Ubiquitous Computing

CONTEXT-AWARE COMPUTING

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Outline

• Motivation
• Context and Context-aware Computing
• Context-aware Applications
• Developing Context-aware Applications
• Handling Multiple Contexts
• Issues and Challenges
Motivation

- Modern computers are divorced from reality
  - Unaware of who, where, and what around them
  - Leads to mismatch

- Computers have extremely limited input
  - Aware of explicit input only
  - Can take a lot of effort to do simple things

- Context-Aware Computing
  - Making computers more aware of the physical and social worlds we live in
  - Breaking computers out of the box
Motivation for context aware mobility

• Use of context for mobility management decision enhances the performance
• Load sharing
• Enables functionalities according to a user's expectation...
What is Context?

• Definition Of Context

  - Any information that can be used to characterize the situation of an entity, where an entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves.

  - Context is typically the location, identity, and state of people, groups, and computational and physical objects.

    Anind K. Dey and Gregory Abowd

Context is not information per se, but rather a property of information.

    Paul Dourish
What is Context?

• Context influences how we *perceive* information.
• Context enables us to *manage* the vast amount of information that surrounds us.
• Context *guides* us through the information surrounding us.
• Context allows to *discriminate* what is important and what is not.
• Context helps us to *adapt* to our surroundings.
Examples of Context

• Spatial: location, orientation, speed.
• Temporal: date, time of day, season, distance.
• Environmental: temperature, light, noise.
• Social: people nearby, activity, calendar.
• Resources: nearby, availability, adjacent.
• Physiological: blood pressure, heart rate, tone of voice, emotion, mood.
Categories of Context

• Computing Context
  - computing information (network connectivity, communication cost, communication bandwidth, nearby resource)

• User Context
  - user’s information (profile, location, nearby people)

• Physical Context
  - environmental information (lighting, noise, traffic, temperature)

• Time Context
  - such as time of day, week, month
Collection of Context

- **Explicit**: manual acquisition of context data from user(s)

- **Implicit**: automatic collection of context data from sensors (ideal)

Use of Context.

- **Active**: application automatically adapts to discovered context by changing the application’s behavior (phone ring)

- **Passive**: application presents the new/updated context to a user or makes the context persistent for the user to retrieve later (in/out)
− **Presentation** of information and services to a user
  − E.g., nearby printers, car on map
− **Automatic execution** of a service
  − E.g., car navigation that reroutes on missed turn, ring-changing cell phone
− **Tagging** of context to information for later retrieval
  − E.g., informal meeting notes collected during a meeting
Context-Awareness

• Computers aware of people, places, objects, info, and activities around them
  - e.g., Time, Identity, Location
  - e.g., Temp, Bandwidth, Current document
  - Info about Past, Present, and Future

• With context, computers can have richer forms of interaction beyond desktop
  - Structure activities
  - Navigate
  - Adapt to unusual situations
Context Awareness Concepts

- User context is any information that can be used to characterize the situation of a user
  - **User preferences**
    - Data the user directly specifies for configuring one or multiple services
  - **Sensor entities**
    - may also augment the user context with additional information
  - **Context deducer**
    - May augment the user context with new, *higher-level* data derived from other context data
Context Awareness

Richness in both capture and behaviors

• Proactive triggering of information display and reactions
  − The last time you performed this task (or a similar task) here are the steps you performed.
  − When your friend was recently here, they saw this.
  − Here is how an expert did this.
  − Your audience is interested in this aspect of your topic, please emphasize this in your presentation.
Context Awareness

• Streamlining interaction
• Remember Past Events
• Reminders for future events
  − Using Triggers, e.g. when I meet X tell him
• Sharing Experiences
  − Tell my daughter about my grandmother's horses when she visits a farm.
Context-Aware Systems

• Context Acquisition
  − How do we get context information?

• Context Representation
  − How do we model and store context information?

• Context Integration
  − How do we relate context information to our application concepts and data?

• Context-Awareness
  − How do we integrate context information into our computations and processes?
Context Awareness Concepts: The Context System

Terminal

External world

Server

GPS

Temperature sensor

Deducer

User preferences

Context platform

Context DB

Application

Application

Context platform

Context DB

Application

Application
Context-Aware Architecture
CONTEXT-AWARE COMPUTING

CONTEXT-AWARE APPLICATIONS
Motivation for context-aware application

- Users application should be available where-ever the user goes, in a suitably adapted form
- Context aware application is one which adapts its behaviour to a changing environment
  - E.g. Follow-Me applications
- Context aware applications need to know the location of users and equipment, and the capabilities of the equipment and networking infrastructure
What Do Applications Do With Context?

• What is a context-aware application?
  - Application that uses context to perform some behavior/service for its user(s)

• 3 types of behaviors:
  - Display context
  - Automatically execute/adapt services
  - Tag captured information for easier retrieval
A Rough Taxonomy of Context-Aware Applications

• Triggers
• Metadata Tagging
• Reconfiguration and Streamlining
• Input specification
• Presentation
A Rough Taxonomy of Context-Aware Applications

• Triggers
  - On X do Y
  - "Notify doctor and nearby ambulances if serious health problem detected"
  - "Remind me to talk to Chris about user studies next time I see him"
A Rough Taxonomy of Context-Aware Applications

- Metadata Tagging
  - "Where was this picture taken?"
  - "Find all notes taken while Mae was talking"
  - Memory prosthesis
A Rough Taxonomy of Context-Aware Applications

• Reconfiguration and Streamlining
  - Telephone forwarding and Teleport
  - Turn off cell phone in theaters
  - Automatically adjust brightness / volume
  - Automatic file pre-caching
  - Select modes in multimodal interaction
  - Multimedia / Bandwidth adaptation
A Rough Taxonomy of Context-Aware Applications

- **Input specification**
  - Send mail only to people in building now
  - Print to nearest printer
  - "Find gas stations nearest me"

- **Presentation of plain contexts**
  - Current location
  - Idle?
  - Currently in?
  - Contextual info about objects
  - Proximate selection
CONTEXT-AWARE COMPUTING

DEVELOPING CONTEXT-AWARE APPLICATIONS
Design Process of Typical Context-aware Applications

1. Specification
2. Acquisition and Representation
3. Delivery/Distribution
4. Reception and Storage
5. Action (the application)
Design Process: Specification

- Context to use
- Context behaviors to perform

It is a key step in the design process.

Design Process: Acquisition

- Install relevant sensors
  - Sensors: infrastructure or personal artifacts
  - Where to sense?
  - How often to update and report?
Design Process: Delivery/Distribution

• Contexts typically captured remotely from applications at different time

• Context captured in sensor-rich environment or device may need to serve multiple applications

=> Need to deliver and distribute context to multiple, remote applications
  – Infrastructure or middleware support

• Application/network-level delivery/routing models and transport mechanism
Design Process: Reception

• Application locates relevant sensors/contexts
  − Service discovery
• Requests contexts via queries, polls, notifications
  − Query language, event-notification mechanism
  − How often to request?
• Additional interpretation/abstraction/processing
  − Collection, aggregation, filtering, correlation, fusion,...
Design Process: Action

- Combine received contexts with previous contexts and system/application states for further analysis
- Perform actions based on the analysis results
- May treat context collection/processing as a separate service

Example: Simple Mobile Tour Guide

- Application:
  - Display list of all unseen locations in the area
  - Highlight relevant and preferred locations
  - Show map centered on user's position
  - Display information about closest location of interest
  - Directions to locations
CONTEXT-AWARE COMPUTING

HANDLING MULTIPLE CONTEXTS
Direct/Indirect Context-Awareness

- **Indirect context awareness:**
  - Situation
  - Context
  - Perceived
  - Sensor(s)
  - Communicate
  - Device A
  - Device B
  - Device C

- **Direct context awareness:**
  - Situation
  - Context
  - Perceived
  - Sensor(s)
  - Device A
  - Device B
  - Device C

Built-in sensors, context processing
Take Multiple-Sensor Approach

• Need to combine multiple simple sensors vs. one camera with powerful recognition capability
  - Gain rich data to infer useful context with little computation
• Real world situations: situations and sensors

<table>
<thead>
<tr>
<th>Situation</th>
<th>Sensor Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>User sleeps</td>
<td>It is dark, room temperature, silent, type of location is indoors, time is “night-time”, user is horizontal, specific motion pattern, absolute position is stable</td>
</tr>
<tr>
<td>User is watching TV</td>
<td>Light level/color is changing, certain audio level (not silent), room temperature, type of location is indoors, user is mainly stationary</td>
</tr>
<tr>
<td>User is cycling</td>
<td>Location type is outdoors, user is sitting, specific motion pattern of legs, absolute position is changing.</td>
</tr>
</tbody>
</table>
Example: TEA

- Technology Enabling Awareness
- Motivation: make personal mobile devices smarter
- Specs:
  - CPU: PIC16F877
  - Storage: 8K EEPROM
  - RAM: 200 Byte
  - Use serial line to communicate with the host
- For example, an acceleration sensor can infer cues like pattern of movement and current speed

**Rules from cue to context:** can be pre-defined or use supervised/unsupervised learning
Application

• Profile activation:
  - A user can have many profiles
  - Activate profiles according to the situation (in-hand, on-table, in-pocket, outdoors)
  - 87% certainty, 30 sec to calculate (not yet optimized)

• Context sharing (and privacy invasion):
CONTEXT-AWARE COMPUTING

ISSUES AND CHALLENGES
Issues and Challenges

Sensing the Context

• Heterogeneous sensors with uncertainty and conflicts (sensor fusion)
• High-level contexts: user’s activity
  - Camera technology and image processing
  - Consult calendar for what user is to do
• Context changes: subscription-notification
  - Polling rate?
Issues and Challenges

Context Interpretation

• Sophisticated applications require higher level forms of context
  ◦ Fusion

• Ambiguity:
  ◦ Sensors not 100% reliable, e.g. confidence value
  ◦ Precision / Accuracy / Granularity
  ◦ Different ways to deal:
    • Improve inference
    • Probability/fuzzy model
    • Bring the user into the loop
Summary

- Context is, any information that can be used to characterize situation of an entity.
- Context-Awareness is a **strategy** for improving interaction.
- Context-Aware System is made up of Context **Acquisition**, Context **Representation**, Context **Integration**, Context **Awareness**

- Design Process of Context-Aware Applications
  - Specification
  - Acquisition and Representation
  - Delivery/Distribution
  - Reception & Storage
  - Action