Yang, S. J. H. (2006). Context Aware Ubiquitous Learning Environments for Peer-to-Peer Collaborative Learning. *Educational Technology & Society*, 9 (1), 188-201.

Context Aware Ubiquitous Learning Environments for Peer-to-Peer Collaborative Learning

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ABSTRACT

A ubiquitous learning environment provides an interoperable, pervasive, and seamless learning architecture to connect, integrate, and share three major dimensions of learning resources: learning collaborators, learning contents, and learning services. Ubiquitous learning is characterized by providing intuitive ways for identifying right learning collaborators, right learning contents and right learning services in the right place at the right time. Our context aware ubiquitous learning environment consists of three systems, namely peer-to-peer content access and adaptation system, personalized annotation management system, and multimedia real-time group discussion system. Since the effectiveness and efficiency of ubiquitous learning heavily relies on learners' surrounding context, in this paper, we will address a context model and context acquisition mechanism for collecting contextual information at run time. We have built a context aware ubiquitous learning environment and in this paper we will address how this newly designed environment can fully support the needs of peer-to-peer collaborative learning.

Keywords

Ubiquitous learning, Context aware, Peer-to-peer, Collaborative learning

Introduction

Various learning systems have been developed in the past decade; the majority of these systems are implemented either with client-server architecture or are centralized server based. The client-server and centralized server approaches are metaphors of student-teacher and repository centric which reflect real world learning scenarios in which teachers act as the content producers while students act as the content consumers.

The ubiquitous learning environment provides an interoperable, pervasive, and seamless learning architecture to connect, integrate, and share three major dimensions of learning resources: learning collaborators, learning contents, and learning services (Chang, & Sheu, 2002; Cheng, et. al., 2005; Haruo, et. al., 2003). Ubiquitous learning is characterized by providing intuitive ways for identifying right collaborators, right contents and right services in the right place at the right time based on learners surrounding context such as where and when the learners are (time and space), what the learning resources and services available for the learners, and who are the learning collaborators that match the learners' needs (Ogata, & Yano, 2004; Zhang, Jin, & Lin, 2005; Takahata, et. al., 2004). As a result, the effectiveness and efficiency of ubiquitous learning heavily relies on the surrounding context of learners. We define the term "context" from two perspectives, one is from the learners, and the other is from the learning services. From the learners' perspective, context is defined as the surrounding environment affecting learners' Web services discovery and access, such as learners' profiles and preferences, the network channels and devices learners are using to connect to the Web, etc. From the services perspective, context is defined as the surrounding environment affecting learning services delivery and execution, such as service profiles, networks and protocols for service binding, devices and platforms for the service execution, etc. Typical learning services for ubiquitous learning are device and network detection services; location tracking services; calendar and social activities services; and content access services.

Virtual learning communities are information technology based cyberspaces in which individual and collaborative learning is implemented by groups of geographically dispersed learners and providers of knowledge to accomplish their goals of learning. There are no agreements on what constitutes a virtual learning community. However, it has gained widespread acceptance that virtual learning communities are knowledge based social entities where knowledge is the key to their success (Bhatt, 2001; Malhotra, 2000). An important activity in a virtual learning community is the collaboration. Many virtual learning communities strive to attract new members or encourage members to learn and to contribute knowledge. However, the knowledge per se does not assure the success of virtual learning communities. It is the collaborative efforts made by the learners and collaborators to manage the knowledge, to enrich the knowledge reservoir, and to help each other accumulate their knowledge in their domain that is central to the continuous growth of the virtual learning communities.

Collaboration in virtual learning communities characterizes itself by heavily relying on interaction among the collaborators (Edwards, 2002; Biström, 2005). The collaborators can be instructors and learners, the interaction can be resources discovery, access, and sharing, as well as group communication and discussion, or simply any collaboration which has occurred among the instructors and learners. In addition, the collaboration should be enacted inside and outside of classrooms without limitation of space and time; it can be over the Internet and beyond the geographical boundary. Nevertheless, such collaboration environment is generally not supported by conventional learning environments. Typical learning services for collaboration in virtual learning communities are content, access of certain learning subjects; making studying notes and annotation on learning subjects; group discussion, brainstorming for knowledge creation and sharing.

Compared with the client-server and centralized approaches, peer-to-peer network makes each peer play as both client and server (Aberer, 2002; Li, Lee, & Sivasubramaniam, 2003; Gnutella, http://www.gnutella.com/), so each peer can access and be accessed of material maintained on the peer If a peer cannot find the material it required from its neighbors, the neighbors will query their neighbors for more resources, in such a way, the peer-to-peer network can find resources in a layered multicast to increase the hit rate of finding materials that peers want. In addition, due to progress of device and communication technology, we can now implement peer-to-peer network under any network channel., This make peer-to-peer network particularly suitable for implementing ubiquitous learning environments for collaborative learning (Brase, & Painter, 2004; Nejdl, et. al., 2002; Biström, 2005; Edutella, http://edutella.jxta.org/).

Context Model and Context Acquisition for Ubiquitous Learning Environments

Context is referred to as any information that can be used to characterize the situation of an entity where an entity can be a person, place and a physical or computational object (Schilit 1994). There are many research efforts for the development of context aware toolkits including; Cooltown (*http://www.cooltown.com/cooltown/index.asp*), Context Toolkit (*http://www.cs.berkeley.edu/~dey/context.html*) and CB-SeC framework (Mostefaoui, Bouzid, & Hirsbrunner, 2003). These toolkits either provide functionalities to help service requesters obtain services based on their contexts or enable content adaptations with user's contextual information. Several OWL-based context models are presented (Khedr, & Karmouch, 2004; Khedr, 2005) to provide high-quality results of service discoveries beyond the expressive limitations of CC/PP. They utilize ontology to describe contextual information including location, time, device, preference and network etc. By combining semantic contextual information with inductive or deductive techniques, they can perform matches against both user and service's context semantically. In contrast, our approach not only provides an ontology based context model but also utilizes three context acquisition methods namely; form filled, context detection and context extraction, for obtaining various contextual information. Besides, we also employ a rule-based matching algorithm with truth maintenance to enhance the recall and precision of context aware service discovery (Yang, Tsai, & Chen, 2003).

Context Description

We conceive context aware is an interactive model between learners and services, thus, we need to address the context description of learners and services. We have developed two types of context ontology for describing learners and services, they are learner ontology and service ontology (Yang, et. al. 2005).The interactive model is enacted by a semantic matchmaker that can perform semantic reasoning for context oriented service discovery and access based on the two context ontology.

We have utilized Protégé (http://protege.stanford.edu/) to build the learner ontology and service ontology as shown in Figure 1.

The major difference between the learner ontology and service ontology are their profiles. The learner ontology contains learner profiles such as personnel profile, accessibility and preferences, calendar profile, social profile, and location profile; The service ontology contains service profile such as input, output, pre-condition, and effect of service execution.

In addition to profiles, both learner ontology and service ontology contains surrounding context such as quality of learning service, environment profile, and device capability profile. Quality of learning services profiles (QoLS) contain functionally and non-functional QoLS constraints; Functional QoLS constraints can be described by network bandwidth and response time; non-functional QoLS constraints can be described by reliability, availability, and cost. Environment profile contains network channel constraints and situated location constraints; Network channel constraints can be used to describe types of channels such as wired or wireless; situation constraints can be used to describe requester situated environments such as in a meeting, reading, walking, or driving. Device profile contains the device's hardware and software constraints. Various devices such as PDA and mobile phones are equipped with different hardware and software constraints. Hardware constraints can be used to describe device hardware capabilities such as platform, CPU speed, memory size, screen size and resolution. Software constraints can be used to describe device software capabilities such as operating system, browser, playable media type and resolution.

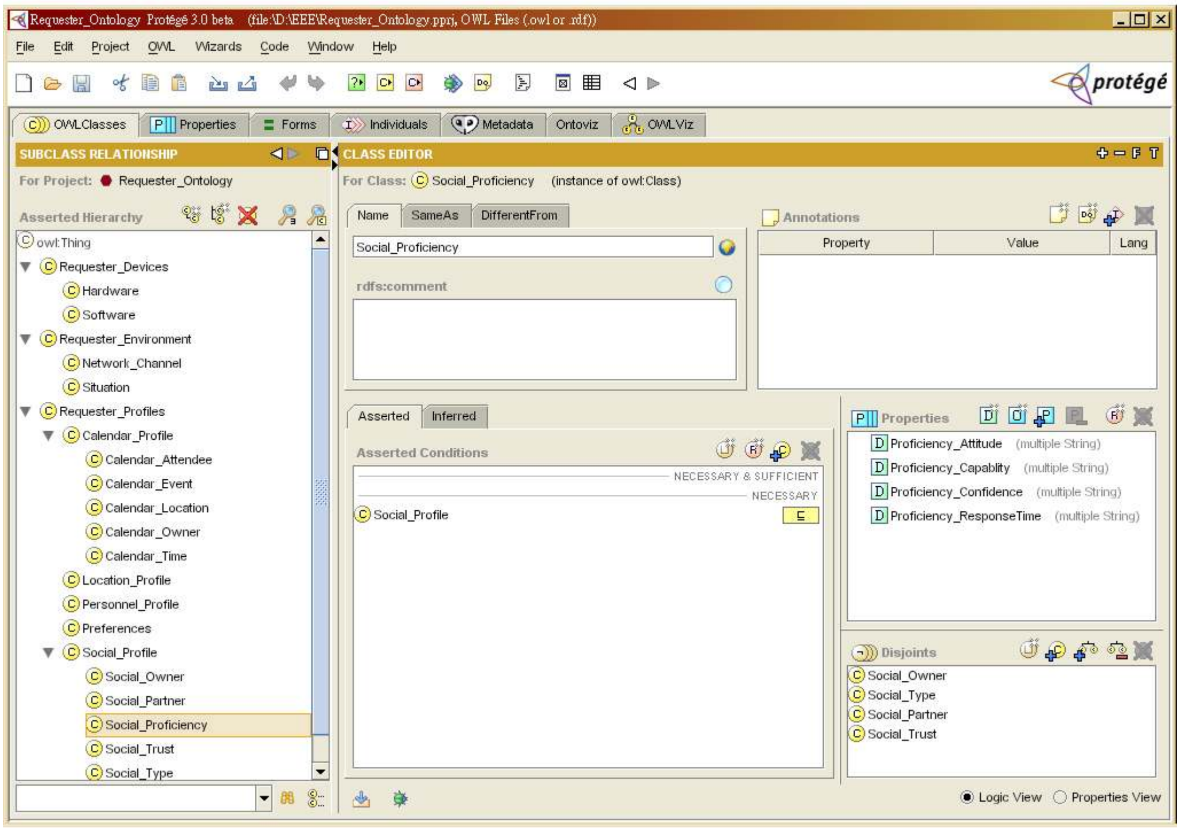

Figure 1: Learner ontology editing with Protégé

The formal definition of learner ontology is defined as follows:

Learner ontology = {Profiles, Preferences, QoLS, Environment, Devices}
Profiles = {Personnel, Calendar, Social, Location}
Personnel_profile = {name, role, ID, phone, address, email, accessibility}
Location_profile = {office, building, home, out of office}
Calendar_profile = {owner, event , time, attendee, location}*
owner = {name, ID, privacy}
event = {title, description}
time = {begin(yyyy:mm:dd;hh:mm), end(yyyy:mm:dd;hh:mm)}
attendee = {name, contact_info}
location = {place, contact_info}
Social_profile = {owner, collaborator+}
owner = {name, ID, privacy}
collaborator = {profile(type, name, context_info), proficiency, trust},
type = {individual | working_team | community}
proficiency = {capability, confidence, attitude, response time}
trust = {reliability, experience, referral network}
Preference = {default device, default environment, default QoLS}
QoLS = {Functional requirement, non-functional requirement}
Functional requirement = {bandwidth, response time}
Non-functional requirement = {reliability, availability, cost}
Environment = {Network channel, Situation}

Network channel = {wired, wireless}
Situation = {normal, meeting, walking, talking, driving
Devices = {Hardware, Software}
Hardware = {platform, CPU, memory size, screen resolution}
Software = {OS, browsers, playable media types}

The formal definition of service ontology is as follows:

Service ontology = {Profiles, QoWS, Environment, Devices}
Profile = {name, ID, description, input, output, pre-condition, effect}
QoWS = {Functional requirement, non-functional requirement}
Functional requirement = {bandwidth, response time}
Non-functional requirement ={reliability, availability, cost}
Environment = {Network channel, Situation}
Network channel = {wired, wireless}
Situation = {normal, meeting, walking, talking, driving}
Devices = {Hardware, Software}
Hardware = {platform, CPU, memory size, screen resolution}
Software = {OS, browsers, playable media types}

Context Acquisition

Knowing learners' surrounding context in a ubiquitous learning environment is referred to as context acquisition. Context acquisition can be realized by a process of getting values of the properties defined in the learner ontology and service ontology. We classify context into current context and past context; the current context reflects the run time environment while the past context reflects a historical execution path. Context acquisition is mainly for detecting current context. When new context has been detected, the current context will become past context and storage as learner ontology. As a result, we can treat learner ontology as a set of past context which can be used for deriving preferences, portfolio, and behavioral patterns.

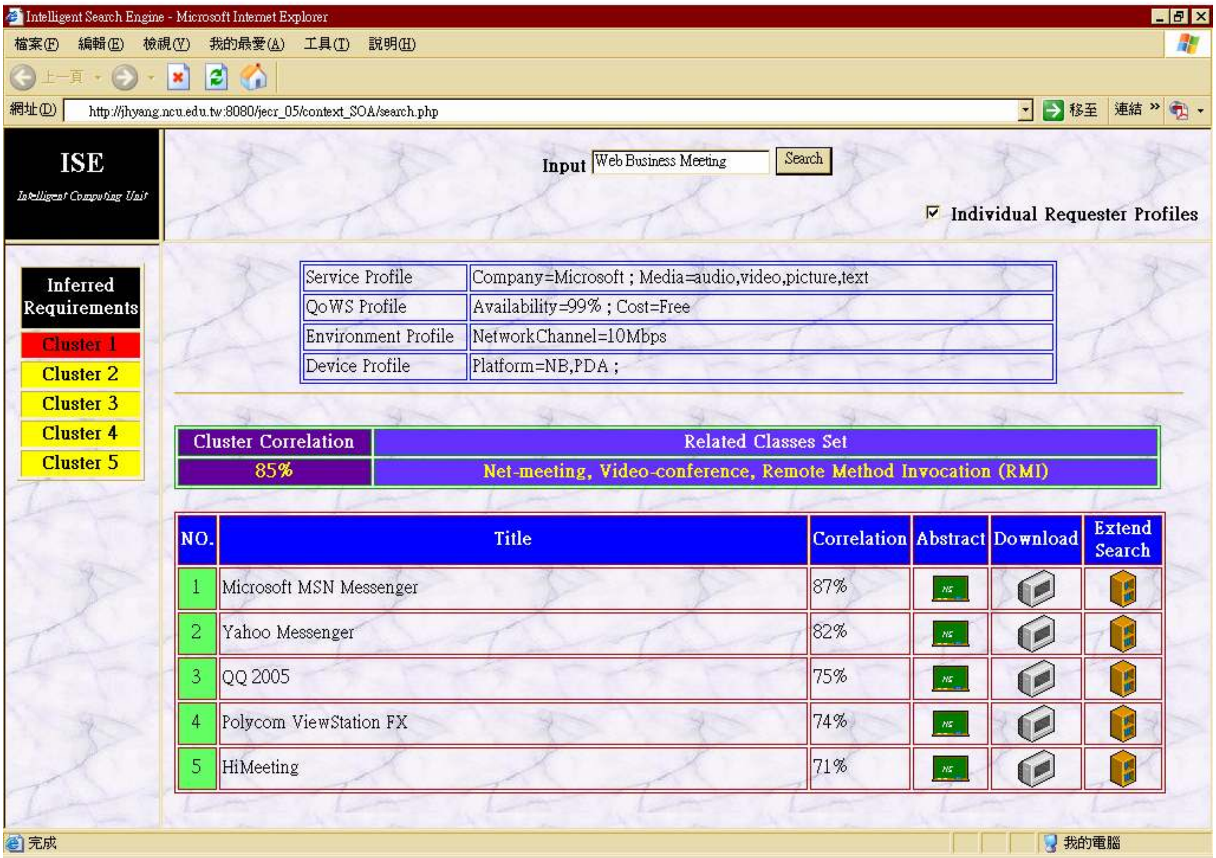

Figure 2: A query user interface for requesters to input their query in terms of keywords

We then separate the context acquisition function from context aware services. This strategy leverages our load by reusing existing context acquisition functions. Context acquisition can be done by three approaches. The first approach is through filling in a form in which context is acquired directly from learners' inputs. The second approach is context detection in which we utilize various sensing, recording, and positioning systems such as GPS, RFID, and sensor networks for location detection. The third approach is context extraction which is to derive contextual information from learner personal ontology and service ontology. The first approach in filling in a form is mainly used to construct personnel profile, preferences, calendar profile, and social profile. Since this approach is self explanatory we will concentrate on the other two approaches, context detection and context extraction.

Context Detection

Context detection is a two-fold mechanism, we need to tackle this from two sides, one is from the server side, and the other is from the client side. From the server side, we have implemented a Web service portal featuring a recording capability as shown in Figure 2. Whenever learners log in to the portal, our portal will take the request and analyze what kind of device the learner is using to build the device profile, as well as detect what kind of network channel the learner is connecting to the Web to build the environment profile. Whether the learner is in a meeting, driving or a normal situation remains unknown at this stage; we need to defer this to context extraction by analyzing the learners' calendar, social and location profiles. Besides detecting the request, our portal also records and keeps a service request history associated with every learner who registers in this portal. Based on the history, we can conduct analysis about the requesting behaviour and requesting pattern which are important references for building learners' preferences.

Figure 3: Smart device with content adaptation capability

From the client side, we have utilized smart devices with content adaptation as shown in Figure 3 and sensor networks to sense and react to the learners' surrounding environment. Almost any information available at the time of an interaction between learners and Web systems can be seen as contextual information such as location and temporal information, knowing where is the learner and what he/she is doing during a certain period of time, whom you are working with, and people that are nearby, resources that are nearby (e.g. accessible devices, and hosts), etc. We are interested in capturing and modeling the contextual information, and how a part of this contextual information is assembled, organized, and structured into learner ontology. Such contextual information is used to design adaptive systems and to provide customized services to learners based on their profile and preferences.

In location tracking services, we will match all possible location tracking functionalities currently available for learners' devices, then filter them based on learner's context. For example, if the learner is outside of a building, then a GPS location tracking function will be invoked to return his/her location in terms of building name/number; while the learner is inside a building, then indoor tracking system (RFID or sensor network) will be invoked to return the location in terms of room number. Once the location is positioned, we will decide whether to disclose the location based on the learner's privacy preference. Please note, the privacy preference is dynamic and can be adjusted based on location and temporal constraints. For example, if the learner is inside an office building, then he/she is willing to disclose the room number where he/she is currently is to the public, while if the learner is out of office, then the position is only disclosed to his colleagues and family members.

Context Extraction

If we can not detect current context explicitly, then we will need to extract from the learner's profiles to derive contextual information associated with the request. Context extraction is used to derive contextual information from learners' preferences and profiles during the run time. There are two approaches to context extraction. One is to extract learner's default context from the preferences and personnel profile. The other is to extract derived contextual information from the calendar profile, social profile, and location profile.

In the first approach, the learner must specify their values such as name, ID, role, email, etc in the required properties because many properties defined in personnel profile and preference have default values and as a result, our system will fill in the default value for the learners if they do not explicitly specify the property values. We refer this kind of process as context wrapping.

In the second approach, we derive contextual information from calendar and social profiles. Social profile is used to find the most related business partners when the learners have not explicitly specified whom he/she is working with. Social profile is also useful when the learner can turn his/her calendar profile to private and you just need to find him/her no matter how. This can be done by querying every partner's calendar profile to find if there is any event involving the target person.

With our calendar extraction, we can locate a learner's position and read his calendar and his social profiles knowing where he is now and doing what, as well as knowing whom the learner is currently working with. Therefore, we can provide a context oriented service to better fit the learner's needs.

If we cannot derive proper learning collaborators from learners' social profiles, the alternative way is to locate collaborators from outside. This can be done by querying collaborators from a virtual community for knowledge sharing with certain specific expertise (Yang, Chen, & Shao, 2004). As a result, we need to maintain an expertise profile for this. Compared with the social profile which is mainly kept in the client side, the expertise profile is kept in the mediator side which can be used for locating suitable collaborators based on the learners' social profile. Contextual information derived from the expertise profile is useful when a learner needs to find matching learning collaborators with specific expertise. The collaborators can be an individual, a working group, or simply a community. We have defined properties as matching indicators which will be used to calculate the degree of matching of fit to the learner's need. The property of expertise indicates what the matching expertise is; the property of proficiency indicates the capability, confidence and response time of the business partners based on previous experience and the property of trust indicates the degree of confidence regarding a particular partner.

The formal definition of expertise profile is as follows:

expertise_profile = {expertise, profile, proficiency, trust}
expertise = {title, description}
profile = {name, ID, privacy}
proficiency = {capability, confidence, attitude, response time}
trust = {reliability, experience, referral network}

The degree of proficiency and the degree of trust of partners with a specific expertise can be calculated with the following equations:

*proficiency = (capability * confidence * attitude) / response time* *trust = reliability * experience * referral network*

Peer-to-Peer Collaborative Learning

Based on a study we have conducted at the National Central University to survey the most anticipated services provided by a learning system (Yang, Lan, & Huang, 2005), as shown in Table 1, we found that learners are firstly interested in who is currently on line, secondly, how to get in touch with their classmates or other learning collaborators via instant message and thirdly, how to find the material that learners really need. The fourth is how can learners take class notes and record these notes and scratch as personal annotation for future references while the fifth is how learning portfolio can be recorded for better personalized service when next reconnected to the system.

Table 1: Students' most wanted learning services in National Central University

Most wanted learning services	percentage
who are currently on line	23%
instant message	23%
learning content search	21%
personal annotation	17%
recording of personal learning portfolio	16%

As a result, our ubiquitous learning environment is designed with the students' most wanted services in mind. This environment also consisted of three systems; they are peer-to-peer content access and adaptation, personalized annotation management, and multimedia real-time group discussion systems.

Peer-to-Peer Learning Content Access and Adaptation

The peer-to-peer network makes each peer act as both client and server, so each peer can access and be accessed of material maintained on the peer. If a peer cannot find the material it required from its neighbors, the neighbors will query their neighbors for more resources, in such a way, the peer-to-peer network can find resources in a layered multicast to increase the hit rate of finding the material that the peer wants. There are two types of common communication in peer-to-peer architecture; one is the message exchange, and the other is file transmission. The message exchange is used for finding which peers possess the material the other peer wants, that is, finding who owns the resources. The file transmission is used for downloading or uploading material between two peers. Peer is like a neuron, it will relay/pass message, discovery service advertisement, and each peer is not only a messenger but also a service registry.

In addition to being both client and server, a peer can also be a mediator to refer a query to a related peer node based on the advertisement in its referral bank. The referral can be further classified into mediator peer referral and provider peer referral. The mediator peer is designed based on the "knowing whom to find help for." Our current approach of peer clustering and categorization is to organize peers into a tree structure and cluster similar peers into domain based on property (content provider) and capability (service provider). For example, within a school our peer-to-peer network is organized with an hierarchy of university, college, department, grade, and student which can be modeled by a tree structure.

As shown in Figure 4, each peer in our peer-to-peer network can be a server or a client. It is a registry containing all the semantic and contextual information pertaining to the personal resources. The learning resources are described by contextual profiles including role profile, environment profile, device profile, QoS profile, calendar profile and social profile which are implemented by peer ontology. In addition to the personal profile, learners can also request for public resources provided by UDDI registry.

Free rider is a common symptom occurring in peer-to-peer network (Biström, 2005). The so-called free riders means peers who consume much more than they contribute, for example, removing shared resources; terminating connections while other peers are downloading. We have defined a credit policy to identify a list of free riders and limit their access to the entire peer-to-peer network until they are removed from the free riders list. The credit calculation in this credit policy is based on the ratio of upload over download in terms of connection time, transmission byte and varieties of files. The peer with a higher credit ratio will be granted higher priority for file downloading.

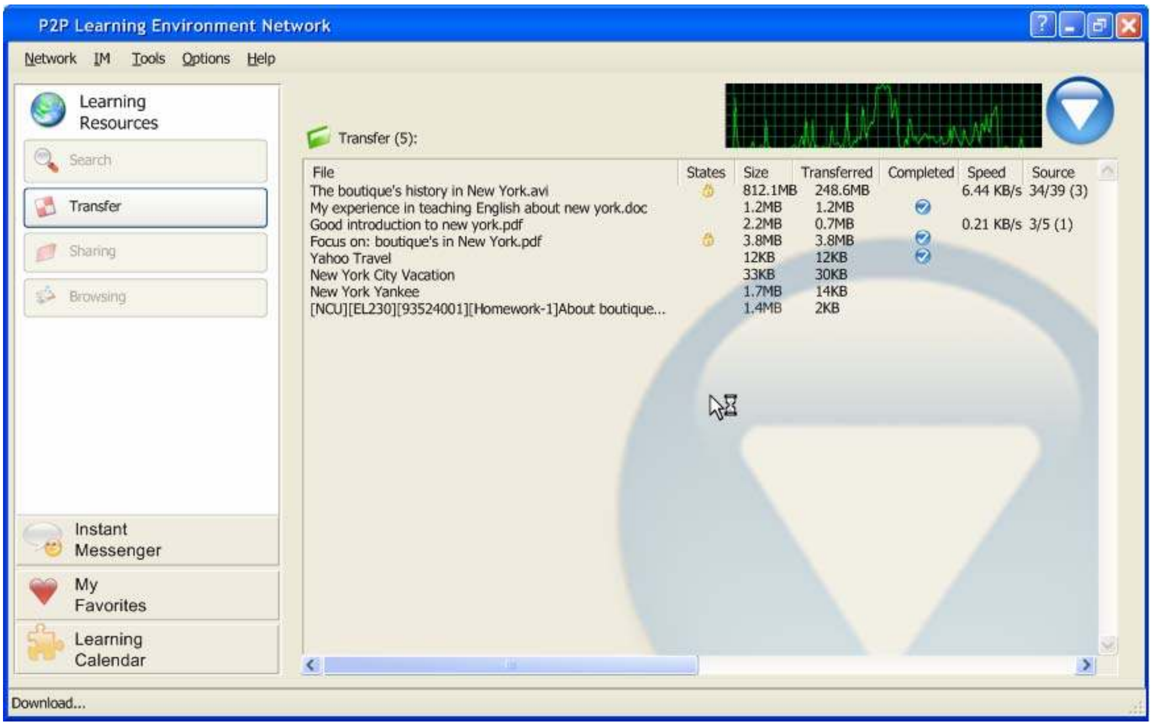

Figure 4: Peer-to-peer network

Figure 5: personalized annotation management system

Our peer-to-peer content access system provides typical services such as content discovery and access, content exchange, content replication, and content synchronization (persistence); services planned to provide a plan if the service request cannot be solved by a single service or by a single peer node: Ontology alignment to perform ontology mapping to reach an agreement of using a common ontology or metadata schema; Query referral to refer a query to other peers if the current peer cannot solve the query; Query transformation to rewrite a query if peers are using common metadata with extension or variation; Peer clustering to cluster peer nodes into a referral network based on their registered capability; Service referral to recommend other peer nodes which are capable or more suitable to provide the requested services; and peer trust management to maintain a trustworthy social network in a peer-to-peer network.

Personalized Annotation Management

From a learners' viewpoint, annotations are not only reminders of things to do, but also concept and thought. The annotated document can be pdf, word, and any web pages in html. Annotators can create their annotations in forms of either text or voice. There are seven types of annotation in our system; they are question, explanation, commentary, bookmark, sketch, drawing, and link. Annotators can choose one of them to distinguish their annotation.

As shown in Figure 5, our personalized annotation management system provides typical services such as the creation and editing of annotation, the retrieval of annotation by query, and knowledge management with annotation.

Multimedia Real Time Group Discussion

Group discussion is another important learning issue in collaborative learning. Gall (1987) mentioned discussion is a process in which a small group assembles to communicate with each other using speaking, listening, and nonverbal processes in order to achieve instructional objectives. Gall also addressed the optimal group size for discussion to be between five and eight participants. Through the discussion, learners can review their ideas and get valuable opinion from another's aspect.

The purpose of group discussion is to form a learning group based on a specific topic for a learning objective. This involves group formation, the mechanism to form a group based on individual knowledge level and capability level as well as interest. There are two approaches of group formation; one is based on the learning objective, the other is learning on demand. For a specific learning objective, group members should have various knowledge and capability levels in order to compliment each other and form a team work. For learning on demand, the grouping is based on certain needs, for example, post a question and looking for help. In this case, the collaborators with certain interests and knowledge are the priority choice.

We are designing our message service from a group collaboration point of view (as shown in Figure 6), that is, to provide message services for group collaboration, such as discussion, instant messenger, message exchange, message filtering, push message, and message synchronization within a group. In our design of group collaboration, each peer is free to initiate a special interest group (SIG) and free to apply to join any SIG initiated by other peers in the peer-to-peer network. The peer who initiates a SIG is the default SIG manager who has the authority to grant a pass to other peers who are interested in joining the SIG.. Typical SIG management includes granting a pass, maintaining the discussion and file sharing which has occurred in the SIG etc.

Our multimedia real-time group discussion system provides typical services such as group formation, email and instant message services for the entire peer-to-peer network, special interest groups, audio and video conference, electronic whiteboard, personal or group calendar services, personal ontology, groups, ontology for ontology management, and session management and synchronization management when peers reconnect to the network.

Illustration and Discussion

In this section, we will illustrate our context aware ubiquitous learning environment with a scenario to demonstrate how the three systems, peer-to-peer content access and adaptation, personalized annotation management, and multimedia group discussion systems we have built in the past few years can help learners in collaborative learning.

A graduate student "Albert," was assigned a project entitled "One week vacation in New York City". He immediately remotely connected to his desktop PC located at his Lab and began to do a peer-to-peer (P2P) search for finding material regarding this project. Albert used a keyword search by typing "New York Vacation," into the P2P system as shown in Figure 7. In order to give Albert the "right content" to fit his needs, our P2P system automatically filtered unrelated material from the keyword search result and left material suitable to Albert. We do such filtering based on Albert's contextual information such as preferences and profiles as addressed in context model.

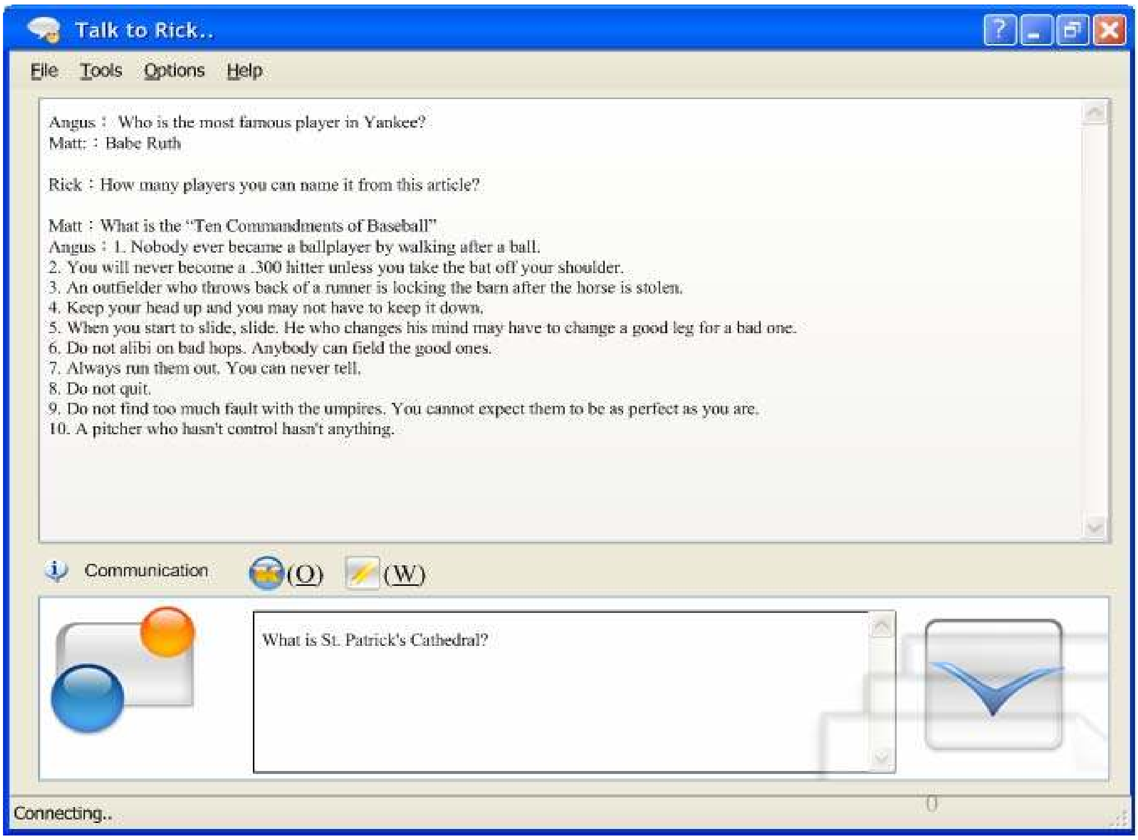

Figure 6: message communication during real-time discussion

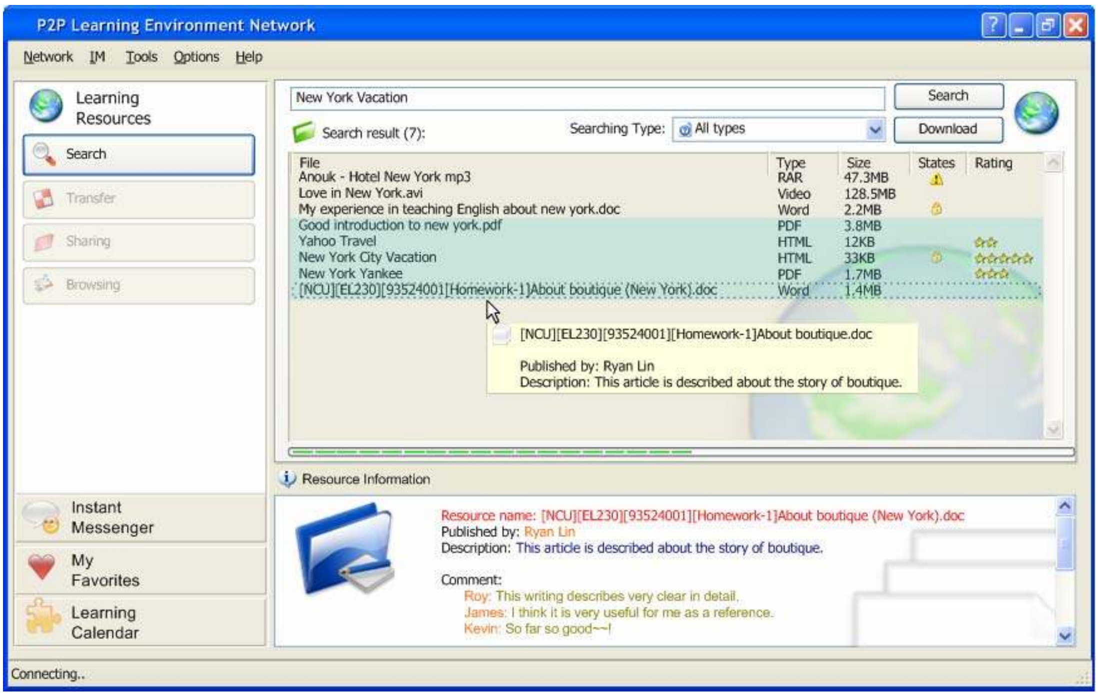

Figure 7: Peer-to-peer content search and its search results

Albert found quite a lot of related material after the P2P semantic search, so he decided to download some. Since downloading is very time consuming due to file size and network bandwidth, Albert decided to have lunch while the P2P network was downloading files. After his lunch, Albert stayed at the Café and talked to his friends. Then he thought it was about time to check the downloading status, so he pulled out his PDA, connected to the P2P network and began to browse some of the downloaded material. Since most of the material is designed for the presentation on PC or NB, our content adaptation system needed to adjust the downloaded material to fit the presentation on PDA. As shown in Figure 8, Albert surfed Yahoo travel pages and browsed the New York pictures with his PDA. This is one way to provide right content on the right device with right presentation. Albert found an article about New York Yankees which was quite interesting, so he decided to go through the details. So far, we have provided a seamless connection and network device detection for finding right content.

Figure 8: Adapted Web content shown on PDA; the screenshots from left to right are Yahoo travel, New York Pictures, and New York Yankees, respectively

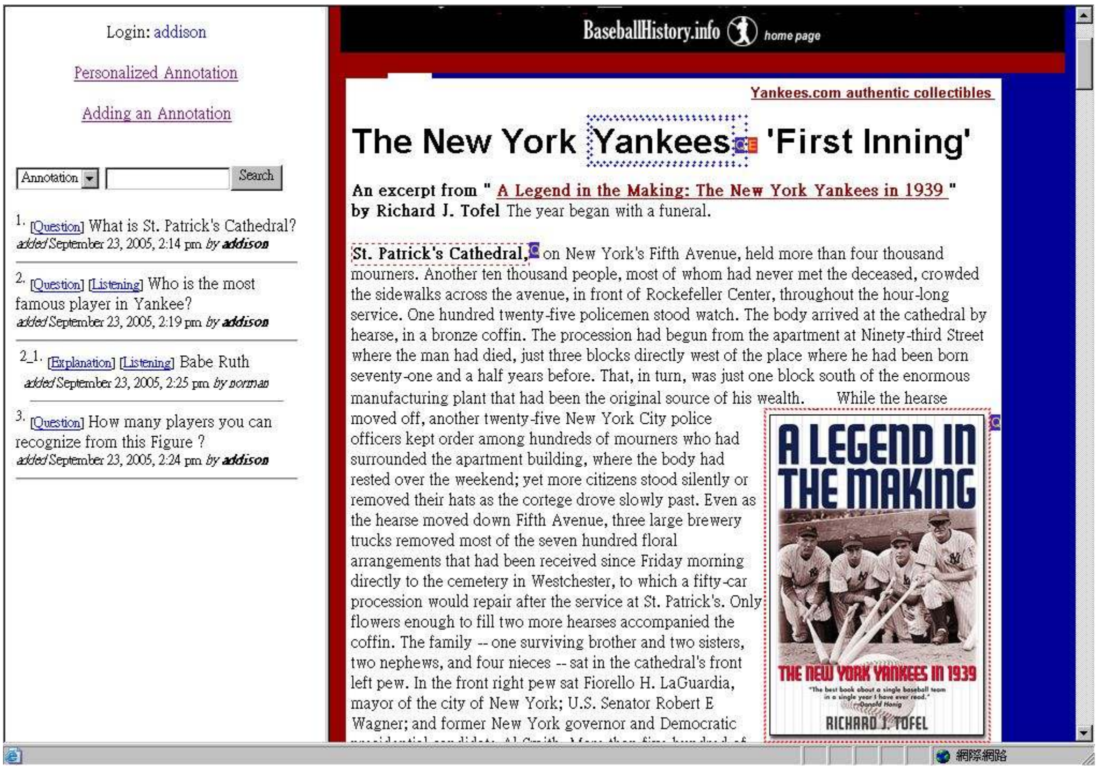

Figure 9: Three annotations of Yankees, St. Patrick's Cathedral, and a Picture

Albert then went to the Library for further studies of the article about New York Yankees. He began to read and make his own notes and annotations with text and voice on this article via our personalized annotation management system. Since Albert is not a native New Yorker, he had no idea of what is St. Patrick's Cathedral, so he annotated as a question, the term “St. Patrick's Cathedral”, which appeared in the article. He continued to make annotations regarding who is the most famous player in the Yankees, and who are those players shown in the pictures on this article as shown in Figure 9.

In addition to making personalized annotation, Albert could also retrieve information such as who else had read or was currently reading this article; find all the annotations made to this article; and find any annotations relating to “St. Patrick's Cathedral” and who made the annotations. So far, we have provided an annotation system to make and find annotations, annotators, and related articles. In addition, this annotation system can help Albert to find peers who share similar interests and knowledge to form virtual learning communities for further collaboration.

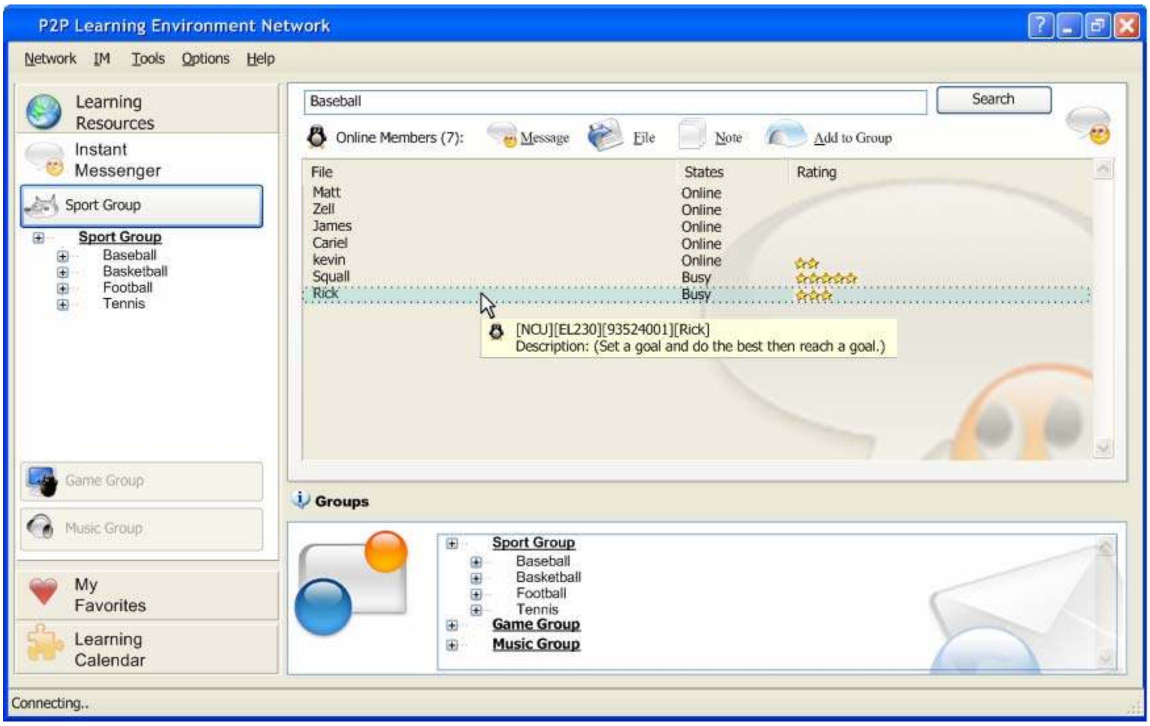

Figure 10: Searching for who is currently on line and available for real-time discussion

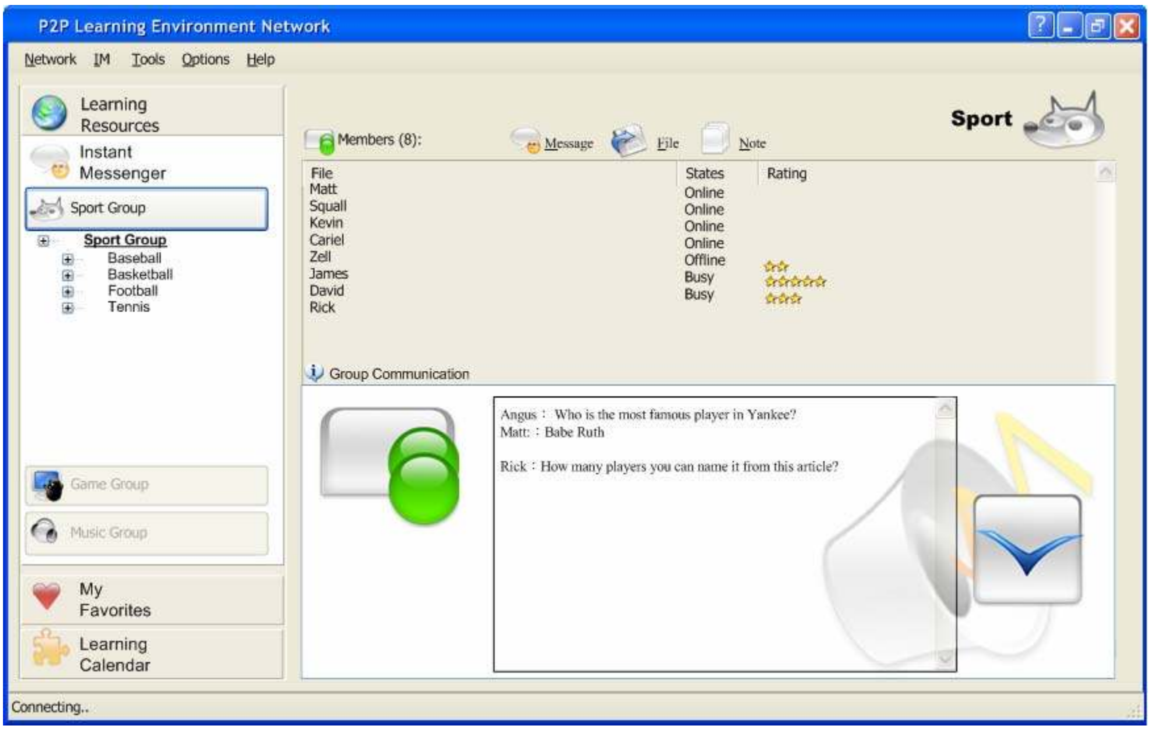

Figure 11: Real-time discussion board

To create more interaction with other peers, Albert wanted to raise a real-time discussion about the term "New York Yankees", and therefore needed to find out who was currently on line and available in his virtual learning community. Through our multimedia discussion system as shown in Figure 10, Albert could search to see if there were other annotators currently on line? Are the authors of this article currently on line? Are Albert's instructor and TA currently on line? Are Albert's Lab mates, class mates, or friends currently on line? Or simply are any peers currently on line. Now Albert could form a small discussion group in his virtual learning community quickly and proceed with a real-time discussion (Figure 11) by using services provided by our group discussion system. Albert could even leave a post-it note to one of his peers who participated in this discussion group as shown in Figure 12.

Figure 12: Leaving a post-it note to peers in the discussion group

Conclusion and future research

In this paper, we have shown a context aware ubiquitous learning environment which consists of three systems, namely peer-to-peer content access and adaptation system, personalized annotation management system, and multimedia real-time group discussion system. Since the effectiveness and efficiency of ubiquitous learning heavily relies on learners' surrounding context in this paper, we also have addressed our context model and context acquisition mechanism for collecting contextual information at run time. Finally, we illustrated a learning scenario and demonstrated how this newly designed context aware ubiquitous learning environment can fully support learners in collaborative learning.

References

Aberer, K., Punceva, M., Hauswirth, M., & Schmidt, R. (2002). Improving Data Access in P2P Systems. *IEEE Internet Computing, 6* (1), 58-67.

Bhatt, G. D. (2001). Knowledge Management in Organizations: Examining the Interaction between Technologies, Techniques, and People, *Journal of Knowledge Management, 5* (1), 68.

Biström, J. (2005). Peer-to-Peer Networks as Collaborative Learning Environments. *Paper presented at HUT T-110.551 Seminar on Internetworking*, retrieved October 25, 2005 from http://www.sit.fi/~johnny/collp2p.pdf.

Brase, J., & Painter, M. (2004). Inferring Metadata for a Semantic Web Peer-to-Peer Environment. *Educational Technology & Society, 7* (2), 61-67.

Chang, C. Y., & Sheu, J. P. (2002). Design and Implementation of Ad Hoc Classroom and e-Schoolbag Systems for Ubiquitous Learning. *Paper presented at the IEEE International Workshop on Wireless and Mobile Technologies in Education*, August. 29-30, 2002, Växjö, Sweden.

Cheng, Z., Shengguo, S., Kansen, M., Huang, T., & Aiguo, H. (2005). A Personalized Ubiquitous Education Support Environment by Comparing Learning Instructional. *Paper presented at the 19th International Conference on Advanced Information Networking and Applications*, March, 28-30, 2005, Tamkang University, Taiwan.

Edwards, K., Newman, M., Sedivy, J., Smith, T., Balfanz, D., Smetters, D. K., Wong, C., & Izadi, S. (2002). Using Speakeasy for Ad Hoc Peer-to-Peer Collaboration. *Paper presented at ACM 2002 Conference on Computer Supported Cooperative Work (CSCW 2002)*, November 16-20, 2002, New Orleans, LA, USA.

Gall, M. D. (1987) Discussion Method. In Dunkin, M. J. (Ed.), *The International Encyclopedia of Teaching and Teacher Education*, Oxford, England: Pergamon, 232-237.

Haruo, N., Kiyoharu, P. H., Yasufumi, K. & Shiho, M. (2003). Designing Ubiquitous and Universal Learning Situations: Integrating Textbooks and Mobile Devices. *Paper presented at the 19th Annual conference on Distance Teaching and Learning, 2003*, August 13-15, 2003, Madison Wisconsin, USA.

Khedr, M., & Karmouch, A. (2004). Negotiating Context Information in Context-Aware Systems. *IEEE Intelligent Systems, 19* (6), 21-29.

Khedr, M. (2005). A Semantic-Based, Context-Aware Approach for Service-Oriented Infrastructures. *Paper presented at the 2nd IFIP International Conference on Wireless and Optical Communications Networks (WOCN 2005)*, March 6-8, 2005, Dubai, United Arab Emirates.

Li, M., Lee, W. C., & Sivasubramaniam, A. (2003). Neighborhood Signatures for Searching P2P Networks, *Paper presented at 7th international Database Engineering and Applications Symposium*, July 16-18, 2003, Hong Kong.

Malhotra, Y. (2000). *Knowledge Management and Virtual Organizations*, Hershey, PA: Idea Group Publishing.

Mostefaoui, S. K., Bouzid, A. T., & Hirsbrunner, B. (2003). Using Context Information for Service Discovery and Composition. *Paper presented at Proceedings of 5th International Conference on Information Integration and Web-based Applications and Services (IIWAS 2003)*, 15-17 September 2003, Jakarta, Indonesia.

Nejdl, W., Wolf, B., Qu, C., Decker, S., & Sintek, M. (2002). Edutella: A P2P Networking Infrastructure Based on RDF. *Paper presented at the 11th International World Wide Web Conference*, May 7-11, 2002, Hawaii, USA.

Ogata, H., & Yano, Y. (2004). Context-Aware Support for Computer-Supported Ubiquitous Learning. *Paper presented at the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education*, March 23-25, 2004, JhongLi, Taiwan.

Schilit, B., Adams, N., & Want, R. (1994) Context-Aware Computing Applications. *Paper presented at the Workshop on Mobile Computing Systems and Applications*, December 8-9, 1994, Santa Cruz, California, USA.

Takahata, M., Shiraki, K., Sakane, Y., & Takebayashi, Y. (2004). Sound Feedback for Powerful Karate Training. *Paper presented at the International Conference on New Interfaces for Musical Expression*, June 3-5, 2004, Hamamatsu, Japan.

Yang, S. J. H., Tsai, J. J. P., & Chen, C. C. (2003). Fuzzy Rule Base Systems Verification Using High Level Petri Nets. *IEEE Transactions on Knowledge and Data Engineering, 15* (2), 457-473.

Yang, S. J. H., Chen, I., & Shao, N. (2004). Ontological Enabled Annotations and Knowledge Management for Collaborative Learning in Virtual Learning Community. *Educational Technology and Society, 7* (4), 70-81.

Yang, S. J. H., Lan, A. Y. Y., & Huang, J. J. S. (2005). Development and Deployment of a Campus wide e-learning Environment at National Central University. *Paper presented at the 6th Internet Application and Development Conference, 2005,* Taiwan.

Yang, S. J. H., Lan, B. C. W., Wu, B. J. D., & Chang, A. C. N. (2005). Context Aware Service Oriented Architecture for Web Based Learning. *International Journal of Advance learning Technology, 2* (4), retrieved October 25, 2005 from http://www.actapress.com/Content_Of_Journal.aspx?JournalID=63.

Zhang, G., Jin, Q., & Lin, M. (2005) A Framework of Social Interaction Support for Ubiquitous Learning. *Paper presented at the 19th International Conference of Advanced Information Networking and Applications*, March 28-30, 2005, Tamkang University, Taiwan.