

**Key Applications for Sensor Data  
Science:**

**Context-Aware &  
Persuasive Computing**

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# Context-Aware Computing



There is more to Context than Location,  
Albrecht Schmidt, Michael Beigl and Hans-W. Gellersen,  
Computers & Graphics Journal 2001

# Context-aware Computing

- **What is context?**
- **Acquiring context**
- Using context info
- Errors
- Human in the loop

# Context-aware Computing

- Contextual and Social User Experience



# Context-aware computing

- “software that examines and reacts to an individual’s changing context” - *Schilit, Adams, & Want (1995)*
- “.. uses context to provide relevant info and/or services to the user” - *Dey (2001)*
- “...aware of its user’s state and surroundings, and help it adapt its behavior” - *Satyanarayanan (2002)*

# What is context?

- “any information that can be used to characterize the situation of an entity”  
Dey et al., (2001)
- Entity: person, place, or object that is relevant to the interaction between a user and an application (including the user and applications themselves)
- Who + What + When + Where -> Why?

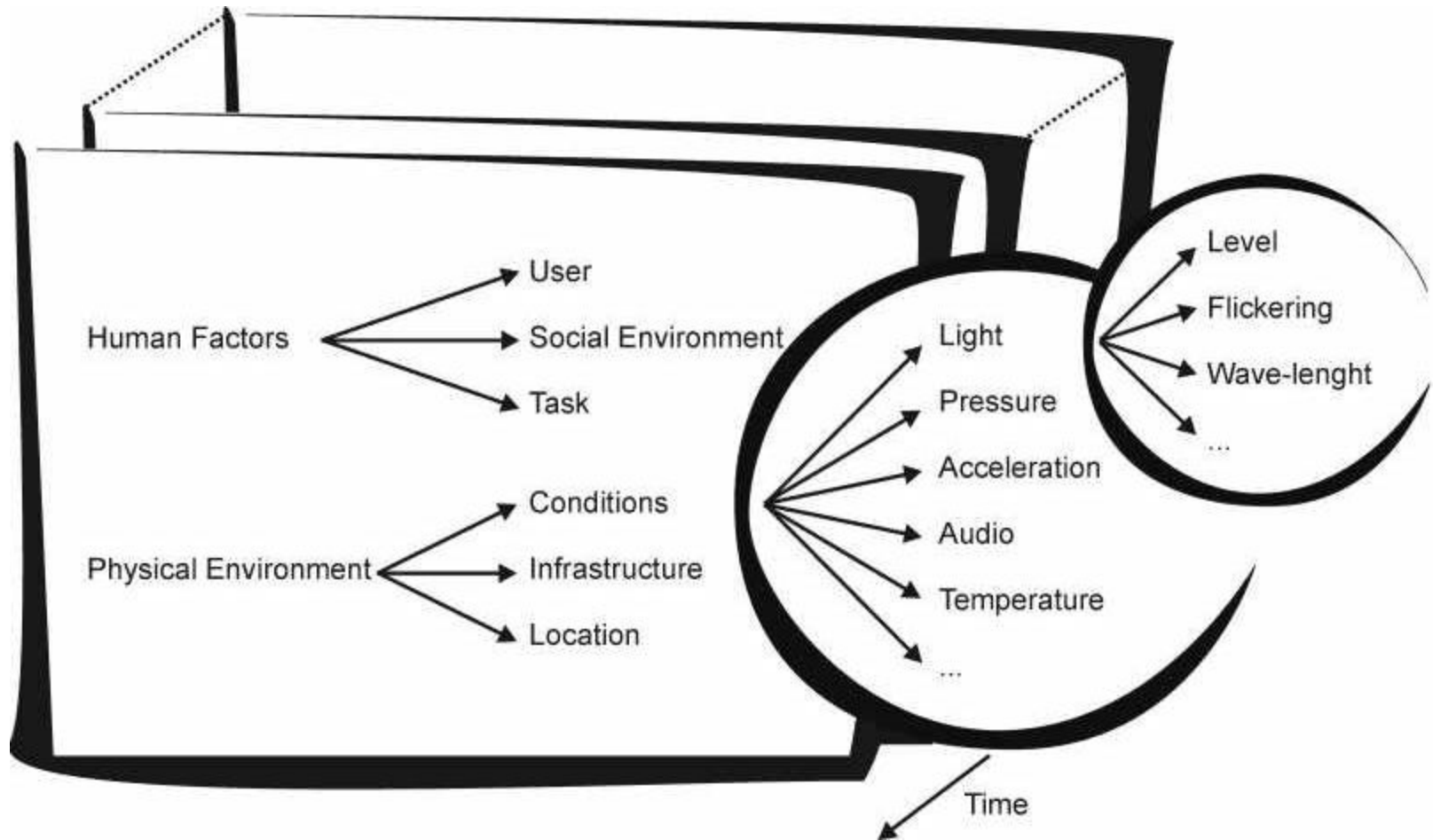
# What is context?

- Schmidt, Beigl, Gellersen's model (2001):
  - A context describes a situation and the environment a device/user is in
  - A context is identified by a unique name
  - For each context a set of features is relevant
  - For each relevant feature a range of values is determined (implicitly or explicitly) by the context

*There is more to Context than Location*

*Albrecht Schmidt, Michael Beigl and Hans-W. Gellersen, Computers & Graphics Journal 2001*

# What is context?










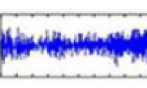



*There is more to Context than Location, Albrecht Schmidt,  
Michael Beigl and Hans-W. Gellersen, Computers & Graphics Journal 2001*



# Beyond Simple Context: SHM

- **Structural Health Monitoring (SHM)** aims to identify **damages** in systems

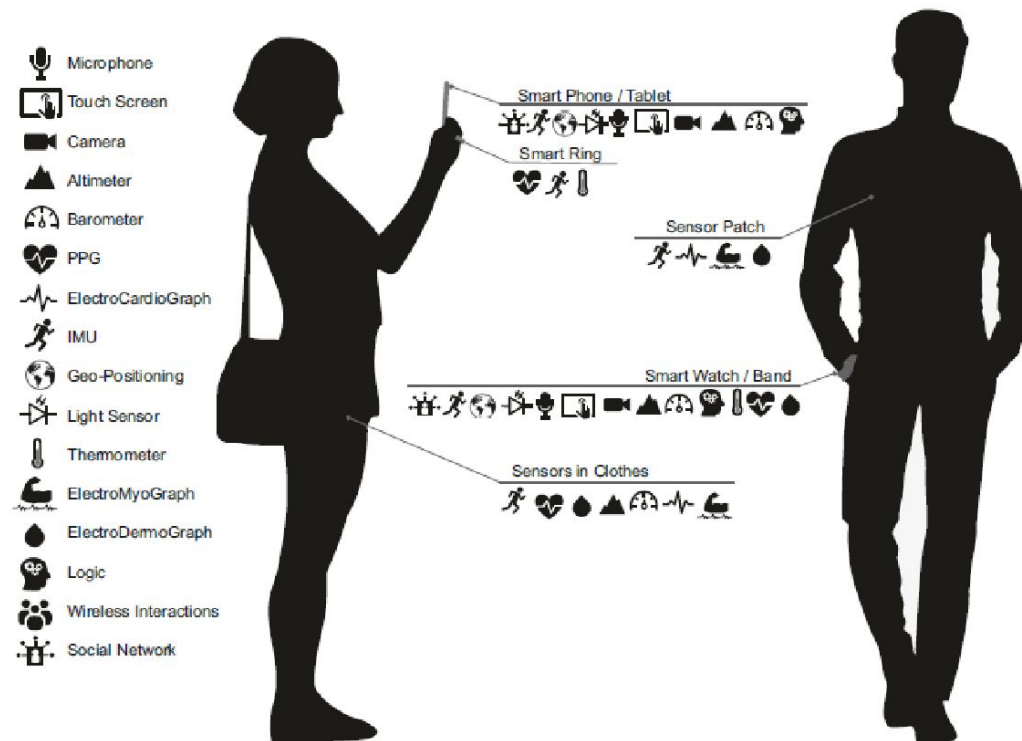
## SHM Analogy

	Human Health Monitoring	Structural Health Monitoring	
System			
Sensor			
Signal			
Expert Analysis			



Application Domains: Aerospace (e.g., airplanes, helicopters), civil engineering (e.g., buildings, dams, tunnels, bridges, mining), transport (e.g., automotive, trains, ships), energy (e.g., wind turbines, oil/gas installations/pipelines)

# Beyond Simple Context: Digital phenotyping/biomarkers

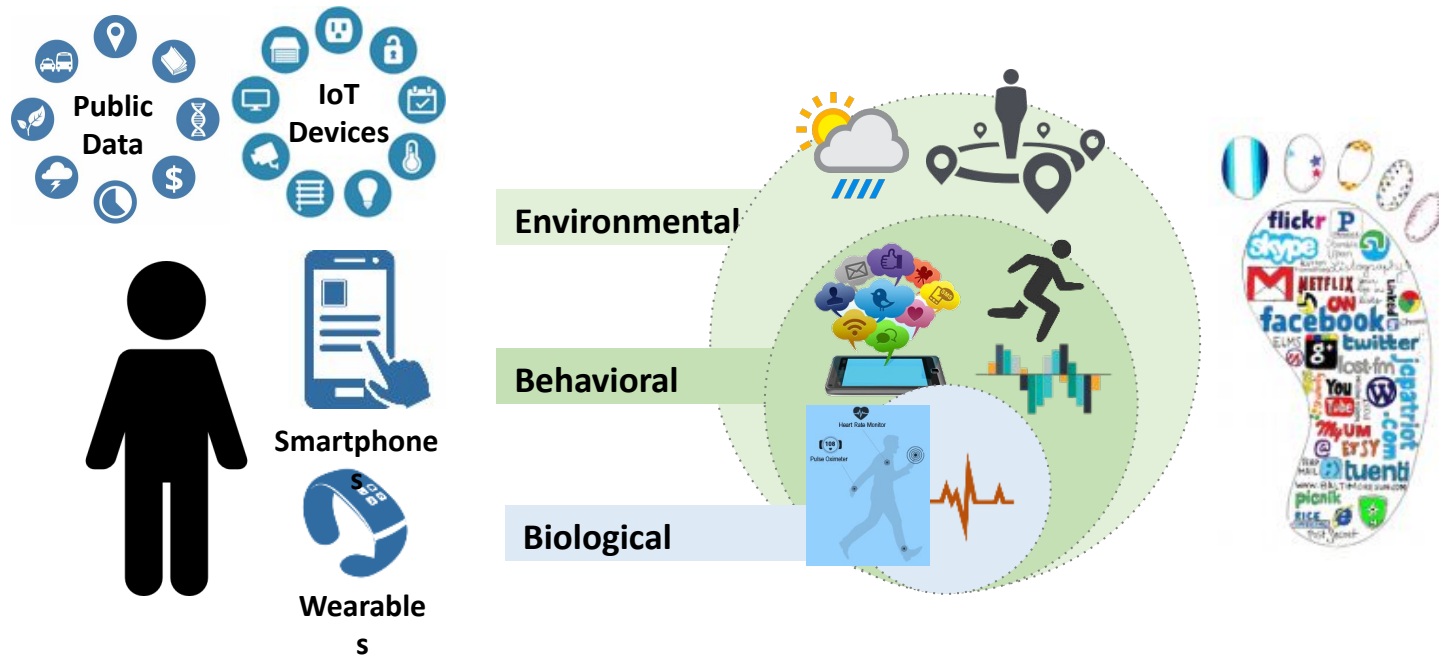


Mobile and wearable devices offer a large personalized,  
direct, and high frequency sensing potential

# Beyond Simple Context:

## *Digital phenotyping/biomarkers*

**Digital phenotype** means personal digital footprints of biological, behavioral, and environmental data, captured either consciously or unconsciously by smart devices and wearables (Nature Biotechnology, 2015)



*Intelligent Positive Computing with Mobile, Wearable, and IoT Devices: Literature Review and Research Directions*, Uichin Lee, Kyungsik Han, Hyunsung Cho, Kyong-Mee Chung, Hwajung Hong, Sung-Ju Lee, Youngtae Noh, Sooyoung Park, John M. Carroll, *Ad Hoc Networks Journal* (Elsevier), 2019

# Acquiring Context

- Smart environment:
  - Infra for obtaining context and for providing context to mobile apps
  - E.g., active badge system: a badge sensing system that obtains location info
- Mobile sensors:
  - Embedded sensors in smart devices
  - E.g., digital cameras w/ motion sensors, smartphones w/ light and motion sensors (automatic brightness control, screen rotation)

# Sensor fusion

- Fusion of multiple sensors to infer a user's context
  - Example:
    - Based on statistical analysis of sensor data, specify rules for context recognition
    - Sensor fusion: sensors  $\Rightarrow$  cues (abstracted representation of sensor data: symbolic)  $\Rightarrow$  context (can be represented using a set of cues)
- (cf. raw sensor data can be also directly used for context learning instead)*

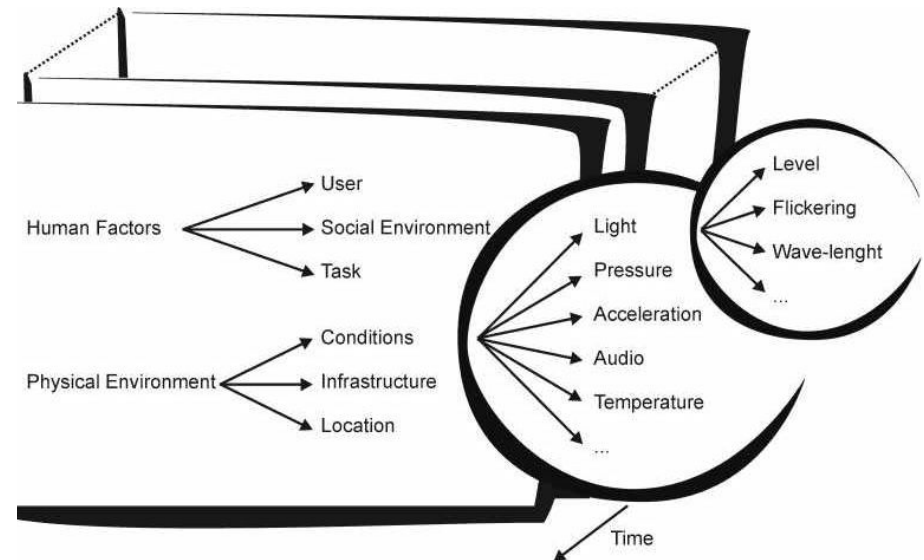
Context	Cues
In the office	Artificial light, stationary or walking, room temperature, dry
Jogging	Natural light (cloudy or sunny), walking or running, dry or raining, high pulse

# Discussion

- Review the definition of context (2 min)
  - What are the key properties? What are the elements?
- Discuss how your mobile phones (or smart watches) can be used for acquiring context information? (3 min)



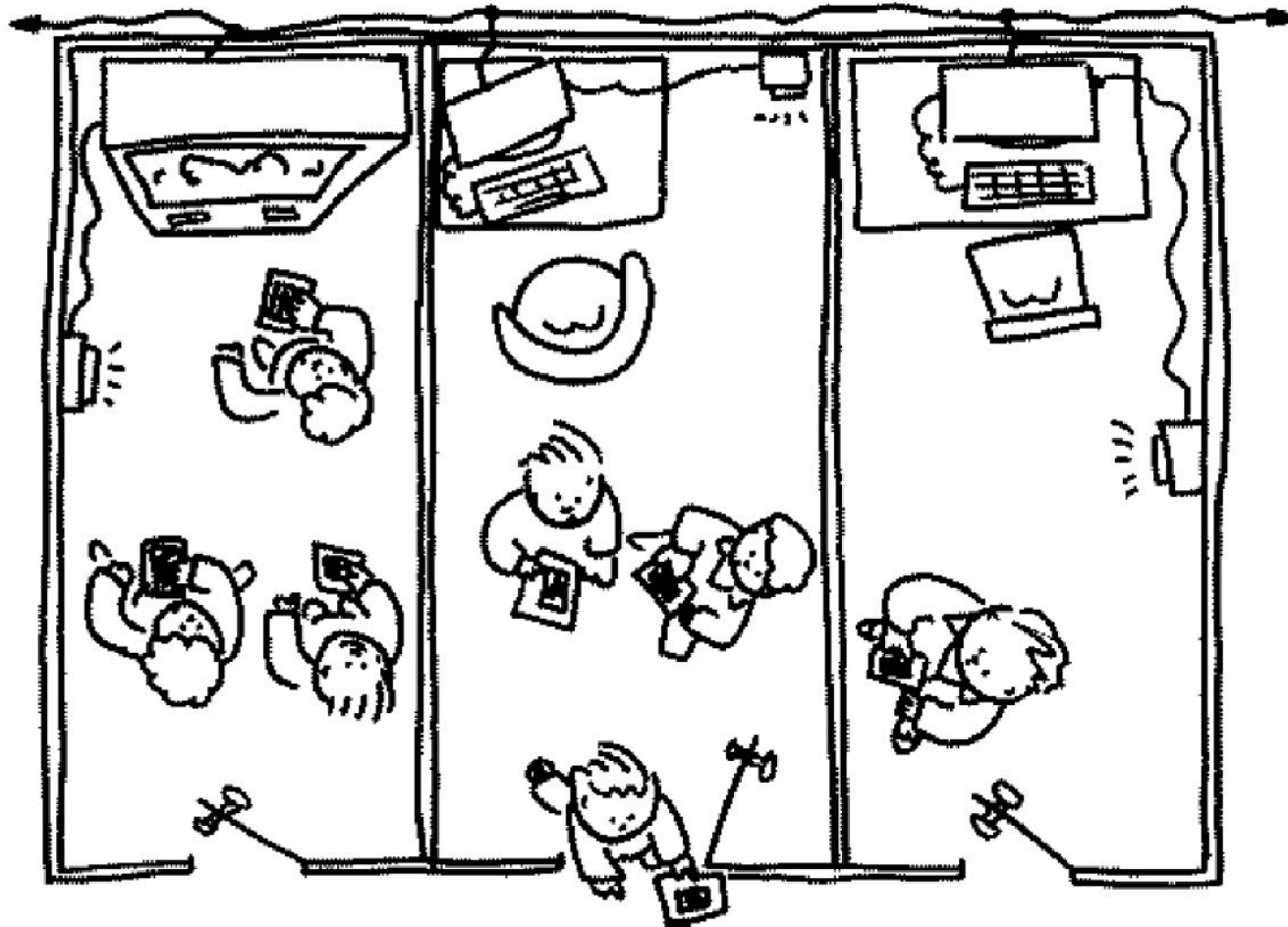
Accelerometer  
Magnetometer (Compass)  
Gyroscope  
Ambient Light  
Proximity  
Camera  
Voice  
Pressure (Barometer)  
NFC  
Heart Rate  
Fingerprint scanner



# Categorizing Context-aware Apps

- Design dimensions
  - Info vs. command: whether the task at hand is getting information or doing a command
  - Manual vs. automatic: whether the task is effected manually or automatically

	<b>Manual</b>	<b>Automatic</b>
<b>Information</b>	Proximate selection & Contextual information	Automatic contextual reconfiguration
<b>Command</b>	Contextual commands	Context-triggered actions



### PARCTAB usage scenarios

(room-level localization + wireless net connections + interactive display (128x64pixel))



# Proximate selection

- A user interface technique that makes the located objects “emphasized” or “being easier to choose”
- Located objects
  - Computing devices; e.g., display, speakers, thermostats, wifi hotspots
  - Non-physical objects and services accessed at a particular location; e.g., menus, lists of instructions or regulations
  - Places that users want to find (like yellow pages); e.g., sorting places according to the distance

# Proximate selection

- Proximate selection dialog for printers (name of the printer, location, a distance from the user)

Name	Room	Distance
caps	35-2-2-00	200ft
claudia	35-2-1-08	30ft
perfector	35-2-3-01	20ft
snoball	35-2-1-03	100ft

(a)

Distance	Name	Room
20ft	perfector	35-2-3-01
30ft	claudia	35-2-1-08
100ft	snoball	35-2-1-03
200ft	caps	35-2-2-00

(b)

Name	Room	Distance
caps	35-2-2-00	200ft
<b>claudia</b>	<b>35-2-1-08</b>	<b>30ft</b>
<b>perfector</b>	<b>35-2-3-01</b>	<b>20ft</b>
snoball	35-2-1-03	100ft

(c)

Name	Room	Distance
caps	35-2-2-00	200ft
claudia	35-2-1-08	30ft
perfector	35-2-3-01	20ft
snoball	35-2-1-03	100ft

(d)

# Proximate selection

- How about using an interactive map?  
(virtual objects = questions in Naver KiN “Here”)



Location-based Social Q&A

# Contextual info and commands

- People's actions can be predicted by their situations, e.g., library, kitchen, office, etc.
- Context parameterizes “context command”; e.g., print
  - by default: print to the nearest printer

# Contextual info and commands

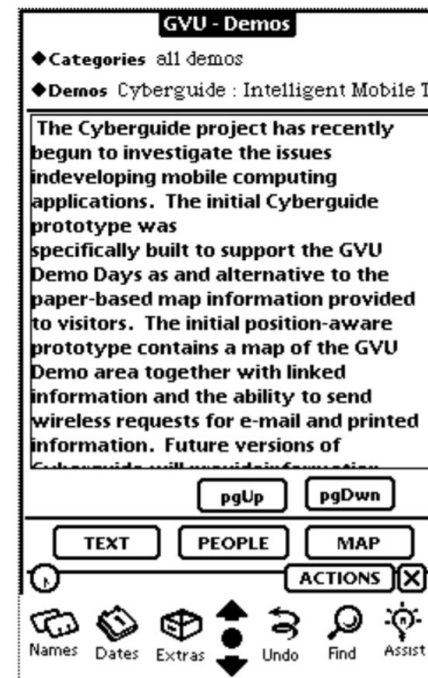
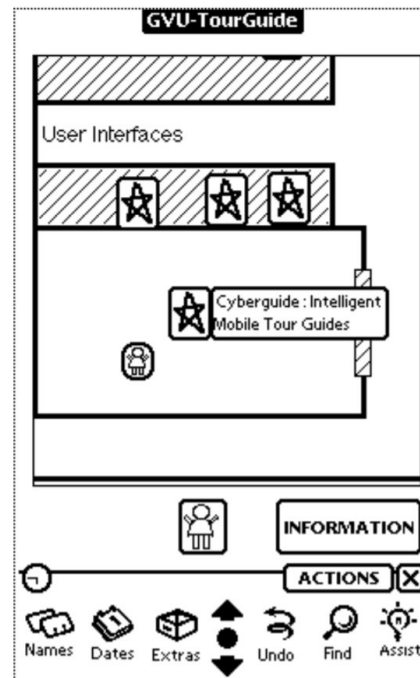
- PARCTAB's location-based file system
  - Directories are location names, containing files, programs, and links
  - Location browser automatically shows the directory that matches with the current location
    - Office: occupants' finger plans, calendar files
    - Lab: general description of the research group
- Location browser also runs “contextual commands”
  - Migrate a remote app's window to a nearby display
  - Display a library catalog (when entering the library, this button pops up)

# Contextual info and commands

- Cyberguide (1997)



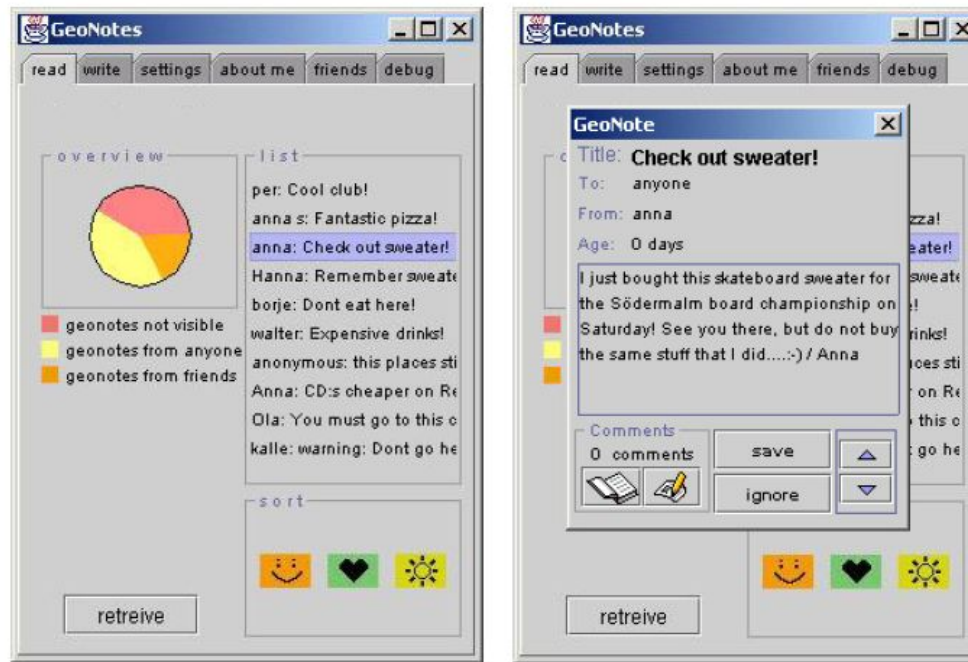
Apple MessagePad



Cyberguide: A Mobile Context-Aware Tour Guide, G. D. Abowd et al, Wireless Networks, 1997  
'Caches in the Air': Disseminating Tourist Information in the Guide System, 1999

# Contextual info and commands

- Geonotes (Espinoza et al., 2001)
  - Real-world annotation (post-it?)



# Automatic contextual reconfiguration

- Process of adding new components, removing existing components, or altering the connection between components
- Components and connections: client UI, servers, their communication channels to clients
  - Changing connections
  - Changing client/server states (internal + UI)



# Automatic contextual reconfiguration

- Light sensitive display
- Orientation-sensitive user interface

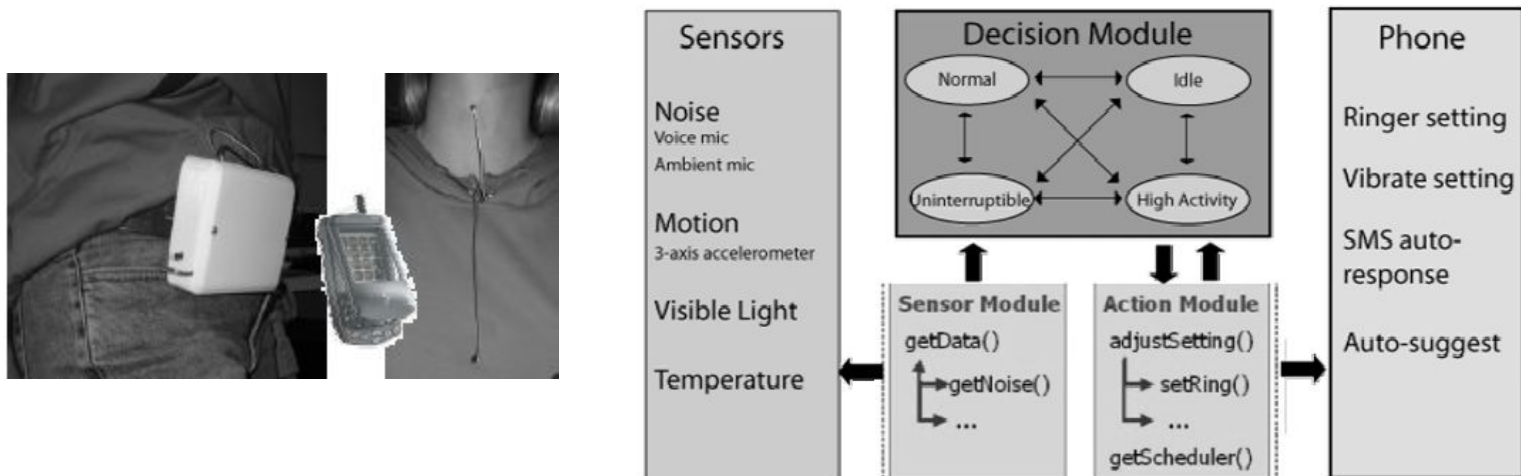


Orientation Sensor



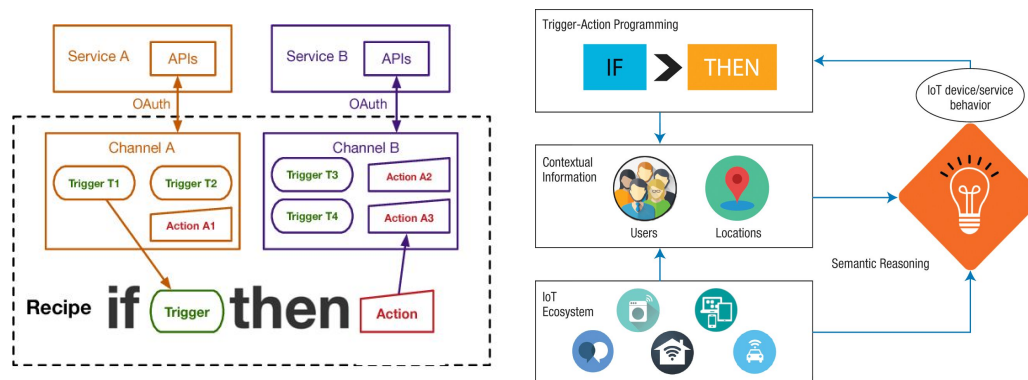
# Automatic contextual reconfiguration

- Virtual whiteboard example:
  - When entering a room, a mobile host automatically binds itself to the room's virtual whiteboard
- SenSay (Siewiorek et al., 2003)
  - A context-aware mobile phone with four states: Uninterruptible, Idle, Active, and Normal (default)



# Context-triggered actions

- Simple condition-action rules invoked automatically
- Challenges:
  - Expressiveness of language for rules
  - Context sensing accuracy used in the condition/action



**IFTTT – simple if – this – then – that rule**

*Supporting mental model accuracy in trigger-action programming, Ubicomp 2015*

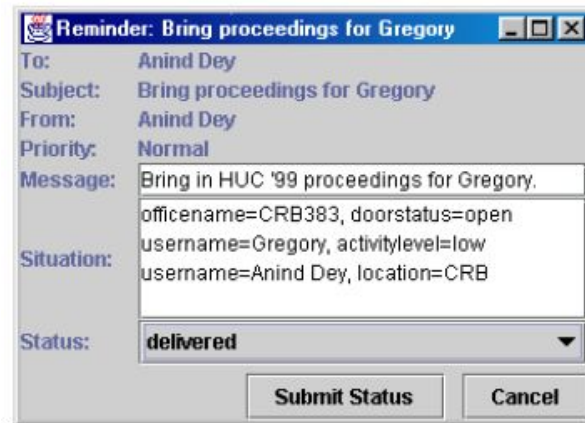
*A Semantic Web Approach to Simplifying Trigger-Action Programming in the IoT, Computer 2017*

# Context-triggered actions

- Active Badge:
  - Rule form: badgeID location event-type action
  - if I go walk by kitchen, remind me to get coffee (e.g., playing a music) – similar to IFTTT



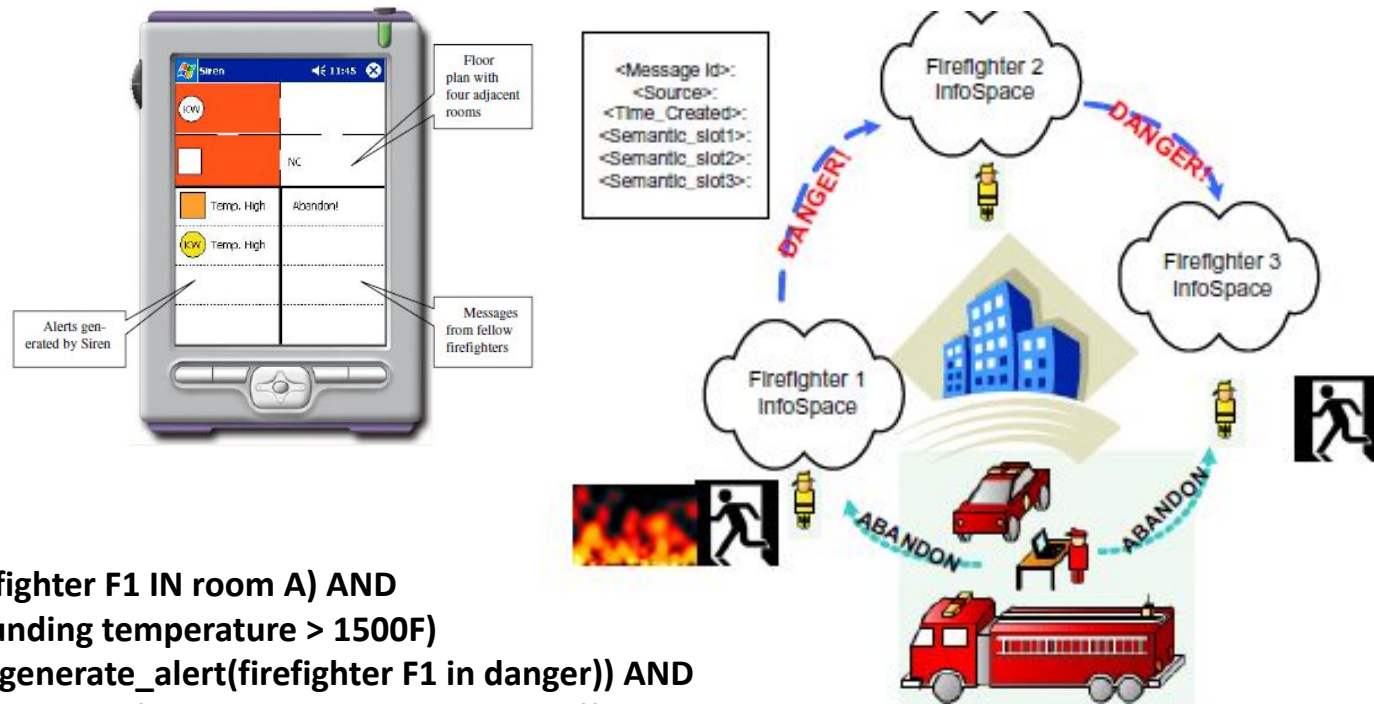
Active Badge



CyberReminder (Dey et al., 2000)

# Context-triggered actions

- Example: Siren (Jiang et al., 2004)



IF (firefighter F1 IN room A) AND  
(surrounding temperature > 1500F)  
THEN (generate\_alert(firefighter F1 in danger)) AND  
(generate\_alert(room A is a dangerous place))

# Persuasive Computing

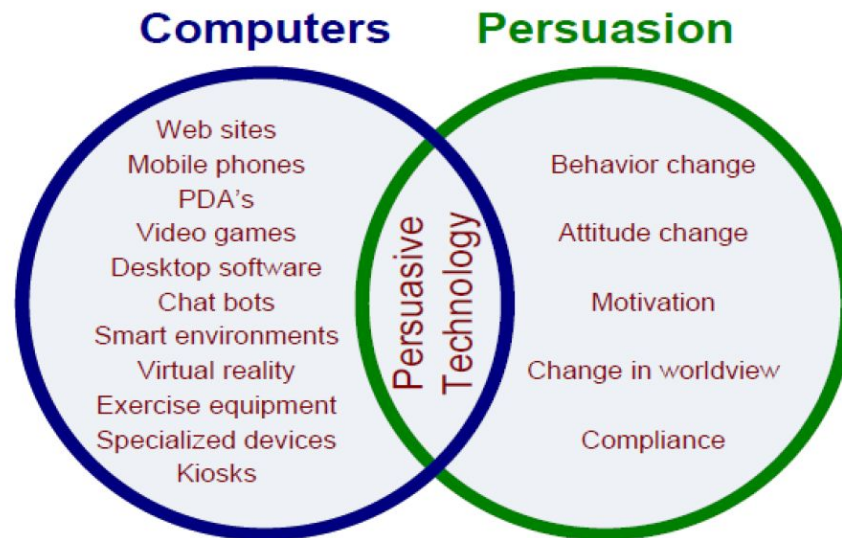


*Persuasive Technology: Using Computers to Change What We Think and Do, B.J. Fogg, 2002*

*Persuasive computers: perspectives and research directions, BJ Fogg, CHI 1998*

# Persuasive Technology

- "Simply put, a persuasive computer is an interactive technology that changes a person's attitudes or behaviors or both." (B.J. Fogg)
- Persuasion is "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action"



# Persuasive Technology

- Attitude or behavior change resulting from human-computer interaction (HCI)
- Planned persuasive effects of technology, not on side effects.
- Endogenous, or “built-in,” persuasive intent, not on exogenous intent.

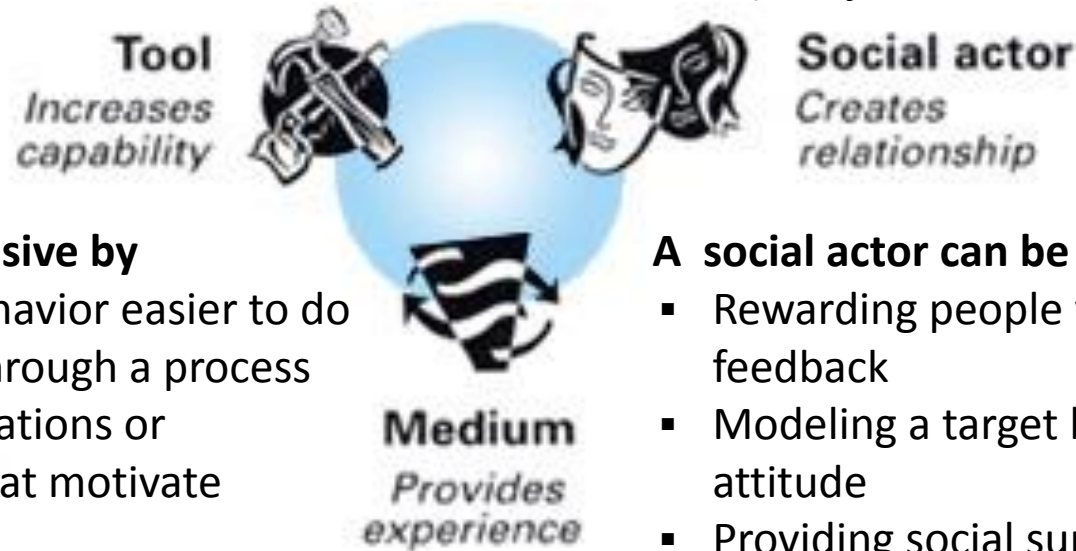


# Advantages over Human Persuaders

- Be more persistent than human beings
- Offer greater anonymity
- Manage huge volumes of data (store/access/process)
- Use many modalities (data, graphics, audio/video, simulation) to influence
- Scale easily
- Go where humans cannot go or may not be welcome (ubiquitous computing!)

# Functional triads of persuasive tech

(role just like “living” entities)



## A tool can be persuasive by

- Making target behavior easier to do
- Leading people through a process
- Performing calculations or measurements that motivate

## A social actor can be persuasive by

- Rewarding people with positive feedback
- Modeling a target behavior or attitude
- Providing social support

## A medium for simulated experiences can be persuasive by

- Providing people with **vicarious experiences** that motivate
- Helping people **rehearse** a behavior (simulating environment or objects)
- Allowing people to explore **cause-and-effect** relationships

# Nintendo's Pocket Pikachu



- Pedometer + Virtual Pet (Pikachu)
- Feeding requires “physical movements”
- Making users to move more! (walk, run, jump)

- Tool – Automatic step counting
- Medium – Not clear
- Social Actor – Pocket Pikachu (virtual pet)

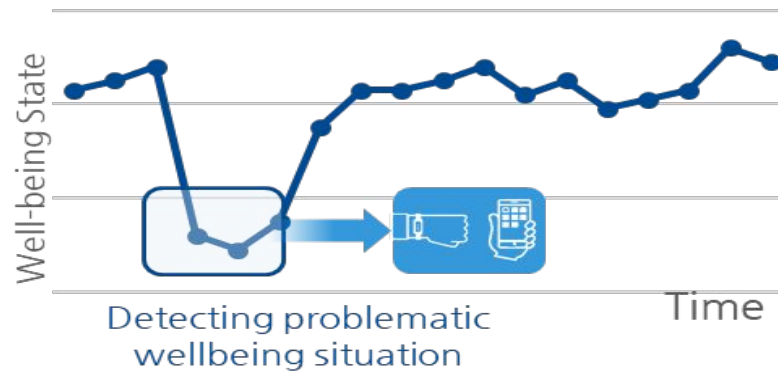
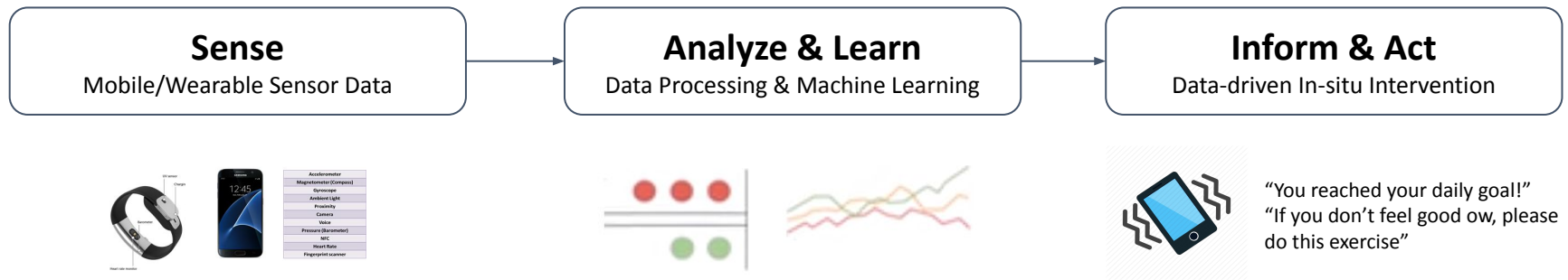
# “Baby Think it Over” Infant Simulator



- Helps teenage girls understand how much attention a baby requires
- Used as part of many school programs

- Tool – Tracking user behaviors
- Medium – Simulating real-world contexts (i.e., baby caring)
- Social Actor – Robot as a real baby to care

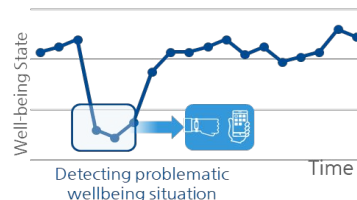
# Data-driven In-Situ Intervention



**Personalized just-in-time intervention  
(e.g., Ginger.io)**

# Discussion

- Select one “persuasive” (+contextual) computing service
  - You can choose any service that you know of
  - Pick a service/app/product that has some interesting points to discuss (from the perspective of “functional triads”)
- Analyze: context sensing + functional triads
  - What kinds of context sensing does it offer?
  - How is it related to each of functional triads?



“Persuasive” computing  
service



Functional  
triads

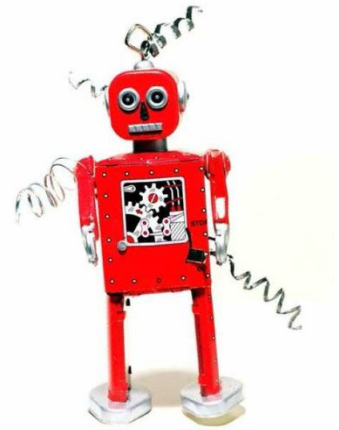
# Errors

- When the system does the wrong thing
  - Automatically locking car doors
  - Screen saver during presentation
  - Microphone amplifying a whisper
- False positives vs. false negatives
  - Application requirement dependent: e.g., machine fault detection (false negative must be minimized)
- Whose fault: System vs. User?
- How to get over such errors?



# Human in the loop

- Context data must be coupled with the ability to interpret it, but computers are bad at common sense
- Having more rules makes the system more complicated; doesn't solve the fundamental problem
- Human in the loop
  - Computers can detect, aggregate, and portray information
  - Allow human users to interpret and act on it
  - Human-AI interaction: query, machine feedback, interpretability





# Summary

- What is context?
- Acquiring context
- Using context info
  - Proximate selection: Nearby printer selection
  - Contextual information and commands: GeoNotes, Map-based info
  - Automatic contextual reconfiguration: Virtual Whiteboard, SenSay
  - Context-triggered actions: Active Badge, Siren
- Persuasive Technology aims to change a person's attitudes or behaviors or both
- Functional triads: (1) tool (increase capability), (2) medium (provide experience), (3) social actor (creates relationship)
- Errors
- Human in the loop