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An Ontology-based Context Awareness Approach in Autonomous Mobile Learning

Jinhong Wu
College of Economic and Management,
Wuhan University of Science and Engineering
Wuhan, China
Wjh707@163.com

***Abstract*—Context is important in personal knowledge and social knowledge construction process. Context awareness means being able to collect environment and learning resource information from the learner and surrounding equipment to provide learners with the context-related learning activities and content. The context elements, including intra object, inter-object, session, social systemic, economic techno-physical and history contexts, in mobile learning (M-learning) are discussed in detailed. And then context ontology is constructed according to these context elements based on ontology technology. Context reasoning is the key of context awareness. An ontology-based context reasoning approach which combined Case-based reasoning method with semantic knowledge organization approach is presented in the paper.**

Keywords- Mobile learning; Context Awareness; Context Reasoning; Ontology; Knowledge retrieval

I. INTRODUCTION

With the development of mobile communication technology and the popularization of mobile equipments, a new learning model of digital-learning is coming. It is Mobile Learning (M-learning), which is a process to construct personal and social knowledge by using mobile devices (such as mobile phones, PDA with wireless communication module, etc.) to get any learning resources and communicate and collaborate with anybody at any time and any place when he want. M-learning is an organic integration of education technology, mobile communication and network technologies. Its advanced learning features of wireless mobility, high portability, extensive, interactive, sharing and personalization in [1] are convenient for learners to study ubiquitously at anytime and anywhere.

But learning is a process of knowledge construction closely related to learning environment. As Brown described in [2], only when learning is embedded in knowledge usage context, the meaningful learning can be achieved. Therefore, mobile devices must be able to access appropriate learning resources and services suitable of learners according to their individual and special learning context varied at different place and time. A context-aware mobile-based learning model is constructed based on Ontology and Case-based reasoning approach in the following. The use of ontology to build context ontology is take advantage of its ability in knowledge sharing and knowledge representation, and to promote the reuse and sharing of context ontology. The CBR approach is close to human's reasoning patterns which can help us to get the true learning contexts. This intelligent context-aware model can perceive real-time context changes around learners dynamically and look for more suitable learning resources and services for learners in their learning contexts. Furthermore, it also can help us to interact with right ones to construct personal and social knowledge. The following section the concept of context and its classification will be described in detailed. And then the process of context awareness in M-learning will be discussed in section 2. In section 3, an M-learning model based on context awareness is presented and its modules and reasoning method and context ontology are discussed in detailed.

II. CONTEXT AWARENESS

Context-awareness is particularly important in m-learning because the application of mobile learning context is highly dynamic. It requires mobile devices can handle restrictions in learning process, such as expressions, interactive methods and communication, etc.

Context-awareness was a new concept created by Schilit et al . (1994) proposed for distributed mobile computing [3]. It means detecting information surrounding learner through smart mobile devices, and then push the required resources or appropriate services to the particular learner according to different situations. In other words, it is to provide learners the related resources and service to learners to satisfy their requirement seamlessly. Furthermore this process is automatic and transparent to users. In traditional education, the process of context awareness is accomplished by learner themselves or teachers. But in the digital age, context awareness is a web-based and virtual feeling way, interactive form and organizational activity, which helps to capture environment information that can not be aware directly in the traditional learning environment. They are transformed into one's cognitive and learning ability through transmission, handling, processing and other sectors in virtual environment using digital technologies and mobile devices.

In an ideal mobile learning, learning resource network is deeply integrated into people's daily life and work just as air and water. Through context-aware mobile devices, learners can easily perceive and obtain more information on learning objects and learning content. The basic learning network is shown in figure 2.

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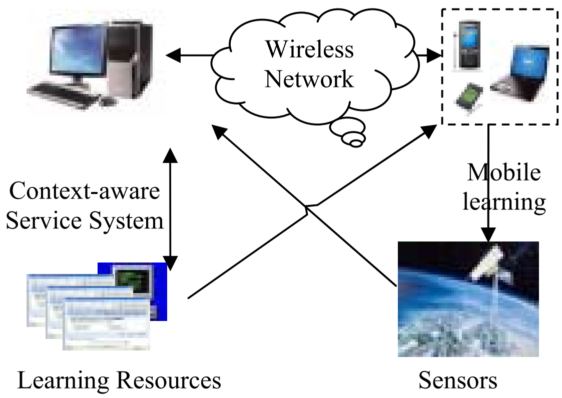

Figure1. Context-Aware Mobile Learning Framework

In which the sensor was referring to a context-aware mobile devices, such as GPS sensors, detectors, collector to capture real-world information of users or equipments, such as the learner 's location, climate, or even information about user's mood. Learning resource network provides a variety of access methods, multi-bearer together to achieve seamless access and perceive changes in user's learning context in order to provide appreciate individual services. Context-aware services system is composed by context-aware devices to detect learner's context information, and automatically trigger situational reasoning mechanism to calculate services for users proactively. It can also accept user's instructions as feedbacks in order to adjust the reasoning process. Wireless network is the infrastructure platform through which seamless communication services are provided to learner and intelligent learning agents.

Here, in general, context is specific environment in which knowledge are created or applied. Weihong Huang and David Webster in his article [4] give a definition: context of an entity (such as an object, a thing or a process) is a collection of semantic environmental information, which can help to make the internal characteristics or operations and external relationship of an entity be a characterization. Context is generally special information difficult to obtain and use, especially in knowledge construction process. In mobile learning, it belongs to a limiting factor to interpret cases in some particular situation.

Context awareness in M-learning plays an important role. In a learning process, one will inevitably be affected by the outside world or his own feeling. As a result, the learning process will always be interrupted and the result of learning will also be deviated from the initial target. Thus it is bound to affect the learner's normal learning activities. But in context-aware learning, it can prevent deviation from the learner's goals by its strong knowledge navigation capacity. Furthermore, it can be able to record the cognitive trajectory in learning as a unique, targeted cognitive map. When the process is interrupted, context awareness will fill the gaps or associated with the role of thinking. Thus intellectual resources and system resources waste caused by cognitive interruption will be avoided.

III. ONTOLOGY-BASED CONTEXT AWARENESS APPROACH

A. *Context ontology*

As described in [5], an ontology is a specification of a conceptualization. It is suitable to describe context elements clearly and explicitly. So we will use ontology to modeling context. The definition of concepts and relationships in context ontology can help learning system to analyze and describe environmental information and user information. Concepts and their related weights are defined and adjusted according to the needs of mobile learning for searching and ranking context from case knowledge base.

There are two principles in context ontology construction process. The first is that ontology can describe information of users and resources comprehensively and accurately. And the other is that description elements in ontology can support

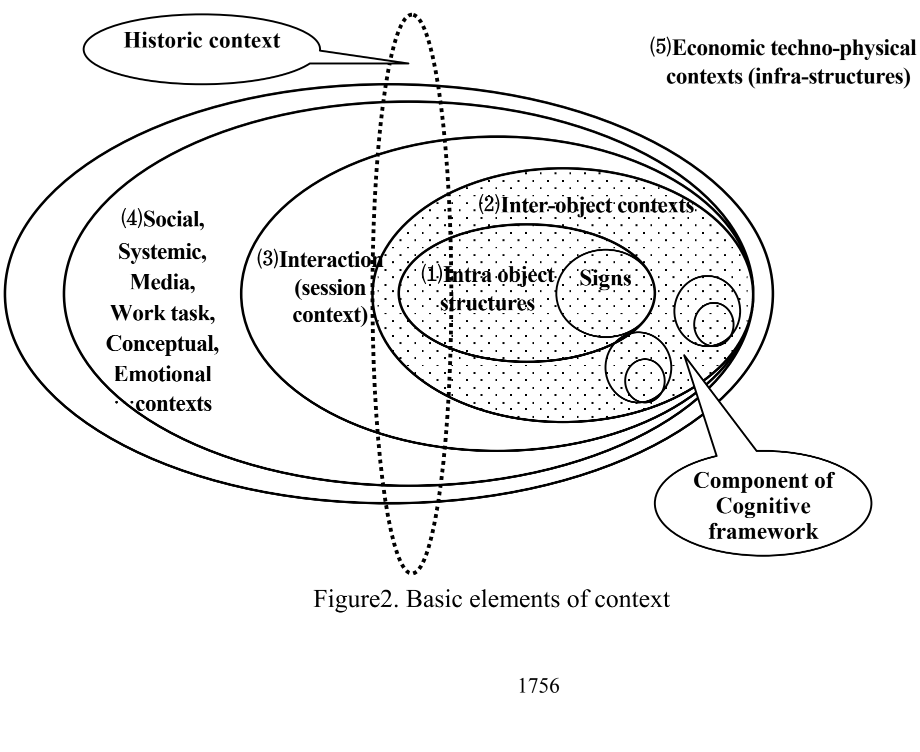

Figure2. Basic elements of context

context reasoning.

Context ontology contains six kinds of information including intra object context, inter-object context, session context, social systemic context, economic techno-physical context and history context.[6-8] Context ontologies, expect the history context, are presented in a nested structure and associated with each central elements or users, as in figure 2.

The intra-object context is innermost in the nested structure including information about objects themselves, such as word, sentence, paragraph and so on. The inter-object context describes relationships among objects. In this layer, each object's was seen as other objects' context. For example, charts can be seen as the context of text and paragraph as the context of single sentence. The session context contains particular and personal information about the learner including preferences, style, experience, knowledge, interest and so on and exists during interaction between learner and system. It can be used by learning system to interpret the learner's cognitive behaviors. The forth and fifth contexts are the external context in the nested structure, including social systemic context, economic techno-physical context. They describe influence in all users, units and interactions impacted by external environment. The history context is an additional and time dimension and across all levels and can be formed by the user expectations of past experience. It has relationships with contexts all above.

The concepts and their weights in context ontology constitute a group of feature vectors: $O=\{(o_1, w_1), (o_2, w_2), \ldots, (o_m, w_m)\}$. Note that the data in the context ontology is not static, they will be adjusted and optimized dynamically according to different needs and applications.

B. Ontology-based Mobile Learning

A context-aware mobile learning model is constructed based on ontology and case-based reasoning approach according to discussions above. The important role of context in m-learning is emphasized in this model. Cognitive contexts are collected as reasoning information to construct personal or social knowledge. In this process, ontology is used to present and organize learner's context in order to make full use of its abilities in knowledge presentation and organization. The basic framework is shown in figure 3.The main process as following:

- Context Input. It is situational information about the learners and the surrounding environment input by learner himself or sensor system and collected by CAA.
- Context Reasoning. Context is sent to Context Reasoning Engine (CRE). And CRE send requests to search the Case Knowledge Base and find cases that have most similar or even entirely anastomosis context. From these cases, the CRE reasoning what services and resources are really wanted by learners.
- Knowledge Service. The learning resource center pushes the related resources to User interface according to the reasoning results.
- Context Adjust. If there is no matching case in Case Knowledge Base, contexts should be adjust or more information should be added into contexts by interacting with the learner to obtain additional information. In some cases, the request context could be added into the case knowledge base as a new case.

The whole process is transparent and natural to the learner. Learners do not be aware of any prominent changes. In other words, learners do not realize that the existence of the learning environment.

The main system components of this model are Context Acquisition Agent (CAA), Context Reasoning Engine (CRE), Case Knowledge Management Agent (CKMA), Ontology Management Interface (OMI), User Interface (UI) and two

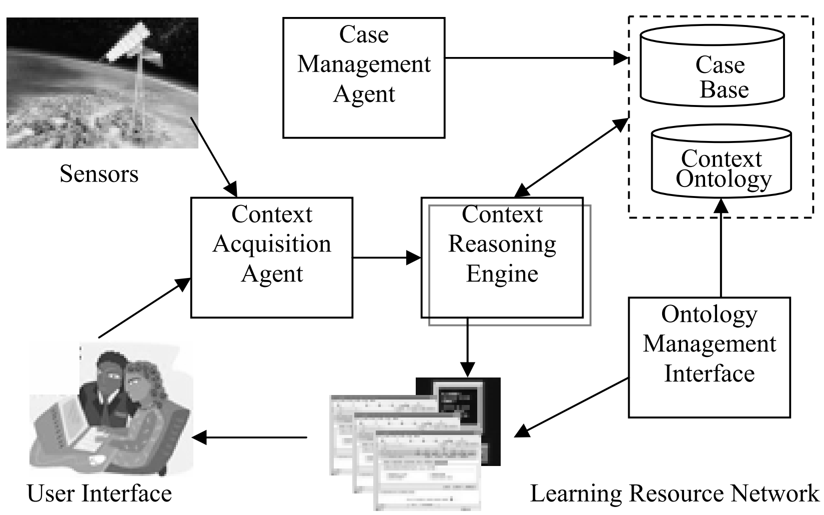

Figure2. Ontology-based Context-aware Mobile learning

bases of case knowledge base and context ontology.

- Context Acquisition Agent. The main function is to collect context information from the learner himself or sensors and to provide this information as context to the CRE.
- Context Reasoning Engine. It will complete 3 tasks. The first task is to implement semantic analysis of learner's context information and select formal concepts related from domain ontology. The second task is to match between user context and cases in Case Knowledge Base, and then chose the most relevant cases to users. The third task is to describe, evaluate and filter resources related to cases with most close context automatically.
- Case Knowledge Management Agent (CKMA). The main function is to adjust the weights and add new cases into case knowledge bases when needed.
- Ontology Management Interface (OMI). The main functions are ontology concept edition, modification, adding and knowledge base construction. It also provides integrated management of ontology, meta-data and context.
- User Interface (UI). This modal integrates all application functions of web using the form of knowledge portal. Visual context service is presented to users through web application servers. It is different from other web pages that there is an interactive tool in this page for user to refine context, such as to delete unrelated context terms.

C. Context Reasoning Approach

Context reasoning is a process that finds out the learner' s situation by surrounding information provided by learner or other sensors. Many reasoning methods are discussed and mainly are based on rules. In our study, a case-based reasoning approach combined with ontology is presented. Compared with rules-based methods, it has a constant ability to learn from a number of new cases and to expand the knowledge base in need.

The specific reasoning method is to collect cases (learning events) context information and then to calculate similarity between context and instances in knowledge base. Each instance in the Case Knowledge Base is a concepts sequence defined in domain ontology formed as (U_1, U_2, ..., U_n) and each U_i is assigned a weight w_i. Thus, each case constitutes a conceptual feature vector U={(u_1, w_1), (u_2, w_2), …, (u_n, w_n)}. Each context instance is defined using a set of concepts in domain ontology and is also defined as a feature vector O={(o_1, w_1), (o_2, w_2), …, (o_m, w_m)}. The matching is to calculate the angle between the two vectors to determine the similarity. The smaller the angle, the greater the similarity[9]. Similarity is calculated using the cosine function:

$$\mathrm{Sim}(O,U)=\frac{\sum_{k=1}^{n}\mathrm{Weight}(O_k)*\mathrm{Weight}(U_k)}{\sqrt{(\sum_{k=1}^{n}\mathrm{Weight}(O_k)^2)(\sum_{k=1}^{n}\mathrm{Weight}(U_k)^2)}} \quad (1)$$

Then Sim (O, U) value is compared with the preset threshold T. If Sim (O, U)>T, then the instance is similar to the case. Otherwise, it is not similar, and continues.

Algorithm 1: calculating similarity between case and instance
Input:
    U={(u_1, w_1), (u_2, w_2), …, (u_n, w_n)}
        // case feature vectors
    O={(o_1, w_1), (o_2, w_2), …, (o_m, w_m)}
    //ontology instance vectors
    T   // preset threshold
Output:
    S   // similar cases
Calculating Algorithm:
    Sim=Φ;
    for each u ∈ U and o ∈ O do
    // calculate similarity between vectors

$$\mathrm{Sim}(O,U)=\frac{\sum_{k=1}^{n}\mathrm{Weight}(O_k)*\mathrm{Weight}(U_k)}{\sqrt{(\sum_{k=1}^{n}\mathrm{Weight}(O_k)^2)(\sum_{k=1}^{n}\mathrm{Weight}(U_k)^2)}}$$

    If Sim(O,U)<T then
        Delete(U)   // not similar
    else
        Add U to S
    Endif
Endfor

The weights cab be preset by the system, but it is not flexible enough to reflect the learner's individual learning requirements. Therefore, it is need to adjust the weights dynamically. Here, we calculate the instance's weight value according to the number of being searched, assuming that the more being searched, the higher the weight. The calculation formula as following:

$$W_{default}^{t}=\frac{W_{default}\times t+W_{user}}{t+1} \quad (2)$$

Where, the $W_{default}$ is the default value given prior to this search, t is the number that the case is searched, W_{user} is the value input by user.

This has the advantage that the weights tend to reflect the real requirements of majority users as the case base being used for a long time.

IV. CONCLUSION AND FUTURE WORKS

Learning process is closely related to learning context. Making full use of context can broaden the communication channel between human and resources. Further more, they can discover implicit relationships by context reasoning automatically so as to forecasting the user's learning intentions. Therefore, involvement of context can bring a full interactive understanding between human and computers, which will help improving learning efficiency greatly.

In the above model, a unique resource context will be assigned to each learning resource, including samples in context and domain ontologies. This research focuses on the application of context in the mobile learning processes. Context navigation and matching methods are implemented throughout the whole mobile learning process. Users are involved in the m-learning system, which means that cognitive tracks of human behaviors saved in user context will influence learning strategy.

Further research includes the following:

- Research on automatic construction of context ontology. The amount of digital resources that support mobile learning is huge and still increasing. Thus, the context ontology construction process needs to be more automatic. Furthermore, learning resources' attributes will change greatly and the context ontology has to change consequently. How to capture these dynamic changes is a breakpoint of automatic construction method.
- Optimization of context matching algorithm. Context matching is happened between user context instance and cases. A suitable matching algorithm can improve the matching efficiency greatly. Semantic context matching that to calculate comparability between user and case base, taking full advantage of the semantic association in ontology, is an attractive research.

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