Internet of Things: Opportunities and Challenges

Tutorial at WPMC2010, Recife, Brazil

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Outline (Parts I & II)

- Internet of Things
- Information shadow
- Identification
  - Barcode, RFID
  - Machine vision and biometrics
- Interaction
  - Natural interaction
  - Egocentric interaction
  - Embedded interaction
  - Tagging based interaction
  - Physical mobile interaction
- Data processing
- Introduction and Techniques
  - Definition
  - WSN
  - RFID
  - SMART Card
  - ..
- Challenges and Concerns

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Part I: IoT and Synergistic Technologies

- Finding information shadow

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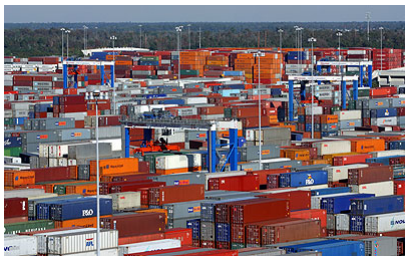
Internet of Things?

- RFID and a unique identifier for every object.
- Sensor data + machine learning (machine perception).
  - For example, use a phone to take a picture and let the phone etc. do the rest (T.O'Reilly and J. Battelle, 2009).



Internet of Things? – cont.

Santo Antônio church

Capibaribe river

Fusing the digital and the physical

(Ryhänen & Huopaniemi, 2006)

Internet of Things

- **A global system interconnecting physical and digital objects that are identifiable and may interact with each other and with users**.
- These objects, each with its own identity, are well beyond only computers and they are our cars, luggage, household applicants, humans and so on.
- The objects may use sensors to gather information from their surrounding and/or use actuators to interact with it.

Internet of Things – cont.

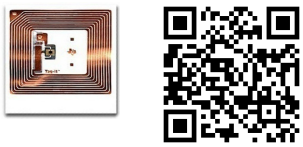
- The inclusion of non-computer objects is the most significant step from the Internet towards the IoT.

(Z.-H. Tan, 2010)

- How to identify them?
- How to interact with them?

Identification

- These objects can be identified via
  - the augmentation of tiny devices like RFID, barcode;



  - natural feature identification e.g. biometric-based identification (CASAGRAS Final Report, 2009).

Interaction

- Interaction with daily objects includes a few new elements, e.g.,
  - no keyboard and mouse available;
  - the user focusing on other tasks in hand and leaving reduced attention for interaction.

- Interaction should be natural, effortless and even invisible.
- Interaction that analogizes the real-life physical interaction may be favored to reduce cognitive load.

Technologies related to and enabling IoT

- Sensor networks: need not necessarily be connected to the Internet
- Ubiqitous positioning: technologies for locating objects
- Biometrics: technology for recognizing people and other living things
- Machine Vision: an approach for monitoring objects (e.g., cameras on cell phones)

SYNERGISTIC Technologies

(Albena Mihovska)

Other Synergistic Technologies

- Geotagging
- Robotics
- Augmented Reality
- Electronic media and virtualization (mirror worlds)
- Telepresence and adjustable autonomy
- Life recorders and black boxes
- User interfaces

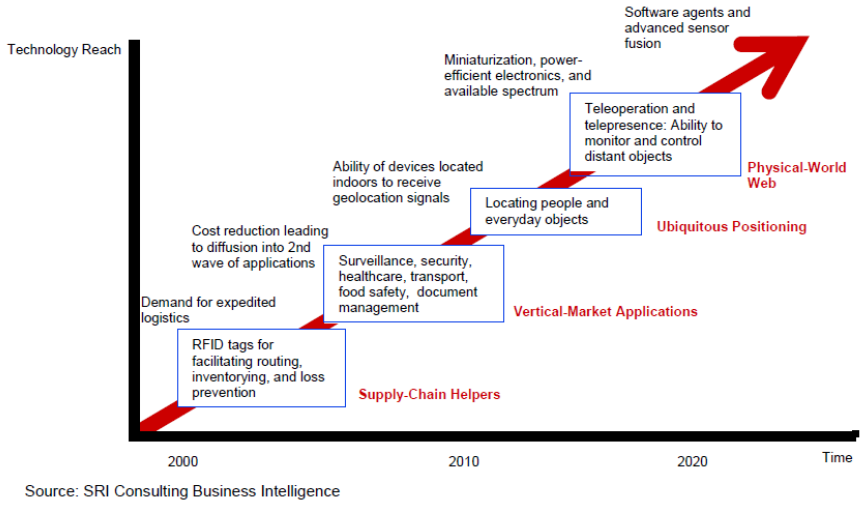
(Albena Mihovska)

Key Uses and Instantiations of IoT

- Retail and logistics
- Product management
- Surveillance
- Smart buildings and green buildings
- Telematics
- Telehealth

(Albena Mihovska)

IoT: Technology Roadmap



Source: SRI Consulting Business Intelligence

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Growth of the digital world

- Our work and life are increasingly dependent on the WWW, which is now beyond a collection of static HTML pages that describe scattered things in the world.
- Growingly, the Web is the world, meaning everything and everyone in the world casts an information shadow in the digital world.

(O'Reily and Battelle, 2009)

Information shadow

- "The significance of technologies like RFID and 2D barcoding is that they offer a low-impact way to 'import' physical objects into the datasphere, to endow them with an informational shadow."

– Greenfield, Adam. Everyware, 2006

Information shadow – cont.

- Information shadow: every identified object exists simultaneously in the physical world and in the world of data.
- "Wireless networking means that we can now instantaneously see the world of information shadows as we're interacting with the world of objects."
  - Mike Kuniavsky, 2009

Finding shadow isn't easy

- "Peter Pan had to find his shadow! He had left it behind the last time he had visited the Darling nursery."
- Finding the information shadow has not been easy, but now opportunities open up.
  - Enabling technologies such as RFID tags or ZigBee modules
  - Synergistic technologies

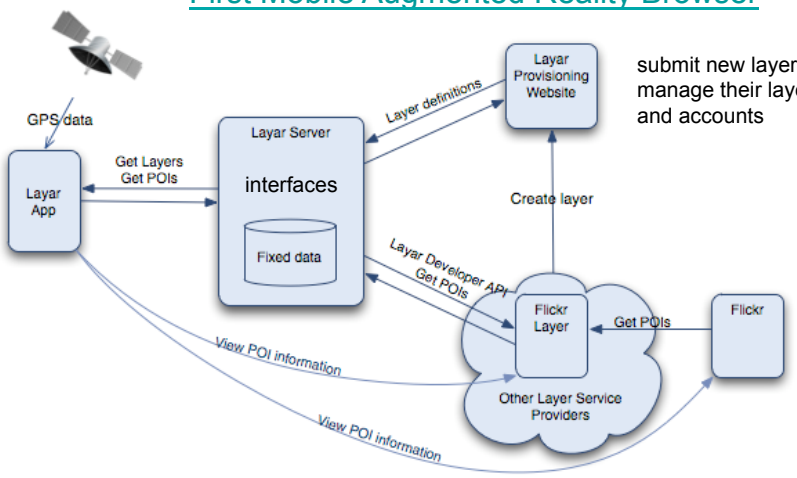
Finding shadow is possible

- Augmented physical objects
  - Radio communication: RFID, NFC, Bluetooth, WLAN
  - Visual markers: barcode
  - Localization: GPS
- Non-augmented objects
  - Computer vision
  - Audition

Youtube video

Layar

First Mobile Augmented Reality Browser



http://layar.com/ : founded in June 2009 in Amsterdam

Layar – cont.

- Superposition of multiple layers: Reality, Design Layout, Point of Interest (POI)
- Layar browses ressources on the server to display the POI.
- Layar uses the HTTP GET request (Requests a representation of the specified resource. A simple action of retrieval.)
- Layar allows the creation of layers by developers. No license costs involved creating a layer.

Layar – cont.

- 500 layers developed by from individuals to small enterprises to large companies; 2000 layers in development.
- Over 1 million active end-users.
- Applications for marketing.
- Support all Android devices and the iPhone 3GS. A Symbian version is in development. Need internet connection, camera, GPS and compass.
- Possibilities to combine with barcodes and RFID.

The world is my interface

- Mobile devices can be used to interact with the "Internet of Things".

Sensors in smartphones to revolutionize the UI:
- microphones
- cameras
- motion sensors
- proximity sensors, and
- location sensors.

Many application examples

http://www.lucidproject.org/

25

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26

Identification

- Due to such reasons as cost or form factor, RFID cannot be used for augmenting all objects.
- Sensor networks and smart mobile devices.
  - Visual tagging, e.g. 2D barcode, can be used for tagging and many mobile phones with cameras are now able to read 2D barcodes – a cheap solution, no requirement for power supply, usually battery.
  - Natural feature identification techniques, e.g. object recognition, are important alternatives, which enable tremendously more things to be able to join the IoT.

Barcode

- An optical machine-readable representation of data.
  - 1D barcode: representing data in the widths (lines) and the spacing of parallel lines.
  - 2D barcode: representing data in patterns of squares, dots, hexagons and other geometric patterns within a 2D image.

1D Barcode – Code 39

- Always starts/stops with a star (*).
- Encode A-Z characters, 0-9 digits and 7 special characters (-, $, %, . , /, +,)
- Each character is divided into 9 elements (5 bars and 4 spaces). Only two sizes for elements: thin or wide. 3 of the 9 elements are wide (value 1), and 6 elements are narrow (value 0). Also known as 3 of 9 barcode.
- No check digit, but a single erroneously interpreted bar cannot generate another valid character.
- http://www.terryburton.co.uk/barcodewriter/generator/

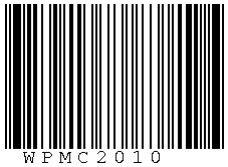
Barcode vs. letters

A B C

1D Barcode – Code 93

- To provide a higher density and data security enhancement to Code 39.
- A start character *, Stop Character *, Termination bar
- Each character is divided into 9 modules (what about code 39?) and always has 3 bars and 3 spaces, thus the name. Each bar and space is from 1 to 4 modules wide.
- Two check characters which are referred to as "C" and "K". The "C" checksum character is the modulo 47 remainder…

ID	Character	Widths	Binary
0	0	131112	100010100
1	1	111213	101001000
2	2	111312	101000100



30

1D Barcode – EAN

- EAN-13 barcode
  - Originally "European Article Number", but now renamed ”International Article Number”; the abbreviation has been retained.
  - A derivation of Universal Product Code (UPC).
- Composed of a number of digits (12+1)
  - 2-3 digits for the country code.
  - the manufacturer code.
  - the article number.
  - 1 digit to check the integrity of the barcode.

1D Barcode – EAN

- Examples of some country codes :
  - US : from 000 to 060 (or 2 digits 00 – 60)
  - France : from 300 to 379
  - Uzbekistan : 478
  - Denmark : from 570 to 579
  - China : from 690 to 695
  - Bulgaria : 380
- It does not always represent the production country but it may be the country where the company is based in.

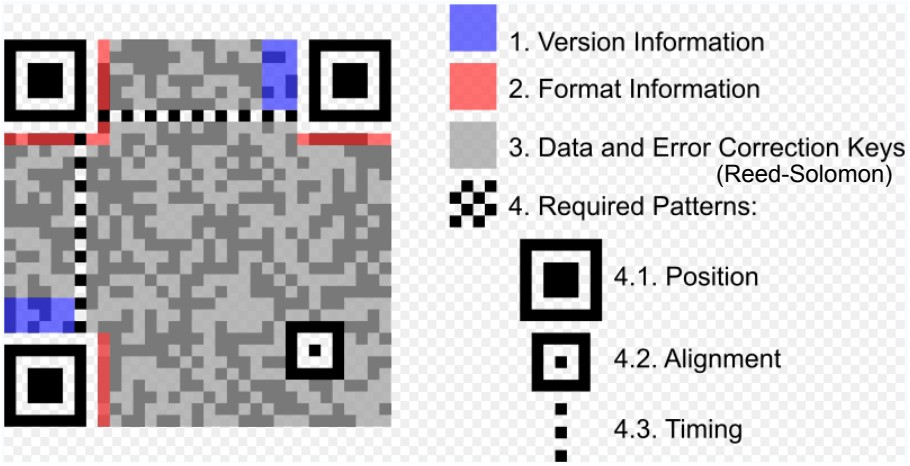
2D Barcode

- A two-dimensional way of representing information.
- Also called matrix code.
- Various types
  - 2D QR (Quick Response) code
  - 2D data matrix
  - …

2D QR barcode

- 2D QR code is composed of different zones:
  - Finder Patterns which are used to detect the position of the QR Code.
  - Timing Patterns which are used to identify the coordinates of the different symbols .
  - The encoded data zone.
  - The format information zone which basically contained the error correcting level and the mask pattern.

2D QR barcode – cont.



Wikipedia.com

2D QR barcode – cont.

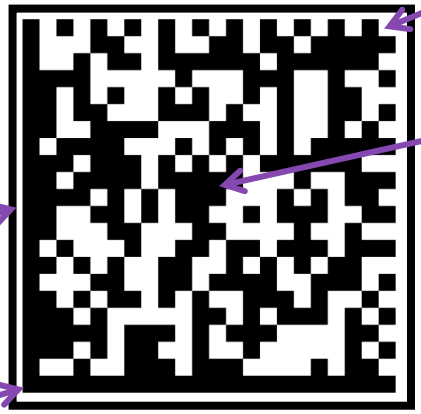
http://kom.aau.dk/~zt

Tel. +45 99 40 86 86

New Window
Save As ...
Print
Exit

http://qrcode.kaywa.com/

2D Data Matrix barcode



The open boundary for identifying the number of rows and columns

The message area

The clear zone surrounding the data matrix code

Max capacity
QR: 1.5kB
Data matrix: 3kB

The fixed boundary for calculating the rotational position of the data matrix code

Barcode readers

Typical Wand or Contact Scanner

- Contact wands:
  - Use a photodiode
  - Use LED as a light source
  - Placed in contact of the barcode and moved across it
- Active non-contact reader:
  - Use laser
- Passive non-contact reader:
  - Use a row of charge-coupled device (CCD)
  - Use ambient light

Camera-based readers

- An array of CCD sensors
- Example – for QR code (print one yourself through http://mobilecodes.nokia.com/create.jsp)

- Download the software to read on your camera, for example:
  - Nokia : http://mobilecodes.nokia.com/scan.htm
  - iPhone : iPhone Apps – QuickMarkLite or 2D Sense
  - Google Android: Android Market place – barcode scanner

39

Barcode

- Cheap, 0.5¢ (U.S.) for a barcode versus 7¢ to 30¢ for passive RFID tag, 20-40$ for active RFID tag.
- Well understood, robust (providing redundancy mechanism)
- Applications in manufacturing, logistics, sales, etc.
- With the common use of mobile phone, 2D barcodes will become the most spread ones.
- Not only will they be used to identify products but also to communicate (SMS, URL, contact cards).
- Low cost, simplicity and universality of barcodes has limited the role of other systems in Auto ID Data Capture (AIDC).
- Likely to be used in conjunction with RFID for the foreseeable future.

40

1D versus 2D

Barcode type	Information density	Information capacity	Information type	Dependence on database	Nature
1D	Low	Small	Numbers, English	Must depend on database or communication network	Object label & index
2D	High	Big	Numbers, English, Chinese, pictures, voice and other binary information	No depend on database or communication network	Description on objects

Source: syscantech.com

Compact Matrix Code (CM) with 32kB max capacity, useful for storing biometric data.

41

2D barcode VS other automatic identification technologies

Information media	Magnetic card	OCR identification	Biological identification	RFID	2D barcode
Identification speed	0.3 – 2s	4 – 8s	1 – 5s	0.3 – 0.5s	0.3 – 1s
Bit error rate	Up to life of magnetic media	1/ 1,000	1/300	Up to noise and angle	1/1,000,000
Technical advantage	Portable and data rewritable	Quick in image and symbol operation	Non-counterfeitable	Quick and batch processing	Quick and accurate
Print cost	Intermediate	Low	High	Very high	Very low (only ink cost)
Sample					

Source: syscantech.com

42

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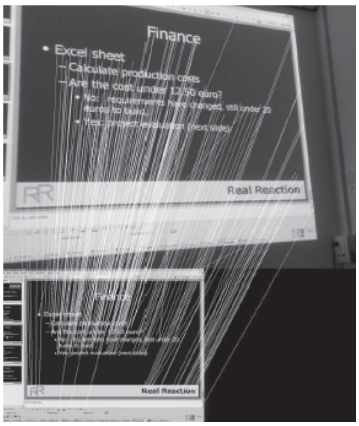
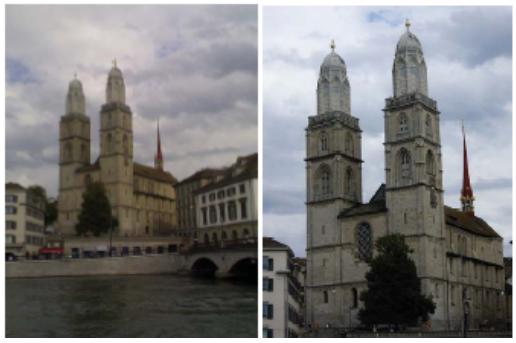
Machine vision for identification

- Marker-based identification & interaction
  - Wireless tags integrated in or attached to the object
  - Visual markers such as barcodes (computer vision)
- Identification & interaction without a marker
  - To request information on objects by taking a picture of them, hyperlinking physical objects with digital world.
- Object recognition
  - Objects not suited to attach markers
  - To request information from distance
  - Information screens

Hyperlinked slides and buildings

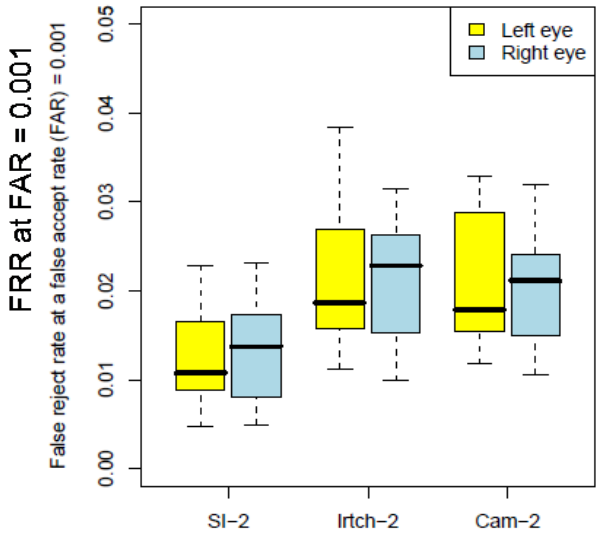




Compare with Layar.

(Quack, et al., Internet of Things 2008 Conference)

State-of-the-art for face recogntion

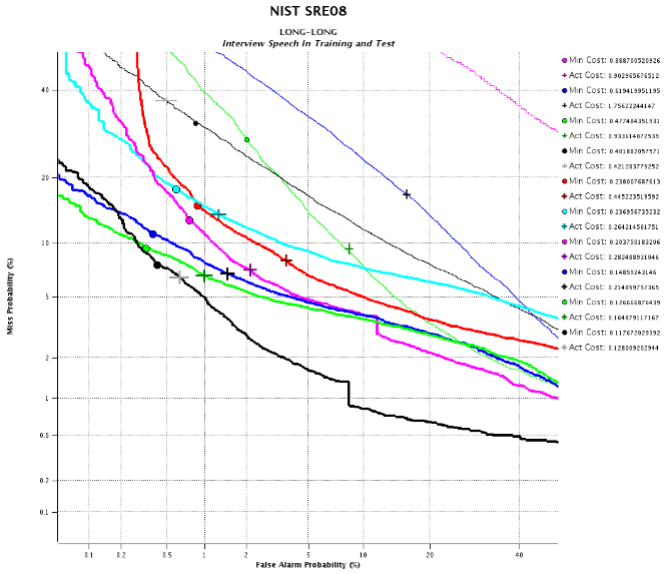


•False rejection rate vs false acceptance rate.
•Better than human.

0.01

2006
FRVT 2006
(Fully Automatic)

Voice biometrics



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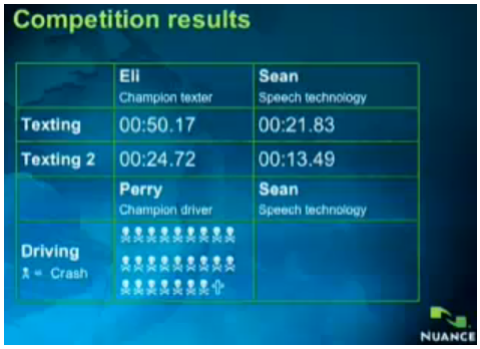
Interaction

- Interaction should be natural, effortless and even invisible.
- Speech recognition for mobile devices etc.

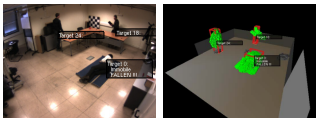
(Z.-H. Tan and B. Lindberg, Springer, 2008)

http://www.youtube.com/watch?v=jHz0DaXPLgw

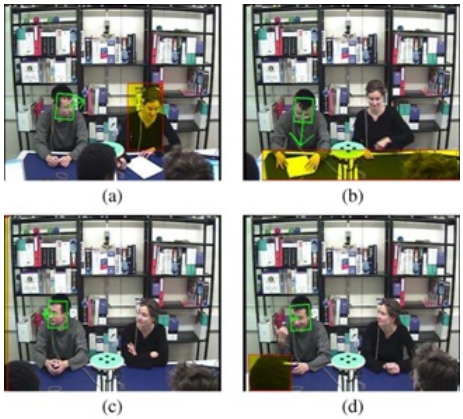


Human tracking

- Visual focus of attention
- Eye-gaze tracking



(M. Andersen, R. S. Andersen, N. Katsarakis, A. Pnevmatikakis and Z.-H. Tan, 2010)

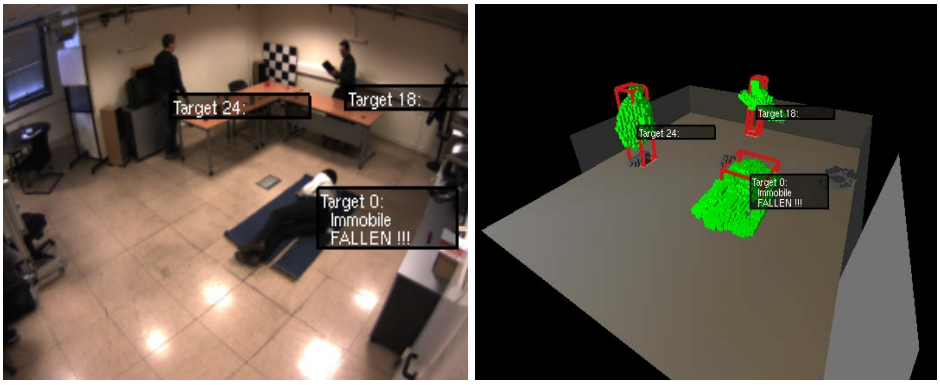


(Ba and Odobez, 2009)

Three-dimensional sensing of persons

a) an image with persons and information overlay

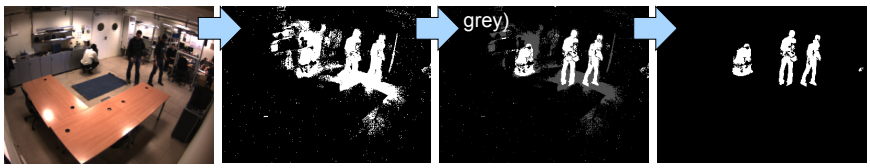
b) detected foreground and information.



(M. Andersen, R. S. Andersen, N. Katsarakis, A. Pnevmatikakis and Z.-H. Tan, 2010)

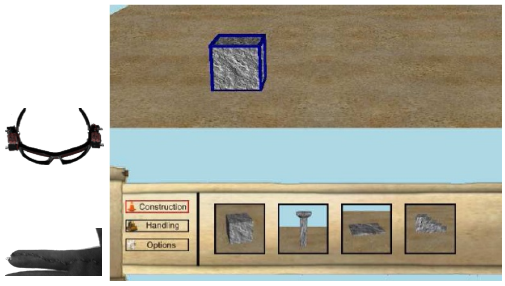
Foreground: Per Camera in 2D

- Problem with per-pixel approaches
  - Shadow
  - Noise



Egocentric interaction

- Exploits the spatial relation between user and device and uses changes in this relation as input commands.

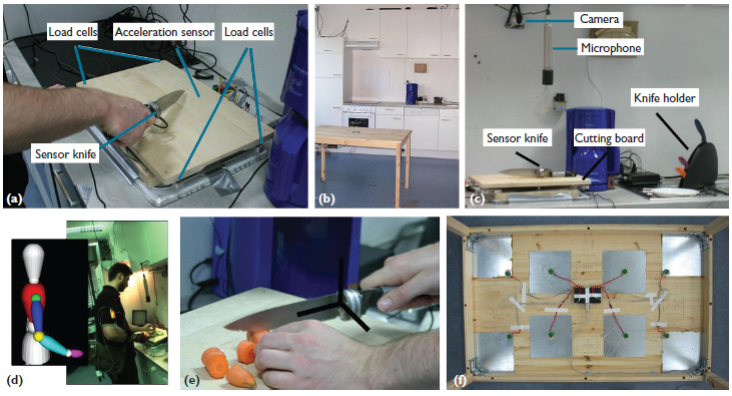


(T. Luel and F. Mazzone, 2009)

(M.H. Justesen, et al. 2010)

Embedded interaction

- Networked gadgets with sensors and actuators are embedded into daily objects such as cutting board, knives and tables in a kitchen environment



(M. Kranz, P. Holleis and A. Schmidt, 2010)

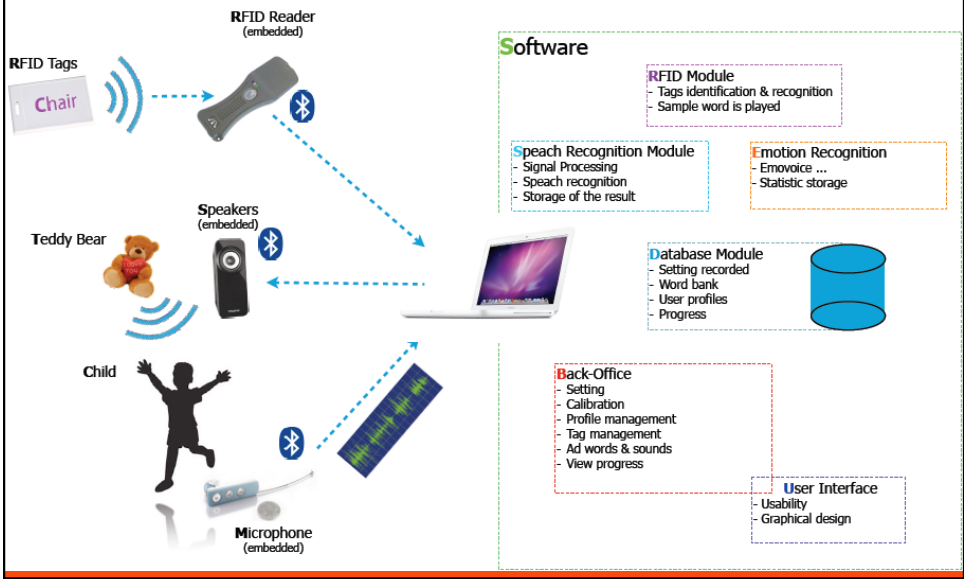
Interaction through tagging

- (RFID, barcode) tagging can make interaction and finding information shadows much easier by eliminating the need for human inputs or interferences.
- Nabaztag:tag and Mir:ror are two interesting examples of interaction through tagging developed by http://www.violet.net.

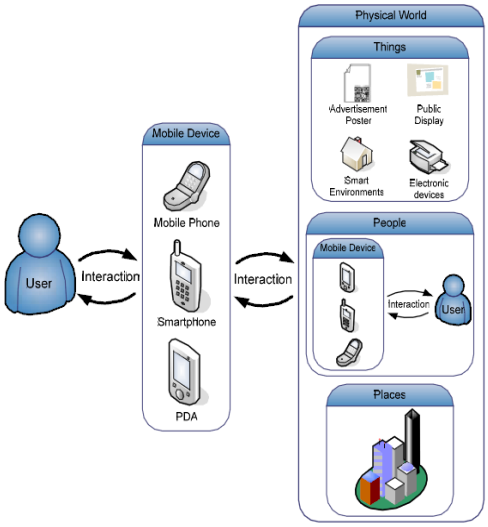
http://www.youtube.com/watch?v=NruxD1ZDdig

55

Toy for Autisms Children

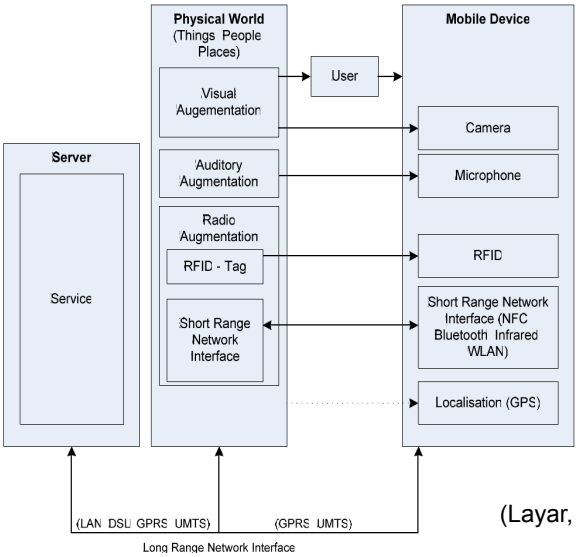


Physical mobile interaction



(Rukzio)

Physical mobile interaction – cont.



(Rukzio)

(Layar, also an example)

Physical mobile interaction – cont.

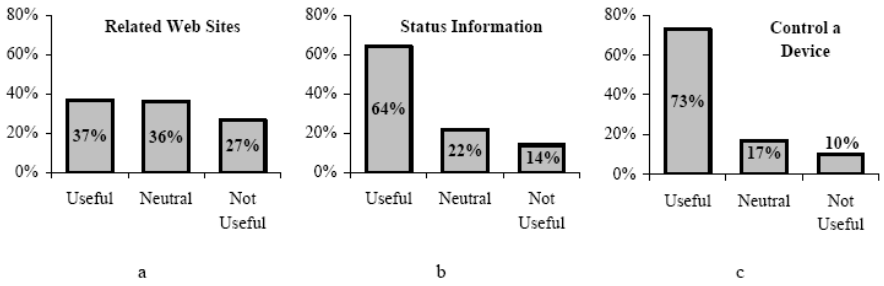


Figure 19: Results of the online survey regarding the usefulness of predefined application areas for mobile interactions with objects in smart environments.

(Rukzio)

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Data Overload

- Sensors and readers can potentially produce hundreds of events per second.
  - A huge amount of data left unprocessed – simply occupying storage space with no use.
- Multimedia data, especially camera sensor continuously generating high-dimensional data.
  - In surveillance and security, lots of human resources
- If Wal-Mart tags things at item level, it would result in 7+ million terabytes of data per day.
- Requirement of filtering and intelligent data handling collectively.

Data processing

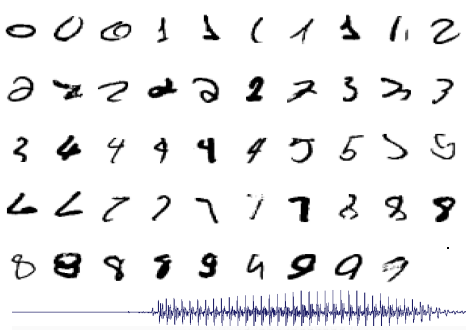
- ”Data is the ’Intel Inside’ of the next generation of computer applications” (O’Reily & Battelle, 2009).
- Important to discover metadata, and then foster an ecosystem around it.
- Rich context and user behavior modeling.
- Data analysis, visualization, and pattern finding techniques are increaseingly valuable.
- Mapping from unstructured data to structured data.
- Machine learning and data fusion.

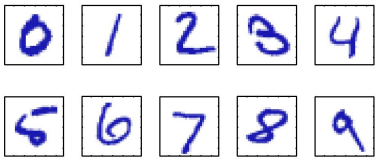
Machine learning

- Machine learning
  - Concepts, supervised learning, unsupervised learning
- Memory-based learning
- Model-based learning

For more details, see http://kom.aau.dk/~zt/cources/Machine_learning
User name: ml; password: aau.

Classification examples

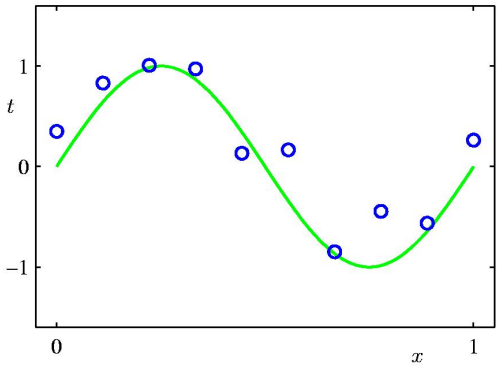




It's not easy to recognize speech.
It's not easy to wreck a nice beach.

Regression example

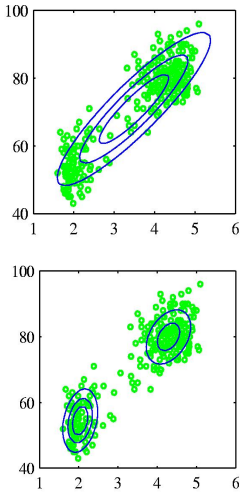
Polynomial Curve Fitting

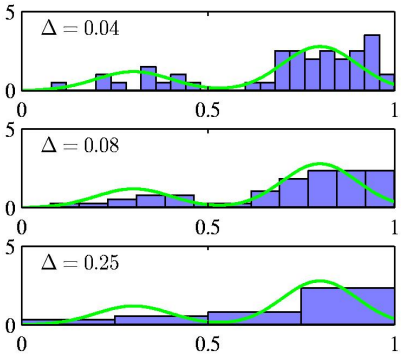


from Bishop

$$y(x, \mathbf{w}) = w_0 + w_1 x + w_2 x^2 + \ldots + w_M x^M = \sum_{j=0}^{M} w_j x^j$$

Density estimation examples





from Bishop

Types of machine learning

- Supervised learning: given inputs along with their corresponding outputs, find the 'correct' outputs for test inputs
  - Classification: 1-of-N discrete output (pattern recognition)
  - Regression: real-valued output (prediction)
- Unsupervised learning: given only inputs without outputs as training, find structure in the space
  - density estimation
  - clustering
  - dimensionality reduction

Data fusion techniques

- Data-level fusion
- Feature-level fusion
- Decision-level fusion
- Hybrid fusion
- Intermediate fusion

Summary (Part I)

- Internet of Things
- Information shadow
- Identification
  - Barcode, RFID
  - Machine vision and biometrics
- Interaction
  - Natural interaction
  - Egocentric interaction
  - Embedded interaction
  - Tagging based interaction
  - Physical mobile interaction
- Data processing

References are available in

Z.-H.Tan, “Machine Perception for Identification and Interaction in the Internet of Things,” WPMC2010.

Summary (Parts I & II)

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- Introduction and Techniques
  - Definition
  - WSN
  - RFID
  - SMART Card
  - ..
- Challenges and Concerns

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