Instrumented Environments

Andreas Butz, butz@ifi.lmu.de, www.mimuc.de

Mon, 10-12 Uhr, Theresienstr. 39, Room E 46

Topics Today

- Some more positioning technologies
  - Camera-based tracking
  - Magnetic and ultrasonic tracking
  - Floor sensors
  - Points of view
    - Inside-out
    - Outside-in
- Wearable Computing

Camera-based Tracking

- Try to detect:
  - Objects directly (people, landmarks, features, textures)
  - Fiducials (e.g., 2D-Barcodes)

- Problems
  - Image processing is still hard
  - Mostly not very robust

CyberCodes (Rekimoto2000)

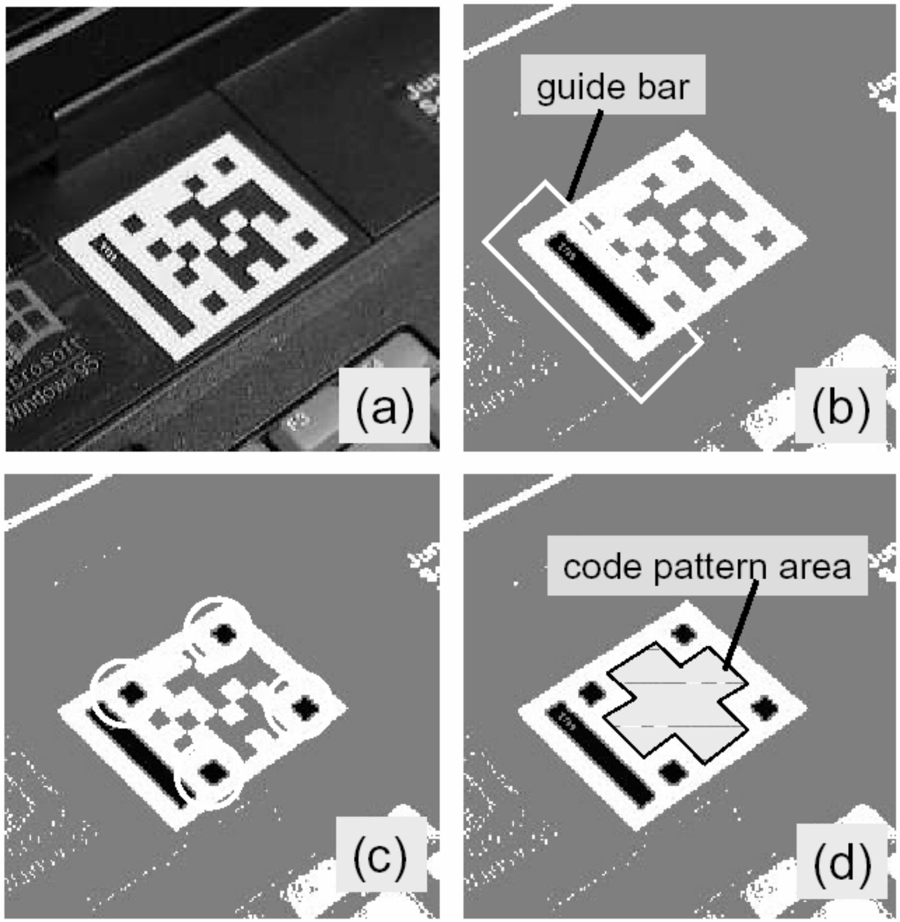
- Idea: use camera to identify 2D-barcodes
- Get orientation, position and id of tags
- Use low-res camera with small form factor
- Cybercodes can be printed on any ordinary laser printer

www.csl.sony.co.jp/person/rekimoto.html

CyberCode enabled devices

Identification Procedure

(a) CyberCode
(b) Identify guide bar
(c) Identify corners
(d) Identify pattern area



AR Toolkit

- Originally by Mark Billinghurst
- Design your own markers:
  - Black fringe with black symbol on white background
  - Edge length depending on camera resolution and distance
- From a video stream determine:
  - X/Y coordinates of markers in the picture
  - IDs of markers
  - Matrix describing the position and orientation of the marker relative to the camera in 3D
- Also wrapper for Java: JAR Toolkit

http://www.hitl.washington.edu/research/shared_space/download/
http://www.ims.tuwien.ac.at/~thomas/artoolkit.php

Feature-Tracking

- Enter … Michael Aron…

Augmented Reality, definition

- Goal: insert some virtual information in a real picture or a real video sequence
  - Applications:
    - cinema post production
    - medical
    - industries
    - interior design, tourism, architecture...

Augmented Reality, some devices...



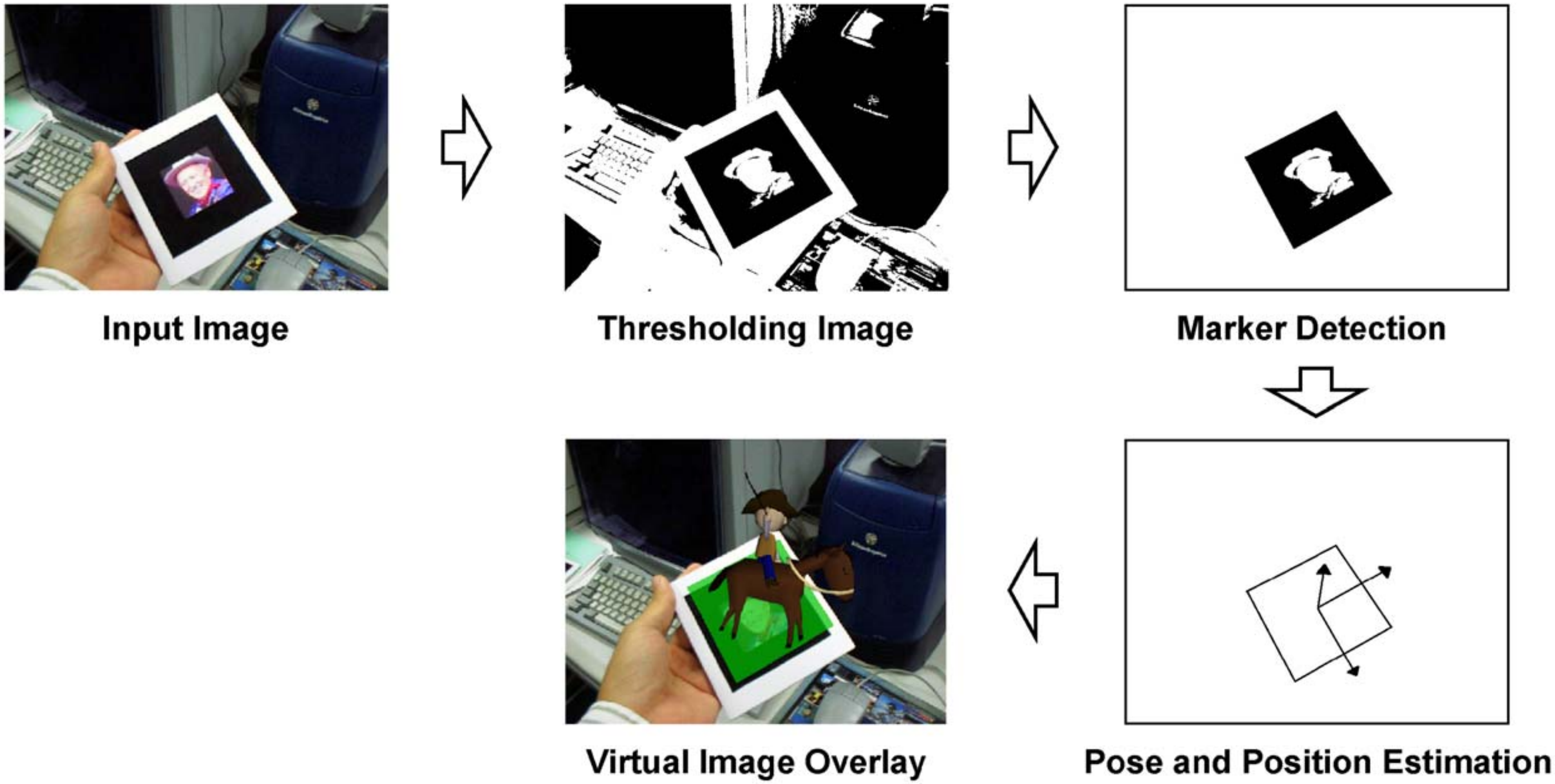


Augmented Reality, actual research

- Main research problem: get the camera pose in order to be able to project the virtual information in the real scene
- But other problems!
    - occlusions
    - realistic lightning (shadows, self shadows...)

Augmented Reality, vision tracking

- Marker tracking: the reference is ARToolkit

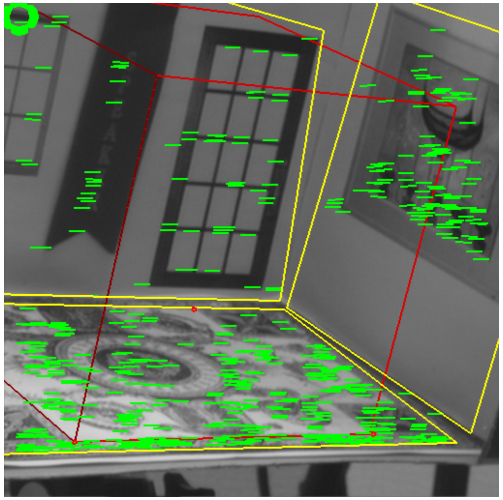


Augmented Reality, vision tracking

- ARToolkit application, two videos:
  - ***VOMAR interface, a real paddle is used used to pick up and place virtual furniture – external view***
  - ***VOMAR interface, augmented view***

Augmented Reality, vision tracking

- Marker-less tracking: one of the main research topic today
  - edge tracking
  - key-points or feature points (Harris & Stephen, SIFT...)

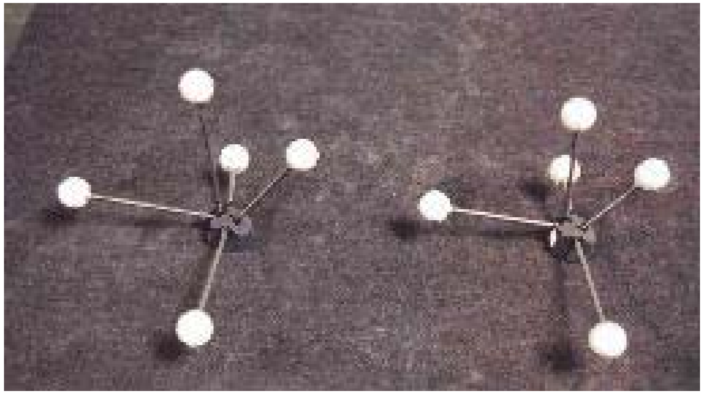


Augmented Reality, vision tracking

- Marker-less tracking:
  - two videos :
    - key-point detection and matching
    - augmented scene

Infrared Tracking

- Camera-based technique (e.g. ART GmbH)
  - Passive markers
  - Active markers
- Image processing relatively simple
  - High speed processing, high resolution.



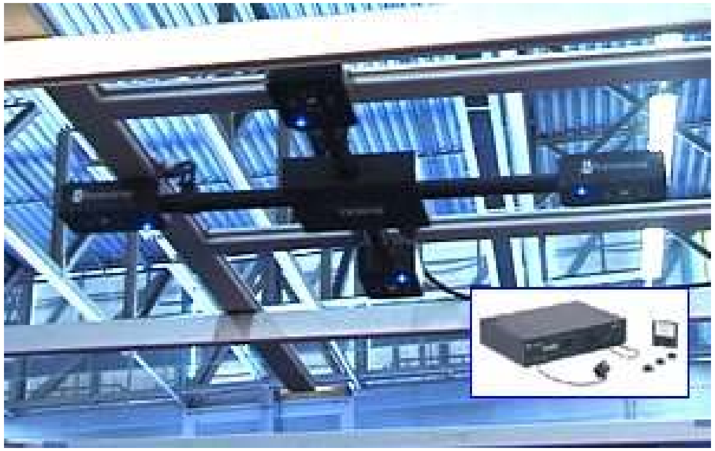
Infrared Hiball-Tracker
(www.3rdtech.com/HiBall.htm)

- LED-Array is sensed by multiple receivers
- High precision (1 mm, 0.3 degree)
- Needs cable-based infrastructure

- Sensors detect flash pattern
- 2000 Hz readings

Ultrasonic tracking (e.g., www.isense.com)

- High precision: 1 mm, 0.05 degrees
- Working area: 0.6-2 m²
- High price
- Very robust
- Application areas:
  - VR, Virtual Studio
  - Medical applications (preparation for surgery)
  - architecture, rapid prototyping



Magnetic Tracking

(e.g., www.ascension-tech.com)

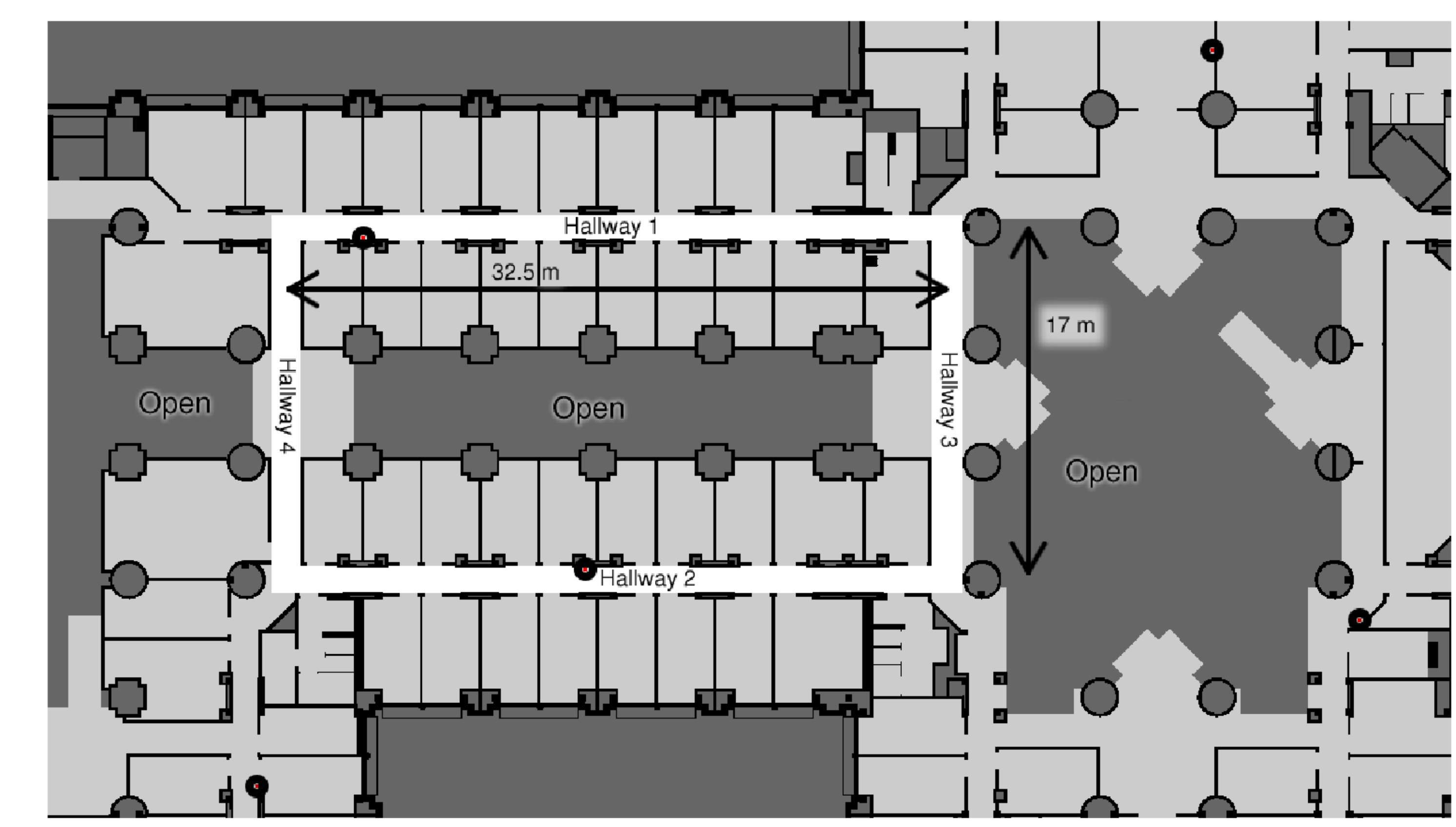
- Ascension Technologies: Flock of Birds
- Create reference magnetic field (using a big electrical magnet)
- Range up to 3m, updates up to 144 Hz
- Accuracy 1,8mm 0,5 degrees
- Use magnetic sensors as targets
    - Cables needed!
    - 6DOF: Position and Orientation
- Problems:
    - Field is warped by metal structures
    - CRT monitors unusable in the field

WLAN Fingerprints

- Use already existing WLAN infrastructure for positioning
- Measuring runtime of signals causes big problems indoor
- Instead: use the “fingerprint” at defined locations (vector of signal stregths)
- Machine Learning approach
- Try to identify the “closest match”

WLAN Fingerprint methods

- Example (Ladd et al. 2002)



WLAN Fingerprints (cont.)

- Sampling at different locations in the hallway every 10 feet
- Over 1300 measurements
- Simple Probabilistic Algorithm (Bayes-rule)
  - Error within 1.5 meters with P=0.77
- Filtering and Sensor Fusion
  - Error within 1.5 meter with P=0.83
- Offline-Processing with Hidden-Markov-Model
  - Error within 1.5. meter with P=0.91

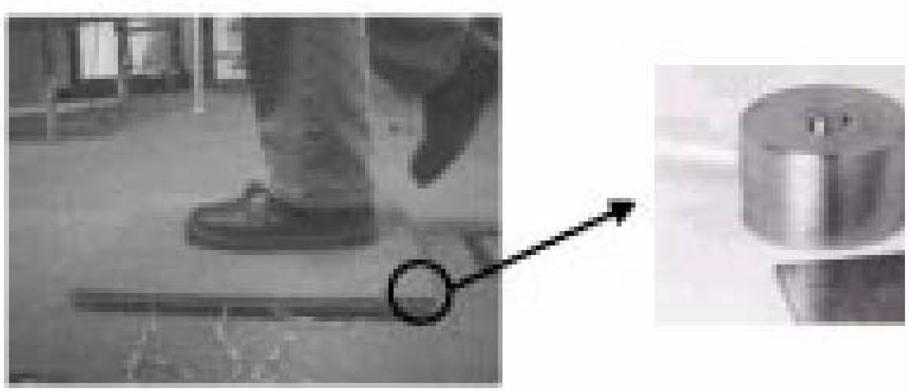
WLAN Fingerprints

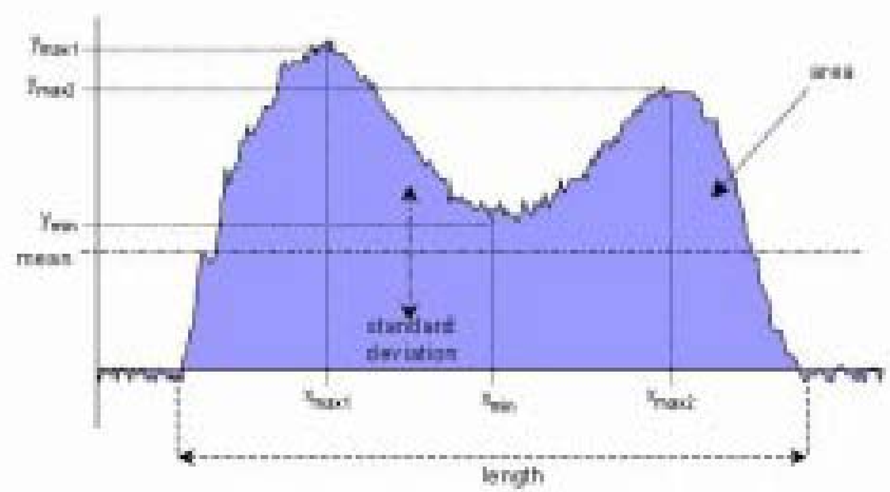
- Problems:
  - Access points may move or (dis)appear
  - The 2.4 Ghz band is absorbed by water
    - Humans (problem with orientation)
    - Weather conditions (rain)
  - Practical precision around 10m
  - Acquires complicated training phase

- Commercially available: www.ekahau.com

Floor Sensors

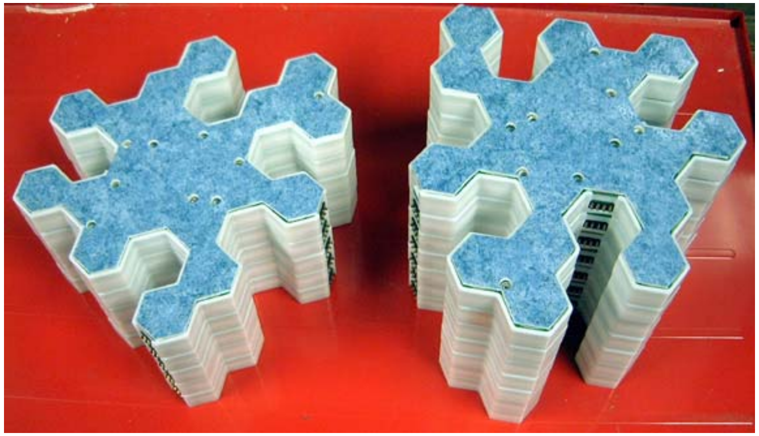
- Weight sensors integrated into the floor
- Measure steps and can even identify individuals
- Problems
  - Multiple users
  - High instrumentation of the environment
- www.cc.gatech.edu/fce/smartfloor/





Floor sensors (ztiles)

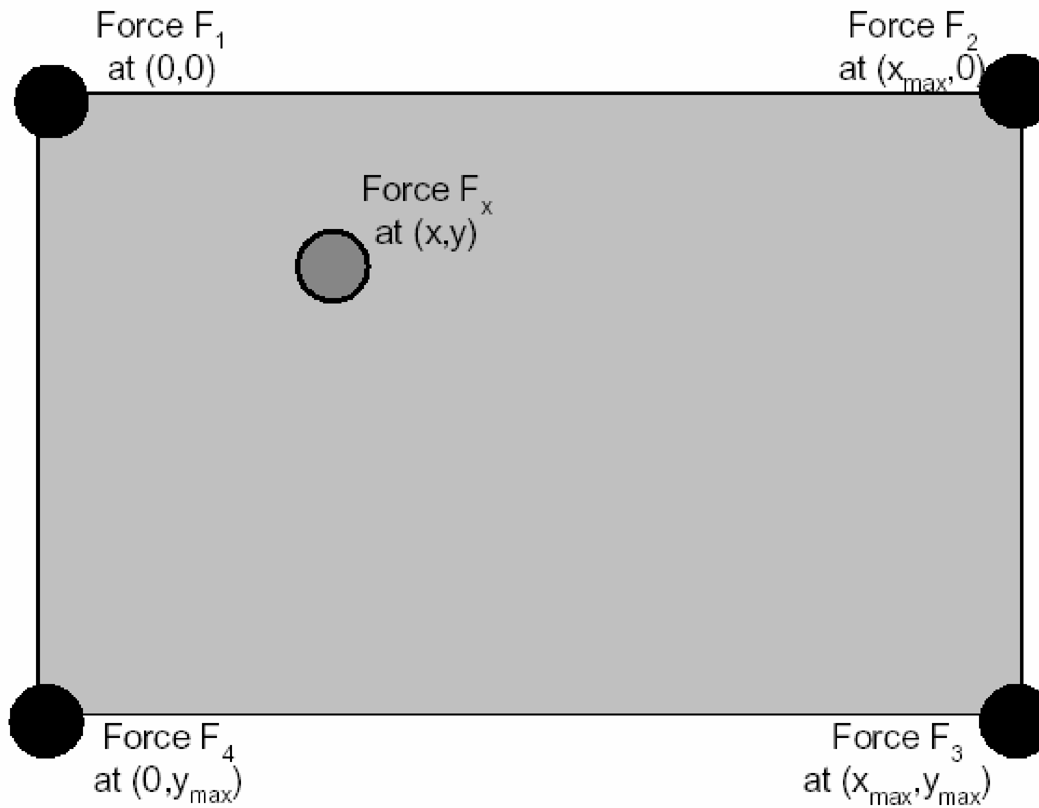
- Development towards pre-fabricated tiles (*McElligot et al. Ubicomp 2002*)
- Ad-hoc networking capabilities
- Easy to install
- Robust against failure of single elements
- www.media.mit.edu/resenv/ZTiles/
- www.idc.ul.ie/ztiles/



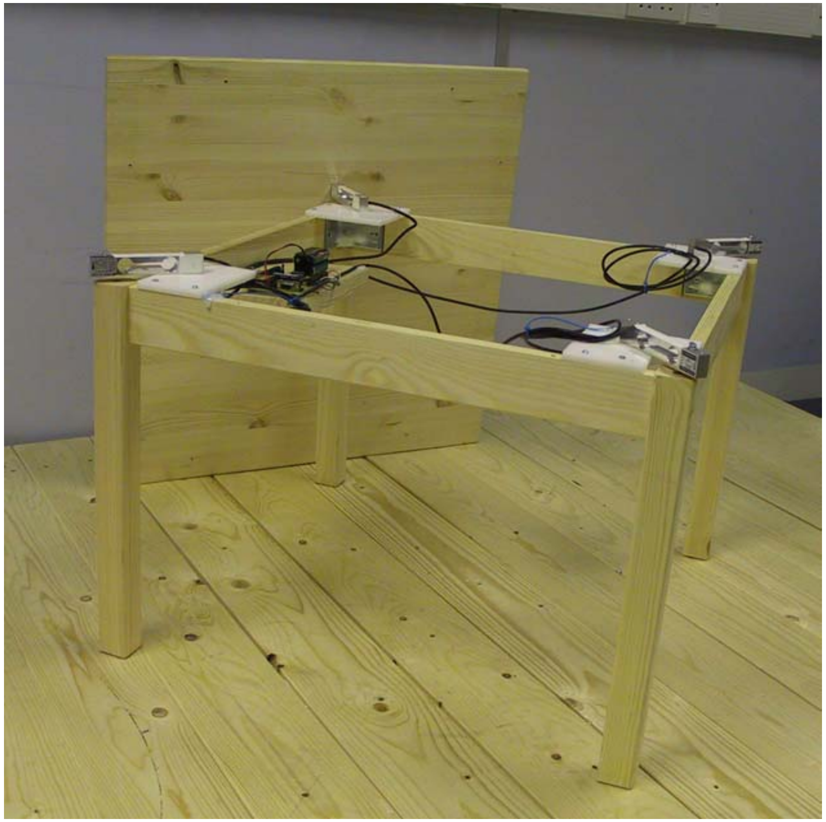
Large load sensor areas

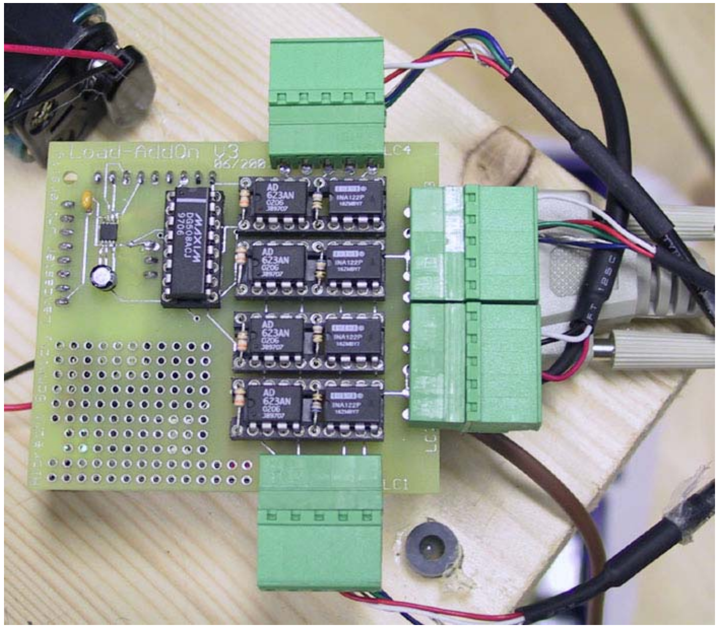
Schmidt et al. 2002, Strohbach, Lancaster Univ.
www.comp.lancs.ac.uk/~strohbach
Use load sensors to detect usage patterns

- on the floor
- on the tables
- on the shelves

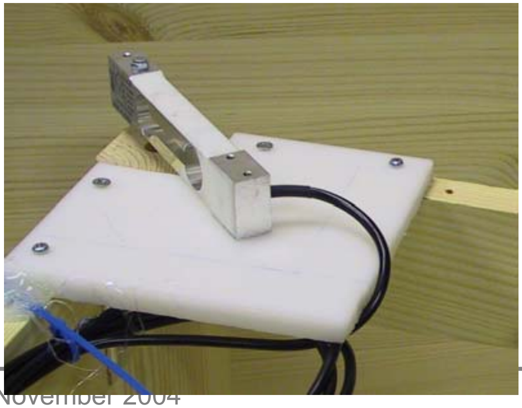


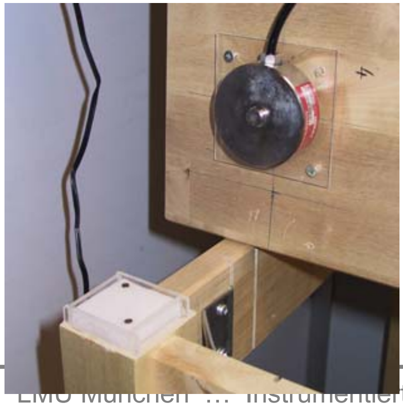
Example I: Table as a Sensors

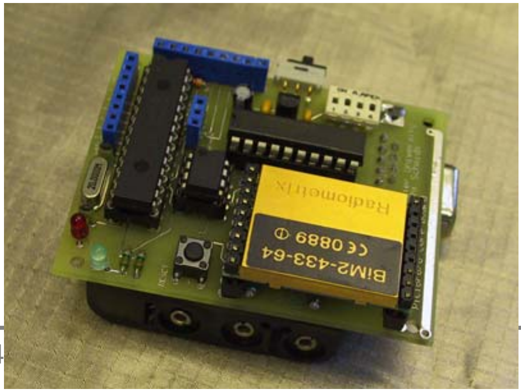




- Smart-Its sensor AddOn board
- 16 Bit DA
- Instrumentation Amps



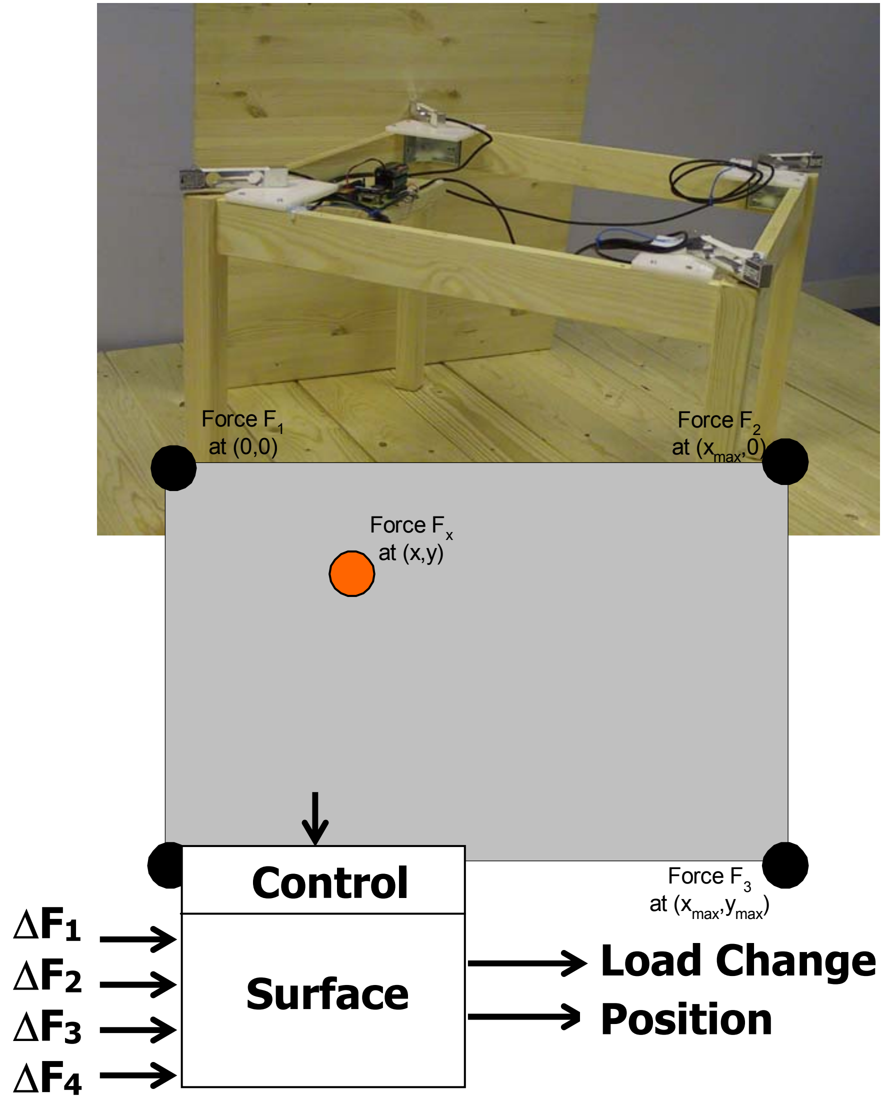




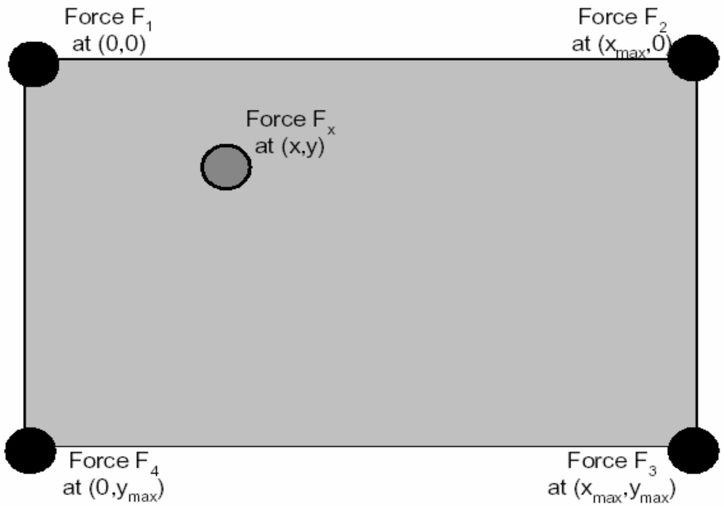
Load-Sensing Surfaces

Concept

- Gravity is ubiquitous
- Surfaces: crossroads for human activity
- Pervasive load sensing
  - Not just weight
  - Position on surface
  - Object movement
  - Particular events
  - Traces



Calculating the position



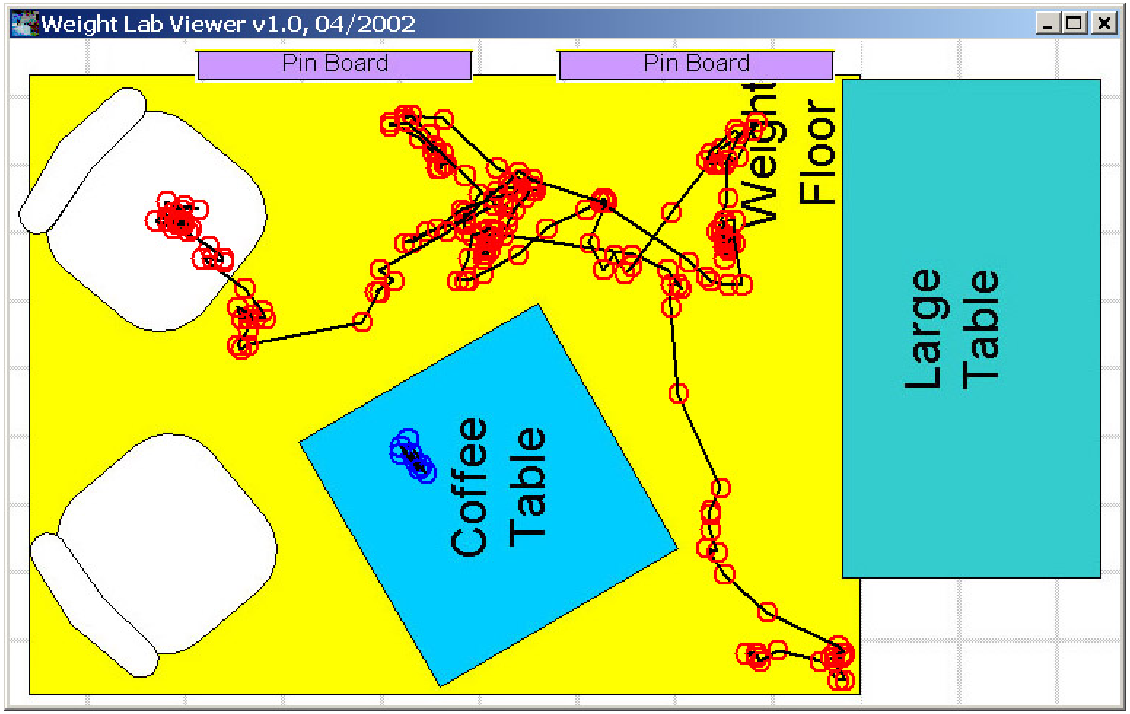
$$F_x = F_1 + F_2 + F_3 + F_4 \tag{1}$$

$$F0_x = F0_1 + F0_2 + F0_3 + F0_4 \tag{2}$$

$$x = x_{\max} \frac{(F_2 - F0_2) + (F_3 - F0_3)}{(F_x - F0_x)} \tag{3}$$

$$y = y_{\max} \frac{(F_3 - F0_3) + (F_4 - F0_4)}{(F_x - F0_x)} \tag{4}$$

Load-Sensing Surfaces



Weight Lab

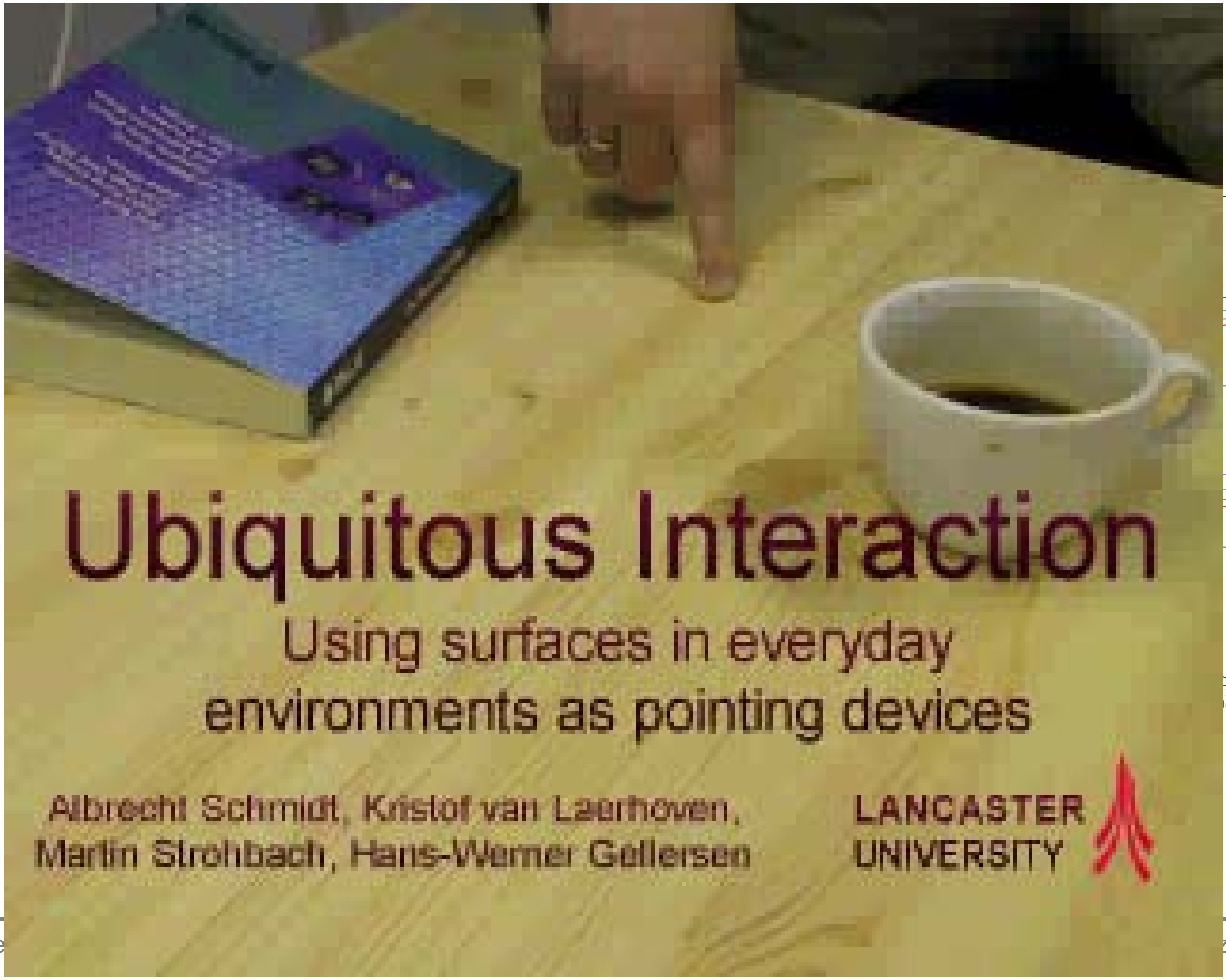
- Lab environment with load-sensing floor, tables, and shelves
- Common furniture, unobtrusively augmented (wireless)

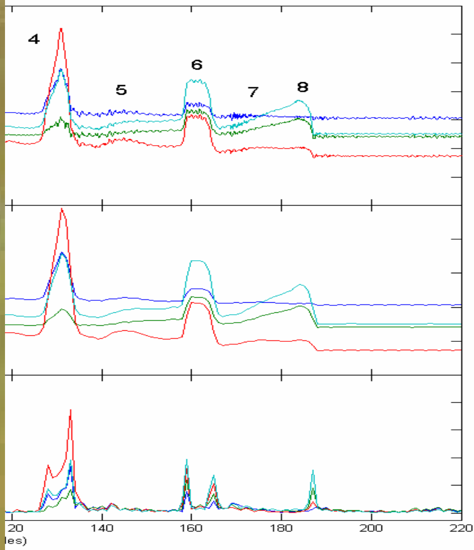
Context Acquistion

- Tracking of people, objects, activities
- In presence of noise (cluttered surfaces)

Example II: Load-Sensing Surface

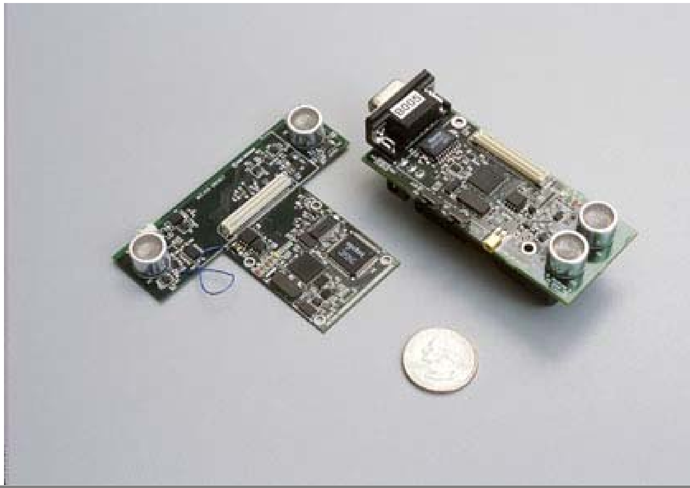
Surfaces as Interaction Device



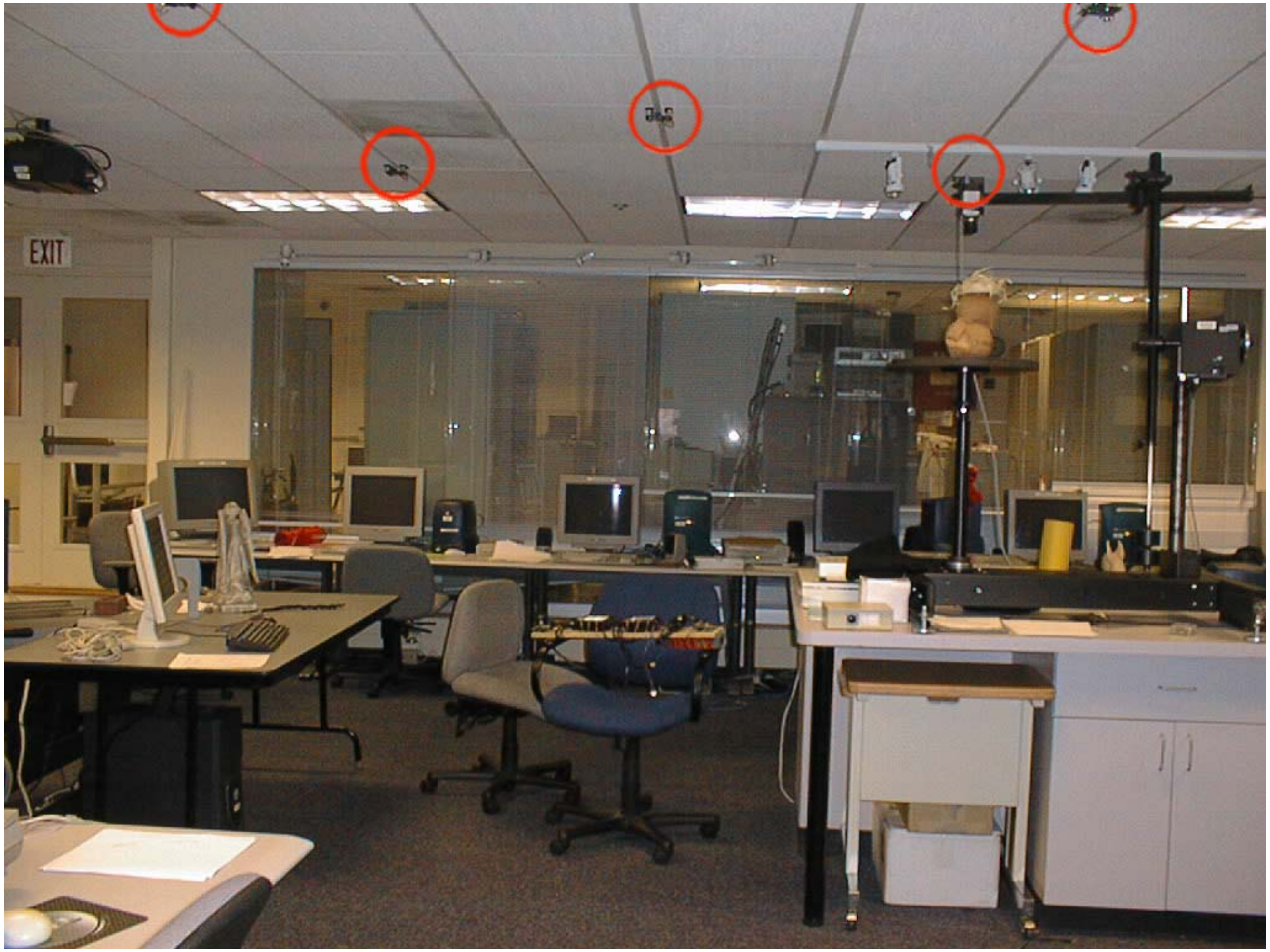


Combined techniques: Cricket (nms.lcs.mit.edu/projects/cricket/)

- Combination of radio and ultrasonic beacons
- Receiver and transmitter on the device
- Small size
- Available right now: Position
- Experimental: Position and orientation
- Precision: 1-3 cm, 5 degrees
- Problems: Multipath, ultrasonic signals difficult to distinguish



Cricket Installation



Approach: Use Differential Distance to Determine Orientation

Assume: Device rests on horizontal plane
Method: Use multiple ultrasonic sensors; calculate rotation using measured distances d1, d2, z

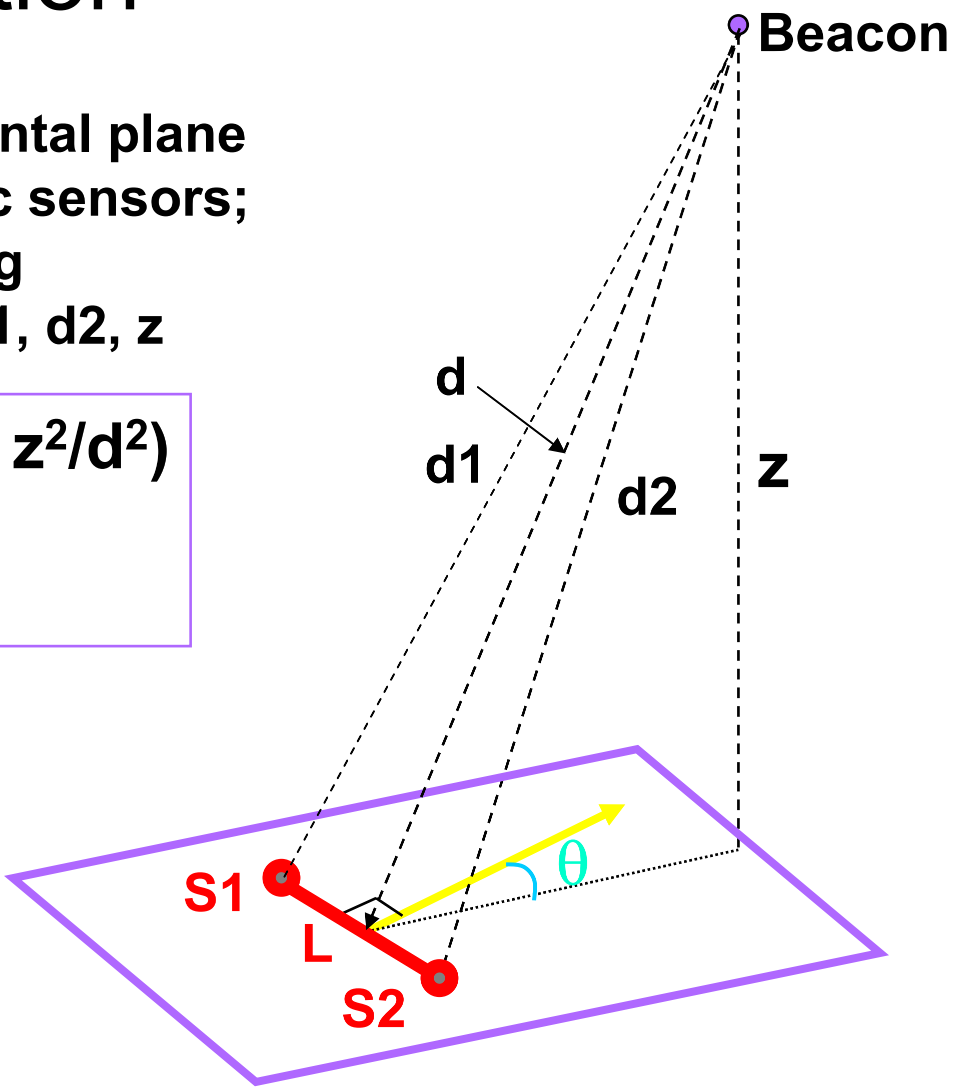
$$\sin \theta = (d2 - d1) / \mathrm{sqrt}\,(1 - z^2/d^2)$$

where

$$d = (d1+d2)/2$$

Need to measure:

a) (d2 - d1)
b) z/d



Cricket Compass v1 Prototype

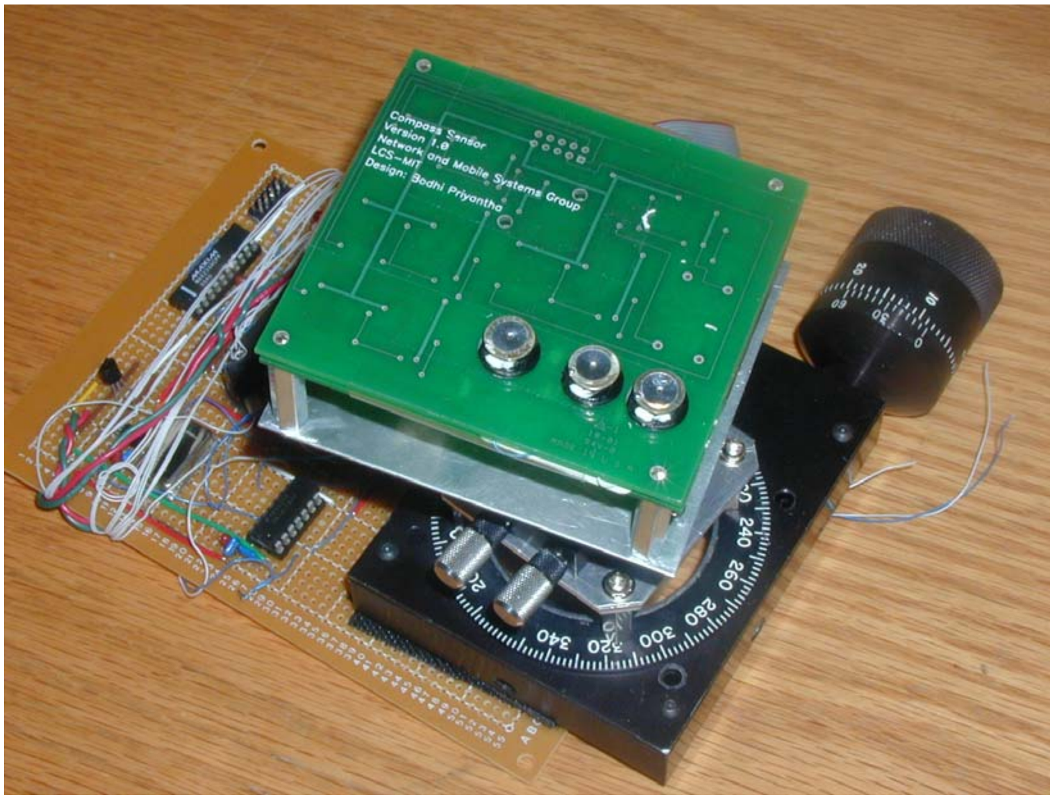
Ultrasound Sensor Bank

1.25 cm x 4.5 cm

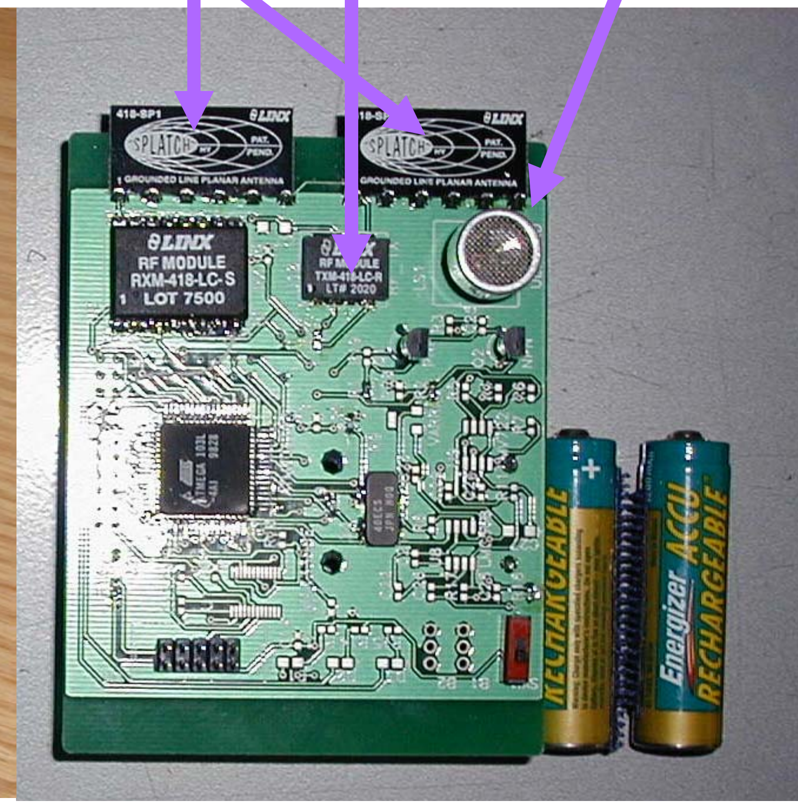
RF module (xmit)

RF antenna

Ultrasonic transmitter



Sensor Module

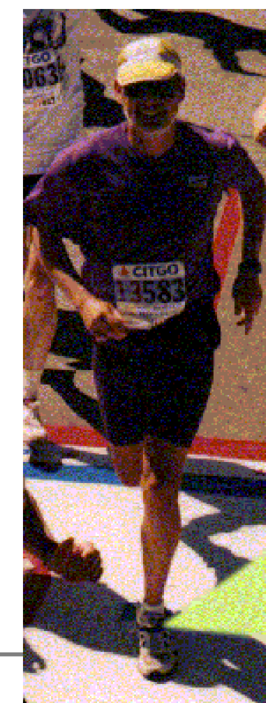


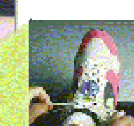
Beacon

RFID Tags (orig. TI + Philips)

“RFID Journal” currently lists 15 manufacturers in Europe alone

- Transponder, external energy supply
  - Small memory, 39bit-ID
- small range (depends on antenna type)
  - from 0.1m to 2m
- Problem of collision detection

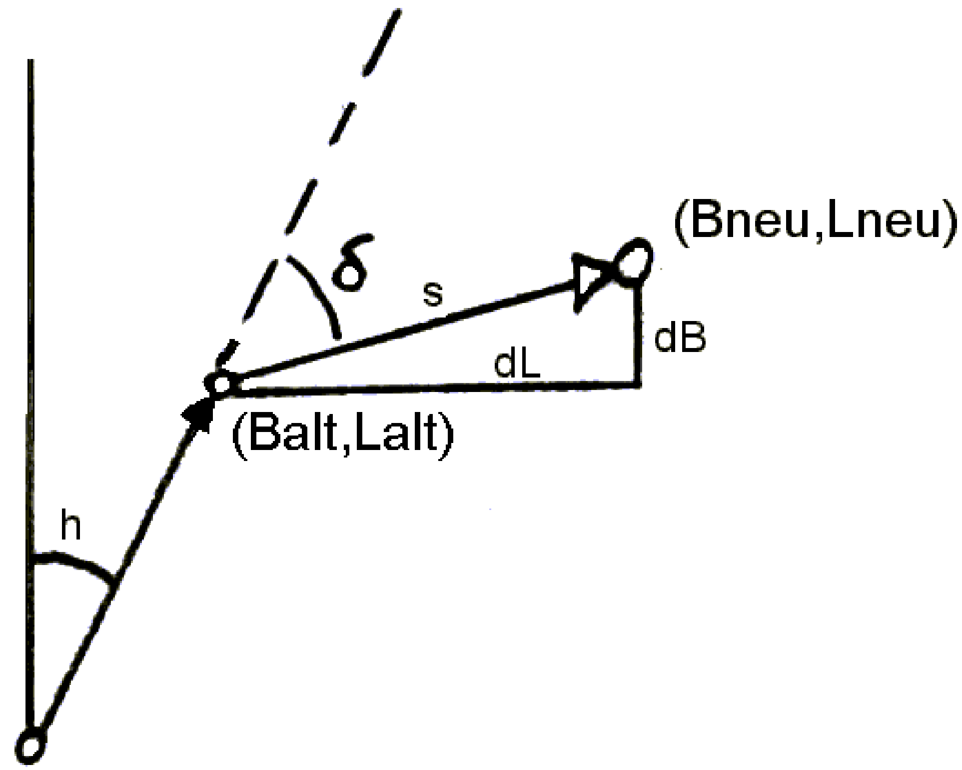




RFID example: smart store

Dead Reckoning

- Oldest navigation technique for sailors
- Starts with one known position (e.g. the harbor)
- Determine new position from measured speed and direction
- For indoor purpose
  - Try to detect steps
  - Use gyro/compass to determine orientation



Inside-out tracking

- Process of positioning is done locally
- Observe external cues
  - Examples: PDA with camera, GPS
- Active localization by processing perceived signals

Outside-in tracking

- Infrastructure observes user
  - Radio, IR, acoustics,
- Environment knows all user positions
- Processing in the environment of signals perceived from mobile unit