Instrumented Environments

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

Topics Today

Context Awareness

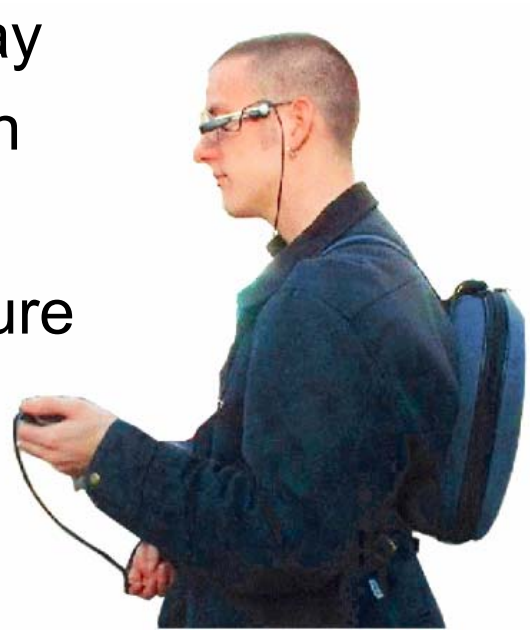
- Some definitions
- Some example projects
- The Context Toolkit
- Low level context acquisition
- Some implementation concepts

Trying to define context

- Context acc. to Bill Schilit (Active badge 1992 + Parctab 1994)
  - „mobile distributed Computing“: Mobile Computers and Users
  - The three (spatial) Ws:
    - Where is the user?
    - Who is near the user?
    - What services can the user use in the vicinity?
  - Important: the temporal changes of the 3 Ws

Trying to define context (2)

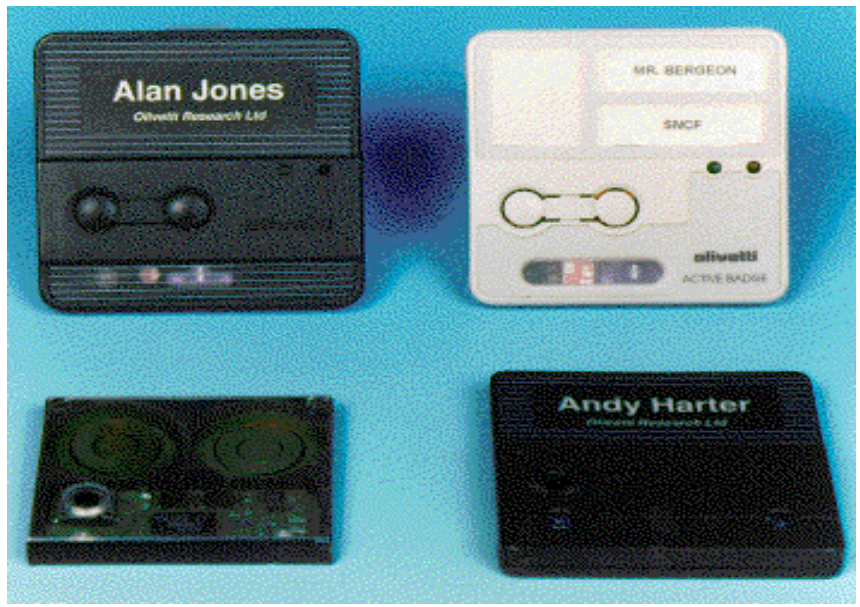
- Context properties
  - Location
  - Lighting/brightness
  - Sound/noise
  - Network availability
  - Network bandwidth
  - Group constellation
  - Dialogue history
  - Position history
  - User interest
  - Time of day
  - Orientation
  - Speed
  - Temperature



Example project: Active Badges

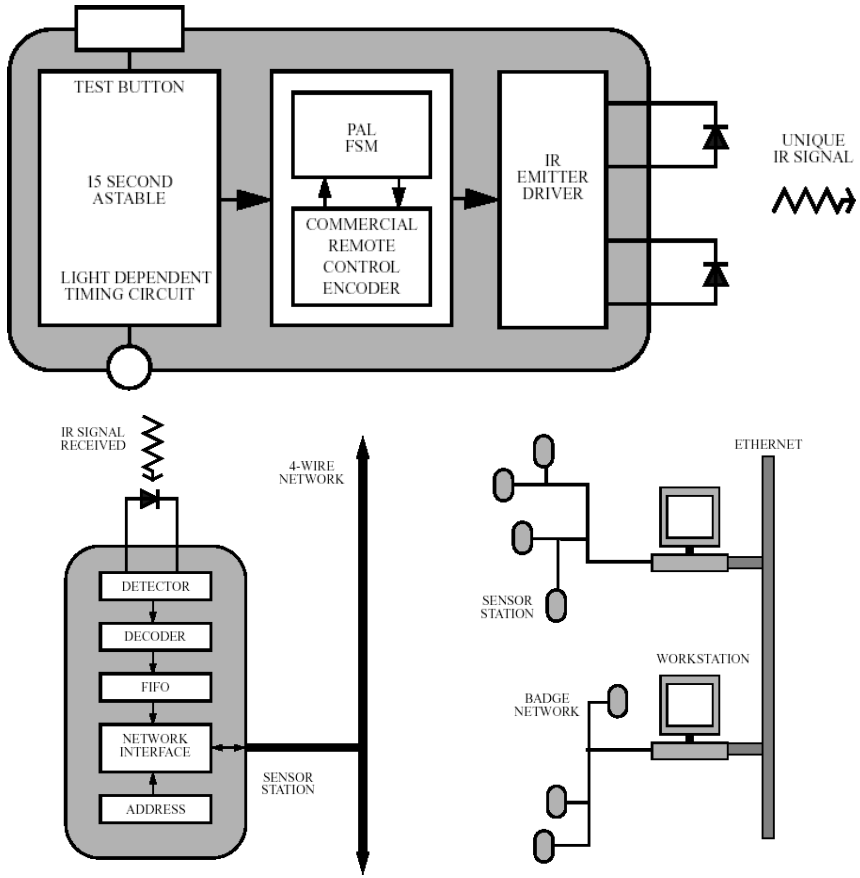
Olivetti / AT&T, Schilit, Hopper, Harter, et al.

- Teleport
  - Redirect screen output from "home" computer to nearby computer
- Phone forwarding
  - Automatically forward phone calls to nearest phone



Active Badges: Technology

- Badges emit infrared (IR remote) signals
- 1 signal every 15 sec.
- Avoid 2 badges in sync
  - use high tolerance components
  - Light sensor changes interval
  - → switched off when in the dark
- Button to trigger events
- Sensors distributed in the building
- Central server scans regularly for „badge sightings“
- Over 1500 badges and 2000 sensors used worldwide



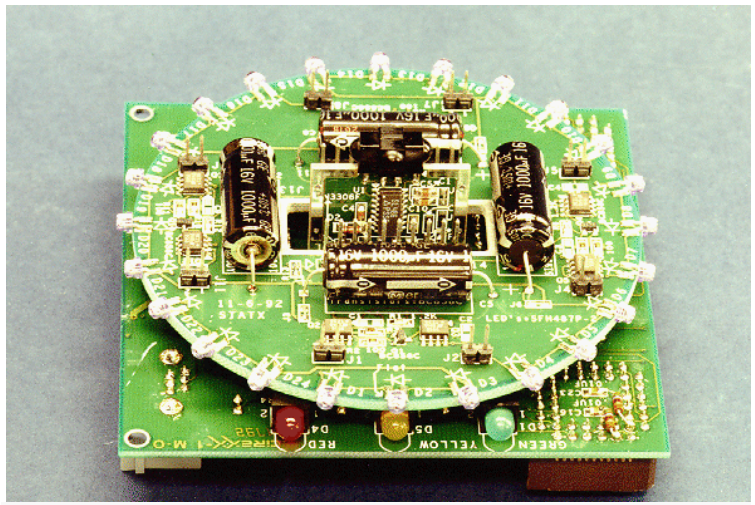
“A disadvantage of an infrequent signal from the badge is that the location of a badge is only known, at best, to a 15-second time window. However, because in general a person tends to move relatively slowly in an office building, the information the Active Badge system provides is very accurate.” ;-))

Active Badges: Initial Services

- **FIND (name)**
  - Provides the current location of the named badge and, if it has recently moved, a list of all the locations it has been sighted at in the last five minutes along with the likelihood of finding it at each.
- **WITH (name)**
  - Locates a named badge and provides information about other badges that are in the immediate locality of that badge.
- **LOOK (location)**
  - Allows an investigation to be made of the badges that are currently near the specified location.
- **NOTIFY (name)**
  - An alarm mechanism that generates an audible indication of when the named badge is next sighted after executing the command. ‘NOTIFY’ is particularly useful when trying to deliver an urgent message to a member of staff who is out of the office on business for long periods of time.
- **HISTORY (name)**
  - Generates a condensed report of the location history for the named badge during a one-hour period. The system intentionally does not record any location data on a permanent storage medium, to dispel concern about long-term monitoring of an employee’s movements.

Xerox ParcTab

http://sandbox.parc.xerox.com/parctab/



- Infrared network
  - Base stations in the ceiling
  - Low bandwith, modulated carrier
  - Transmission radius ~7m
- Mobile tab-sized devices
  - Unistroke input via pen
- Context-aware applications:
  - Information access
  - Communication
  - Collaboration

Information Access

- Weather (Internet/local)
- Dictionary, Thesaurus
- UNIX file browser
- WWW browser (mit Einschränkungen)
- Calendar manager (Sun's cm)
- Dateimanager (ortsabhängig)

Communication

- email: permanent access
- pager
- locator
- „Communicator“, media-space controller
  - Tab proposes best communication devices in the surroundings and initiates connection

Collaboration

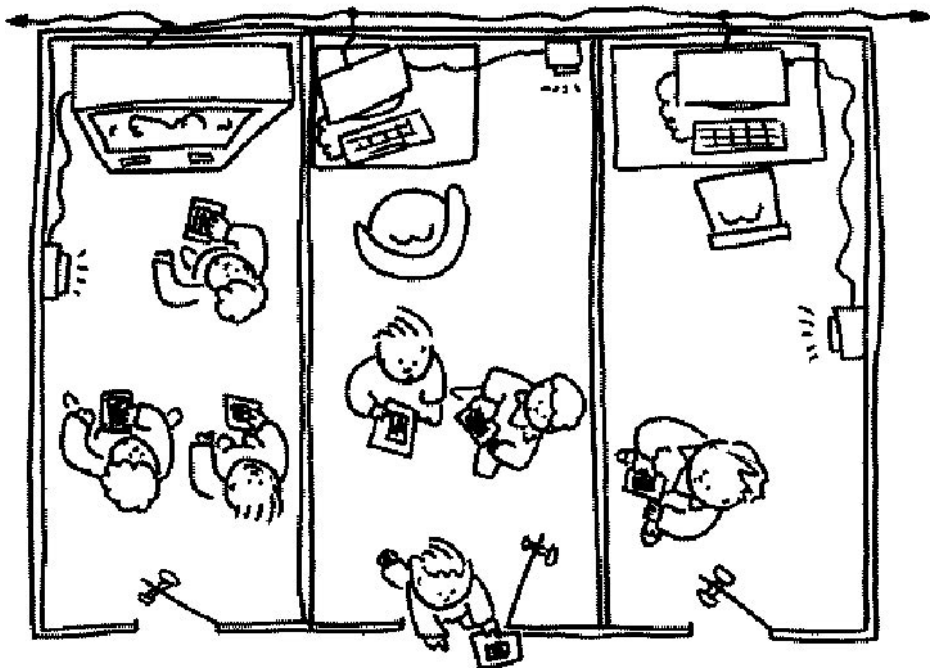
- Tab as pointing device
  - Remote pointer control for liveboard
  - Move pointer with pen on the tab screen
- Tabdraw: collaborative drawing
  - One canvas per room
- Arbitron (Tool for voting)
  - Tell the presenter to speed up or slow down

Other Applications

- Remote Control
  - Control of physical environment
  - Universal (self-configuring) remote control
- Local (on Tab) applications
  - For offline use
  - Note pad for memos

Techniques in Context-Aware Computing

(Schilit et al. 1994)



- Proximate selection
  - E.g., list closes devices first
- Automatic contextual reconfiguration
  - E.g., automatically select nearby devices for output
- Contextual information & commands
  - Commands with different meanings in different contexts
- Context-triggered actions

Context-triggered actions

- Simple If-Then Rules, similar to Unix CRON-Demon:
  - Coffee Kitchen arriving „play -v 50 /sounds/rooster.au
  - schilit * attention „emacs -display $NEARESTHOST:0.0“
- Contextual reminders: information is displayed under certain conditions. Example:

$DATE=„after April 15“
AND $TIME=„after 10“
AND $room=„35-2-200“
AND $WITH-USER=Adams“
AND Color($DISPLAY)=„true“

Context-sensitive Systems

- Scientific problems
  - How to recognize relevant context (Sensors)
  - How to use the obtained context information (adaptive/reactive Systems)
    - Implicit vs. Explicit control of systems
    - Reactive Systems
    - Situated Systems
    - Adaptive Systems

Situated Systems

- Activity as context
  - Location and identity
    - Simple, but only weak characterization of situations
  - Complex Sensors (e.g., cameras)
    - rich information
    - high computing power needed
    - endangered privacy
  - Integration of many simple sensors
    - TEA Project Karlsruhe
    - Context Toolkit

TEA Project

EU-funded 1998-2000, TECO, Starlab/Be, Nokia/Fin

- TEA: Technologies for Enabling Awareness
  - Combination of simple sensors instead of complex image processing
  - Combine multiple sensors with context information
  - HW/SW-Addon for mobile devices
    - low-energy, low-cost
    - Target platform: cellular phone

TEA Project

- GSM Telephone as the TEA Host
  - User expects different behavior of the phone according to the situation
  - State of the art: manual profile selection
  - TEA enables automated profile selection depending on sensor data
- Application Context-Call
  - Caller dials the number of the user, and is told the user's situation by TEA (e.g., „In a meeting“)

TEA Project

- TEA-Hardware:
  - light, audio, acceleration, and temperature sensors
  - Microcontroller controls the sensors and extracts hints
  - Final decision is made on the host

First prototype

second Prototype

Active artifacts

- Concept:
  - Determine activity where it occurs
  - Add “self perception” to everyday things
  - Communicate their own state
  - The artifact digitally “supports” its own applications
  - Example: MediaCup
    - http://mediacup.teco.edu/

Mediacup (Teco, Univ. Karlsruhe)

- First experimental „active artifact“
- Technical Info:
  - PIC-Microcontroller, 15k/384Byte, low-energy
  - IrDA physical level communication
  - 3 acceleration, 1 weight, 1 temperature sensor
  - 2 condensers as power supply
- „Self perception“:
  - Reading out sensors periodically
  - Compute important events : in the shelf, full, empty, currently in use, etc...

Mediacup

- Small number of cups
- In use since 1999
- 95% correct recognition of Multi sensor events
- Important design criterion: Energy consumption, heavy influence on outward appearance

Limited Resources

- Technical resources (of the environment)
  - Available media: e.g. displays, loudspeakers
  - Media attributes: screen size & resolution, colors
  - Quality of positional data: user's location (e.g. indoor/outdoor), orientation and speed
  - Available CPU-power and memory
  - Communication bandwidth

Limited Resources (2)

- Cognitive Resources (of the user)
  - Cognitive load:
    - Use of working memory
    - Time pressure
  - Familiarity with the environment
  - Personal preferences:
    - Media, content and presentation styles
  - Limited vision, hearing, motor skills, etc.
  - Communication abilities: limited use of modalities, e.g. use of gesture and speech

Types of resource adaptivity

- Adapt to available resources
  - Technical resources
  - Cognitive resources
- Resource-adapted Systems
  - Systems which are optimized towards a certain resource limitation
  - Result is optimized to the limitations of the sensors in the environment.
  - Different resource situations lead to failure
  - Examples: TEA, MediaCup

Types of resource adaptivity

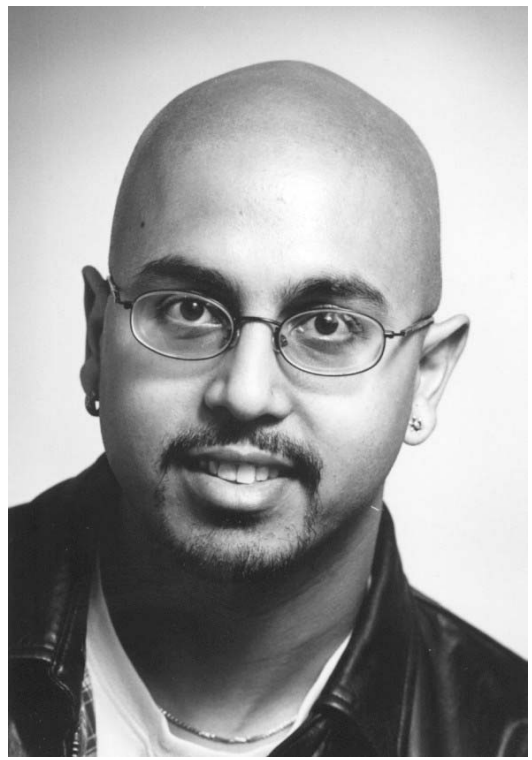
- Resource-adaptive systems
  - Implementation of a strategy to adapt to a limited resource
  - Result is improved with increasing availability of resource (example: any-time algorithm)

- Resource-adapting systems
  - A Meta-strategy chooses between different resource-adaptive strategies to fit the resource limitations
  - Implementation of a meta-cognitive system level

Context Toolkit

(with slides courtesy of Anind Dey)

- Anind K. Dey (Intel, Univ. Berkeley)
- Toolkit to support Context-Aware applications
- Strong formalization of “context”
- Implementation in Java.
- Can be distributed on several machines in the environment



Context and Context-Awareness

- Focused on input
- Context: *any information relevant to an interaction that can be used to characterize the situation of an entity*
- Context-Awareness
  - General model of interactive computing
  - Addresses subset of ubicomp problems: input

Value of Context

- Potential for improved usability
  - Very important for mobile users with poor input devices
- “Smarter” applications
- Increased communications bandwidth

Design Space for Context-Aware Applications

- Toolkit allows exploration of design space
- Basic types of context:
  - Location, identity, time, activity
  - Simple/singular → complex/multiple
  - Combinations
- Uses of context:
  - **Present** to user
  - Automatically perform set of **services**
  - **Tag** captured information to ease retrieval

Example

- Tour guides, travel assistants, personalization software

- Reminder to buy milk
  - When to deliver: not time/location specific
  - How to deliver: appropriate modality

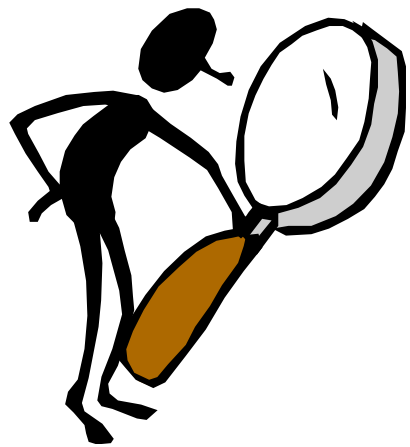
Building Applications

- M. Weiser: The whole point of ubiquitous computing, of course, is the applications.

  - But … what if the applications are hard to build? And, what if this inhibits our ability to build compelling applications?

Issues in Context-Awareness

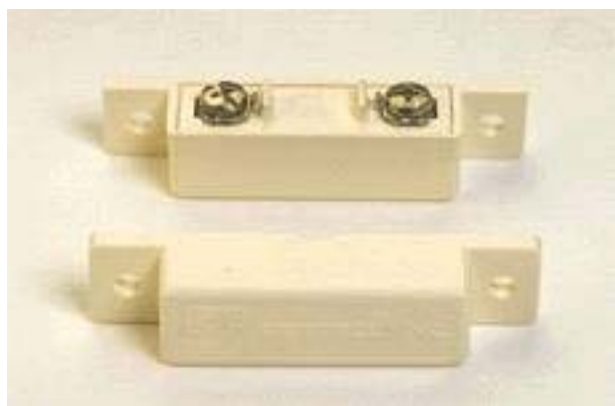
- What is context?
- Representation of context
- Application domains
- Which behaviors to support
- When to execute behaviors
- Privacy, Quality of Service, …
- Evaluation of applications



- Make it easier to build ⏩ explore

Why Context is Hard to Use

- Acquired from sensors
  - Not just keyboards and mice – lots of heterogeneous devices
- Need to abstract data
- Distributed
- Dynamic



Results of Difficulties

- *Ad hoc* application building
  - Difficult to build, reuse and evolve
- Small variety of sensors
- Small variety of context: mostly *location*
- Few applications, mostly simple: mostly *presenting context*

- Practical: difficult to prototype, test and evaluate

Context Toolkit: Research Contributions

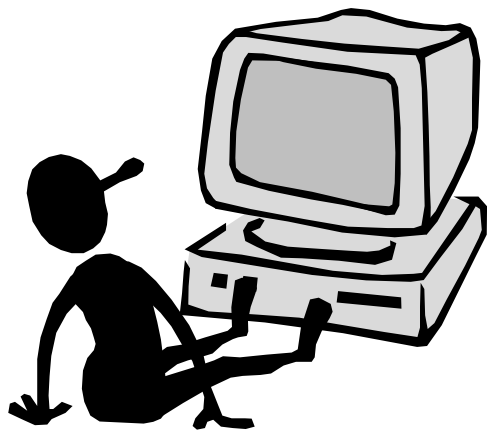
- Conceptual framework requirements
  - Provide framework for designing apps more easily
  - Lower threshold to enable more designers
- Context Toolkit itself
  - Implementation and exploration of design space
- Support investigation of complex problems and more realistic apps
  - Raise ceiling
  - Privacy, uncertainty, security, end-user programming

Toolkit Requirements

- Context specification
- Discovery
- Separation of concerns
- Storage
- Constant availability
- Transparent communications
- Interpretation

Look to input handling

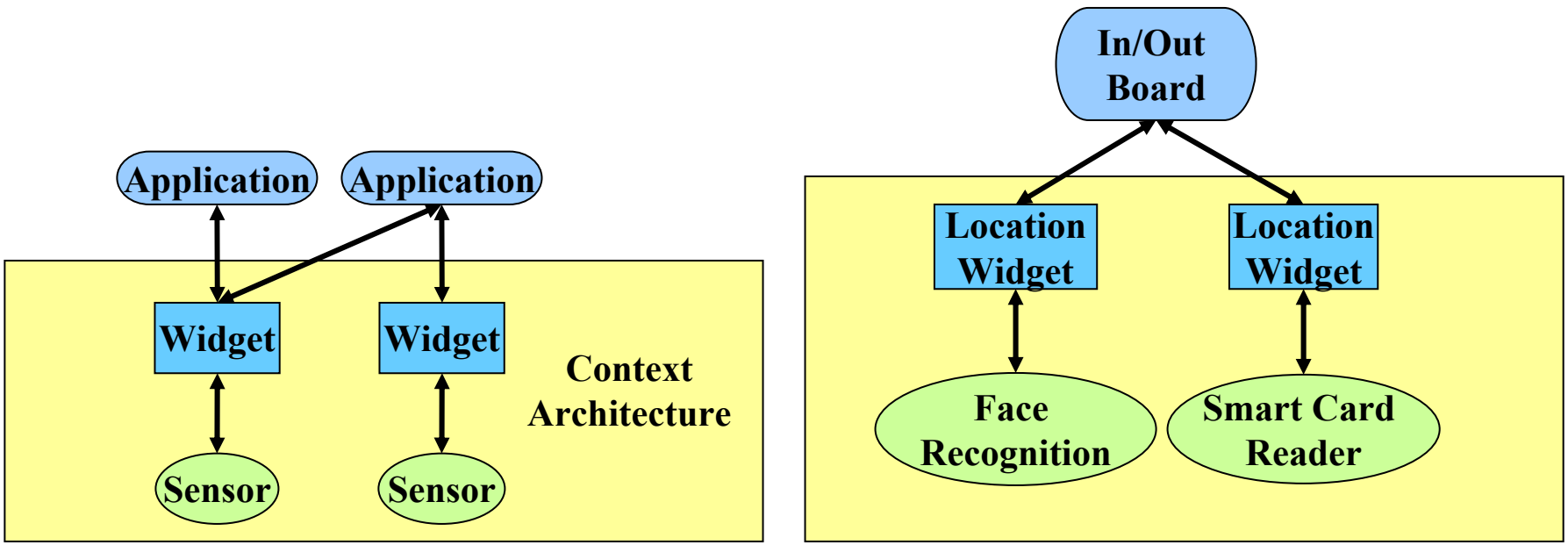
- Graphical User Interface (GUI) widgets
  - separation of concerns
  - callbacks and attributes
  - query/subscribe
  - common interface



  - e.g. button

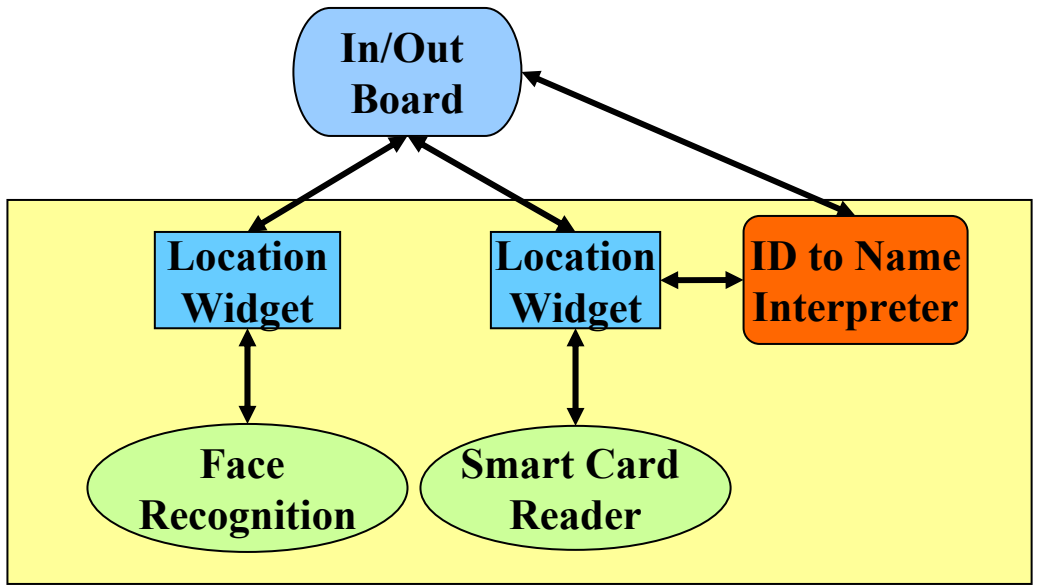
Context Widgets

- Responsible for acquiring and abstracting data from particular sensor, separation of concerns, storage



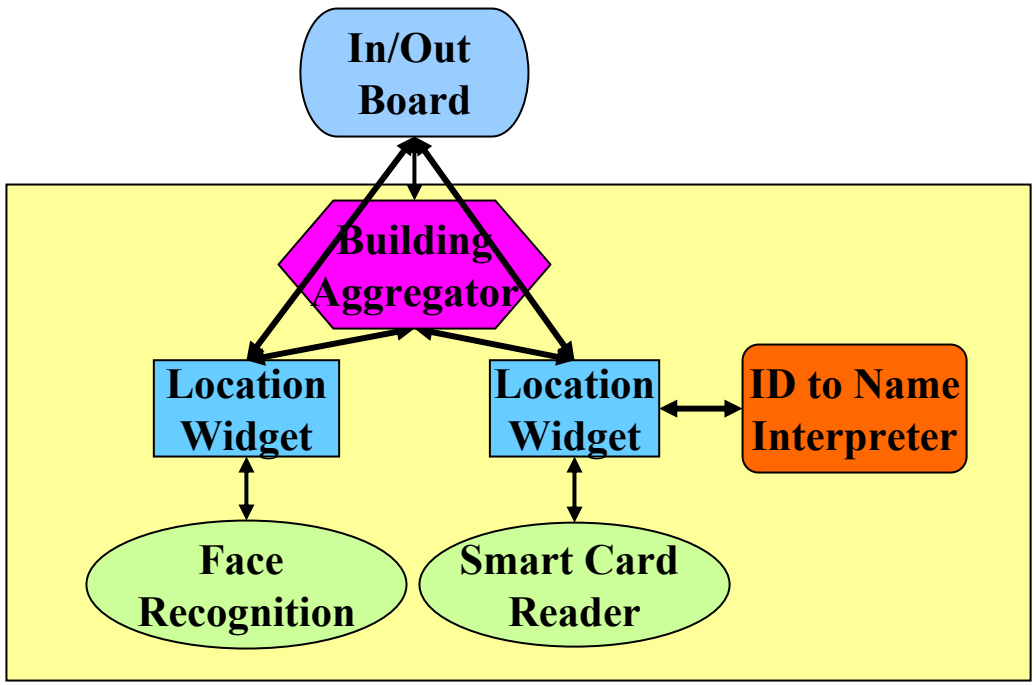
Context Interpreters

- Convert or interpret context to higher level information
- Context not available at appropriate level



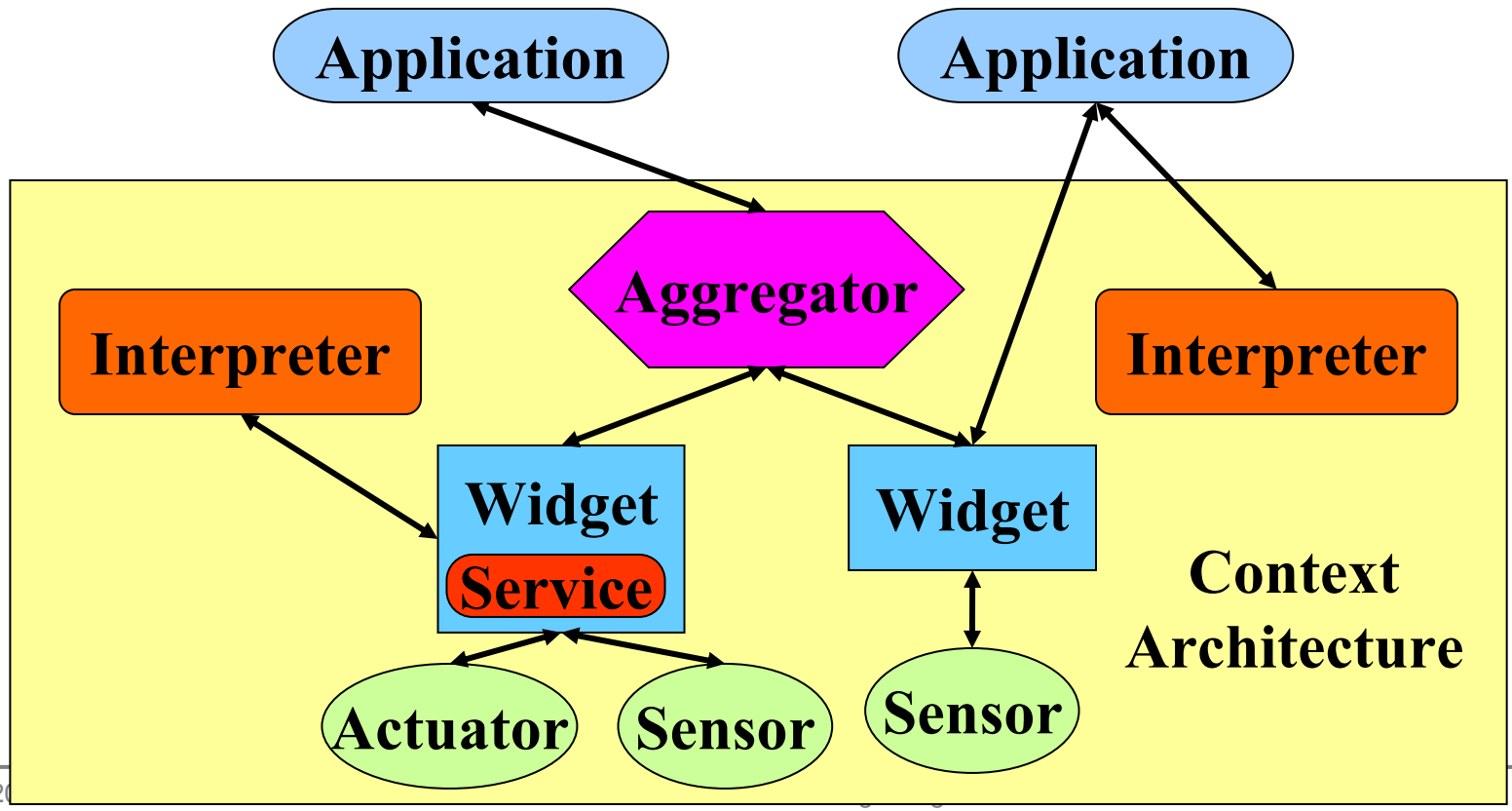
Context Aggregators

- Collect context relevant to particular entities (recall definition)
- Further separation, simplifies design



Context Toolkit Framework

- Supports real-world model/methodology and provides library (distributed: XML/HTTP, input-focused)
- Component model: facilitates building of applications



Experiences: Benefits

- Provides separation of concerns
- Lightweight integration and re-use of components
- Easy to create and evolve apps, allowing exploration of the design space
  - Add context to context-less apps
  - Add more context to context-aware apps

Aware Home (MANSE '99)

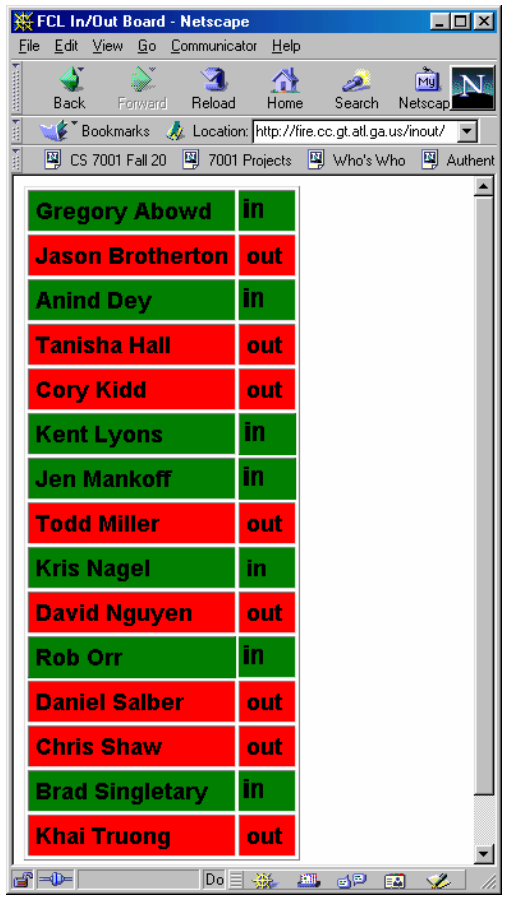
- Great testbed for context-aware computing
- 3 goals: elderly, infants, everyone
- Context Toolkit is the s/w infrastructure in the Aware Home

Applications Built

- Simple use of location:
  - Turn lights on and off (perform service)
- Location and id (perform service)
  - Information Guide: present info about user's group (CHI '99)
  - Context-Aware Mailing List

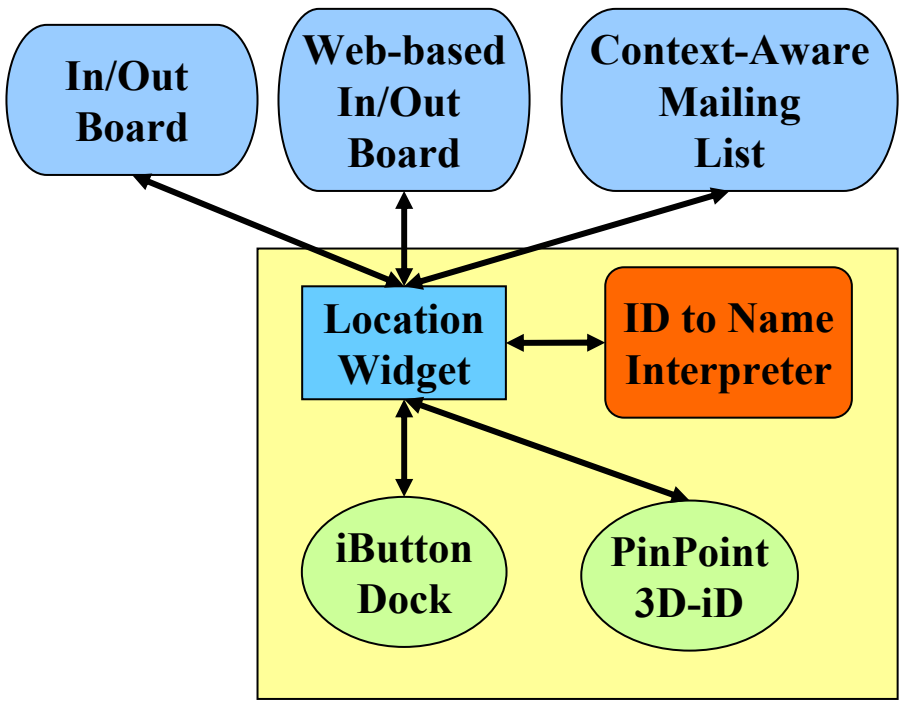
In/Out Board – 3 versions (CHI '99)

- Context used: location, identity, time
- How used: present context



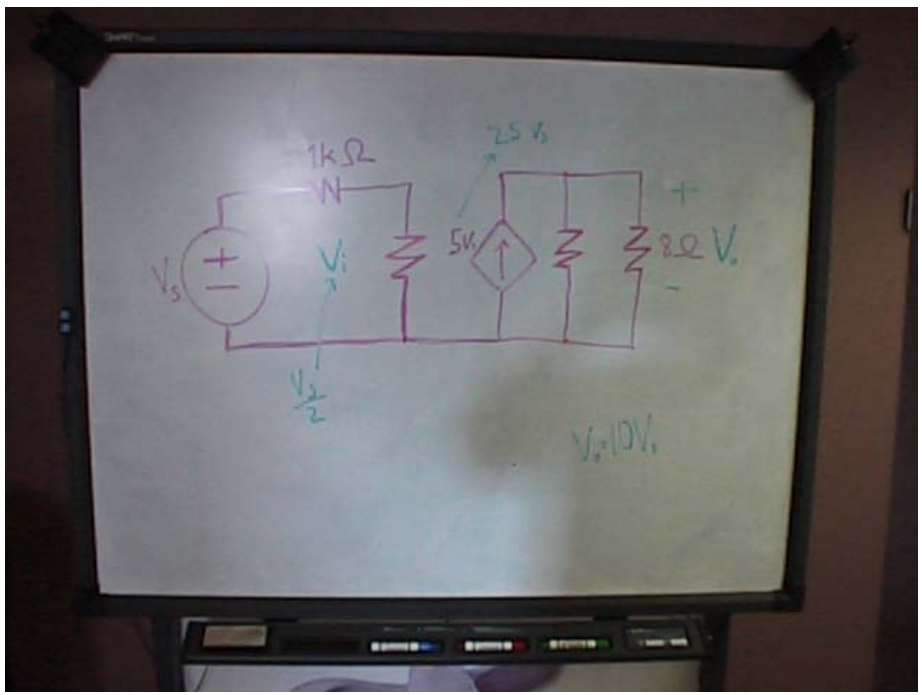
In/Out Board Architecture

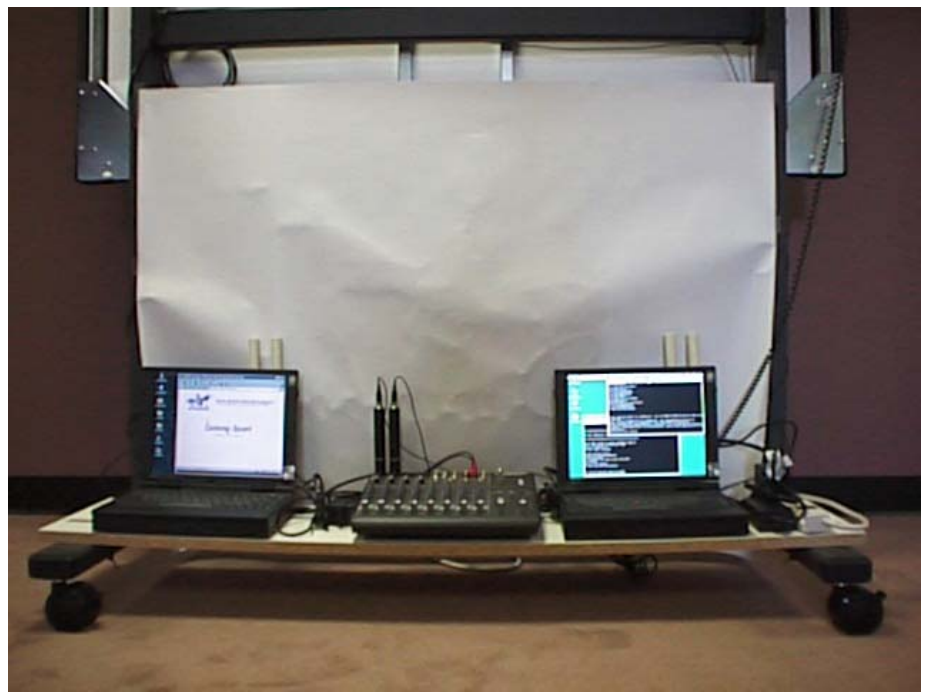
- Simple app demonstrates support for reusability (don't have to re-build infrastructure on per-application basis) and evolving applications

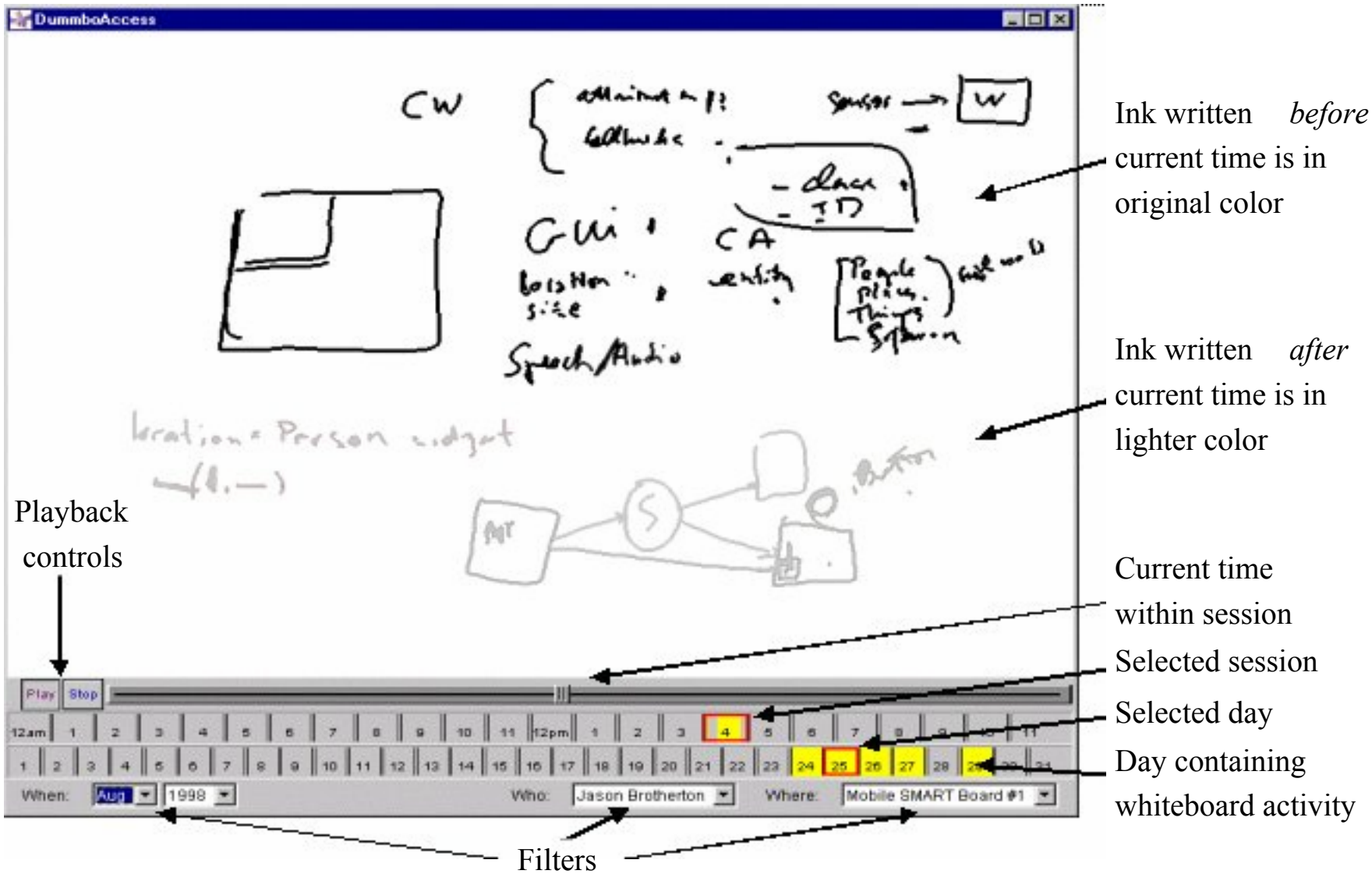


Serendipitous Meetings

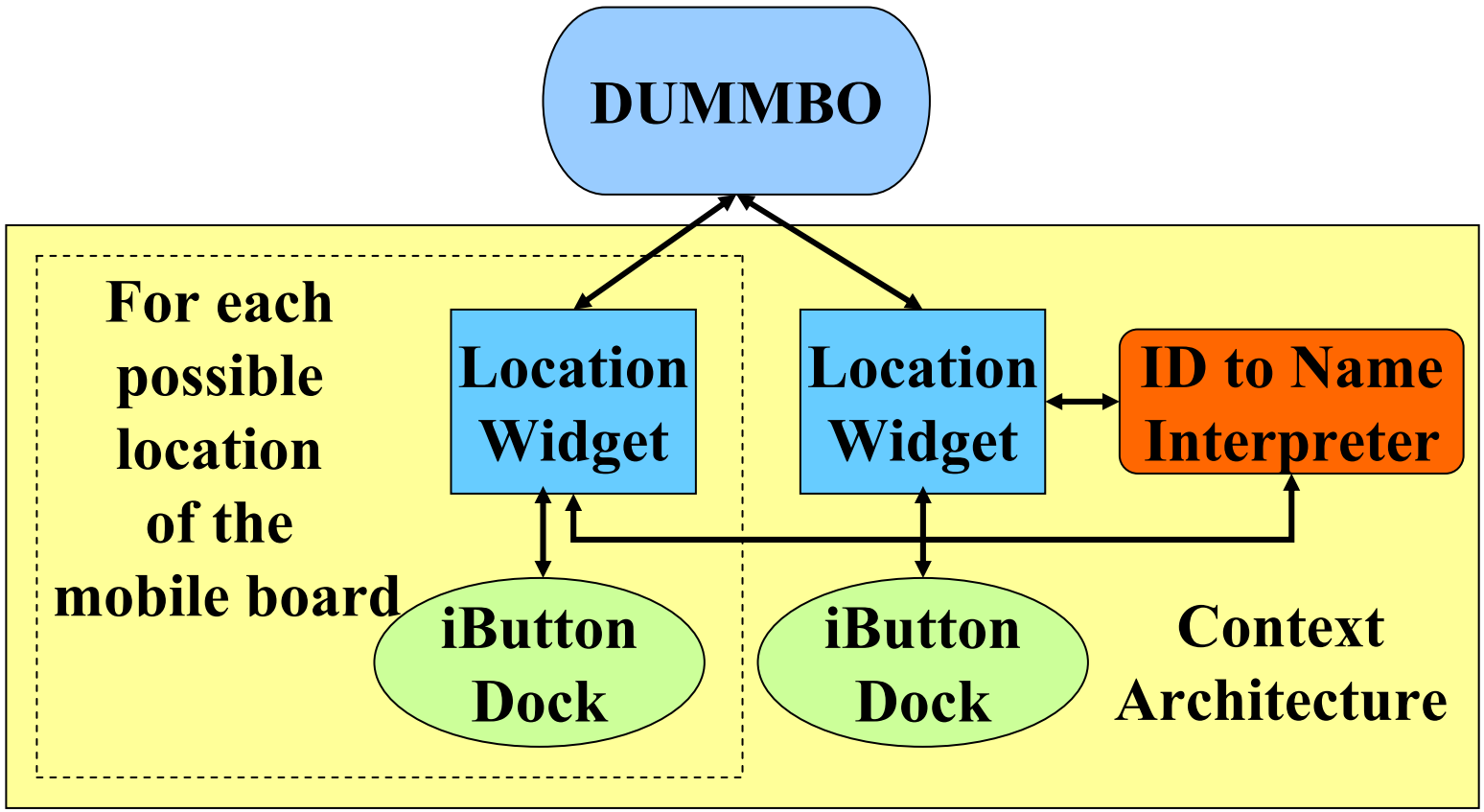
- Context used: location, id, time, activity
- How used: present, perform service, tag
- record and tag drawings and audio for later retrieval

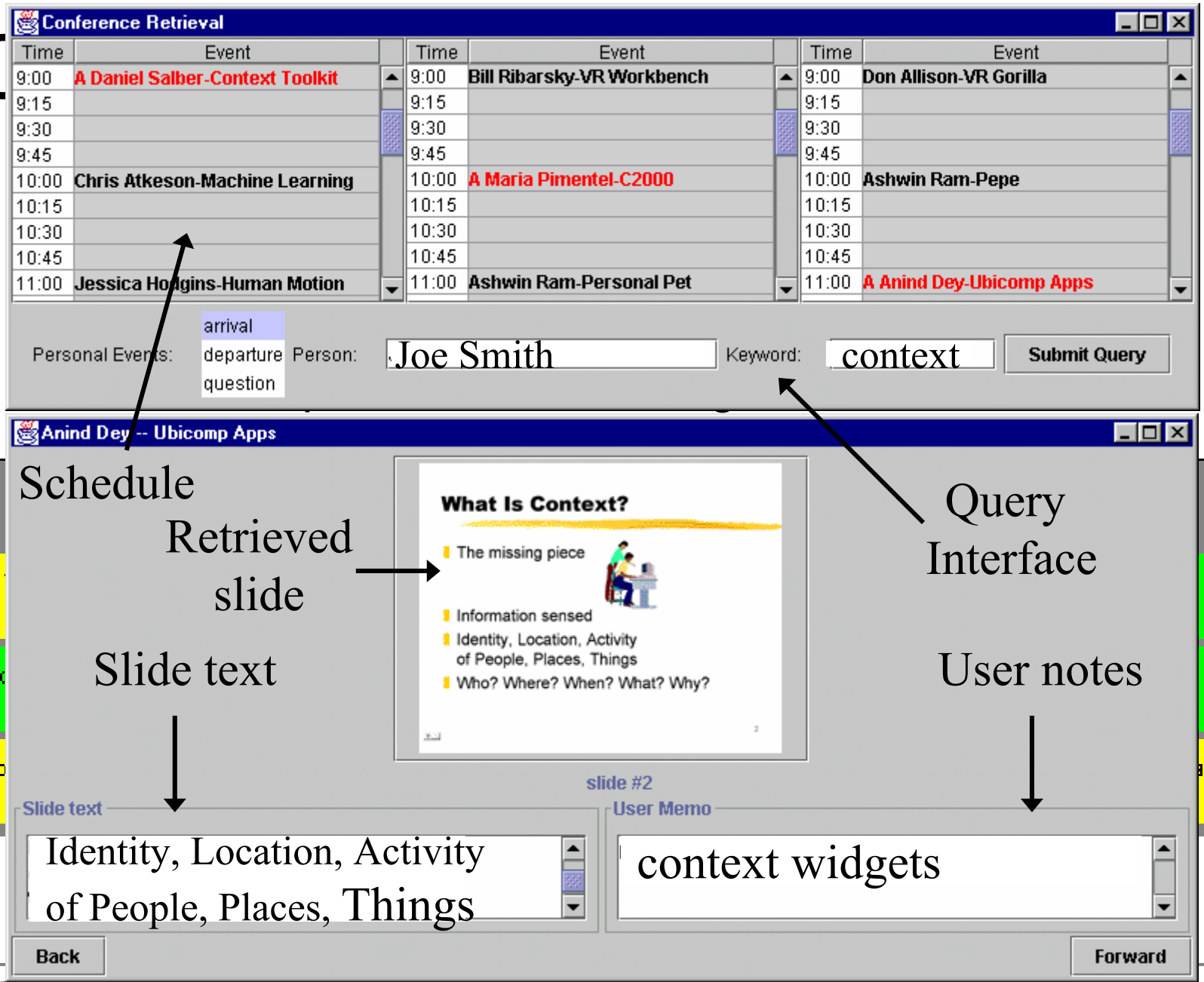




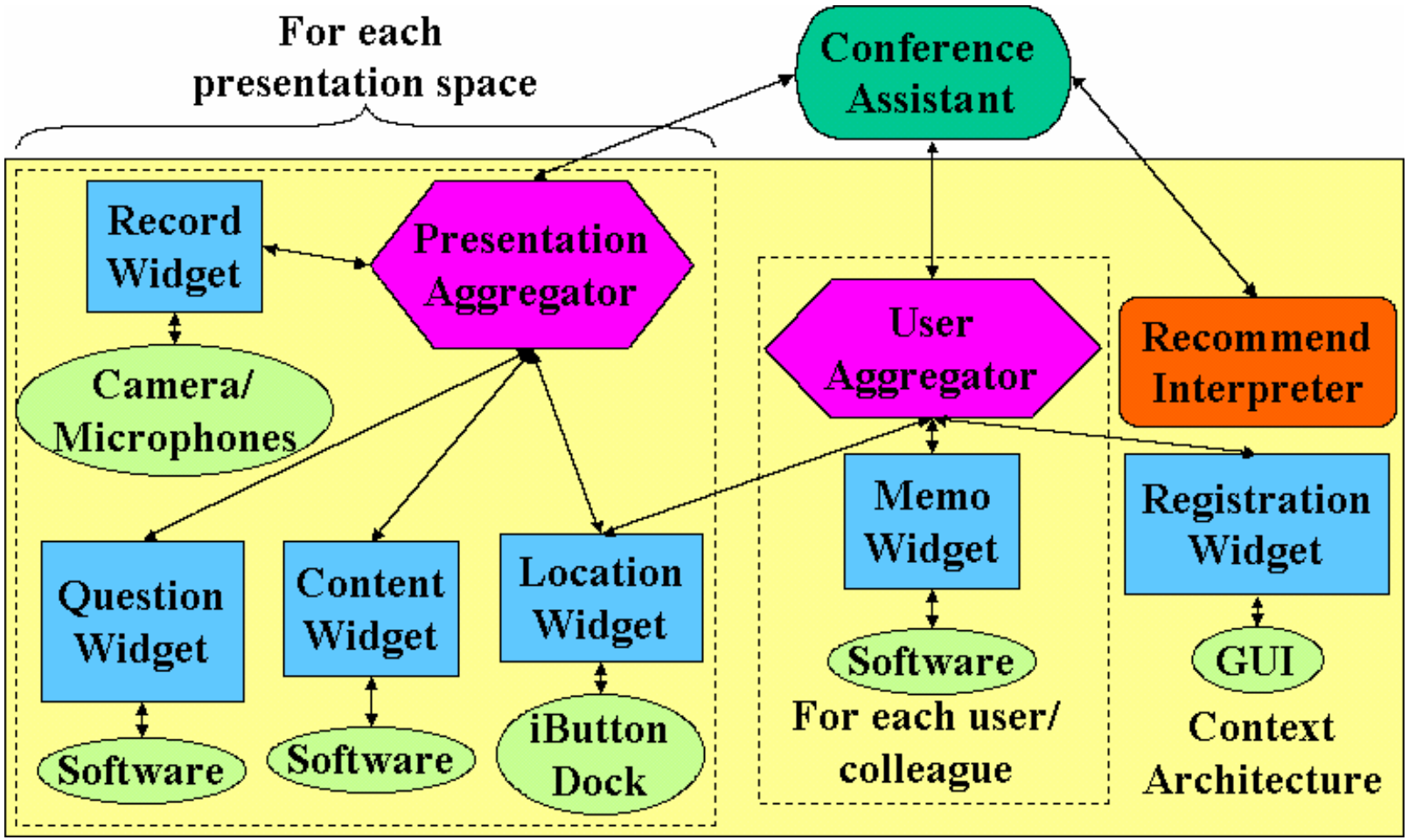

DummboAccess
Play
Stop
When:
Aug
1998
Who:
Jason Brotherton
Where:
Mobile SMART Board #1
Ink written *before* current time is in original color
Ink written *after* current time is in lighter color
Playback controls
Current time within session
Selected session
Selected day
Day containing whiteboard activity
Filters

Meeting Architecture




Conference Retrieval
Time
Event
9:00 A Daniel Salber-Context Toolkit
9:15
9:30
9:45
10:00 Chris Atkeson-Machine Learning
10:15
10:30
10:45
11:00 Jessica Hodgins-Human Motion
9:00 Bill Ribarsky-VR Workbench
9:15
9:30
9:45
10:00 A Maria Pimentel-C2000
10:15
10:30
10:45
11:00 Ashwin Ram-Personal Pet
9:00 Don Allison-VR Gorilla
9:15
9:30
9:45
10:00 Ashwin Ram-Pepe
10:15
10:30
10:45
11:00 A Anind Dey-Ubicomp Apps
Personal Events:
arrival
departure
question
Person:
Joe Smith
Keyword:
context
Submit Query
Anind Dey -- Ubicomp Apps
Schedule
Retrieved slide
Slide text
What Is Context?
The missing piece
Information sensed
Identity, Location, Activity of People, Places, Things
Who? Where? When? What? Why?
Query Interface
User notes
slide #2
Slide text
Identity, Location, Activity of People, Places, Things
User Memo
context widgets
Back
Forward
9:00
Context
VR Work
VR Go
Devices
Tracking
art Floor

Conference Assistant Arch.



Low level context recognition

(Cakmakci et al. 2002)

- Design “context aware hardware”
- Enhance wearable computing
- Detect simple user activities, like sitting, walking, looking at the watch

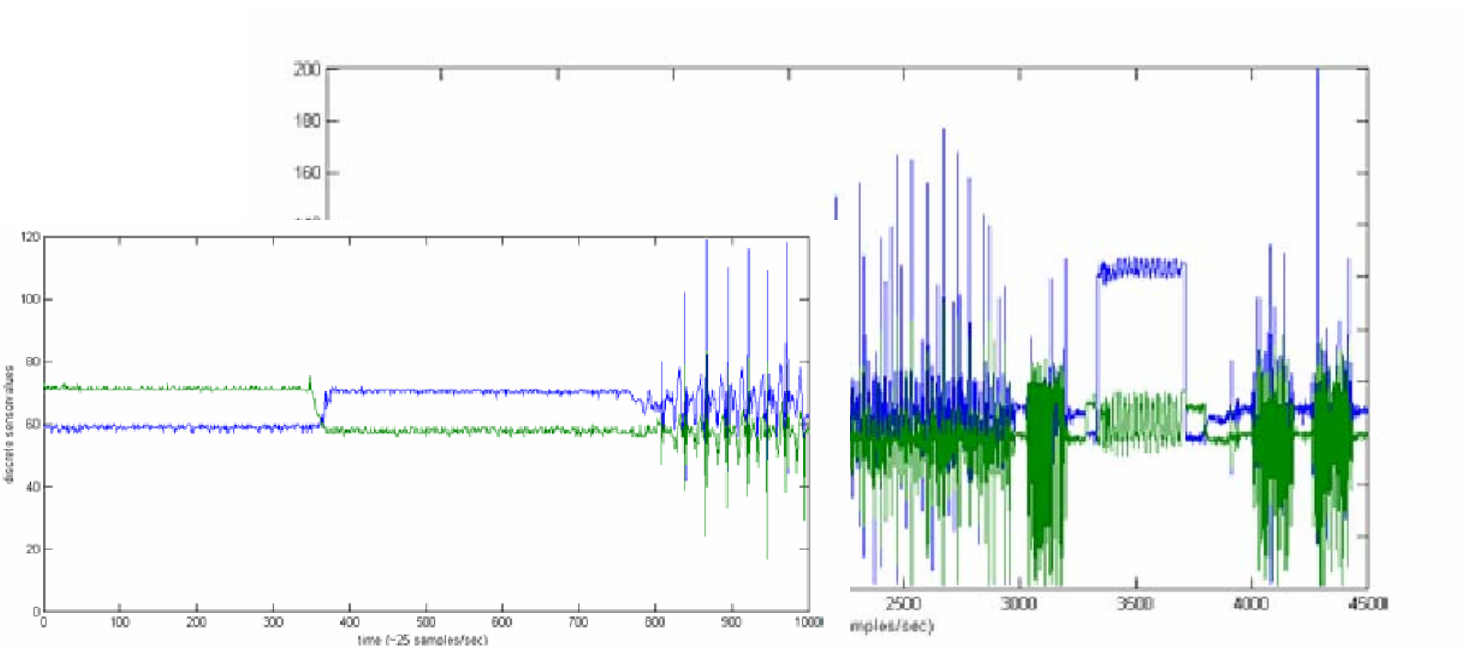
Low level context recognition

- Use statistical modeling techniques from robotics to determine context
- Use accelerometers to record movement changes
- Apply Bayes rule to determine probability of certain contexts:

$$p(context \mid sensordata) = \frac{p(sensordata \mid context) * p(context)}{p(sensordata)}$$

Low level context recognition

- First simple Experiment: Detect whether users are sitting, standing and walking



Acceleration over 4500 data points during the experiment

Use the first 1000 data points for learning

Low level context recognition

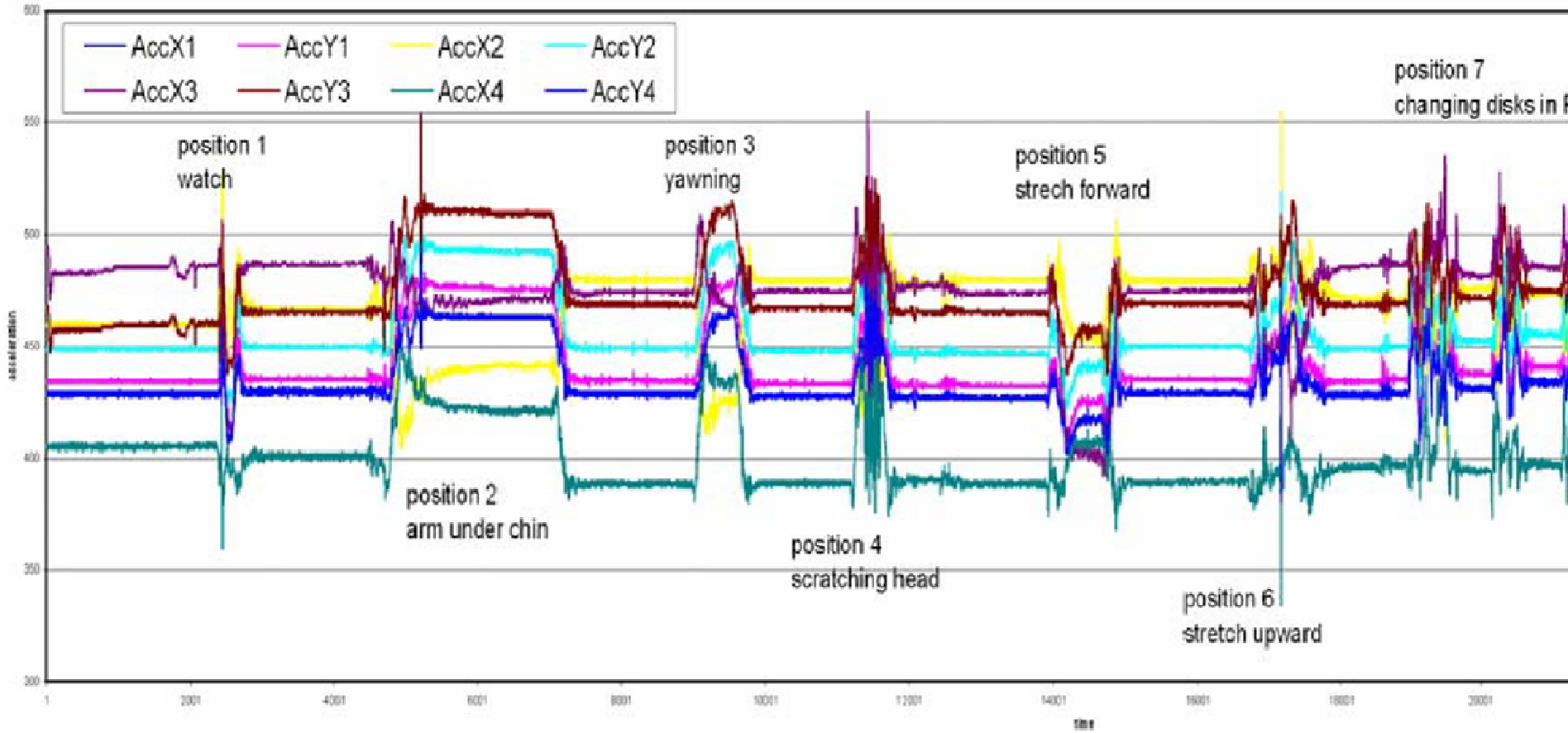
- Results of recognition

Activity	Recognition rate
Sitting (occurs 3 times during the experiment)	95.66%
Standing (occurs 2 times during the experiment)	80%
Walking (occurs 9 times during the experiment)	93.11%

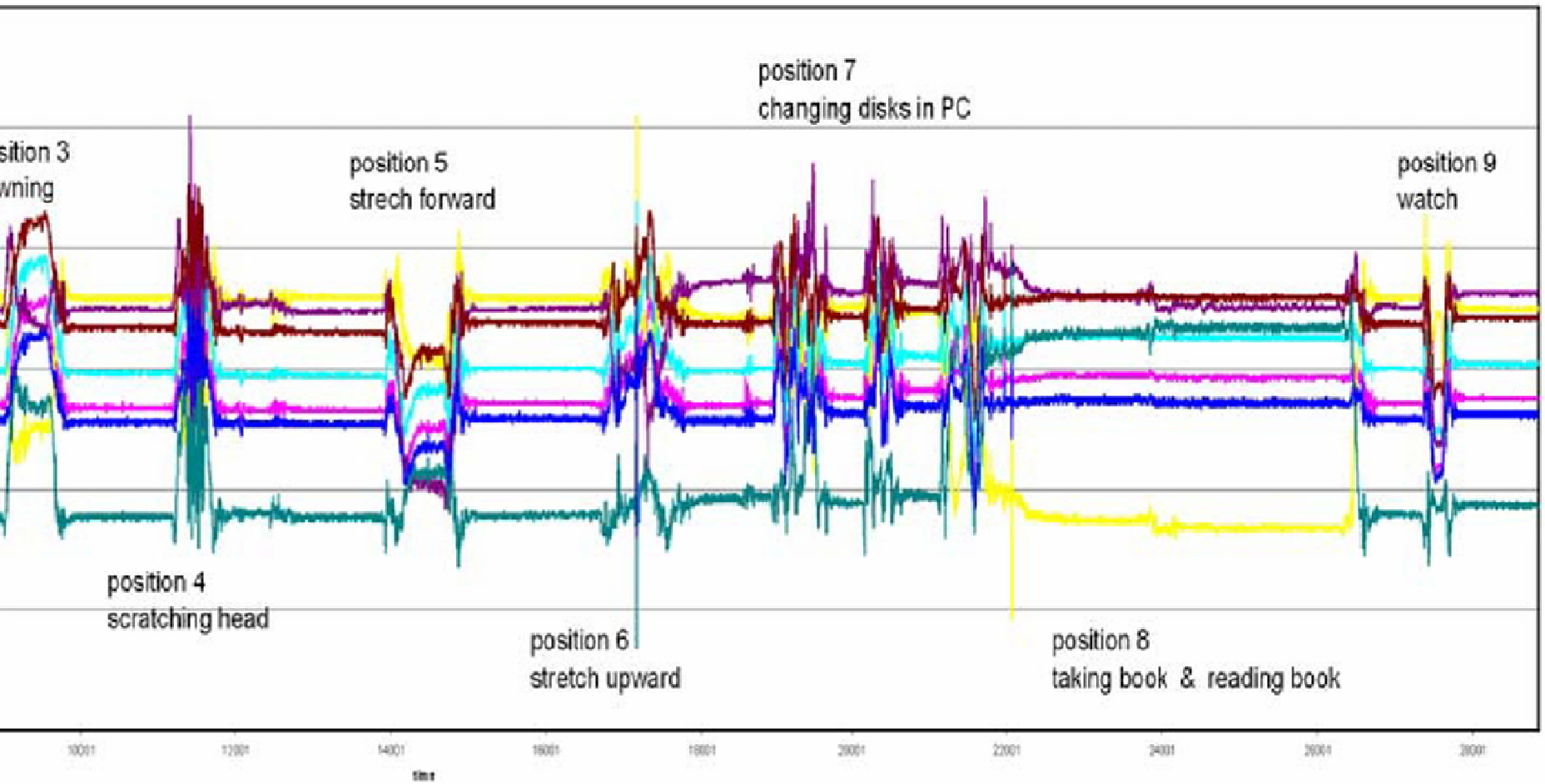
Low level context recognition

- 2nd experiment: Detect when users glance at their watch
- Idea: reduce power of watch (e.g. toggle display) during use
- Extremely important for a wristwatch computer (IBM WWC: ARM7 processor, 8Mb flash memory, 8Mb of DRAM, serial, IRDA, and expansion interfaces).

Low level context recognition



Evaluation set in a blind experiment


sition 3
wning
position 4
scratching head
position 5
strech forward
position 6
stretch upward
position 7
changing disks in PC
position 8
taking book & reading book
position 9
watch
10001
12001
14001
16001
18001
20001
22001
24001
26001
28001
time

Low level context recognition

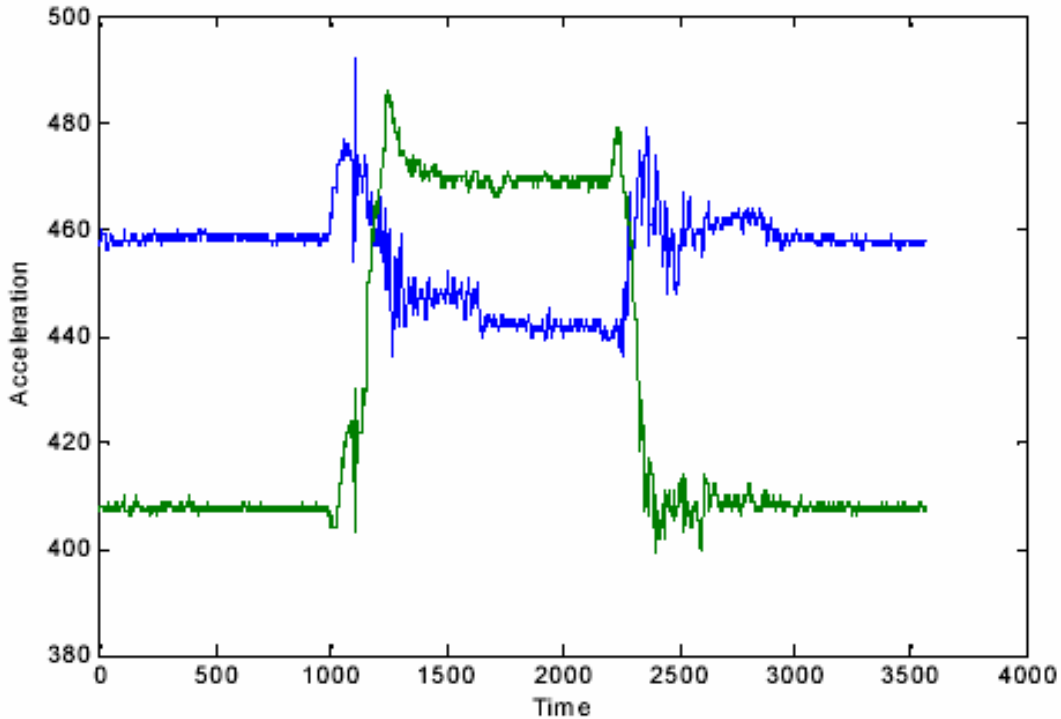
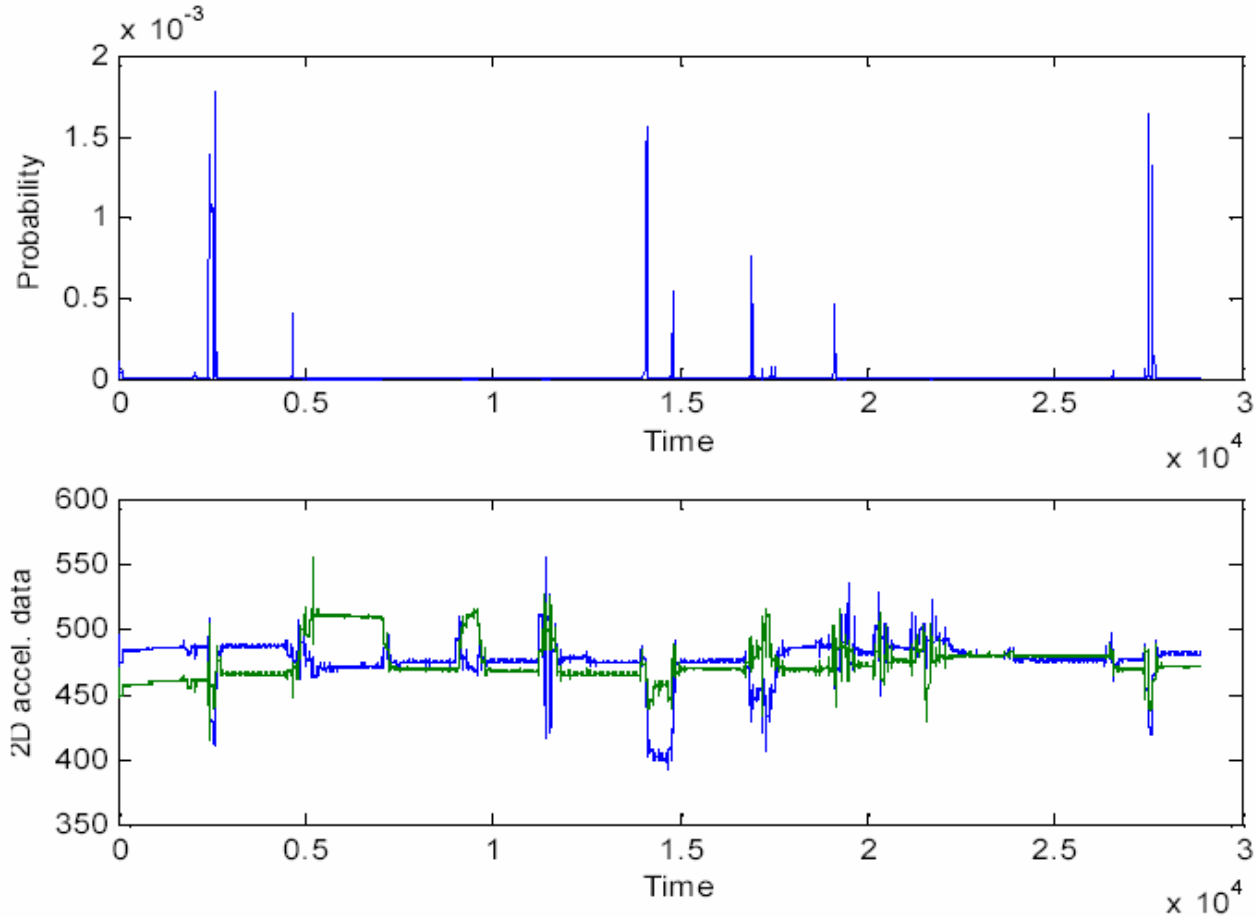


Figure 4. A typical example of training data for looking the watch gesture.

Use a single hypothesis approach to model “wrist watching”
(Only one well defined class)

Low level context recognition



Results:

Probability of certain data points belonging to a wrist watch action

Guest lecture by Marc Böhlen

- **Machines for Supermodernity**
- Dienstag 14.12.04, 12:15 Uhr
  LMU Hauptgebäude, Raum 129 / M010
- Abstract at
  www.mimuc.de