Instrumented Environments
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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...)

18 November 2004 | LMU München ... Instrumentierte Umgebungen ... WS04/05 ... Butz
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 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 topics today
  - edge tracking
  - key-points or feature points (Harris & Stephen, SIFT...)

![Image of augmented reality scene with tracking markers]

![Image of tracking overlay on a real-world environment]
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 strengths)
- 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/](http://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/](http://www.media.mit.edu/resenv/ZTiles/)
  - [www.idc.ul.ie/ztiles/](http://www.idc.ul.ie/ztiles/)
Large load sensor areas

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

\[ F_x = F_1 + F_2 + F_3 + F_4 \]  
\[ F_{0x} = F_{01} + F_{02} + F_{03} + F_{04} \]  
\[ x = x_{\text{max}} \frac{(F_2 - F_{02}) + (F_3 - F_{03})}{(F_x - F_{0x})} \]  
\[ y = y_{\text{max}} \frac{(F_3 - F_{03}) + (F_4 - F_{04})}{(F_x - F_{0x})} \]
Load-Sensing Surfaces

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

Context Acquisition
- 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 $d_1$, $d_2$, $z$

\[
\sin \theta = \frac{(d_2 - d_1)}{\sqrt{1 - \frac{z^2}{d^2}}}
\]

where
\[
d = \frac{(d_1 + d_2)}{2}
\]

Need to measure:
\a) \((d_2 - d_1)\)
\b) \(\frac{z}{d}\)
Cricket Compass v1 Prototype

Ultrasound Sensor Bank
1.25 cm x 4.5 cm

Sensor Module

RF module (xmit)
RF antenna
Ultrasonic transmitter

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