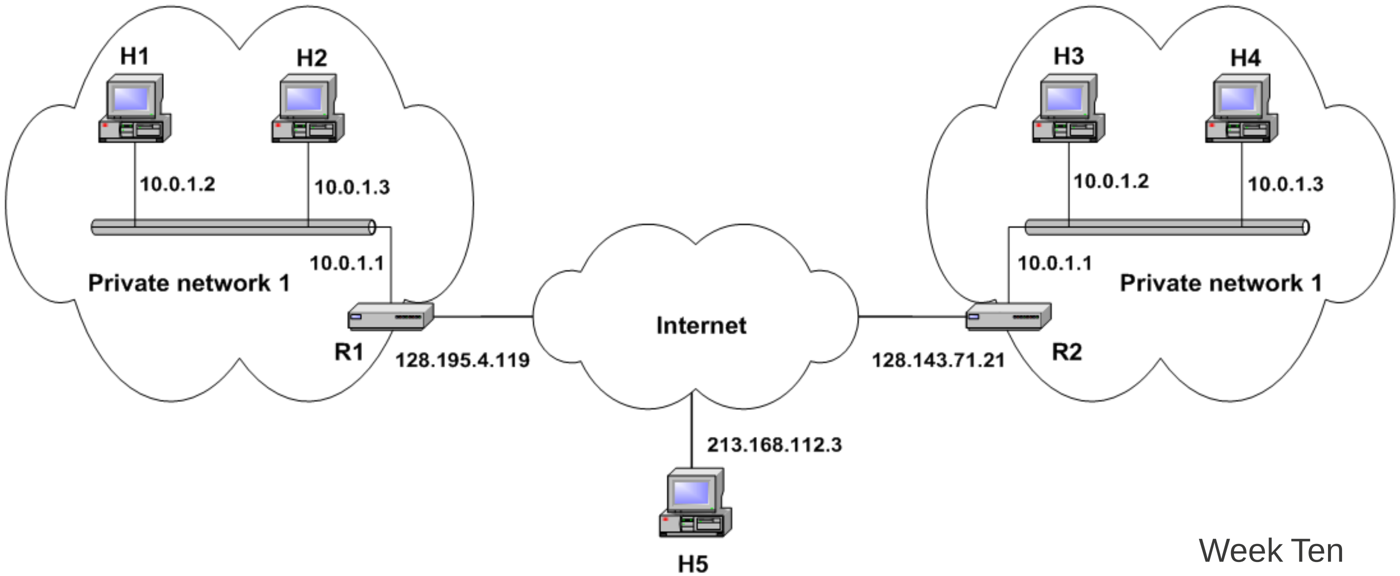
IPv4 Address Structure

- An IP address consists of:
  - Network Identifier (netid)
    It defines the network to which the data packets will be routed
  - Host Identifier (hostid)
    It defines which machine/host on that network
- Classful addressing (A, B, C, D): e.g. Class B address: **130.194.**7.10
- CIDR (Classless Inter-domain Routing): e.g. 192.168.100.0/22



Private Addresses

- ❑ Most hosts didn't require direct connectivity to other Internet hosts
- ❑ For this purpose, private addresses used (not globally unique)
  - Private addresses are reserved by Internet Assigned Numbers Authority (IANA)
- ❑ Private addresses are not reachable on the Internet (not routable)
- ❑ Private address ranges reserved by IANA
  - 10.0.0.0, 172.16.0.0, or 192.168.0.0
- ❑ To connect to Internet, private addresses translated into a public address



IPv6

- IPv4 Exhausted, started to run out around 1996
- Internet Protocol version 6 (IPv6) was developed to address the IPv4 problems
- Standard representation is set of 128 bits or 16 bytes
- The exact number of IPv6 addresses available is….

  "340,282,366,920,938,463,463,374,607,431,768,211,456"

  ~ 340 undecillion (!!) addresses

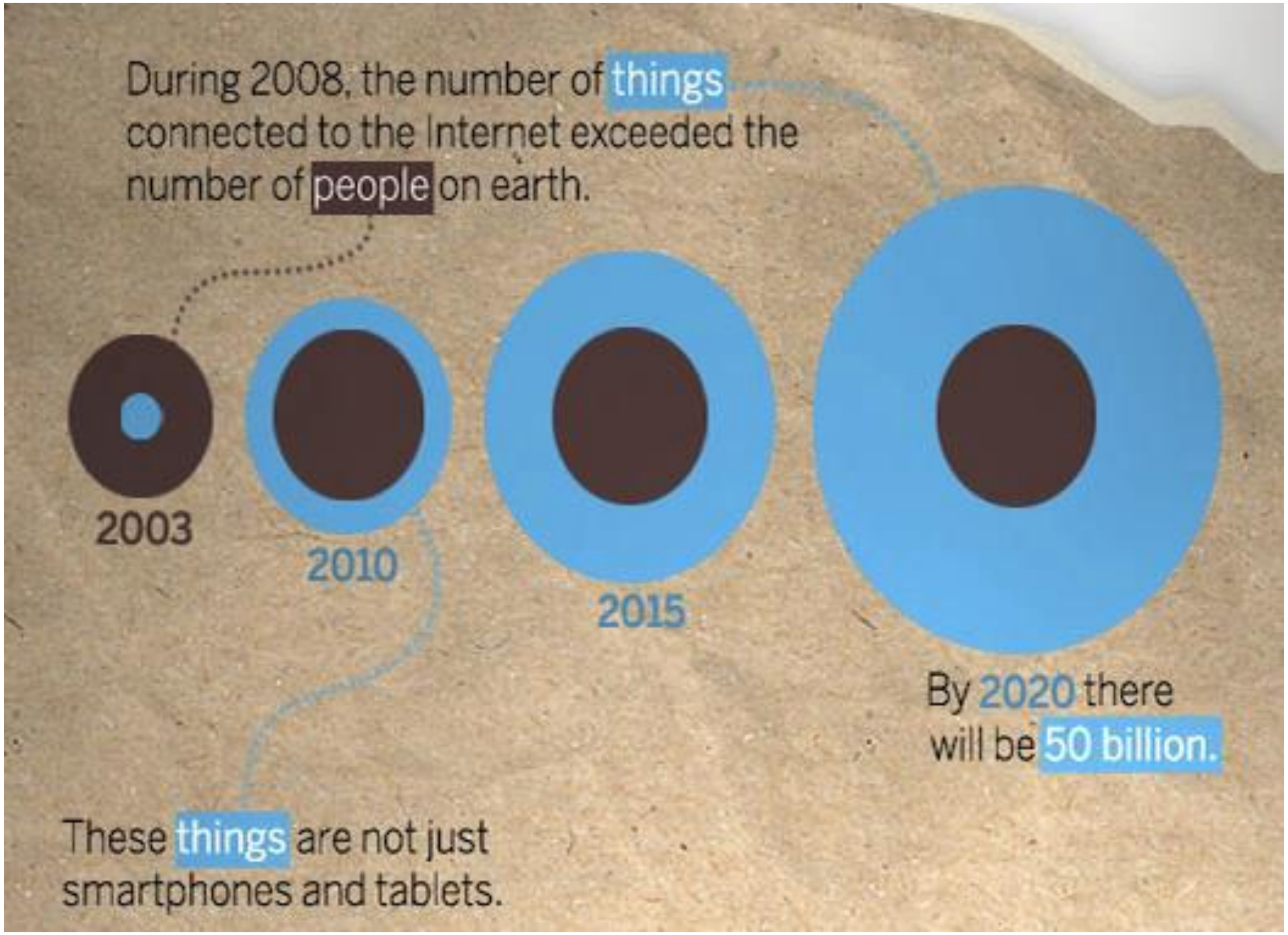
  e.g. 47CD:1234:3200:0000:0000:4325:B792:0428
- Smooth transition path from IPv4

Types of Things in IoT

- **Tagging things** that have identity and can be identified by other things
- **Sensing things** that use services and may have sensing capabilities
- **Computing things** that can initiate communication, do reasoning and make decisions
- **Things that can control**, coordinate, create, manage and remove other things
- **Internet of Everything** (IoE) Consists of: People, Data, Processes, Things

http://internetofeverything.cisco.com/vas-public-sector-infographic/

Numbers of connected things..



IoT Phases

- IoT phases:
- M2M phase (from 1990s to 2010)
  - Industrial applications connecting via proprietary networks to a data center (e.g. fleet management and asset monitoring)
- IoT silo phase (from 2010 to 2016)
  - Applications connected to the internet and cloud such as connected homes and cars, wearable computing
- IoT systems phase (since 2016)
  - To connect IoT silos (using cloud and network edges) to enable interconnected applications

(Steven Cook, 2016, Adobe Summit: IoT Moves Into ‘Systems’ Phase)

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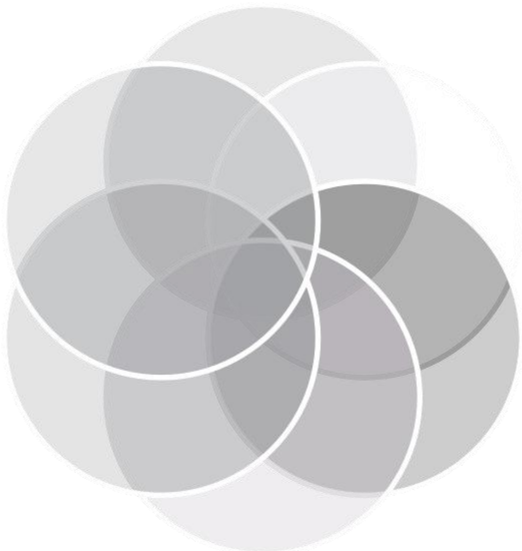
Smart Cities

Activity Recognition



Internet of Things (IoT)

(Mobile) Crowdsensing

Integrated Robotics

M2M

[Smart Cities Video]

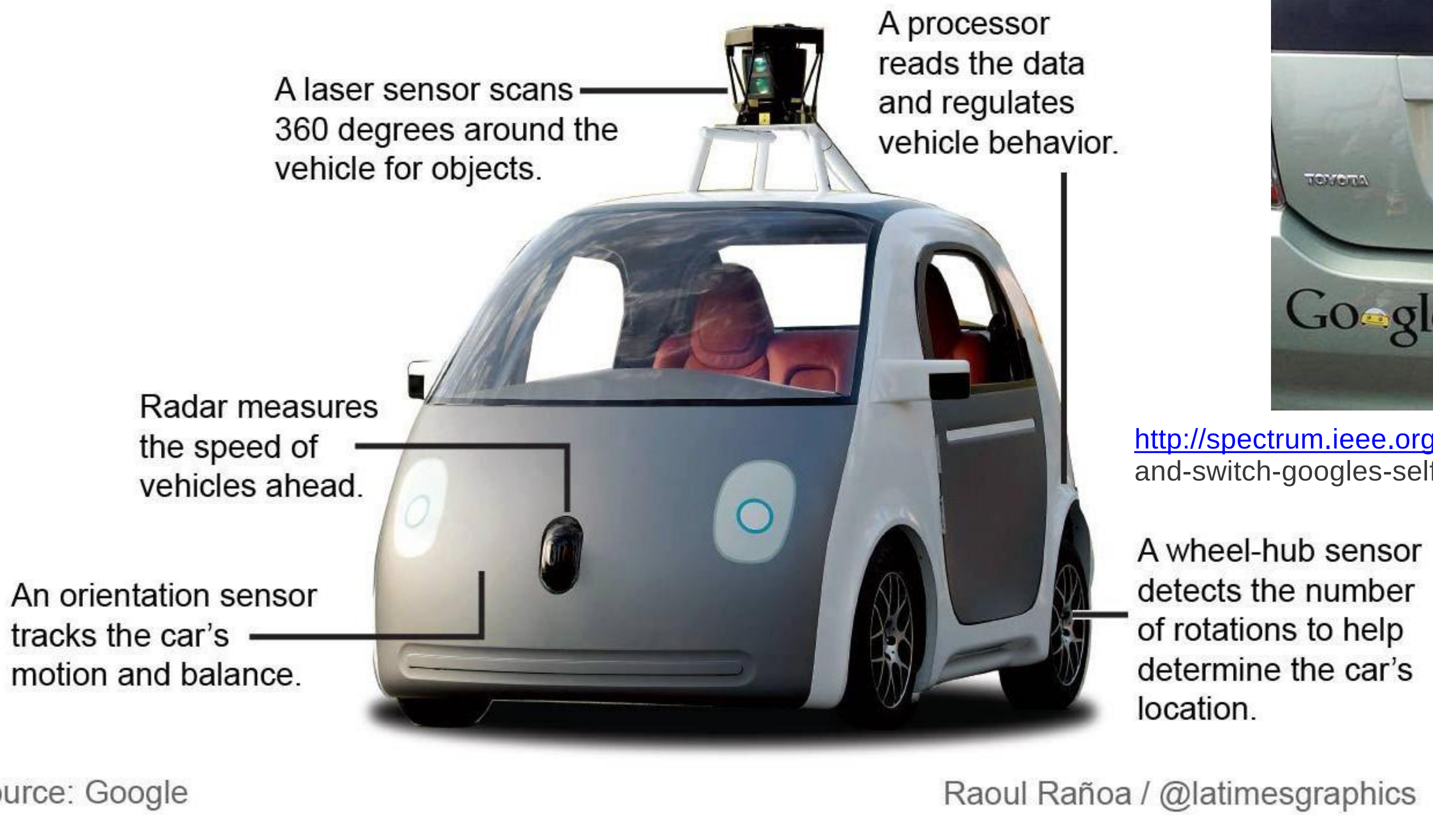
Smart context/situation aware Cities

- E.g. Barcelona : Sentilo (http://www.sentilo.io/wordpress/)

A platform that enables information generated by sensors distributed across the city to be gathered, used and disseminated
(Source: BCN Smart City)

A Current Example

- [Google self-driving car]
- "AU-001" is a historic license plate, the first one ever issued in the United States to an autonomous vehicle



http://spectrum.ieee.org/transportation/advanced-cars/plate-and-switch-googles-selfdriving-car-is-a-transformer-too

Google Physical Web

- ❑ The number of smart devices exponentially increasing, and not practical/possible to have an application per device

- ❑ The Physical Web by Google:
  - Introduced by Scott Jenson
  - It aims to let anyone interact with any device at any time without downloading an app first
  - An approach to enable interaction between devices on demand
  - Open source (on Github) https://github.com/google/physical-web
  - At the experimental stage
  - Google Physical Web

How does this work?

The Physical Web enables you to see a list of URLs being broadcast by objects in the environment around you. Any object can be embedded with a Bluetooth Low Energy (BLE) beacon, which is a low powered, battery efficient device that broadcasts content over bluetooth. Beacons that support the Eddystone protocol specification can broadcast URLs. Services on your device such as Google Chrome or Nearby Notifications can scan for and display these URLs after passing them through a proxy

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