UNDERSTANDING USER ACTIVITY IN DISTRIBUTED INTELLIGENT ENVIRONMENT

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Abstract.
User activity is the most complex part of the context awareness mechanism in an Intelligent Environment. Unfortunately, the computer environment changes overtime. The problem confronting the user is how to enable transparent distribution computing to continue operation across a changing circumstance in a seamless manner and how the environment recognises user activity. This paper describes an approach to determine and recognise user activity based on user location. A sa part of user activity, a mobile access point for a 'guest' user to access resources in an unfamiliar domain is also introduced. This work is based on DiCPA architecture, a distributed context processing architecture for smart environments. We show how the scalable distribution of context and context information is managed to characterise user activities.
Keywords: *User Activity, User Location, Context Awareness, Pervasive Computing, Ubiquitous Computing, Active Office, Intelligent Environment*

1. Introduction

As we aware in the last decade computer environment changes over time and at the same time user needs also become more complicated. The changing includes user profile - from a single profile for a single device to many profiles and many devices for a user -, user location, situation and resources as well as the network configuration. This is one of the impacts that enable technology from wired network to wireless network, from Local Area Network to Personal Area Network or to Wide Area network.

The problem is how to enable transparent distributed computing to continue operation across a changing circumstance in a seamless manner. How to exploit the changing environment that is aware of the context of the location use, the collection of nearby people and objects, the accessible devices and the change to those objects over time. Moreover, how smart environments have the capability to assist and help people with a variety of activities by detecting a users' current state/context to determine what actions to take based on the context.

Recently, scientists in the Intelligent Environment (IE) area are researching ways to make embedded computing and ubiquitous computing work better for people by creating and equipping a smart environment, such as an active home or an active office, with technologies that can identify user needs and meet them speedily, efficiently and unobtrusively.

The goal of context aware computing in general is to make user interacting with the computer easier in the smart environment where technology is spread throughout (pervasive), computers are everywhere at the same time (ubiquitous) and technology is embedded (ambient) in the environment. It need not difficult, tedious or need hard learning to the user. It should potentially be safe, easy, simple and enable new functionality without need to learn a new technology. It provides relevant information and a simple way for a user to deal with it.

The end uses of such technology could simply be convenience in an active home, knowing when the occupant wakes up and what radio station he likes to listen to without waking up the rest of the house. On the other hand it could be life saving by detecting when he had fall and needs medical help.

Our approach is to locate a person within an environment using the wireless connections in devices that they normally carry for other purposes, for example, a mobile phone, PDA or a laptop computer. The location of these devices, and hence the person with them, is determined by a mixture of precise, proximate and predicted location sensors. The data from these sensors is turned into a predictor to precisely locate the device, and thus the person. Once a user is located such services can be delivered based on the current situation from a resources manager.

To manage and respond to rapidly changing aggregation of sensor data, we develop a DiCPA architecture (Mantoro and Johnson 2004). This is a scalable distribution context processing architecture in the IE. The architecture provides continued operation across changing circumstances for users, the collection of nearby people and objects, the accessible devices and the changing to those objects over time in the environment. This approach leads us to understand user location and user mobility to user activity. The context information of user activity can be used to characterise of user situation.

2. Related Works

Recently, researchers who work in the area of user activity fall into three categories, i.e. develop equipment using wearable device to be worn by the user to sensing user activity and recognise user location, study user behaviour in the workplace area and home, and the last category is to develop a system/device to equip the environment.

In the area of wearable devices for instance (Lee and Mase 2002) it is possible to determine a user's location using a dead-reckoning method to detect the transition between preselected locations and recognize and classify sitting, standing and walking behaviour.

In the study of user behaviour, user activity changes in work and society are impinging on the place where the user works and how the work gets done. For example, the increasingly international nature of work has led to a growing amount of travel despite the use of advanced collaboration technologies (Churchill and Munro 2001). It has been argued that many more people are experiencing a blurring of division between 'home' and 'work' domains as different forms of work become possible within the physical space of the home.

- Wearable device → User location
  → Sitting, standing, walking behaviours

- User behaviour → Activity zone
  → Places of communication → Ecological habitats
  → Activity centers
  → Coordinate displays

- Equipping (smart) Environment →Activity centric

Fig 1. Research categories in user activity

While Koile proposes activity zones to construct an activity area, Crabtree introduces places communications. Activity zones are a physical form – e.g. wall, furniture – which partition places into zones of human activity and places of communications that are familiar in the home the production, management and consumption of communication. Activity zones were constructed by tracking systems to observe people's activities over time. Crabtree considers three different properties: ecological habitats, activity centers and coordinate displays, where Activity centers are places where media are actively produced and consumed and where information is transformed (Crabtree, Rodden et al. 2003; Koile, Toolman et al. 2003).

To equip the environment, (Prekop and Burnett 2002) developed an Activity-Centric context, i.e context aware applications that are capable of supporting complex and cognitive user activities in a smart room. Mantoro studied user mobility based on user location lead to user activity in the Active Office (AO) (Mantoro and Johnson 2003). Currently there are a number of smart environments already in use in research organisations, for example, MIT's Intelligent Room (Benerecetti, Bouquet et al. 2000), Stanford Iroom Project (Brown, Bovey et al. 1997), NIST's Smart Space Lab (Budzik and Hammod 2000), Georgia Tech's Aware Home project (Kidd, Orr et al. 1999) and ANU's Active Office (Mantoro 2003; Mantoro and Johnson 2003; Mantoro and Johnson 2004).

To provide a dynamic environment of located-objects, Schilit proposed an Active Map Geographic Information to manage information about the relationship that exists between locations. In people's daily lives two kinds of spatial relationships are commonly used: containment and travel distance. Schilit mentioned that Euclidian distance between positions within a coordinate system are not suite for human activity (Schilit 1995).

Recent technical advanced technology in Active Badge/Bat (Cambridge), Wearable Computing (University of South Australia), Cricket (MIT), and Smart Floor are also enabling the creation of such Intelligent Environments (Thomas, Demczuk et al. 1998; Orr and Abowd 2000; Priyantha, Chakraborty et al. 2000; Harter, Hopper et al. 2001) These advances technology to equip the environment have demonstrated the potential to observe user activity, but have also shown that these kinds of systems are still extremely difficult to develop and maintain (Hong and Landay 2001; Mantoro and Johnson 2004).

3. Determining User Mobility and User Activity

In pervasive and ambient systems, location information is the most important aspect which provides a context for mobile users, e.g. finding the nearest resources, navigation, locating objects and people. We have studied user mobility in an AO (Mantoro 2003; Mantoro and Johnson 2003). We began from understanding user location. People can be identified by the activity of accessing available resources at static locations or by sensing the user's mobile computing devices (PDA/handheld). Then, we studied user mobility based on user changing location from a current location to another location and store it in history data. By analysing the history data we get the pattern of the user mobility. We strongly believe that by understanding user mobility we can better understand user activity.

Numerous location models have been proposed in different domains, and can be categorized into two classes:

- Hierarchical (topological, descriptive or symbolic).
- Cartesian (coordinate, metric or geometric).

In our experiment, we use hierarchical models for representing locations and enabling rapid changes of location information between distributed context services within a certain space.

The hierarchical location model has a self-descriptive location representation. It decomposes the physical environment to different levels of precision. We use a tree structure to handle location structure and we store it as an object/entity in a relational database model.

The other important issue is the location of representation. Most context awareness applications adopt a distributed collaborative service framework that stores location-modelling data in a centralized data repository. Location related queries issued by end-users and other services are handled by a dedicated location service. This distributed service paradigm is attractive because of its scalability and modularity. However, we need an effective and efficient location representation method to make this work (Jiang and Steenkiste 2002).

We also categorise user locations in an Active Office as follows:

1. Precise Location
2. Proximate Location
3. Predicted Location

The above category is based on the sensor's capability in covering an area. Precise location is based on sensors that cover less than a meter range, e.g. swipe card, keyboard activity, biometric sensor/finger-print, iButton, etc. Proximate location is based on a sensor that covers more than a meter range, e.g. WiFi, Bluetooth, WiMedia, ZigBee, active/passive badge (depending on the range), voice recognition (microphone), face recognition (digicam), smart floor, etc.

In an Active Office, proximate location, which is detected by Wireless PAN/LAN, is an interesting proximate sensor because it can be used to access the network and also it can be used to sense a user location within the scale of a room or an office. Bluetooth and IrDA (Infrared), as a wireless personal area network, favours low cost and low power consumption, over a range and peak speed. On the other hand, WiFi as a wireless local area network, favours higher speed and greater range but has higher cost and power consumption. The range of the Bluetooth to sense another Bluetooth in a closed space, such as an Active Office, is about 3 meters for class 2 and 25 meters for class 1. The range of WiFi to sense a user with a WiFi device is about 25 meters (Mantoro and Johnson 2003).

Since IrDA connections are limited to two devices with direct line of sight, IrDA is not very useful in sensing a user's location. On Bluetooth, Bluetooth class 1 permits scanning about 25 meters (100 m in open space) between devices then Bluetooth signal strength can be use for sensing a user's location. On WiFi, it does not only have a higher speed and longer range than Bluetooth but the signal strength and signal quality of WiFi also can be used to detect user location precisely.

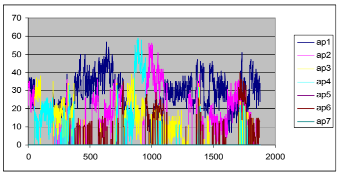
The problem is how to combine these known location data to determine the user's actual location for office activity purposes, which is a different precision matter and when user location is not available at arbitrary times. How to characterise the pattern of user location based on aggregate current sensor data and history sensor data is also a problem.

Our approach is to study the signal behaviour in every room. We collect the signal strength and signal quality of 802.11b/g. We do not use a triangulation method because of the signal strength and signal quality is very easy to change by a very simple disturbance. We use a self organizing map (Kohonen map) approach of artificial neural network to cluster the signal strength and signal quality.

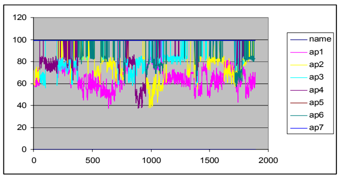
Kohonen has reported an interesting and useful result on self organizing map used for pattern recognition tasks. These maps classify a pattern represented by a vector of values in which each component of the vector corresponds to an element of the pattern. Kohonen's algorithm is based upon an unsupervised learning technique. Once trained, an input (signal strength and signal quality) data from a given class will produce excitation that represents the classification (Mantoro 1994). A self organizing map using a Kohonen map is suitable to cluster locations based on signal strength and signal quality data measure in the local IE. Using this method we can directly determine current user location. In our experiment measuring WiFi signal strength on two buildings, the result was promising to predict current user location. We could predict accurately (96%) in rooms of 3 meters width (Mantoro and Johnson 2003).

We collect data from precise and proximate users' locations sensor. When a user accesses to identify himself (such as when pressing iButton, typing at a desktop computer or logging into the network) or when the receptor/sensor /actuator (such as web cam, handheld, active/passive badge) captures the user's identity in a certain location, we record the event to history database in IE repository.

Signal Strength							Signal Quality							Room Name
ap1	ap2	ap3	ap4	ap5	ap6	ap7	ap1	ap2	ap3	ap4	ap5	ap6	ap7	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
58	66	99	99	99	99	99	36	28	0	0	0	0	0	N235
66	68	99	99	99	99	99	27	26	0	0	0	0	0	N235
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
99	99	99	73	99	99	99	0	0	0	21	0	0	0	Corridor
99	99	65	78	99	99	99	0	0	26	14	0	0	0	Corridor
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
99	99	57	82	99	99	99	0	0	38	4	0	0	0	Stairlvl1
99	99	56	84	99	99	99	0	0	37	7	0	0	0	Stairlvl1
99	99	99	73	99	99	99	0	0	0	19	0	0	0	Seminar
99	99	99	77	99	99	99	0	0	0	17	0	0	0	Seminar
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
99	99	99	75	99	99	99	0	0	0	20	0	0	0	Seminar
99	99	60	80	99	99	99	0	0	35	13	0	0	0	Stairlvl1
73	99	69	77	99	99	99	22	0	27	17	0	0	0	Stairlvl1
65	83	79	77	99	99	99	29	12	16	17	0	0	0	Stairlvl1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...



WiFi's signal quality of user Activity



Wifi's signal strength of user Activity

Fig. 2. An example of signal activities from wireless sensors within 7 hours

We use extended SQL query to find user location and using multimodality service such as speech context agent (SpeechCA) to interact with the user. SpeechCA uses speech synthesis and speech recognition by cross platform Java Speech API (JSAPI). It makes the Active Office recognise and understand instructions from user. At different levels, SpeechCA queries the history data cluster and feeds the answer to the speech synthesizer as the Active Office responds to the user's query (Mantoro and Johnson 2003).

4. Exploring Mobile Access Point

In an AO, a staff member who is employed in the office can get a guest. Generally, a guest is under the responsibility of the staff member especially for limited access to the office resources. How AO provides support for a guest user of the office resources is a common problem. We propose to use a staff mobility device as a mobile access point for a guest. A mobile access point is an access point from any available mobile equipment belongs to the staff. At the same time we can locate proximate a guest location from the mobile access point.

For example, John brings his smart personal assistant (SPA) such as a laptop/PDA that uses wireless connection to the networks. It can be connected by wired or wireless local area network in his office. When he has a guest who comes and bring his SPA, mobile phone PDA for instance, he should be able to create an ad hoc network through John's SPA, where John's PDA acts as mobile access point for his guest but still as a client for the AO server. The incoming and outgoing data of the guest is under John's responsibility. Moreover, the server can deliver information of his location to his PDA.

As we aware, communication between small embedded devices and sensing devices is an integral service in a ubiquitous computing in an AO. The existing communication technologies such as wired local area network using fibre optic, RJ45 or USB networking, wireless local area network such as WiFi, mobile phone network such as GSM, or wireless personal area networks such as Bluetooth or IrDA, form the communication network.

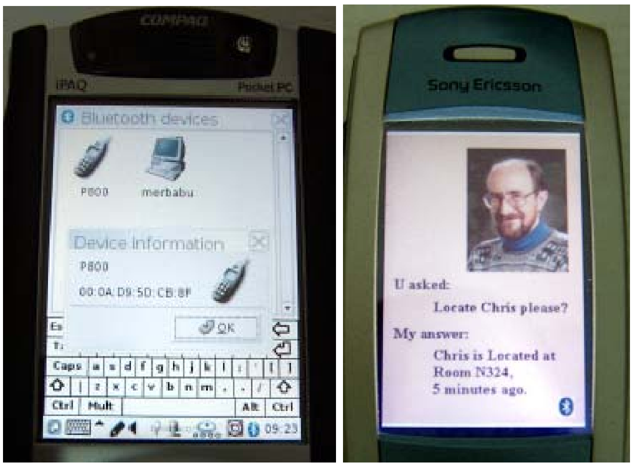


Fig. 3. Snapshot Bluetooth access point on PDA and user client on Mobile Phone PDA

In our implementation, we use several access points of Bluetooth and WiFi that cover our building. It attached to Linux servers and WiFi using VPN (cipe) and DHCP to register user MAC address equipment for security purposes. SPA's user connects to a server using wire or wireless LAN. When users use WiFi, a cipe client should be set up and bluetooth networking as NAP (Network Access Point) in the single SPA's user. So when a guest comes and brings his PDA with bluetooth or USB capability then a scattered bluetooth network or USB network can be built easily.

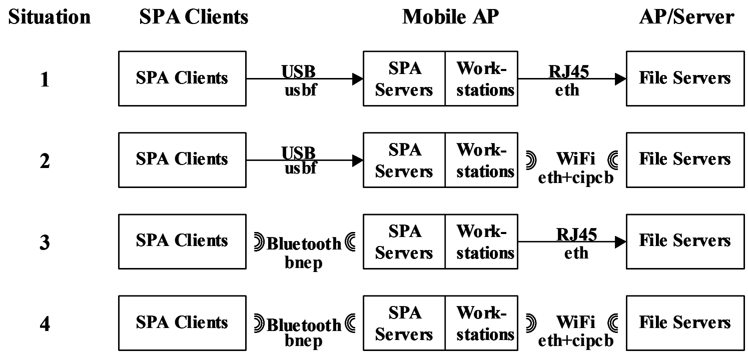


Fig. 4. The possible connectivity of mobile access point to File Server.

In our experiment we use a PDA (IPAQ H3970 and H5550) with Linux Familiar O/S and laptop with Linux Fedora to build USB networking or Bluetooth networking. While using Bluetooth Networking, we set up laptop/PDA as a Bluetooth NAP (network access point) and PDA or Sony Ericsson P800 using Symbian O/S as a Bluetooth PANU (personal access network user) (figure 3).

To develop an application on the mobile access point to send user location data to clients, we consider Bluetooth, WiFi, USB and RJ45 connection as a regular connection in the IE. We can explore four situations below (figure 4):

1. SPA client uses USB Networking (usbf) to connect to Mobile access point and mobile access point connect uses RJ45 (LAN/eth0) to connect to the File Server.
2. SPA client uses USB Networking (usbf) to connect to Mobile access point and mobile access point uses WiFi (eth1+cipcb0) to connect to the File Server.
3. SPA client uses Bluetooth Networking (bnep) to connect to Mobile access point and mobile access point uses RJ45 (LAN/eth0) to connect to the File Server.
4. SPA client uses Bluetooth Networking (bnep) to connect to Mobile access point and mobile access point uses WiFi (eth1+cipcb0) to connect to the File Server.

Table 1. SPA client location category.

Category	SPA Client	Mobile AP	AP/Server
1	Fixed/Precise Location	Fixed/Precise Location	Fixed/Precise Location
2	Mobile/Proximate Location	Mobile/Proximate Location	Fixed/Precise Location
3	Mobile/Proximate Location	Fixed/Precise Location	Fixed/Precise Location
4	Mobile/Proximate Location	Mobile/Proximate Location	Fixed/Precise Location

After we study the situation above, we find that the user location for the SPA client depends on location of mobile access point. When the mobile access point moves then the SPA client also moves. Table 1 shows 5 situations occur when the SPA client comes to the proximate user location, the rest is still in fixed/precise user location. It happens when a mobile access point or an SPA client is using a wireless connection (Bluetooth/WiFi).

We monitor (guest) user activity (using ntop) of mobile users that have access to our resources.

5. System Monitoring User Activity in an Active Office

Contexts have been defined as complex, rich objects that contain information relevant to the problem or domain being examined. This information is used to characterize the situation of user entity and environment entity, where user entity is a person being in the environment and an environment entity is an open or closed space that is embedded/equipped by smart sensors.

We define a user activity as association between a user and smart sensors in the environment or any sensors being in active use to access the resources. The context information from user activity can be used to characterise of user situation.

To monitor user activities, several important variables are needed such as user identification, user location, register fix devices/sensors, network availability (WLAN: Bluetooth, WiFi), and service status of the room in the Active Office. The user identity, devices/sensors and network availability as objects would have object identification, an object name and other characteristics. Once there exists a relationship between user identification and other objects such as user location, register devices, etc., this object will be registered and stored in the IE repository as a transaction in a user model.

User Identity: John Blog
U4011906

Date: Friday, 20 February 2004
Time: 11:35:22.01

User Activity: John is in his room (Rm N235), sitting in his chair near the main desk, join in an audio conf. with Pelican group.

Office Environment: Room N235

Register equipment:
Workstation 1: fix place, in the main desk, thepenguin (150.203.xxx.xxx), Wired LAN, Fedora
Workstation 2: fix place, in the window desk, Semeru (150.203.xx.xxx), Bluetooth server, Windows XP
Notebook: mobile, in the main desk, Laptop119 (Dinamic IP Address), WiFi, Wired LAN, Bluetooth PAN, multiboot, Windows XP, Windows 98, Fedora
Telephone: fix place, in the main desk, +61261253878
PDA: mobile, in the main desk, PDA119 (Dynamic IP address), Wifi, Bluetooth client, Familiar 2.1, GPE 2.1

Sensor:
Ibutton: fixed place, near the door
WebCam: fixed place, in the corner near the window desk, attached to Workstation 2
Temperature: 26ºC

Network available in room N235:
Wired LAN: 2 socket, fix IP - subnet 150.203.xxx, dynamic IP - subnet 192.168.2
Wifi: 3 Access Points cover the room, ANUNorth, dynamic IP using VPN (CIPE) with 128 bit encrypted link.
Bluetooth: 1 Bluetooth server (PAN), 3 Bluetooth clients (PANU)

Status Services on room 235:

Telephone: available, connect, (Audio Conference: running)
Fax: Available, share in resources room
Email: available, IMAP 4, active in Workstation 1, Workstation 2, Notebook, PDA
Printer, available, share in resources room, Hplaserjet, Kyoceira 3750
Webcam: active, recording
Ibutton: active, no capture data
Temperature: active, sensing, 26ºC
Web server: Apache, not available, last available: 20 February 2004 11:33:33.30
Meeting maker: active

Fig. 5. A snapshot of a user current location and a user activity recognition window

User location can be recognised by WiFi or Bluetooth. We use a proximity location sensor in the active office. In case the user has two devices with two connectivity's capability, using WiFi and Bluetooth for instance, the active office environment will check both devices, then use the latest user location and store it in the IE repository as the current location.

The service status will capture directly from the resources manager which accesses the IE repository and the user model. The IE repository and the user model are holding the information from every sensors/devices and relationship between user identification and sensors/devices.

The user activity has the same treatment as other devices/sensors status, but it concerns only with user id and the transaction between user id and the objects (it can be sensors, devices, services, etc.).

Snapshot at figure 4, is an example of monitoring user activity. John Blog is in his room (room N235), sitting in his chair, near the main desk, join teleconference with Pelican Group. It can be monitored by John logging into his computer (John is in room N234 and room N234 belongs to John), he sit in his chair (the iButton/RFID in the chair and keyboard activity is in active mode as John continues typing) and he registered in conference with Pelican Group (based on John's schedule, he is in the teleconference with the Pelican group and at the same time the phone status is in audio conference).

The context information above shows John's activity in the teleconference situation.

6. Summary and Further Study

As we are aware, the computer environment changes over time. This situation makes harder to understanding user activity in an AO. The problem confronting the user is how to enable transparent distribution computing continue operation across changing circumstance in a seamless manner and how the environment recognises user activity.

This paper describes an approach to determine and recognise user activity based on user location. We also introduce mobile access point for a 'guest' user to access resources in an Active Office in a seamless manner. This is important for communication when an employee have a guest. It also provides the mechanism by which AO manages authorisation for the guest user.

This work is based on DiCPA architecture, a distributed context processing architecture for smart environments. We show how the scalable distribution of context and context information is managed to characterize user activities.

Further study to be considered from this work is to analysing the context information of user activity to characterize user situations.

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