What is Context-Aware Computing?

• “Software that examines and reacts to an individual’s changing context.” [Schilit, Adams, Want 1994]

• “...aware of its user’s state and surroundings, and help it adapt its behavior” [Satyanarayan 2002]

• Systems that are able to adapt their operations to the current context without explicit user intervention

• Aim at increasing usability and effectiveness by taking environmental context into account
What is Context?

- “… any information that can be used to characterize the situation of an entity.” [Dey et al. 2000]
- Places, People, Things
  - Location (where?)
  - Identity (who?)
  - Time (when?)
  - Activity (what?)

Traditional Computer View

Context independent: acts exactly the same

input → Computer System → output

Human in the loop
From Abstraction to Context Sensitivity

- Traditional black box view comes from the desire for abstraction
- This is based on several assumptions:
  - Explicit input/output: slow, intrusive, requiring user attention
  - Sequential input-output loop
- Move away from the black box model and into context-sensitivity
  - Human out-of-the-loop (as much as possible)
  - Reduce explicit interaction (as much as possible)

Context as Implicit Input/Output

**Context:**
- State of the user
- State of the physical environment
- State of the computing system
- History of user-computer interaction
- ...
Context

- Identity (user, others, objects)
- Location
- Date/Time
- Environment
- Emotional state
- Focus of attention
- Orientation
- User preferences
- Calendar (events)
- Browsing history
- Behavioral patterns
- Relationships (phonebook, call history)
- ... the elements of the user’s environment that the computer knows about...

Classification

- External (physical)
  - Context that can be measured by hardware sensors
  - Examples: location, light, sound, movement, touch, temperature, air pressure, etc.
- Internal (logical)
  - Mostly specified by the user or captured monitoring the user’s interaction
  - Examples: the user’s goal, tasks, work context, business processes, the user’s emotional state, etc.
## Why Context-Aware Computing?

### Existing Examples

<table>
<thead>
<tr>
<th>Potential Examples</th>
<th>Context Types</th>
<th>Human Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto Cell Phone Off In Meetings</td>
<td>Identity, Time, Location</td>
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<td>Proximal Reminders</td>
<td>Activity, Proximity</td>
<td>Memory</td>
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<td>Health Alert</td>
<td>History, Activity</td>
<td>Safety</td>
</tr>
<tr>
<td>Service Fleet Dispatching</td>
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### Potential Examples

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### Categories of CA Applications

<table>
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<tr>
<th>Manual</th>
<th>Automatic</th>
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<tr>
<td>Getting Information</td>
<td>Proximate Selection &amp; Contextual Information</td>
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<td>Automatic Contextual Reconfiguration</td>
<td>Contextual Commands</td>
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<td>Executing Command</td>
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<td>Contextual Commands</td>
<td>Context-Triggered Actions</td>
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### Proximate Selection/Contextual Information

**Table 2: UI Techniques for Proximate Selection**

<table>
<thead>
<tr>
<th>Name</th>
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<th>Distance</th>
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<tr>
<td>caps</td>
<td>35-2200</td>
<td>200ft</td>
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<td>35-2108</td>
<td>30ft</td>
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<td>snoball</td>
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</tbody>
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Computer Science and Engineering - University of Notre Dame
Proximate Selection/Contextual Information

- Bluetooth®

**Discovery Results**

**Select a PC:**
- L000572VF51
- PALMONE-OW36v71
- Jim’s PC
- PALMONE-712AZAS
- StenDinBlue
- Bonnie

**Devices**

1. New
2. Edit
3. Delete
4. Set as Hands-free

Done Menu

Proximate Selection/Contextual Information

- MacMini
- DELL AXIM X50
- iPAQ 2215
- MacMini

Computer Science and Engineering - University of Notre Dame
Automatic Contextual Reconfiguration

- Add, remove, or alter components based on context
- SenSay project: context-aware mobile phone
Contextual Commands

- Users can parameterize commands with context-filtered values; execution changes based on context.
- Example: universal remote control.

Context-Triggered Actions

- Simple if-then condition-action rules, automatically invoked.
- Reminder: if I step into the car on weekday morning and don’t have suitcase with me, remind me to get it.
- CybreMinder:
Context-Triggered Actions

- Challenges:
  - Expressiveness of language for rules
  - Accuracy of context information

- Siren:

![Image of a mobile device with a context-triggered action interface]

\[IF\text{ (firefighter T1 IN room A) AND (surrounding temperature > 180°F)}\]
\[THEN\text{ (generate_alert (firefighter T1 is in danger)) AND (generate_alert (room A is a dangerous place))}\]

Context-Awareness

- Context-awareness helps technology to “get it right”
- But context is hard to sense (quantity, subtleness)
- Computers are not self-aware like humans

- Problems:
  - When the system does the wrong thing
    - auto-locking car doors
    - screen saver during presentation
    - microphone amplifying a whisper
Context-Awareness

- Context data must be coupled with the ability to interpret it, but computers are bad at “common sense”.
- More rules ≠ intelligence
- More rules = more complexity, harder to understand

- “Human in the Loop”:
  - computers can detect, aggregate, portray information
  - allow human users to interpret and act on it
  - Is this a good strategy for all context-aware systems?

Encourage Healthy Dietary Behaviors

- Interactive game to assist teachers to improve dietary behaviors of kindergarten children (“smart lunch tray”)
AudioIndex

- Allowing visually impaired to browse and search audio books. Main device around neck, earpiece with audio feedback, pointing device on index finger.

Emergency Medical Response

http://www.aids.org
Protech Parolee Monitor

- A “child safety product”
- Activates an alarm when a child wanders more than 15 feet from the adult “base” unit
- Also alarms if submerged in water
5 Design Considerations

1. Improving relevance
   – Deciding when a communication is relevant to the person’s current (or near future) situation.
   – For example, getting notification about an email from your travel agent regarding itinerary changes while packing to leave for the airport.

2. Minimizing disruption

3. Improving awareness

4. Reducing overload

5. Selecting channels
5 Design Considerations

1. Improving relevance
2. Minimizing disruption
3. Improving awareness
   - Deciding what information and mechanisms can help people make intelligent communication decisions.
   - For example, the caller should be told you are at the movies before the call goes through.
4. Reducing overload
5. Selecting channels
5 Design Considerations

1. Improving relevance
2. Minimizing disruption
3. Improving awareness
4. Reducing overload
5. Selecting channels
   - Deciding which communication device should be used to get in touch with somebody.
   - For example, routing calls to your home phone instead of your cell phone when you are at home and cellular reception is poor.

The “research context” of “context-awareness computing in health care”

- Context-aware medical applications
  - Vocera communication system (St. Vincent hospital, USA)
    - Communicator badge system for mobile user
      - Push-to-call button, small text screen, voice dialing, hand-free conversation
      - Biometrically secured with speaker verification

- Hospital-based prototypes
  - Hospital of the future (Centre for Pervasive Healthcare, Denmark)
    - Hospital bed with a built-in display
      - Bed “knows” who is using it, and what and who is near it
    - A context-aware pill container that is “aware of the patient”
    - A context-aware Electronic Patient Record
      - Medication scheme or patient record
  - Intelligent hospital software (University of Cambridge, UK)
    - Scenarios of use
      - Remote consultation, tracking of patients and equipment, notification of awareness and patient data
    - Implementing a prototype
      - QoS DREAM: middleware platform
Research in health care domain

Table 3 - Trends in context awareness

<table>
<thead>
<tr>
<th>People</th>
<th>Research in health care domain</th>
<th>Prototype</th>
<th>Medical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA—MIT Media Lab [11-12]</td>
<td>Several media lab projects.</td>
<td>Comp. 4</td>
<td>++</td>
</tr>
<tr>
<td>USA—Georgia Institute of Technology [16-18]</td>
<td>Ausses House Out Tools.</td>
<td>Comp 6</td>
<td>++</td>
</tr>
<tr>
<td>USA—Institute of Technology, Chicago [20]</td>
<td>Design Comp. 8: + (context)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA—Stanford University [21]</td>
<td>Stanford Interactive Workspaces Project</td>
<td>Comp 9</td>
<td>++</td>
</tr>
<tr>
<td>USA—Nile Alba Research Center [22]</td>
<td>Center for mobile computing</td>
<td>Comp 10</td>
<td>++</td>
</tr>
<tr>
<td>Australia—University of Sydney [23]</td>
<td>métrico</td>
<td>Comp 11</td>
<td>++</td>
</tr>
<tr>
<td>Australia—UTS (Research Centre) [24]</td>
<td>QMobileHealth: concept of “ubiquitous hospital”.</td>
<td>Comp. 12</td>
<td>++</td>
</tr>
<tr>
<td>Denmark—Centre for Biomedical Informatics, Aarhus [25-26]</td>
<td>EIC: interactive hospital.</td>
<td>MedicalInfo. 14</td>
<td>++</td>
</tr>
<tr>
<td>Denmark—Aalborg University [27]</td>
<td>MobileWard: concept for the future hospital.</td>
<td>MedicalInfo. 15</td>
<td>++</td>
</tr>
<tr>
<td>Mexico—CCN, Mexico [28]</td>
<td>Mexican Electronic Patient Record.</td>
<td>MedicalInfo. 16</td>
<td>++</td>
</tr>
<tr>
<td>Italy—Applied Technologies for Psycho-Ps. Milan [29]</td>
<td>European VISION project.</td>
<td>MedicalInfo. 17</td>
<td>++</td>
</tr>
</tbody>
</table>

References and names are those directly cited in this paper. General trends and project names referred to general description of the theme directly from their web sites.

The “research context” of “context-awareness computing in health care”

- Hospital-based prototypes (cont’d)
  - Context-aware mobile communication (CICESE, Mexico)
    - Mobile devices to recognize the context in which hospital workers perform their tasks.
      - Instance messaging with context such as circumstances
    » Location, delivery timing, role reliance, an so on
  - MobileWARD (Mobile Electronic Patient Record, Denmark)
    - Supporting morning procedure tasks in a hospital ward
      - Information and functionalities according to the location of the nurse and the time
- Other prototypes
  - medication consumption, distant monitoring and new assistants
- Scenario
  - Representation of context for a hospital information system that uses PDAs to deliver patient information to doctors (Institute of Design, Chicago)
    - How context could be described by combining contextual information from the environment, person and activity
Hospital-based Projects

<table>
<thead>
<tr>
<th>Type</th>
<th>Use</th>
<th>Setting</th>
<th>Activity feature</th>
<th>People features</th>
<th>Environment features</th>
<th>Is context integrated</th>
<th>Description of the project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Healthcare Project (Hospital)</td>
<td>M</td>
<td>P</td>
<td>Hospital EDA artifact PC</td>
<td>Yes</td>
<td>Physical artifact</td>
<td>Patient ID, professional ID, role</td>
<td>No</td>
</tr>
<tr>
<td>Patient-AID (Periklis, Bove)</td>
<td>P</td>
<td>P</td>
<td>Hospital mobility PCA</td>
<td>No</td>
<td>Physical artifact</td>
<td>Professional ID, status of patient, location, ID/role</td>
<td>No</td>
</tr>
<tr>
<td>Context-aware mobile communication in hospital setting</td>
<td>M</td>
<td>P</td>
<td>Hospital mobility PCA, PC, phone, artifact</td>
<td>Instant messaging</td>
<td>Role, reliance, identification, context</td>
<td>Location, time</td>
<td>No</td>
</tr>
<tr>
<td>Follow my voice application, (Lawrence, Anderson &amp; Emergency Department UCB, Mubarek)</td>
<td>M</td>
<td>P</td>
<td>Hospital active badge</td>
<td>Physical artifact</td>
<td>Patient ID</td>
<td>Professional ID, patient and artifact location</td>
<td>No</td>
</tr>
<tr>
<td>Context-aware framework (Bowness, Chicago)</td>
<td>M</td>
<td>P</td>
<td>Hospital mobile device</td>
<td>Physical artifact</td>
<td>Location</td>
<td>Yes, but only scenario</td>
<td>Combination of contextual information, generates list of influences which affect the use of the sub-system</td>
</tr>
<tr>
<td>Voice Communicating System (Voice, 2014)</td>
<td>A</td>
<td>P</td>
<td>Hospital mobile device</td>
<td>Physical artifact</td>
<td>Location</td>
<td>No</td>
<td>Communication system with speech recognition, chat, speaker identification</td>
</tr>
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- M: model, P: prototype, A: application, S: scenario
- Pi: presentation of information, ES: Execution of services, SI: Storage of contextual info.

Diabetes Self-Care

- Eat the right foods
- Get and log daily physical activity
- Take medications as prescribed
- Test blood glucose regularly

- **Diabetes self-care with mobile phones:**
  - People forget or don't keep a detailed log
  - Recalling similar previous situations becomes difficult
  - Create a context-driven recommender application

- **Benefits of the application**
  - Time and location monitoring
  - User input on food consumption and insulin dosage
  - Find correlations between time/location and activities
  - Augment blood glucose level logs with contextual data
  - Use context to find similar situations in the past
• Declarative event-condition-action rules that govern application behavior
  • If (battery.load < 30%)
      Then disableComponent('BluetoothDiscovery')
  • If (battery.load < 15%)
      Then invoke('UserInterface.warning()')

• Application specific behavior:
  • Normal blood glucose: 80 – 150 mg/dL
  • < 50 mg/dL: hypoglycemic diabetic coma
  • > 500 mg/dL: hyperglycemic diabetic coma