



## Redundant vs. Imperfect Positioning for Context-dependent Services

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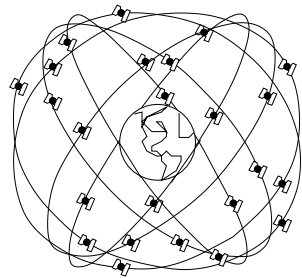
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[until 2003 Fraunhofer  in Berlin, Germany]

- ■ Positioning as a driving factor for ubiquitous / pervasive applications
- ■ numerous technologies / devices developed in the lab
- ■ few of them are actually used commercially
  
- ■ some combinations and fusion approaches described – typically 2 technologies
  
- ■ pervasive, extremely cheap devices
- ■ visual tracking / recognition
- ■ biometrics
- ■ wireless coverage
  
- ■ new quality of interworking position and context aware systems
- ■ massive redundancy
- ■ synergetic heterogeneity
- ■ self-learning and self-healing vs. misleading, wrong and outdated information
- ■ tailor positioning + confidence to application requirements

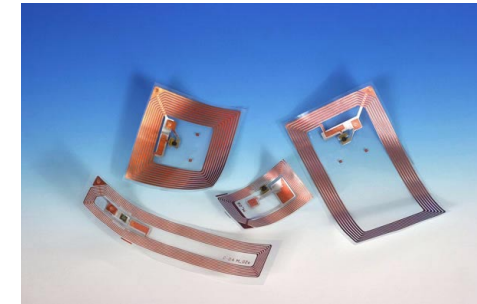
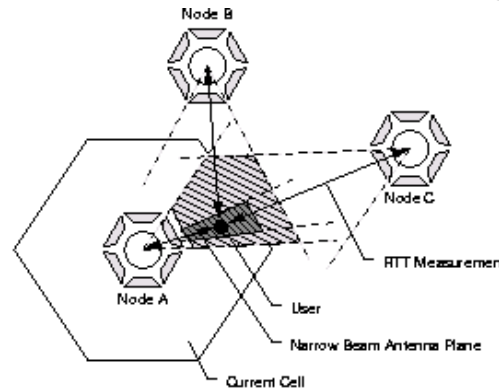
## Widespread commercial systems

Radar (ships, aircrafts)



GPS

GSM/3G cell/subcell positioning



RFID  
(transponders used for decades,  
new momentum with EPC)

## Location inference

technologies not primarily developed for this purpose, but bearing implicit information

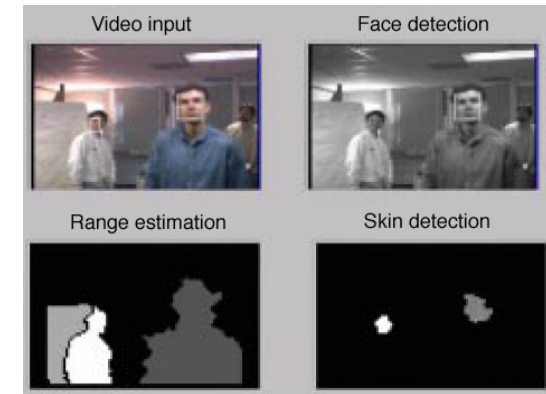
- readers (at fixed positions) for magnetic swipe cards or chip cards
- network addresses (IP, MAC) can be mapped to positions
- Wifi software positioning  
(cellular access points, signal strength triangulation, mapped signal fingerprints)
- Bluetooth devices can be recognized in proximity to each other

## Niche markets and laboratories

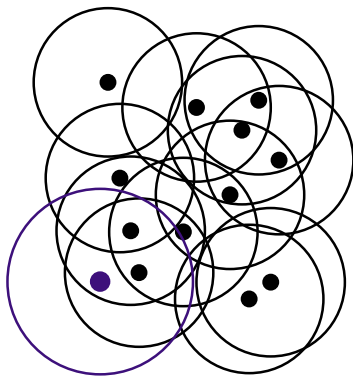
Ultrawideband Positioning  
(Ubisense)

Biometric devices

Weight/force measuring  
(Active Floor, Smart Carpet)



Visual Tracking/Recognition



Wireless Sensor Networks



Active  
Badges  
(Infrared)

Ultrasonic Devices  
(Active Bat, Cricket Compass)

## Fusion of location data

■ “the use of multiple location systems simultaneously to form hierarchical and overlapping levels of sensing ... to increase accuracy beyond what is possible using any individual system” [Hightower/Borriello]

### Single device fusion:

PointMan™

- GPS + Dead Reckoning
  - tilt-compensated magnetic compass,
  - electronic pedometer and
  - barometric altimeter

- designed exclusively for personnel on foot.

3.1" = 7.9 cm

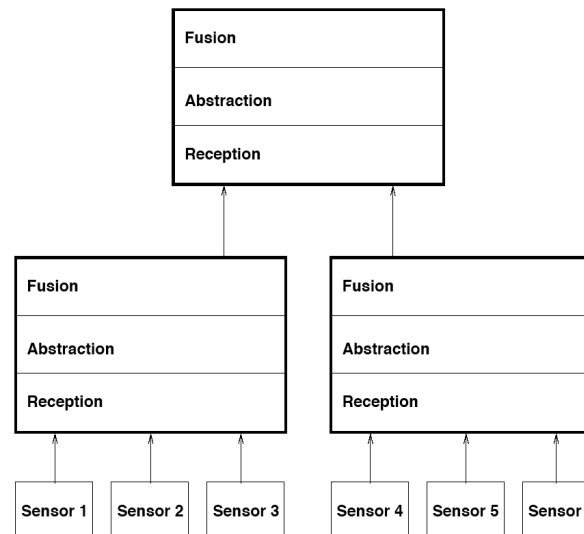


DRM<sup>®</sup>-III OEM Module

### Recursive Location Fusion

[Leonhardt/Magee  
Imperial College, London]

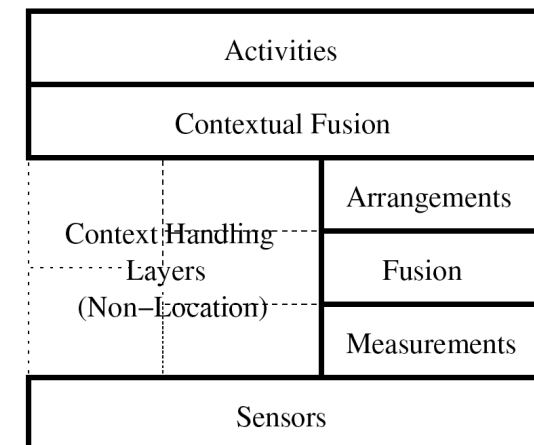
- three layer stack
- can then be layered on to its self



### Six layered model

[Hightower/Borriello, Intel research]

- OSI-network-layer inspired
- location sensor as well as context information fusion
- proposed as a replacement to “monolithic” systems
- applied to IR / Ultrasound fusion



## Imperfection

■ Errors  
and misleading information

■ Confidence:  
multiple aspects: not a  
single percentage value

■ Human recognition

■ Technical application

■ different classes of errors occur:

- geometrical uncertainties, dilution of precision (the only class considered so far)
- mismatch of temporal expectations (temporal validity)
- change of relation between objects (incidentally or intentionally)

■ large number of individual characteristics: facial properties, size, typical glasses, style of clothing, voice, ...

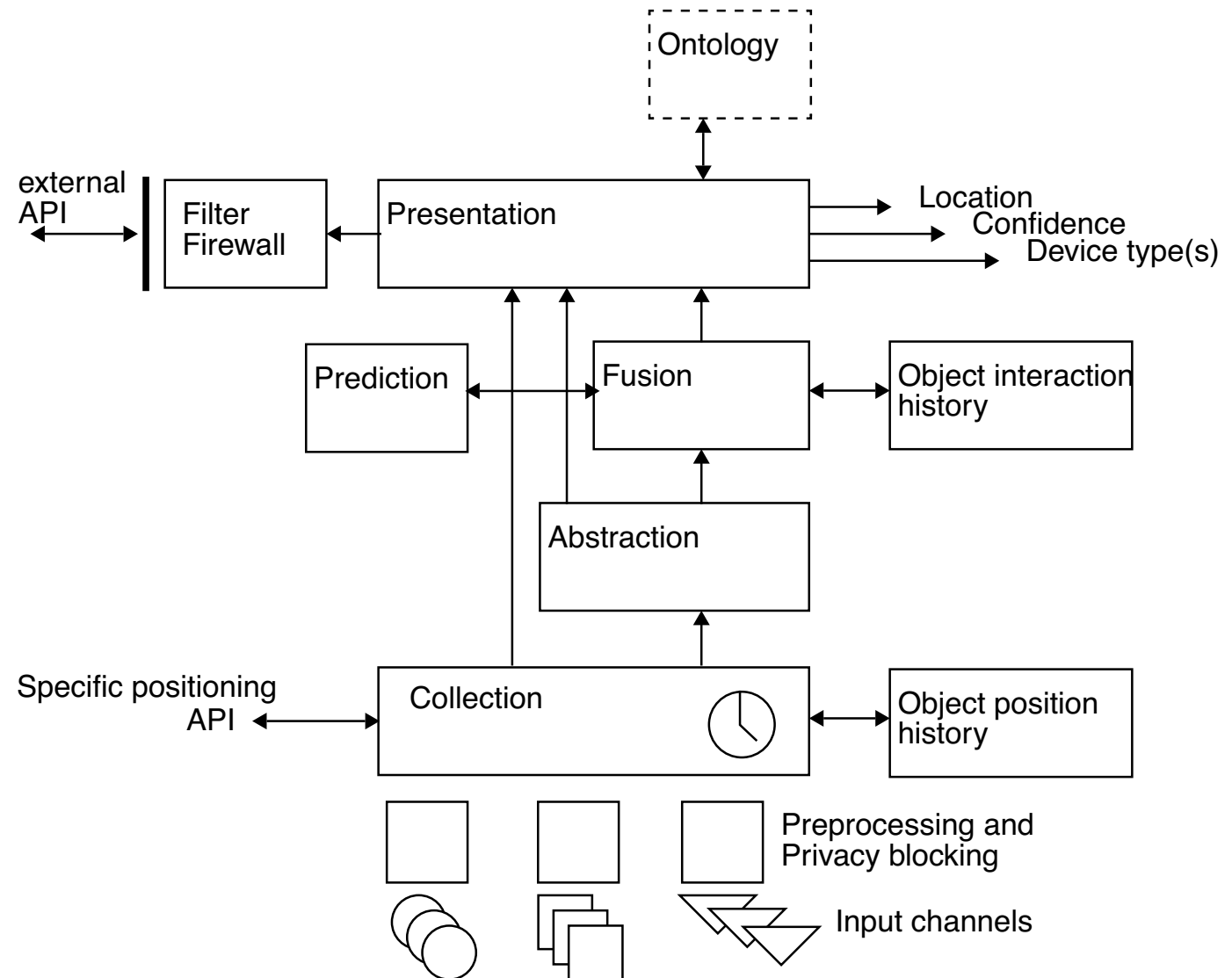
■ if one of these properties does not match,  
– recognition succeeds due to the *redundancy* of the other,  
– compensating misleading information  
– adjust in a learning process to new values, e.g. the new hair cut or other clothing.

■ *redundant positioning*

- vast amount of sensing nodes of different kind
- contributing to the whole image, consideration of misleading and wrong information

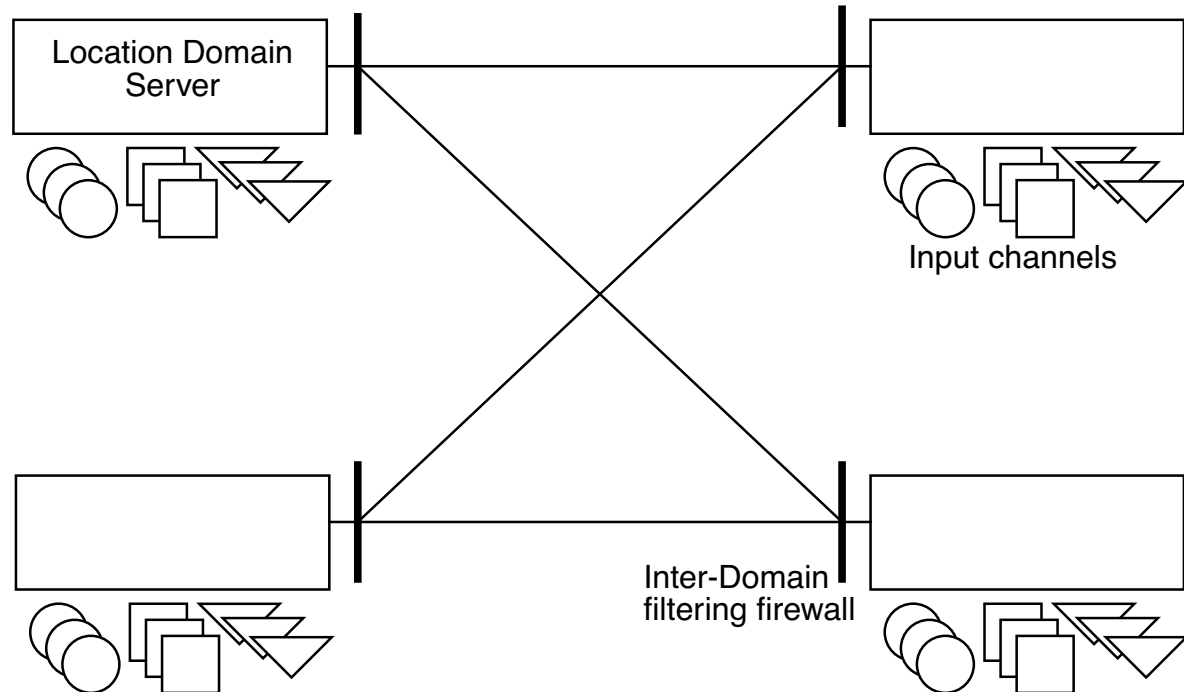
## Redundant Positioning Architecture

- deriving positions from all existing and specific systems



## Inter-Domain communication

- loosely coupled cooperating domains
- peer to peer location information network
- message format / protocol for heterogeneity of data:
  - positions (geographical, room-relative, mapped)
  - characteristics of objects (RFID, visual image, extracted features, measurements, etc.)
  - biometric data sets,
  - object interactions
- filtered and firewalled (different authorization levels)



## Security and privacy

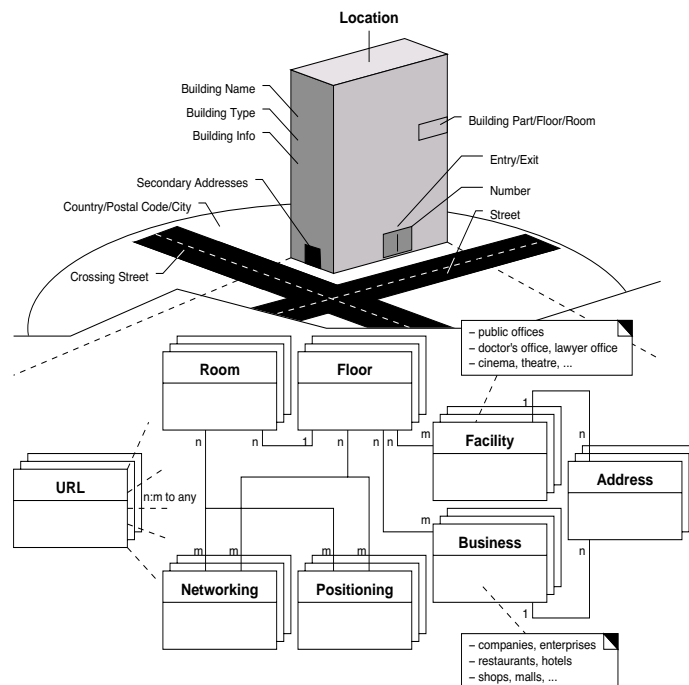
- data collection – where acceptable?
- early avoiding of unnecessary collection
- filtering and firewalling, restricted access



## Testbed at Waterford Institute of Technology

- ■ ■ Exploiting all these sources  
→ critical mass of  
redundant data for  
implementation and  
experiments
- ■ ■ Wifi positioning technology (software based) already  
deployed in WIT campus, used for mobile group-  
interaction experiments together with psychologists  
(NOMAD), adding triangulation hardware now
- ■ ■ existing partnership with O2 GSM/GPRS operator:  
sub-cell location data for campus area  
nearly complete penetration of GSM/GPRS handsets  
among the students
- ■ ■ GPS devices
- ■ ■ Ultrawideband positioning in office spaces
- ■ ■ RFID reader technology is being installed at  
numerous points around the campus,  
tags dispensed in a large number  
(mobiles, office property, teaching material, etc.).
- ■ ■ Visual tracking cameras for selected labs
- ■ ■ dual Swipe/Smart Card campus card in use, cash  
debiting in a central database → data about the  
specific cash terminal as positioning
- ■ ■ patch-panel database for IP connection

## Research and Implementation



## Data model

- different areas of interest:
  - 10 cm within a building distinguishes two rooms
- Location model required:
  - longitude / latitude
  - different geodetical models of the earth
  - mapping to street locations
  - floor / room / sub-room addressing within the building

## Modelling

- different fusion algorithms
  - evaluation of approaches in logistics
- ## Mathematical Analysis and Simulation

- processes a vast amount of data
- Traffic analysis
- continuity and timeliness of the arriving data

## Interworking with other classes of context