CPET 565/CPET 499
Mobile Computing Systems

Context Aware Computing

Lecture 7

Paul I-Hai Lin, Professor
Electrical and Computer Engineering Technology
Purdue University Fort Wayne Campus

Context-Aware Computing

- Introduction
- Definitions and Types of Context
- Context-Aware Computing and Applications
- Ubiquitous Knowledge Management
- Middleware Support
- Summary

Introduction

- Adaptive Mobile Systems
  - Application-Transparent approach
    - Uses system software
  - Application-Aware Approach
    - Use collaboration between the system software and application software
    - Context-aware computing paradigm

Introduction

- Context-Aware Computing Paradigm
  - Adaptation to changes in the availability of computing and communication resources
  - Presence of contextual information
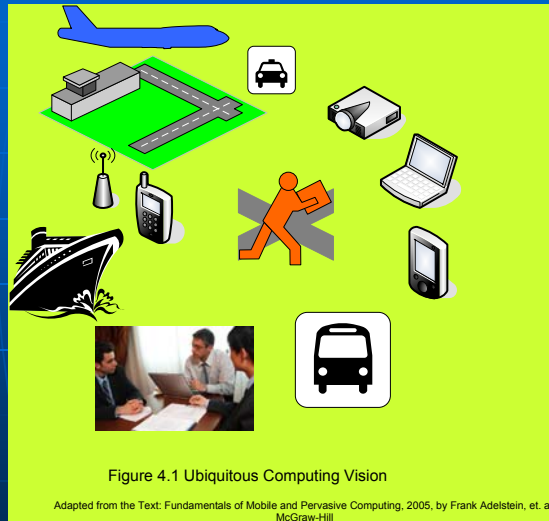   - Who, When, Where, Emotion, Action, Intention

Introduction

- Context-Aware Computing Paradigm
  - Contextual information collection mechanisms
    - Environment sensing - Sensor networks
    - Repositories of historical data tracking
    - User info & profile
  - Context-based information service (Web Information Systems Engineering)
    - Itinerary
    - Preferences
    - Current location
    - Hotel reservation

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Ubiquitous/Pervasive Computing

Figure 4.1 Ubiquitous Computing Vision

Adapted from the Text: Fundamentals of Mobile and Pervasive Computing, 2005, by Frank Adelstein, et. al, McGraw-Hill

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Definitions and Types of Context

- Merriam-Webster's Collegiate Dictionary:"
  - (1) the parts of a discourse that surround a word or passage and can throw light on its meaning;
  - (2) the interrelated conditions in which something exists or occurs

Types of Context – Role-based

- Another Context Definition: Chen and Kotz, 2002
  - "the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user."
- Two other types of Context based on this definition:
  - Active Context
    - The contextual info used by the application to adapt its behavior
  - Passive Context
    - **Not critical for application adaptation**
    - **Provided for enhancing the understanding of the situation**

Types of Context

- Classification of Context-Aware Computing
  - Enumeration-based context-aware computing
  - Role-based context-aware computing

Categories of Context – Enumeration-based

- Chen and Kotz's (2000) refinement of Schilit's definition of context
  - **Computing Context**
    - Network connectivity, communication costs, bandwidth, local resources, etc
  - **User Context**
    - User profiles, location, people in the vicinity
  - **Physical Context**
    - Lighting, noise level, traffic conditions, temperature
  - **Temporal Context**
    - Time of day, week, month, season of the year
  - **Context History**
    - Recording of computing, user, physical context across a time span

The 5 W's of Context

- Classification according to the Context Types Used by an Application (5 W) - Abowd and Mynatt, 2000
  - **Who** (social context) is the user? Who are the people the user is interacting? Who is near by?
  - **What** (functional context) is the user doing?
  - **Where** (location context) is the user? Home? Work? Familiar shop?
  - **When** (temporal context)? What time is it?
  - **Why** (motivating context) is the user performing a certain task?

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The 5W's of Context

- Who (social context)
  - A user identification
  - Identification of people near the user
- What (functional context)
  - Information about what tasks the user is performing
  - Information about what tasks the user is performing

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The 5W's of Context

- Where (location context)
  - System's location
  - Latitude and longitude of the user
  - Number of room in which the system is currently operating

The 5 W's of Context

- When (temporal context)
  - Time of day, week, month, season of year
- Why (motivating context)
  - Why the user is performing a certain task
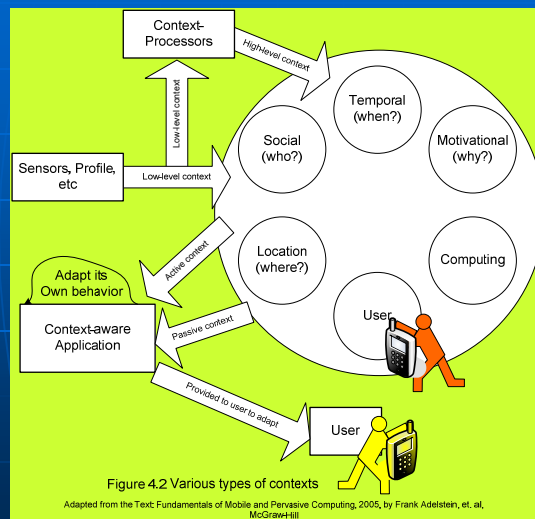
Types of Context – Enumeration-based

- High- and Low-Level Context – Chen and Kotz, 2000
  - Low-Level Context
    - Sensing through sensors and signal processing
    - Accessing a database
    - Reading room temperature
    - Actuating a device
  - High-Level Context
    - Amalgamation of low-level context
    - Sophisticated processing techniques
      - Machine vision
      - Artificial Intelligence

Types of Context – Role-based

Figure 4.2 Various types of contexts

Adapted from the Text: Fundamentals of Mobile and Pervasive Computing, 2005, by Frank Adelstein, et. al, McGraw-Hill

Context-Aware Computing & Apps

- Context-Aware Computing Devices & Applications - Mobile applications
  - User's context changes frequently
  - Need context-aware behavior
- Capability & Features
  - Proactive in acquiring contextual information
  - Adapt their response based on the acquired info

Context-Aware Requirements

- **Context sensing**
  - Detection of environment states
- **Context adaptation**
  - Capability of the system to adapt its behavior by using contextual information
- **Context resource discovery**
  - Capability to discover available resources in an environment
- **Context argumentation**
  - Capability to associate contextual information with some digital data
  - Example: Association of a particular meeting place and meeting place and attendees with a set of minutes
  - Example: Association of a digital photo with a specific location

Types of Context-Aware Apps

- Types of Context Awareness Applications
  - Function or Service Type
    - Providing information
    - Actuating commands
  - Initiating Agent
    - Manual
    - Auto
  - Adaptation (contextual selection)
    - Information
    - System
    - User Interface
    - Command (behavior): IF-THEN rules

Context-Aware Computing & Apps (cont.)

- Developing Context-Aware Applications
  1. Identifying relevant context – application dependent
  2. Specifying context-ware behaviors: considering reuse
  3. Integrating with mechanisms for acquisition of contextual information – platform dependent

Context-Aware Computing & Apps (cont.)

- Specifying Context-aware Behaviors
  - Reuse
  - Two Example Approaches
    - Context-triggered actions
    - Stick-E notes

Context-Aware Computing & Apps (cont.)

- Specifying Context-aware Behaviors
  - Context-triggered actions
    - Active Badge Location System
    - Watchdog and contextual reminder for active badges
    - System configuration files – parameters, (location, action)
    - Watchdog Monitoring Activities & Events:
      - Arriving
      - Departing
      - Settle-In
      - Missing
      - Attention

Context-Aware Computing & Apps (cont.)

- Specifying Context-aware Behaviors
  - Stick-E Note (Brown, 1995; Pascoe, 1997) motivated by Post-It note
  - Supporting platform
    - For PDA with wireless connectivity to a communication network
    - Equipped with various sensor: GPS, etc
  - Major components
    - Context
      - Location, nearby users, time (where, who, when)
    - Content
      - Information
      - Actions
      - Interfaces

Context-Aware Computing & Apps (cont.)

- Stick-E Note (Brown, 1995; Pascoe, 1997)
  - The Stick-E Note Architecture: Extending the Interface Beyond the user, Jason Pascoe, ACM Digital Library, http://portal.acm.org/citation.cfm?id=238344&coll=portal&dl=ACM
  - Position sensing:
    - Active badge system GPS, Beacons, cell phones, bar-codes scanners
  - Standard Generalized Markup Language (SGML)
    - <note> tag
    - <at> tag
    - <body> tag
    - <optional> tag

Context-Aware Computing & Apps
(cont.)

- Mobile Computing in a Fieldwork Environment (Oct. 1997)
  - MCFE Metadata Elements, version 0.2, http://www.cs.kent.ac.uk/projects/mobicomp/Fieldwork/Notes/mcfemeta.html
  - Goals
    - Supporting data collection
    - Resource creation and access to previous recording information using hand-held computers in the field
  - Main Components
    - MCFE Field Notes
    - Mobile context-aware applications for hand-held computers
    - Field note management tools for desktop computers

Context-Aware Computing & Apps
(cont.)

- Extension of Context-aware through WWW
  - The Ubiquitous Web as a Model to Lead Our Environments to Their Full Potential, Juan Ignacio Vazquez, Joseba Abaitua, and Diego Lopez de Ipina,
    http://www.w3.org/2006/02/Deusto_Position_Paper_v1.0.pdf

Context-Aware Computing

- Introduction
- Ubiquitous or Pervasive Computing
- Definitions and Types of Context
- Context-Aware Computing and Applications
- Middleware Support
- Ubiquitous Knowledge Discovery
- Summary

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Middleware Support

- Challenges - Context-aware applications
    1. Context-aware applications need support for the acquisition and delivery of context data
    2. Contextual info – from various heterogeneous and distributed sources
    3. Same type of contextual info may have to be obtained from different sources at different times
    4. The low-level contextual info must be abstracted to be useful
    5. Context-awareness is most relevant when the environment is highly dynamic (mobile)

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Middleware Support

- Contextual info – from various heterogeneous and distributed sources
  - Hardware and software sensors: motion detectors, noise, temperature sensors, location systems
  - System recorded input – user-system interaction history
  - Other applications
    - User's personal computing space:
      - Schedules, calendars, address books, contact lists, and to-do lists
    - Distributed computing environment
      - Obtained from applications running in the vicinity of these devices: shopping malls, freeway, etc

Middleware Support

2. Same type of contextual info may have to be obtained from different sources at different times
   - GPS receiver – outdoor positioning system
   - Indoor positioning system
3. The low-level contextual info must be abstracted to be useful
   - GPS position info (latitudes and longitudes)
   - → Tour guide, location info
4. Context-awareness is most relevant when the environment is highly dynamic (mobile)
   - Real-time detection, trigger commands, auto reconfiguration

Middleware Support –
Contextual Services

- Middleware Infrastructure that can provide the following services (acquire contextual input from sensors)
    1. Contextual subscription and delivery service
    2. Context query service
    3. Context transformation service
    4. Context synthesis service
    5. Discovery and management service
- Actuator Services
    - Perform a context-dependent output function

Middleware Support –
An Example

- The Context Toolkit - Publications, http://www3.cc.gatech.edu/fce/contexttoolkit/
- Software components for context acquisition
    - Context widgets
        - An interface between sensors and applications
        - Provides an abstraction layer
        - State: a set of attributes
        - Behavior: call back function
        - Persistent entities that can be shared by multiple applications
    - Context interpreters (info translators)
    - Context aggregators
        - Entity: person, room, software systems, hardware devices
    - Discoverer
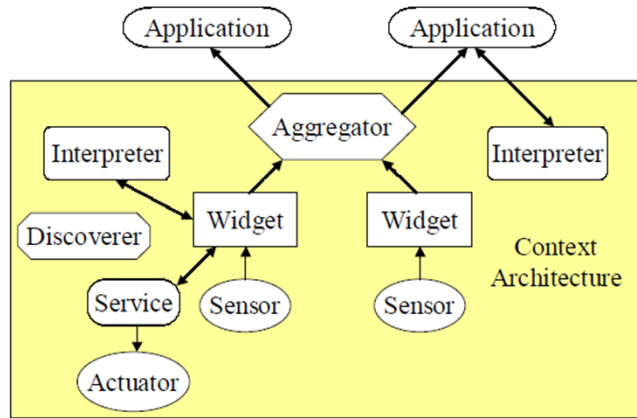   - Discovery and management services

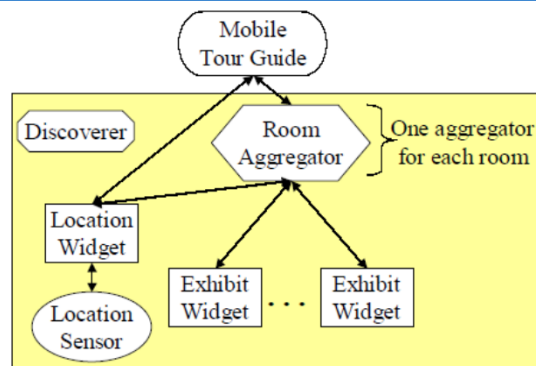Figure 1. Example configuration of Context Toolkit components

Figure 3. Architecture diagram for the mobile tour guide application.

Middleware Support – Location Context

- A Location information system (LIS) provides location information of a person or resources to the application.
- Location information from various sources
  - Indoor locating system, e.g., infrared or RF based active badge
  - Wireless nanocell communication activity
  - Outdoor locating systems such as GPS
  - Device input activity from various computers
  - Motion sensors and cameras
  - Explicit information from the user

Middleware Support – Location Context

- Issues
  - Privacy
    - Solution: provide user control over location information
  - Accuracy of the location information
    - Spatial resolution
    - Temporal resolution
      - How frequently LIS updates the location information of each user
      - How sensitive the sensing technology is

Ubiquitous Knowledge Discovery

- Following excerpts are from the Proceedings of the Workshop on Ubiquitous Knowledge Discovery for Users, Sept. 18-22, 2006, Berlin, Germany, http://vasarely.wiwi.hu-berlin.de/UKDU06/#Proceedings
- A key research area for the coming years
- It encompasses the whole process of turning data into knowledge:
  - Algorithms
  - Business/Application Understanding
  - Data Understanding
  - Data Preparation
  - Modeling
  - Evaluation, and
  - Deployment

Ubiquitous Knowledge Discovery

- Users play a pivotal role in this process
  - They create data
    - Documents and/or references
    - Links between documents
  - Data are related to them
    - Explicit reactions to questions such as the input of registration data, and the behavior that leave traces, biometric measurements, etc. in log files
  - They are the ultimate beneficiaries of the discovered knowledge
    - The user models – foundation for general-audience or personalized improvement of services and devices
    - Activities which directly benefit the end user or another human stakeholder (Web site owner, government agency, etc)

Ubiquitous Knowledge Discovery

- Dimensions of Ubiquity
  - Ubiquity of devices and data
  - Ubiquity of processing
  - Ubiquity of people and contexts
  - Information ubiquity
  - Standards for Ubiquity

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Summary

- Google Location Dependent Search Engine: http://local.google.com/lochp
  - Find business
  - Get directions
- Serendipity – MIT Media lab project: a wireless, proximity-based dating service
  - can accidentally discovers something fortunate
  - http://www.media.mit.edu
- BlueJAQ- Pull on an unsuspecting stranger in close proximity who has a Bluetooth-enabled phone: http://www.bluejackq.com/

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