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TOWARD THE RECOGNITION OF USER ACTIVITY BASED ON USER LOCATION IN UBIQUITOUS COMPUTING ENVIRONMENTS

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Abstract

Human Activity is not a well defined concept in Ubiquitous Computing discipline because human activity is very complex and the computer environment is very limited in capturing user activity. However, user activity is an essential ingredient for the determination of appropriate response from Intelligent Environment in order to provide appropriate services with or without explicit commands. This paper describes an approach to the determination and recognition of user activity based on user location. The characterisation of user activities can be deduced from sensor activities based on the scalable distribution of context location information. This approach does not require users to label their activities.

Keywords: User Activity, User Location, Smart Sensors, Ubiquitous Computing, Intelligent Environment.

1. INTRODUCTION

Scientists in the Ubiquitous Computing area are researching ways to make embedded computing and Ubiquitous Computing work better for people by creating and equipping an Intelligent Environment, such as an active home or an active office, with technologies that can identify the user's needs and meet them speedily, efficiently and unobtrusively.

The goal of Ubiquitous Computing in general is to make user interaction with the computer easier in the Intelligent Environment where technology is spread throughout (pervasive), computers are everywhere at the same time (ubiquitous) and technology is embedded (ambient) in that environment. The context-aware application should reduce the load of the user and adapt to users seamlessly [1,2]. While a user is doing his daily activities, his access to the Intelligent Environment should not be difficult, tedious or need considerable learning on the part of the user. The interaction should be safe, easy, simple and enable new functionality without need to learn a new technology. As human activity is a central part of the user context [1], the context-aware system would provide relevant information and a simple way for a user to deal with the computing environment. Context information cannot be supplied by the user. It should be sensed automatically using sensors in the computing environment, in making these smart environments have the capability to assist people with a variety of activities by detecting a users' current state/context to determine what actions to take based on that context.

An important problem in an Intelligent Environment is how the system could characterise user situation based on user activity, where user activity is based on any objects (such as smart sensors) being in action relating to a particular person's use. It could provide complex and rich information which is relevant to the situation/domain being examined.

This information is used to characterise the situation of user entity and environment entity. The user entity is a person being in the environment, and an environment entity is an indoor or outdoor space that is embedded/equipped with smart sensors. A set of user activities can be identified by reading and interpreting any association between a user (user entity) and smart sensors (in the environment entity).

In an indoor space such as home environment, the benefit of such technology might simply be convenience and enjoyment at home, for example, knowing when the occupant wakes up and what radio station they like to listen to without waking up the rest of the house. On the other hand, the active home could be life saving by detecting when an occupant collapses and needs medical help.

For an office environment, the benefit would be the capability in measuring user productivity. If user productivity is a goal of the use activity, then it can be measured by counting the number of tasks completed per unit of time, and can also convert these measurements to measurements of time per task. Our approach is to locate a person within an environment using wireless connections in devices that are normally carried 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.

User activity can be shown from sensor activity in capturing changes in state, time and location. To manage and respond to rapidly changing aggregated sensor data, DiCPA architecture [3] is used. This scalable distribution context processing architecture in the Intelligent Environment allows continued operation across changing circumstances for users, the collection of nearby people and objects, accessible devices and changes to those objects over time in the environment. The DiCPA architecture is implemented to recognise user location and user mobility. This could lead to the understanding of the concept of user activity. The context information of this user activity can be used to characterise the user situation.

This paper contributes mainly to 1. the study of user activity based on location in smart environment which proposes an approach to the determination and recognition of user activity based on user location. 2. propose the strategy in providing service to unregistered (guest) user as a unique perturbation situation in office environment, including how to estimate the location of this type of users (Section 5).

In the following section, a related work in user activity area is also discussed, followed by 1. the user activity concept, 2. Activity-Based processing model 3. the role of user location to user activity 4. Mobile Access Point concept and 5. monitoring user activity. The paper is closed by conclusion and closing remarks.

2. RELATED WORK IN USER ACTIVITY

In the current literature, researchers who work in the area of user activity fall into three categories, they: 1. develop equipment using wearable devices to be worn by the user to sense user activity and recognise user location, 2. study user behaviour in the workplace area and home, and 3. develop a system/device to equip the environment (Figure 1).

Firstly, in the area of wearable devices, it is possible to determine a user's location using a dead-reckoning method to detect the transition between pre-selected locations, and recognise and classify sitting, standing and walking behaviours, for instance in [4].

Secondly, 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 [5]. It has been argued that many more people are experiencing a blurring of the division between 'home' and 'work' domains as different forms of work become possible within the physical space of home.

While Koile proposes activity zones to construct an activity area, Crabtree introduces communication places. Activity zones have a physical form – e.g. wall, furniture – which partition places into zones of human activity and places of communication that are familiar at home as areas of 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. Activity centers are places where media are actively produced and consumed and where information is transformed [6,7].

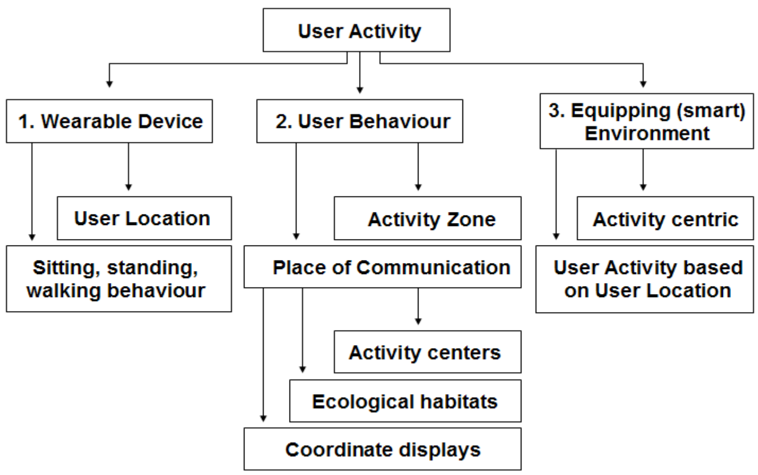

FIGURE 1: Research Categories in the Area of User Activity

Thirdly, in the area of developing a system/device to equip the environment, Prekop and Burnett [8] 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 leading to user activity in the Active Office [9]. As mentioned earlier, this work mainly proposes an approach to the determination and recognition of user activity based on user location in a smart environment.

Currently, there are a number of smart environments already in use in research organisations, for example, MIT's Intelligent Room [10], Stanford iRoom Project [11], NIST's Smart Space Lab [12], Georgia Tech's Aware Home project [13] and ANU's Active Office [3,9,14,15].

To provide a dynamic environment of located-objects, Schilit [16] proposed 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. In addition, Schilit also mentioned that Euclidian distance between positions within a coordinate system are not suitable for human activity.

Related study in user activity also considers the social aspect of the user. The user social aspect research area mostly studies in user dimensions, instead of environment dimensions or technological aspects, such as the study of the use-of-time [17]. Time use studies typically have a single focus: to study the frequency and duration of human activities.

According to Stinson [18], the use-of-time for Canada's telephone administration can be placed into two categories, i.e. firstly **in places**, such as a respondent's home, a workplace, at someone else's home, at another place (including park, neighbourhood); and secondly **in transit**, such as in a car (driver or passenger), walking, in a bus or subway, on a bicycle, others (airplane, train, motorcycle). Throughout the world, most of the currently used activity classification systems have evolved from the original structure developed by Alexander Szalai for the Multinational Time-Use Project of the 1960s. These activity codes are typically arranged into mutually exclusive behaviour groups that cover all aspects of human activity. These primary divisions of behaviour, which may be considered for the study of user activity in the Intelligent Environment, generally include:

- Personal care activities
- Employment related activities
- Education activities
- Domestic activities
- Child care activities
- Purchasing goods and services
- Voluntary work and care activities
- Social and community activities
- Recreation and leisure
- Travel time

However, the recent technically advanced studies 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 in capturing and understanding user activity [19,20,21,22]. These advances in 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 [3,23].

3. USER ACTIVITY CONCEPT

In the Context-Aware Computing or Ubiquitous Computing discipline, user activity is not a well defined concept, this may be because of:

- the transition between activities is sometimes not very clear,
- an activity can be seen as part of another activity,
- an activity can be in sequence mode (for example, open the door and followed by walking) or in parallel mode (for example, receiving phone call while walking) or both together,
- different views can be deduced from different activities.

For example, the difference between a running and walking activity; it needs clear variables to be defined, several variables which may involve, e.g., the length of the user's leg, the speed of movement, the number of steps taken in each minute, etc. When a user cleans his house, he needs to move or walk. Thus, it may not be clear whether the activity of the user is walking or cleaning the house. A different view and a different perspective can lead to the assumption of a different user activity.

User activity in the Intelligent Environment is divided into 4 categories:

a. activity as any association between a user and smart sensors in the environment
b. activity as a node in a work flow or job breakdown
c. activity as a physical movement mode or state
d. activity as a mode of state of human intent

In this study, user activity in an Intelligent Environment is defined as *a sequence of any association between a user and the smart sensors in the environment that can be determined and recognised as an activity.*

To recognise a user's activity while accessing resources, the context-aware application requires user identification. A user's identity can be captured from the user's mobile computing devices or user's image/voice recognition. Users can be characterised by several means, i.e., identification and authentication, user profile, user's terminal and user's access network characteristics, and service adaptation to user environment (the detail implementation is discussed in Section 7).

User characteristics can be recognised when any association exists between a user and smart sensors, and the association is recorded in a sensor database which contains information relating to user identity, sensor identity, location identity, time and state. The collection of this data, user activity history data, forms a pattern of the user's mobility and the regularity of a user's activity pattern also capable of being recognised. This pattern can predict a future user activity based on a user routine activity by querying the user activity pattern.

Many earlier projects acknowledge the need for the capability to capture user activity in the complex relationships between a user and the environment:

a. the activity as an essential ingredient for determining appropriate reactive behaviour as requirements for Response Offices at Xerox PARC [24].
b. the need for tracking activity such as EasyLiving at Microsoft acknowledges [25], or tracking activity of daily living to identify the short- and long-term changes in the health of elderly people [26].
c. the utilisation of the activity based approach such as in the second generation of iRoom at MIT [27]. This approach is similar to the activity-centric context model at DSTO, which have agents and activities as key components. The activity centric context model adopts a knowledge management approach to support the hand-over of artefacts from one individual or group to another. For example, to hand over a system design it is necessary to pass the formal artefacts of the design activity but it is also important to pass the tacit system design context, the mental models, assumptions and other factors that exist when the design was developed [28].

In our work, the capability to capture user activities outlined above was considered and followed the prediction of future user activity by the use of history data to form an activity pattern.

4. ACTIVITY-BASED PROCESSING MODEL

An activity-based approach uses the abstraction of the sensor data that is accessed by a user in the computing environment. In this part, the activity-based processing model will be discussed. The model has 5 stages as shown in Figure 2, i.e. Sensors, Smart Sensor, Resolver, Resources Manager, and Presentation.

Sensors

In recognising user activity, the principle questions are: How many sensors are needed to recognise a user activity and at what precision? Can activities be recognised using simple sensors that detect changes to the states of objects and devices in a complex office setting? The answer is sometimes simple, for a simple activity, a single simple sensor can often provide powerful clues to activity. For instance, a keyboard activity sensor can capture user typing activity and a pressure chair sensor can strongly suggest that a user is sitting on the chair, both types of sensors can show user location as well. However, these sensors cannot show other activity, such as that a user has a meeting activity. It also depends on the type, function and the capability of the sensor in capturing the user data.

An Active Office in this experiment has two types of sensors, i.e., proximate and fixed sensors. It uses proximate sensors, such as WiFi, Bluetooth, RFID and IrDA. These sensors have been used to sense user activity. The other sensors can be added as required by the room to capture user activity, such as UWB, eye-movement sensors, etc. For fixed sensors, magnetic phone sensors, pressure chair sensors, magnetic door sensors, keyboard activity sensors, mouse activity sensors and swipe cards are used. Fixed sensors can also be extended to other sensors such as biometric/finger print sensor, iButton sensor, etc.

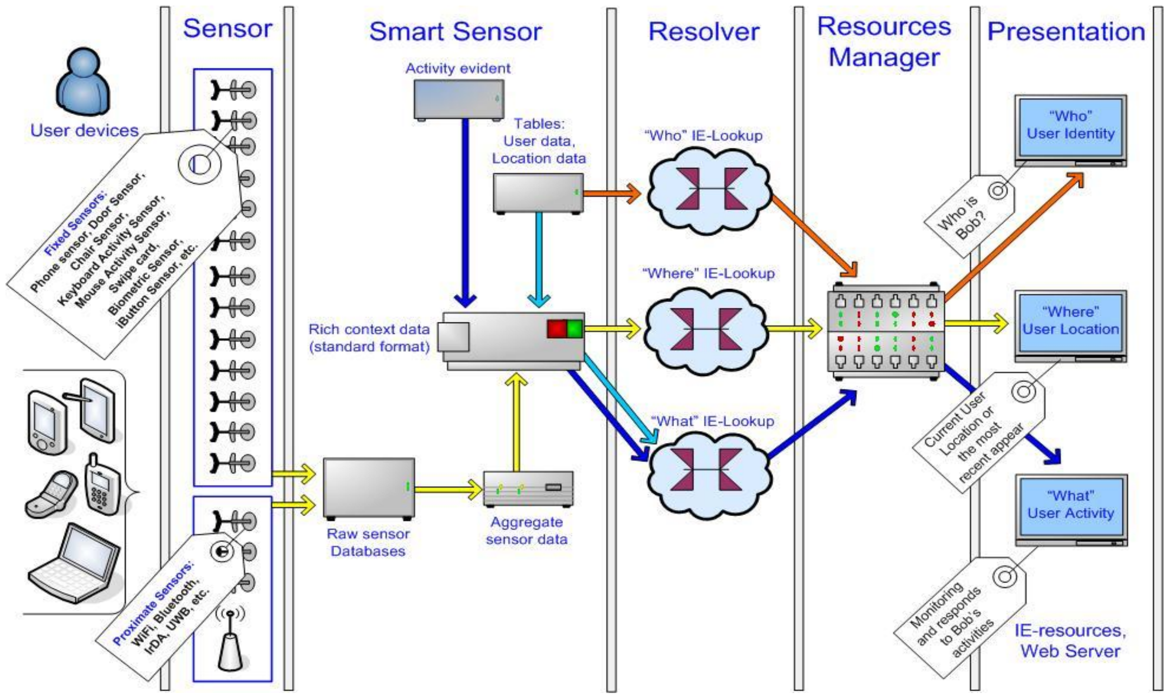

FIGURE 2 User Activity Processing Model

Smart Sensors

A smart sensor is one or more sensors (array sensors) with the integrated application that has the capability to make decisions for certain purposes including recognised user activity. Aggregation of sensor data is the only one of the processes in the sensor application to characterise user activity. The smart sensor is based on three kinds of data, i.e., raw sensor data, activity-evident data, and data-tables, such as user data-table, location data-table, etc. The raw sensor data which is recorded in a spatio-temporal database is a key entity for the smart sensor to deduce what kind of user context information is. Aggregate sensor data is the extracted data from a raw sensor database. The spatio-temporal database in this model can be used for two purposes, i.e.: speeding the process query and showing the scalability of the query.

Resolver

Resolver is the procedure for looking-up user identity, location and activity. This approach is similar to the DNS server lookup host table. DNS server can resolve host name to ip-address and vice versa. In our model, the resolver uses the DNS idea more widely, it resolves three variables i.e., User Id, Device Id and MAC address. It covers for a user to have several devices and the possibility for each device to have several MAC addresses, and hence possible for a user to have many identities in the environment. There are three functions of the resolver in this work that have been designed for Active Office purposes, i.e. 1. for user identity purposes, it uses user identity lookup tables; 2. for location purposes, it uses scalability of location lookup tables and 3. for user activity purposes, it uses several entities (databases) to deduce user activity.

Resource Manager

In Active Office's network management, a resource manager acts as the coordinator. It maps available resources. It contains agents such as resolution agent, inter-domain agent, ICMP agent, SNMP agent, Content Routing agent, etc. For user activity purposes, some of the resources manager's functions may not be used much, such as accepting the object's global name from the resolution server or the use as persistent mapping to request persistent location from the resolution server. In this part, the resource manager's function is to coordinate the resources based on the status of the sensor data including the aggregate sensor data to provide a complete set of context-aware information which contains user identity, location and activity information.

Presentation

The presentation is in the form of response or action from IE. The pesentation is based on data processing from the resource manager. User activity can be shown whether virtually, in a web page, in computer monitoring (see Section 7), or in direct action to the user.

5. THE ROLE OF LOCATION TO USER ACTIVITY

When smart sensors sense a user and recognise a user location, the possible activity of the user can be estimated based on the user location itself. For example, in Table 1, when a user is found in his office (N235), the possible activities in his room are working on the computer, working on his table, using the telephone, or having a meeting. The user activity is not reported by the user while he is on the move. In this section, how to recognise user activity based on sensor data will be discussed. This approach does not need the subject to label his activities such as in [28, 29], where it could be difficult to adapt to individual patterns of activities.

To clarify the tree of the user activity, some parts of user activity can be formed in a tree structured as follows:

- Working on the computer
  - Office Application
    - Word processing
    - Spreadsheet
    - Presentation software
  - Mail agent
    - Read email
    - Forward and write email
    - New email and write email
  - Web application
    - Download paper/image
    - Searching information
    - Web email
      - Read email
      - Forward and write email
      - New email and write email
    - Monitoring equipment
- Working on the table
  - Read a paper
  - Make a note
  - writing a paper
- On the phone
  - Internal call
  - Local call
  - Inter-local call
  - International call
- Meeting
  - Meeting with staff
  - Have a guest
  - Meeting with supervisor

When a user is working on the computer, the mouse and keyboard activity sensors can be used to detect in which windows and with which applications the user is engaged. Hence, when the location sensor finds his location is in room N235, the mouse and keyboard sensor can then report an activity such as user id, windows and application. These could then be used to deduce the type of user activity.

In the case of a user working with email, there are many ways to access email, such as remote access and open mail agent, create a pop email script and convert to special word format, etc. This is not recommended in the Active Office, because it will lead to difficulties in recognising user activity. In the Active Office, working with email is only recognised when a user makes common use of a regular mail agent (such as Microsoft Outlook, Mozilla Thunderbird, Eudora, Pine, etc.) or web-mail (such as mail.google.com, mail.yahoo.com, etc.).

Recognising user activity when the user may be working on his table is not simple, so far in the Active Office only user location data have been recognised from WiFi signals, and chair sensor data using a pressure sensor that is embedded in the chair, but as yet no sensor has been embedded in the table. Once the Active Office has a pressure sensor covering the whole surface of the table, the Active Office will be able to deduce when the user is working on his table. However, the situation where a user works on his table is a different situation from that where the user is on the phone, since, as the Active Office has a phone sensor, it can be easily recognised when the user is having a phone call.

In the case where the user has a meeting, when it is found that other users are also in the same location (room) for a certain period, it can be deduced that the user has a meeting with other people. If the other user status is recognised as student then it is a meeting with a student, the same thing can happen when the user identity is found to be his supervisor. The context-aware application will deduce the activity based on the recognition of the user's identity. However, when there is a user/guest and his location is recognised but no identity is available, then the Active Office needs to find a way to recognise the existence of that user/guest, one option is by identifying his mobile device using resolver.

When a user leaves his office, user activity status will be undetectable. This status will be the same when the user does not allow the Active Office to detect his location. When a user's location is found to be in a seminar room, and it also matches with the seminar schedule, it can be deduced that joining the seminar is his user activity status.

Room	Visit (times)	Duration (minutes)	Possible Activities
N235	7	337	Working on the computer. Reading a paper. Make a note or writing a paper. Telephone. Meeting.
Undetectable	1	56	Out of office. Not allowed to detect.
Seminar	1	53	Join DCS seminar.
DCS café	1	16	Afternoon tea. Morning tea.
Corridor	9	9	Walk through.
Toilet	2	7	Toileting.
Stair Level 1	6	6	Walk through.
Resources Room	1	3	Picking up print out. Check mail. Fax. Binding. Pick up stationery/paper. Pick up reading material. Photocopy.

TABLE 1: Summary of a Staff Member's Activities on a One Day Observation.

A similar deduction may be made when a user is found in the DCS café; if he has stayed for more than 5 minutes and the time is in the morning about 11am, then it can be deduced that he has a morning tea activity. This applies also for afternoon tea activity.

When a user's location is found to be in a corridor or on the stairs, and his location changes at a reasonable speed, it can be deduced that he walks in a corridor/on stair activity. When a user's location is found in toilet for more than 3 minutes, it also can deduce that he may be so engaged.

Table 1 shows the summary of the duration of a staff member's activities on a one day observation, sorted by the duration of visits to rooms. The measurements are based on data collection using various fixed and proximate sensors. If proximate sensors reported user location, it used nk-Nearest Neighbour algorithm to estimate symbolic user location [30]. This table also shows that the user spent 69% of his office hours on that day in his office which may relate to the measurement of user productivity. This approach proposes the tagging of each room with the function of the room and how often the users have activities in a particular room.

To have a better understanding of the recognition of user activity based on location, activity zones can be created, as explained in [7]. Activity zones can be mapped by including observed location features in regions corresponding to activities or sets of activities. In this study, a 3-D pattern of user locations is not further explored, instead short-range sensors, such as an RFID sensor, which can be embedded in any Active Office object used to allow recognition of user activity. 3-D location of users or an RFID sensor is useful but alone is insufficient as context information. In this experiment, the raw RFID sensor data is combined with raw WiFi data.

The partition of space/zone is based on simple proximity or relies on user specified maps of regions. Location regions can be learned from observed activities, including user changes to location/motion. Each zone corresponds to a region in which a person is likely to be engaged in similar activities. Activity zones can overlap in space, since motion can indicate a different activity. This activity map can be used at run time to contextualise user preferences, such as allowing "location-notification" settings of messaging, environmental control and multi-media delivery [7].

For example in the case of a resources room in our department, as shown in Figure 3, if a user's location is found by WiFi sensors to be in the resources room, and RFID sensors in front of the Reading Material zone sense that a book has just been moved from the shelf, the Active Office can deduce that the user is picking up a book.

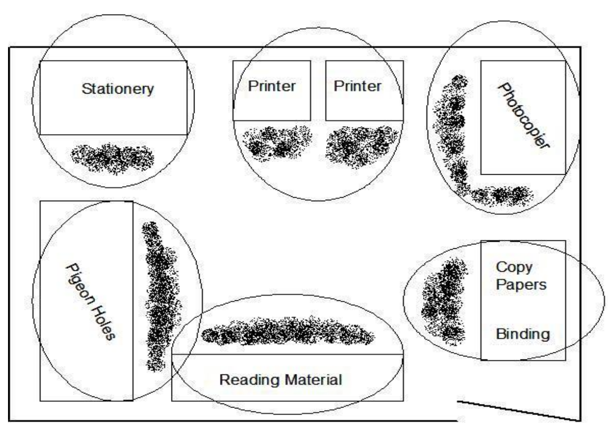

FIGURE 3 Access Zone in the Resources Room

A more complex application allows the recognition of a complex user activity by the addition of the semantic of an object (knowledge of objects such as chair, desk, and computer) and the semantics of human behaviour (such as people who come to the office around 9 am, read and write at a desk). In an Active Office, user activity depends on the type of organisation and the location/position. In the case of the University organisation, especially in the head of department room at department level, the most frequent activities are working on the computer, talking on the phone, having a guest, a staff meeting, or meeting with a student.

Some activities in the Active Office, such as in the University, could easily be detected, for example working on the computer or talking on the phone. However, recognising the difference between when the Head of Department is having a guest, and the Head of Department is meeting with a staff member or a student, is a still problem, since at the moment not all people have an identity that can be recognised by the Active Office. If user productivity is a goal of the Active Office, it can be measured by counting the number of tasks completed per unit of time, and can also convert these measurements to measurements of time per task [31].

The most complex activity occurs when a group of people share their activities. The social exchange and actions within a group of people have direct impact on group activity. A working group is situated in a rich context of organizational strategies and objectives, job roles and responsibilities, interpersonal relationships, task assignments and interdependencies and tool-handling and material resources [32] and makes the group's activities harder to understand than that of a single user's activity. This context is in the domain of user activities.

Group activity implies knowledge of how task components are identified, coordinated and carried out. Task components must be understood and pursued in the context of the overall purpose of a shared activity, the goals and requirements for completing it, and how individual tasks fit into the group's overall plan. When collaborative activity is carried out and the collaborators are in different time zones or cultures, it will not include face-to-face interaction and many interaction resources will be disrupted i.e., field of view is reduced, the possibility of gesture use is limited, facial expressions are eliminated/constrained, auditory cues are diminished, tools and artefacts cannot be as easily shared, deixis and spatial co-references are difficult to resolve [33,34]. It is also difficult to repair miscommunication.

6. MOBILE ACCESS POINT

Mobile Access point is an access point that is capable to follow a user or the user follows the access point, and to establish a connection to the network for that user and deliver service while the user is on the move. The purpose of the development of the mobile access point is to monitor user activity based on user location of "unregistered but legal" user or unknown device in the Active Office.

This will not only have implications for the context-aware application in providing service to the unregistered user, if it is allowed, but also to the development of the social policy of the environment as well, as a unique perturbation situation in an Active Office. The generic social scenario for this situation is when a staff member has a guest. A guest user, a user without enough knowledge of the local network, gains access to the Active Office and in the view of the guest user, Active Office is unfamiliar domain for the user. This is a unique situation in a social model in ubiquitous computing environment.

In an Active Office, a guest is a different user category from that of a visitor, such as visiting fellow, a guest may visit only for a couple of hours but a visitor may stay for several days and as a consequence of this situation, a visiting fellow may register in a local server, but a guest clearly may not.

"Having a Guest" Scenario

How Active Office provides support for a guest user to office resources is a common problem. Generally when a guest user/colleague comes to the office, he is under the responsibility of the staff member, especially if the guest has limited access to office resources.
For that purpose, the policy of the office needs to be developed, how confident the office administrator is of the network's security when it is accessed by an external user, such as a guest user, or other guest user categories (every guest user has his own characteristics and needs).
The social policies designed for "having a guest" in our Active Office follow the requirements below:

- A user (staff member) who is employed in an Active Office is allowed to have a guest.
- A guest user is under the responsibility of the staff member.
- Active Office provides support for a guest user to gain access to limited general resources but, for security reason, a guest cannot directly use his workstation.
- Mobile computing equipment (Notebook or PDA) of a staff member can be used as a Mobile Access Point for his guest user in accessing Active Office resources.
- A mobile access point can be used by the staff member and his guest user while they are on the move in an Active Office.
- At the same time, an Intelligent Environment application can locate a Mobile Access Point that turns to approximate guest user location.

In the implementation, a staff mobile device is set up as a mobile access point. This mobile access point is an access point for a guest user device to access the network. Staff members and their user guests can access the resources in the four buildings and the surroundings which have several fixed sensors and are covered by the wireless network. While they are on the move in the Active Office, these resources can be accessed anytime, anywhere.

The following is an example scenario of "having guests" in an Active Office.

> *John Blog has a smart personal assistant (SPA), a laptop with Linux Fedore, that uses wireless connection (WiFi and Bluetooth capable device) to the networks in his Active Office. When Adrian, Mick and Walter come to John's office and they bring their own SPA: Adrian brings his Phone PDA with Windows CE, Mick brings his PDA with Linux Familiar and Walter has a smart phone with Symbian operating system, all with Bluetooth capability. When they have a meeting and need connections to the net, they are able to create an ad hoc network through John's SPA using Bluetooth network. The different types of devices and operating system platforms are not the barrier.*
>
> *John's SPA is set as a mobile access point using Bluetooth network for his guests, but it remains as a client of the Active Office server using WiFi network.*
>
> *When Adrian device is connected to the Active Office network, the MAC address of his device is caught up by the resolution server to find his profile including his identity from his local server in his university office (outside John's office). The Active Office can then deliver a welcome message to Adrian. The same way happens to Mick from his industry server and Walter from his government server out there and the meeting begins.*

The Active Office provides the mobile access point through John's laptop, calculating the guests' incoming and outgoing data which is stored as John's responsibility. The handling systems or Persistent-URL systems is used for a resolution server to recognise the guest identity, if his device is not registered in Active Office. Moreover, the Active Office server can deliver information relating to John's location to his laptop which can lead to the location of their guests. The proximate location of a guest user measured by finding the proximate location of the mobile access point and turned to a proximate guest user location by using the symbolic or coordinate user location algorithm mentioned in [30].

Guest User Location Based On Mobile Access Point Connectivity

Communication between small embedded devices and sensing devices are an integral service of the Active Office. The existing communication technologies use wired and wireless local area networks to form the communication network. The wired local area network uses fibre optic, RJ45 or USB networking and the wireless local area network uses WiFi, or wireless personal area networks (Bluetooth or IrDA). In an Active Office, the use of mobile phone network (GSM/GPRS) by the guest is allowed but not supported, since the access to mobile phone network is not under control of the Active Office infrastructure and the cost of connection also needs to be considered by the guest user. However, the guest has an option to connect to the network through 3G telecommunication service, for example, without any interference of Active Office systems.

Category	SPA Client	Mobile AP	AP/Server
1	Fixed/Precise Location	Fixed/Precise Location	Fixed/Precis e Location
2	Mobile/Proximat e Location	Mobile/Proximat e Location	Fixed/Precis e Location
3	Mobile/Proximat e Location	Fixed/Precise Location	Fixed/Precis e Location
4	Mobile/Proximat e Location	Mobile/Proximat e Location	Fixed/Precis e Location

FIGURE 4 The Possible Connectivity of a Mobile Access Point to File Server.

In our implementation, several access points of Bluetooth and WiFi are used to cover the three buildings and their surroundings. The users are attached to the Active Office servers through the WiFi Access Points using Virtual Private Network (secure mode), and the server provides authoritative dynamic IP address service by registering the user's MAC address devices for security and zero-configuration purposes. It is possible for an SPA user to connect to a WiFi server using wired or wireless LAN. When a user uses WiFi in an Active Office, his mobile device will be set up as a secure client to the WiFi's server to provide a connection for his guest, and his mobile device also needs to be set up as a Network Access Point (NAP) especially when his guest needs to connect using Bluetooth networking (Figure 4). When a guest brings his PDA with Bluetooth or USB capability, a scattered Bluetooth network or USB network is available to access the Active Office resources.

In this experiment, three PDAs (WinCE and Linux Familiar) and a Smart Phone are used as clients and a laptop (Linux Fedora) is used to build USB networking or Bluetooth networking. While using Bluetooth Networking, the laptop was set up as a Bluetooth NAP and the PDAs and a Smart Phone were set up as a Bluetooth Personal Access Network User clients (PANU).

To develop an application on the mobile access point to send user location data to clients, the Bluetooth, WiFi, USB and RJ45 connection can be considered as a regular connection in the Active Office. The four situations in which the connection to the Active Office can be formed are as follows (Figure 4):

From the study of the situation above, it is obvious that the user location for the SPA client depends on the location of the mobile access point. If the mobile access point moves, then the SPA client will also move. Table 2 shows only five possible situations (grey shading) which can occur when the SPA client comes to the proximate user location, while the rests are in fixed/precise user location. This happens when a mobile access point or an SPA client is using a wireless connection (Bluetooth/WiFi). The guest activities in accessing the resources while the guest user is on the move were monitored using network monitoring application.

An Active Office provides full support to any resource movement (user mobility devices), in the sense of the availability of the independent resources. In the case of a mobile access point, it is possible for the staff member to change his connection from wired to wireless connection, but his guest continues to access the service transparently through his mobile access point, which is also his mobile device.

7. SYSTEM MONITORING USER ACTIVITY IN AN ACTIVE OFFICE

As mentioned earlier in Section 4 – Resources Manager, in Active Office's network management, a resource manager acts as the coordinator. It maps available resources. This section presents a sample map in Active Office for a user.

When a user has an activity in an Active Office, which is recognised by any sensors being in active use by a user or where any transaction occurs between a user and smart sensors in the environment, the user activity can be detected and monitored. The user activity information can be used to understand the user situation.

User Identity: John Blog
U4011906

Date: Friday, 20 February 2008
Time: 11:35:22.01

User Activity: John is in his room (Rm N235), sitting in his chair near the main desk, joined Pelican group audio conference.

Office Environment: Room N235

Register equipment:
Workstation 1: fixed place, in the main desk, thepenguin (150.203.xxx.xxx), Wired LAN, Fedora
Workstation 2: fixed place, in the window desk, Semeru (150.203.xx.xxx), Bluetooth server, Windows XP
Notebook: mobile, in the main desk, Laptop119 (Dynamic IP Address), WiFi, Wired LAN, Bluetooth PAN, multi-boot, Windows XP, Windows 98, redhat
Telephone: fixed place, in the main desk, +61261251301
PDA: mobile, in the main desk, PDA119 (Dynamic IP address), WiFi, Bluetooth client, Familiar, GPE

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

Network available in room N235:
Wired LAN: 2 socket, fixed IP - subnet 150.203.xxx, dynamic IP - subnet 192.168.xxx
Wifi: 3 Access Points cover the room, ANU North, dynamic IP using VPN (CIPE) with 128 bit encrypted link.
Bluetooth: 1 Bluetooth server (PAN), 3 Bluetooth clients (PANU)

Status Services on room N235:

Telephone: available, connected, (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, HP LaserJet 4200, Kyocera 3750
Webcam: active, recording
Ibutton: active, no captured data
Temperature: active, sensing, 26°C
Web server: Apache, not available, last available: 20 February 2008 11:33:33.30
Meeting maker: active

FIGURE 5 A Sample Snapshot of a User's Current Location and a User's Activity Recognition Window

To monitor user activities, several important variables need to be considered, for example:

- user identification,
- user location,
- register of fixed devices/sensors,
- network availability (WLAN: Bluetooth, WiFi),
- service status of the room in the Active Office.

All objects, such as user identity, devices/sensors and network availability, have:

- object identification,
- an object name,
- other characteristics.

Once a relationship exists between user identification and objects such as user location or register devices, this relationship will be registered and stored in the Intelligent Environment repository as a transaction of a user model.

User location can be recognised by WiFi or Bluetooth. A proximity location sensor is used in the Active Office. In the case when the user has two devices with two connectivity capabilities, 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 Intelligent Environment repository as the current location.

Service status captured directly from the resources manager, which accesses the Intelligent Environment repository and the user model. The Intelligent Environment repository and the user model holds the information from all sensors/devices and the relationship between user identification and sensors/devices.

The snapshot in Figure 5 is an example of monitoring of user activity. John Blog is in his room (room N235), sitting on his chair, near the main desk, and joins a teleconference with Pelican Group. John is monitored logging onto his computer (John is in room N234 and room N234 belongs to John), he sits on his chair (the iButton/RFID in the chair and keyboard activity is in active mode as John continues typing) and he registers onto the conference with Pelican Group (based on John's schedule, he is having a teleconference with the Pelican group and at the same time his phone status is in audio conference).

The user activity process (Figure 5) has the similar process as the other smart sensors, the deduction is concerned to user-id and the transaction between user-id and the objects i.e., sensors, devices, services.

The deduction from the context information above shows John's activity is a teleconference situation.

8. CONCLUSION

This paper discussed an approach towards the determination and recognition of user activity in Ubiquitous Computing Environments. This approach is relied on location information. One of the motivations of this work is that user activity is not well defined in the Ubiquitous Computing discipline. This may occur because the transition between activities is sometimes not very clear. An activity can be seen as a part of other activity, it can be in sequence mode or in parallel mode or both together, and different views can be deduced from different activities.

User activity in the Intelligent Environment can be defined as any association between a user and smart sensors in the environment, or any sensors being in active use to access the resources. It is divided into 4 categories, i.e., 1. as association between a user and smart sensors in the environment, 2. as a node in a work flow or job breakdown, 3. as a physical movement mode or state, or 4. as a mode of state of human intent.

This paper also presented a system monitoring user activity, based on the user activity processing model. The user activity processing is based on DiCPA architecture which is implemented in a smart office (Active Office). In an Active Office, a Mobile Access Point is developed and analyses the gathering of the guest user location which leads to guest activity.

For office environment, our user activity approach can be used to measure a user productivity based on time and location, depending on the variable that is measured, for example by measuring the use of time of the user. For home environment, this approach can measure the enjoyment and relaxing activities of the occupants.

However, as the computing environment changes over time, monitoring user activity becomes progressively more difficult.

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