Context Awareness & Context-aware Computing

What are context & awareness?
Context-aware computing
Context-aware systems & apps

Human Computer Interaction (HCI)

Human to Personal Computer



Human to Internet/Web/Cyber



Human to Physical Object/Environment/World

Construction of the second sec

Various Devices in Ubicomp

Devices: sensor, RFID, smartphone, wearable, robot, etc.
They are interfaces to physical world, cyber world and other people.



General Ubiquitous System Model

 A ubiquitous/pervasive/AmI/CPS system can be regarded as a special kind of information systems which use sensors to acquire various information (of called context), process the contextual information, and then take some responses through actuators.



What is "Context" in General?

- Context is the part of a text or statement that surrounds a particular word/passage & determines its meaning. [Linguistics]
- Context is the relevant constraints of the communicative situation that influence language use, language variation, and discourse. [Language use]
- Context is the set of facts or circumstances that surround a situation or event. [WordNet]
- Context is the surroundings, circumstances, environment, background, or settings which determine, specify, or clarify the meaning of an event. [Wikipedia]
- Contextual (adj), Contextually (ad), Contextualize (verb)

What are Aware & Awareness in General?

- Aware (adj), Awareness (noun), Unaware (ant.)
- Aware Conscious or having knowledge of something.

 \rightarrow I <u>am aware of</u> who are you and where are you from.

- Aware implies knowledge gained through one's own perceptions or by means of information.
- Awareness The state/level of consciousness where sense data can be confirmed by an observer.
 - \rightarrow I gradually passed from sleep to full awareness.
- Awareness The state/quality of being aware of something
 - \rightarrow The awareness of one idea fosters an awareness of another idea.

What is Context-Aware/Awareness?

- Context-aware/awareness originated as a term from ubiquitous computing or pervasive computing which sought to deal with linking changes in the environment with computer systems. [Wikipedia]
- Context-aware/awareness in terms of computing was first proposed/used by <u>Bill N. Schilit, Norman Adams, Roy Want</u> in their paper "<u>Context-aware</u> <u>computing applications</u>" in IEEE Workshop on Mobile Computing Systems and Applications (WMCSA'94), Santa Cruz, CA, US, 1994.
- They divided context into *three* categories:
 - Computing context: connectivity, bandwidth, resources (printers, displays)...
 - > User context: user profile, location, nearby people, social situation, activity, ...
 - Physical context: temperature, lighting, noise, traffic

→ Why Context is important in computing?

Traditional View of Computer Systems





- 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

Pioneers' Work – Active Badges

Problem: **locating** researchers Solution: badge tied to identity, tracked as researcher moves

Name	Location	Prob.	Name	Location	Prob.
P Ainsworth	X343 Accs	100%	J Martin	X310 Mc Rm	100%
T Blackie	X222 DVI Rm.	80%	O Mason	X307 Lab	77%
M Chopping	X410 R302	TUE.	D Milway	X307 Drill	AWAY
D Clarke	X316 R321	10:30	B Miners	X202 DVI Rm.	10:40
V Falcao	X218 R435	AWAY	P Mital	X213 PM	11:20
D Garnett	X232 R310	100%	J Porter	X398 Lib.	100%
J Gibbons	X0 Rec.	AWAY	B Robertson	X307 Lab	100%
D Greaves	X304 F3	MON.	C Turner	X307 Lab.	MON.
A Hopper	X434 AH	100%	R Want	X309 Meet. Rm.	77%
A Jackson	X308 AJ	90%	M Wilkes	X300 MW	100%
A Jones	X210 Coffee	100%	Wilson	X307 Lab.	100%
T King	X309 Meet. Rm.	11:20	S Wray	X204 SW	11:20
D Lioupis	X304 R311	100%	K Zielinski	X402 Coffee	100%
		12.00 1st Ja	nuary 1990		



Assistant sees this view

- knows where researcher is
- can forward call
- [Want & Hopper, 1992]

Pioneers' Work – PARCTAB



ParcTab

Xerox PARC Want, Schilit, et al, 1994

- Rough location + ID
- Showing information of the room the user in
- Help find resources
- Show all files in a directory when enter a room
- Locate others
- Different control choices in different rooms (location, time, nearby devices, file system state)



Figure 1: A Context-Aware Computing System (PARCTAB)

PARCTAB-based Applications

Approximate Selection





Figure 1: A Context-Aware Computing System (PARCTAB)

Definitions of Context

- Schmidt et al.: "knowledge about user's and IT device's state, including surroundings, situation, and to a less extent, location"
- <u>Dey & Abowd</u>: "any information that can be used to characterize the situation of an entity"
 - Entity: person, place, object that is considered relevant to the interaction between a user and an application, including the user and the application themselves.
- Kotz: "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"

Examples in Active Badges & PARCTAB

Application: where are users and facilities

Entity	Characteristic Info (context)	
Researcher	Badge ID/Name, location, Time of the workday (morning, lunch, dinner)?	
Room	Presence of a phone Presence of printer, where	

Museum Audio Guide Example

Application: digital museum guide



Entity	Characteristic Info (context)
Museum Patron (user)	Education, age, spoken language, location in museum, previously viewed artifacts
Exhibit	What area of museum What artifacts in the area
Mobile Interface	Light, noise, battery life, nearby people

History of Context Aware Computing

- The early 1990's saw the arrival of context-aware computing with the introduction of small mobile computing devices (by Schilit, et al, led by M. Weiser).
- Olivetti Lab's Active Badge (1992) used infrared communication between user badges and sensors placed in a building to monitor movement of users for forwarding calls.
- PARC's PARCTab system (1993) uses location information to allow applications to adapt to user's environment.
- Context-aware applications serve as tour guides by presenting information about the user's current environment. Ex: Cyber Guide from Georgia Tech (1996).
- In the later 90's, frameworks built to support context-aware applications began to be developed. Ex: Georgia Tech's Context Toolkit (1999).
- Since 2000, more and more researches and applications

Examples & Classifications of Context

- Identity: user characters, needs
- Spatial: location, orientation, speed
- Temporal: date, time of day, season
- Environmental: temperature, light, noise
- Social: people nearby, activity, calendar
- Resources: nearby, availability, energy
- Computation: CPU, OS, memory, interfaces
- Network: wire/wireless, bandwidth, error rate
- Physiological: blood pressure, heart rate, tone of voice
- Psychology: preference, emotion, tiredness, ...
- External Context (physical)
 - Measured by sensors, Ex: location, light, sound, pressure, etc.
- Internal Context (logical)
 - Captured from user's interaction, Ex: user's goal, emotion, etc.

Classification of Context

<u>Computing Context</u>

- Network connectivity
- Communication cost
- Comm. bandwidth
- Nearby resources

<u>User Context</u>

- User profile/preference
- User mood/behavior
- Other's presence

- <u>Environmental Context</u>
 - Lighting
 - Noise level
 - Traffic conditions
 - Weather
- <u>Physical Context</u>
 - Time, Date
 - Location

<u>Context History</u> – Stored Context of Past
 Computing, User, Environment, Physical Context

Classification of Context (cont.)

5W

Who

Where

When

What

Why

Primary Category

- Identity
- Location
- **Time**
- Activity
- Etc.

Secondary Category

- Indexed by primary category
- E.g. identity -> email address, phone number, carrier, age, etc.

5W Context Awareness

- Who: Deals with identifying current user and object recognition.
- Where: Deals with location identification of user, object, service, ...
- When: Deals with temporal aspects of past, present & future
- What: Deals with identifying activities of user or object
- Why: Deals with subtle context such as user's need, emotion, ...



Contextual Information & Characteristics

Contextual information is a set of data, gathered from sensors, applications and users, that conforms to a context model and provides a snapshot that approximates the realworld context at a given point in time.

Exhibits a range of temporal characteristics

- Static vs. dynamic (highly variable in persistence)
- Context histories (past and future)
- May be incorrect, inconsistent, incomplete
 - Failure, faulty info, transmission delay, ...
- Has many alternative representations
 - at different level of abstraction, relations between representations
- Is highly interrelated (by derivation rules)

General Model of Context-Awareness



Generation

Contextual information is obtained from UI or sensor

Processing

- Change raw data to meaningful information
- Usage
 - Use of contexts and possible reaction as output

General Context Layer Model

application storage/management preprocessing raw data retrieval sensors Sensing the Context Raw contextual information

Location, time, light level, sound, etc.

High-level contextual information

User's current activity - big challenge!

Context-Aware Computing/System?

- Context-aware computing refers to a general class of mobile systems that can sense their physical environment, and adapt their behavior accordingly. [Wikipedia]
- The term 'context-aware' was used by <u>Schilit</u> and <u>Theimer</u> in their 1994 paper "Disseminating Active Map Information to Mobile Hosts" where they define a context-aware systems as one that can adapt according to its context.
- Dev defines that "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task."

Context-Aware Computing/System

Context aware systems are concerned with

- \rightarrow the acquisition of context (e.g. using sensors to perceive a situation),
- → the abstraction and understanding of context (e.g. matching a perceived sensory stimulus to a context), and
- → application behaviour based on the recognized context (e.g. triggering actions based on context)
 - → Active Context Awareness: "an application automatically adapts to discovered context by changing the application's behavior"
 - → Passive context awareness: "an application presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later"

Various Context-Aware Computing

- Location-Aware Computing
- <u>User-Aware</u> Computing
 - → Preference/Need/Intention/Emotion Aware Computing
- <u>Energy-Aware</u> / Power-Aware Computing
- Resource-Aware Computing
- Service-Aware Computing
- Network-Aware Computing
- Environment-Aware Computing
- Situation-Aware Computing
- <u>Safety/Security/Privacy-Aware</u> Computing
- <u>Chance/Opportunity-Aware</u> Computing

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Context-Aware Application Types

- 1. Context-aware delivery/presentation of information and services
 - Active Badges, ParcTab, Tour guide
- 2. Context-aware automatic execution of services in physical/cyber environments
 - Smart homes (turn off lights, adjust temperature)
- 3. Tagging of contextual information to objects/events for later retrieval and use
 - Digital camera meta-data (time, location, etc.)

Context-Aware Applications

- -- CA applications shown in video below --
- Context Aware Dynamic Lighting
- Gimbal Context Aware Platform
- Outdoor Location-aware Application
- Indoor Location-based Application
- Location-Aware Music Album
- Location Aware Services

Location-based Applications

- Finding services based on location
 - physical services (stores, restaurants, ATMs, ...)
 - electronic services (hot spots, printers, ...)
- Using location to improve (network) services
 - incoming or outgoing communications adapts to location
- Using location to provide information
 - tourist guides
 - advertisements
- Making others aware of user location
 - presence (individual)
 - popularity, movement (group)
- Security
 - grant access based on user's location

Location-based Applications



Location-based Social Networks

LBSN Software/Apps

Loopt







Dianping



- Users share photos, comments or check-ins at a location
- Expanded rapidly, e.g., Foursquare gets over 3 million check-ins every day (2011)

LBSN Recommendation

Location Recommendations in LBSN

- Recommend locations using a user's location histories and community opinions
- Location bridges gap between physical world & social networks
- Existing Solutions
 - Based on item/user collaborative filtering
 - Similar users gives the similar ratings to similar items



Context-Aware Computing Architecture

Sensors

Context Direct Processing

- Tightly coupled
- No extensibility

Context Middleware

Hiding low-level sensing details Extensible/Scalable

Context Server

- Multiple remote accesses
- Appropriate protocols, QoS



Abstract Layer Architecture

Application

Storage/Management

Preprocessing

Raw data retrieval

Sensors

Sensors

- Physical sensors
 - sensor, camera, microphone, accelerometer, GPS, biosensors, etc.
- Virtual sensors
 - From software: browsing an electronic calendar, a travel booking system, emails, mouse movements, keyboard input, bandwidth, etc.
- Logical sensors
 - Combination of physical and virtual sensors with additional information (e.g. context history) from databases

Abstract Layer Architecture (Cont)

Raw data retrieval

- Drivers and APIs
- Query functionality
- Exchangeable
- Preprocessing
 - Reasoning and interpreting
 - Extraction and quantization
 - Aggregation and compositing
- Storage/Management
 - Public interface to the client
 - Synchronous (pull/polling) and asynchronous (push/subscription)

Applications

 Actual reactions on different events and context-instances are implemented to provide desired information/services



Sensors

Abstract Layer Architecture (Cont)



 ◆ Simple/Specific Context-Aware Architecture
 →Context direct processing/use E.g., Active Badge, Cyber Guide

- Complex/General Context-Aware Architecture
- \rightarrow Context Middleware
- → Context Server



Architecture of Context-Aware System (2)

From SRIT



CR: Context Refiner; CA: Context-Aware Application

Architecture of Context-Aware System (3)



Context-aware Computing Issues

- Context is most useful in dynamic, mobile environments. But what is the **relevant information** in various situations?
- Mobility results in continuous updates of context information. How can we efficiently manage this?
- How can we **share** context?
- How do we handle uncertainty of context information?
- How do we ensure **privacy** control and management of context information?
- How do we reach a common understanding of implications and semantics of (shared) context information?
- How to effectively use context with resource restrictions
- How to exploit the past context or context history

Homework

- Access the following websites and papers to learn more about concepts and features of context, context awareness, context-aware computing, etc.
- <u>Context Awareness Wikipedia</u>
- Context-aware pervasive systems Wikipedia
- B.N. Schilit, et al, Context-Aware Computing Applications
- > A.K. Dey, Understanding and Using Context
- > A. Soylu, et al, Context and Adaptivity in Pervasive Computing
- Context-aware Computing, Intel Labs, IDF2010
- Context Is Everything (Video by Lama Nachman, Intel)
- Location Based Apps (Video)
- > Others you like \rightarrow Important to get materials from Web!!