An Intelligent Context-Aware Learning System Based on Mobile Augmented Reality

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Abstract. Learning content using context-aware mobile technology, whether the content is manual or interactive, is hardly expected to arouse learners to interest or immersion because most of real-life environment is discrete from mobile content. For this reason, Augmented Reality is used to fix the drawback and to provide learners with an educational environment fit for desirable practice of the theory of situated learning. Increasing interest in Augmented Reality in recent years has led to multiple study efforts to build applications based on Augmented Reality, most of which require additional hardware or software, resulting in difficulties in establishing proper learning environment in the field of education. Therefore, in this paper we propose an intelligent context-aware learning system based on mobile Augmented Reality that provides a hassle-free desirable learning environment requiring nothing but a common mobile device.

Keywords: Mobile, Situated Learning, Context-Aware, Mobile Augmented Reality, Intelligent Agent.

1 Introduction

Rapid development in information and communication technology and mobile device infra has driven the ubiquitous computing concept, a user-oriented computing paradigm guaranteeing computing resources are accessible wherever and whenever. At the same time, efforts have been made actively to link the ubiquitous computing paradigm with education. As smaller but smarter and faster computers have arrived, mobile or wearable computing technology has come into the spotlight for its location and context awareness.

In light of learner-content interactions, Augmented Reality(AR) differs from Virtual Reality(VR), in that Augmented Reality enables a learner living in the real world to participate in direct and intuitive interactions with virtual content or service[1].

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Further, studies on mobile AR have been performed with a view to integrating the interactive aspects of AR with mobile computing so that learners can be represented regardless of time and place and provided with necessary information effectively[2].

However, to build a ubiquitous computing environment, relevant technology is required to encompass features to personalize learner-oriented service or content, to support content sharing and collaboration between learners through dynamic communities and to use diverse contexts. In short, context-awareness mobile AR need be studied to get over the existing technical limitations and to converge it to ubiquitous computing environment[3].

Context-aware mobile Augmented Reality is a new computing concept that in a ubiquitous smart space learners use portable personal mobile devices to collect, manage and apply information in line with their needs and contexts; to augment service or content in accordance with their contexts in real space; and to selectively share information for seamless interaction and collaboration[3].

Currently, in school education, context learning has been investigated actively as a means to provide learners with diverse and creative education. In compliance with demands for new types of effective services meeting the interest of learners rather than one-way uniform services, intelligent agents enabling situated learning as per each learner's situation and condition have been the subject of educational research.

However, most of study efforts associated with situated learning have focused on web-based virtual space so far. To go beyond the limitations found in web-based content learning, investigators have turned their attention to mobile environment, where learners can directly download content fit for contexts from web servers or search the content fit for their needs in the data stored in their mobile devices to practice contextual learning. Still, such approaches lack in inciting interest and immersion in learning due to the discreteness of learners' real life environment from the content they use on mobile devices, irrespective of the content being manual or contextual[4].

Although studies on Augmented Reality are far from being universal, there are a few cases of AR-based applications. Unfortunately, such applications require additional hardware or software, which makes it rather infeasible to establish desirable learning environment in the field of education.

Given the impracticable reality abovementioned, the present study attempts to solve the problem using a vision-based AR technology that allows provision of such learning environment requiring nothing but common mobile devices. Further, using the technology, this study proposes an intelligent context-aware learning system based on mobile AR that can automatically recommend learners appropriate learning content for their contexts. As an example of effective learning taking advantage of the proposed learning system, English conversation is selected here. As the proposed learning system provides learners with English sentences appropriate for the real situation the learner is in, it promotes connections between knowledge and real-life experiences in the context where the knowledge is practically used.

2 Related Study

2.1 Situated Learning

According to Situated Learning, knowledge acquired in the context of real life is more practically applicable to problem solving in reality, maximizing the effects than the one gained through direct teaching[5]. Therefore, learning in context is one of the new learning methods drawing most attention in the field of education in recent times.

So far, studies related to learning in context have mostly concerned learning in virtual space on the web. However, as the mobile technology has brought about innovative changes in each field of the society and culture and met with the limitations of the web-based contextual learning, study efforts have been furthered in respect of the learning in context.

Existing Situated Learning using mobile devices, however, relies on cell phones characterized by small screens, difficulties in using multimedia features and limitations in storing learning content. Also, even though knowledge can be delivered in real time through the wireless internet, learners themselves have to perform Situated Learning and get learning content necessary for current contexts by downloading it from the web server or by searching the content on their mobile devices. In view of the passivity of content including the time and procedure taken to download content from the web server, and to search information necessary on mobile devices and the lack of skills in handling mobile devices can hamper motivation for learning. Even interactive content is hardly expected to stimulate learners to become interested and immersed in learning because most of real-life environment and the content on the mobile devices are discrete. Thus, an educational environment that can translate Situated Learning into reasonable action needs implementing.

2.2 Intelligent Agent

An intelligent agent is a system attempting to achieve goals rather autonomously in a complex and changing environment and has been studied in the field of artificial intelligence. A manually designed intelligent agent requires sufficient knowledge on the application domain and has a disadvantage in that system performance is fixed at the very beginning. To cope with the disadvantage, machine learning that develops computer algorithm automatically through experience is used to design an intelligent agent[6][7].

Machine learning is a technology that generates programs by extracting rules or patterns from large-scale data sets, using neural network, decision tree, genetic algorithm, SVM (Support Vector Machine) and Bayesian Network[8]. As the method to design an intelligent agent using machine learning constructs the agent based on information collected from the surrounding environment, it is applicable to diverse domains and maintains the quality of work by adaptively changing the agent following changes in the environment or learners' characteristics[6][9].

A few application cases of machine learning in intelligent agents are as follows. Mitchell et al. applied the machine learning to an agent managing meeting schedules by modelling learners' characteristics with a decision tree[6], and Lee & Pan used the genetic algorithm to learn learners' characteristics by optimizing a fuzzy model in designing meeting schedules[9]. Schiaffino and Amandi used the reinforcement learning to learn learners' characteristics or habits and to provide appropriate notification service.

In an intelligent agent performing information search, machine learning has been adopted to understand learners' intention more accurately. Hsinchun, Yi-Ming, Ramsey, Yang et al. analyzed learners' search preference using genetic algorithm and proposed a personalized information search agent[10]. Horvitz, Breese, Heckerman, Hovel and Rommelse used the Bayesian Network to apply an interactive agent to MS-Office that infers learners' intention and provides corresponding information through natural language[11] and modelled expert knowledge with neural network in a personalized information system based on the Hamdi multi-agent[12].

In the present study, an intelligent context-aware learning system is implemented for mobile environment requiring real-time data processing based on the Bayesian Network, a model-based collaboration filtering method.

2.3 Augmented Reality

Augmented Reality(AR) technology capable of combining actual reality with learning information can implement a teaching method nearly conforming with the contextual learning, which is why AR draws much attention as a new learning medium maximizing learning effects. AR-applied learning environment can serve many effective ends including increase in sensory immersion, experience-oriented learning by direct manipulation, promotion of contextual awareness and building cooperative learning environment. Examples of AR applied to education are as follows.

'Invisible Train' implemented by Daniel Lederman et al. is the first example of using PDA to build an AR, where two learners can interact. The small wooden railway represents a real context, and the virtual train built on the railway is manipulated as part of the game. As it works on PDAs, the system can be used by diverse users and applied to different fields[13].Archaeology and Culture Heritage' developed by M.White, F.Liarokapis et al. represents information on cultural heritages based on AR techniques. Learners can watch the 3D images implemented with the AR along with physical heritages on the web[14].

The University of Tokyo's Mono Gatahari project is an example of applying AR to science class, where on touching a trilobite fossil, learners can see images of its fossilization process and inner structure through a wearable spectacles-like display and hear explanation, which is a story-telling learning environment implemented[15].

In Austria, D. Wagner developed ‘Kanji Teaching' system working on PDAs. This system is for learning Chinese characters based on AR games. Paper cards on which Chinese characters are printed are put on the table, and users find character cards corresponding to the icons presented on PDAs. Once they flip cards found, corresponding pictures are displayed in 3D[16].

'AR-Memo' developed by the U-VR Lab in the Gwangju Institute of Science and Technology enables learners wearing HMD to take notes on real images with a virtual pen augmented at the tip of their fingers and to see memos on the palm while they are in motion. Unfortunately, owing to costly devices and complicated environment setup as well as HMD, the system is far from being widely used[17]. This study suggests a realistic alternative to those problems mentioned above. The mobile AR-based intelligent context-aware learning system proposed here can provide such a learning environment that requires nothing but common mobile devices.

3 Intelligent Context-Aware Learning System Based on Mobile AR

The proposed learning system operates in ubiquitous computing environment, where information on learners and surrounding environment is delivered to portable information terminals for mobile learners' awareness of context. Each mobile device analyzes acquired information and user requirements for the purpose of service and provides service content meeting learners' preference. The proposed intelligent learning agent consists of the learner-oriented context-aware information module, the learner profile information inference module and the learning content recommendation module. Fig. 1 shows the modules the proposed system interacts with to perform mobile personalization.

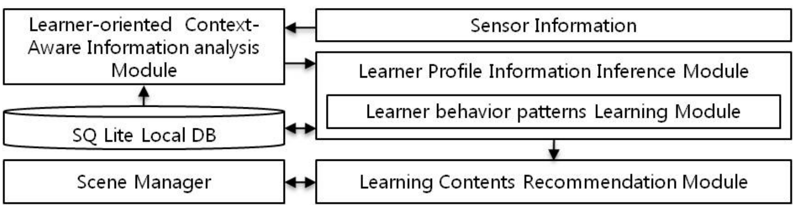

Fig. 1. The Proposed System

3.1 Learner-Oriented Context-Aware Analysis Information Module

The learner-oriented context-aware analysis information module models learner-oriented context-aware information to express diverse context-aware information for a learner. The learner-oriented context-aware information module as in Fig. 2 acquires information from diverse external sensors and analyzes learners' context-aware information.

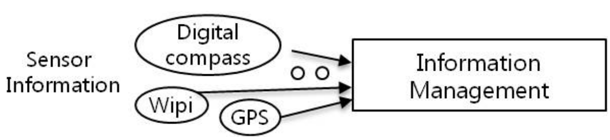

Fig. 2. Learner-oriented context-aware information module

3.2 Learner Profile Information Inference Module

Learner-related context-aware information among diverse types of context-aware information scattered around a learner is an essential element providing the personalized service. In general, to determine personal preference for service, basic personal profile information and personal tendency or characteristics in using services over time must be collected and analyzed. The following formula yields a learner's preference.

$$P_{learner} = (LO_{e1} \times \omega_1) + (LO_{e2} \times \omega_2) + ... + (LO_{en} \times \omega_n) \quad (1)$$

Here, LO_{e1}, LO_{e2}, … LO_{en} are factors influencing the preference for learning objects; ω represents weight values of e; and ω_1, ω_2, …ω_n add up to 1.

Mobile devices learners carry collect and learn learners' service use and feedback information to easily analyze contextual conditions related to each service used. By doing this, services can be optimized without learners' direct specifying contextual conditions, which in turn saves the burden on the server side to manage and update each learner-specific preference for service. Also, by learning the information on service used by each learner to provide personalized service, the system can provide services reflecting each learner's personal preference information.

The learner profile information inference module applies each learner's interest and behavior patterns in using services and compares the information with predetermined learner profile to determine through the inference engine the information that is most suitable for learner's context. Namely, based on learner profile, the context-awareness learning system uses the Bayesian classifier to recommend the contextual service most suitable for each learner without human intervention. The Bayesian classifier is easy to implement and allows reasonable explanation on results derived, which is why it is used in many learning systems. Also, it learns the context of each learner using the learner profile history. In the proposed system, the module results in information, which is used to automatically predict and provide services necessary for each learner.

Fig. 3 shows overall operation process of the learner profile information inference module.

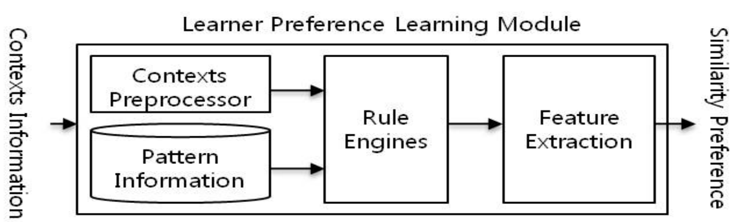

Fig. 3. Learner profile information inference module

First, in the Context Preprocessor, diverse information on each learner gained from each sensor is processed into certain types of context-aware information. Next, the Preference of Learner consists of the Rule Engines and the Naive Bayesian classifier and learns the preference of each learner. The Rule Engines defines and manages the rules on each learner's preference. Defined rules go through the Bayesian classifier to provide services that are most suitable for each learner. The Naive Bayesian technique is the most simple form in the Bayesian Network and assumes that every factor is independent to estimate probability relatively easily and simply, so it is very useful in implementing the system that enables learning the preference of each learner.

3.3 Learning Content Recommendation Module

The learning content recommendation module is the very core of the proposed system, where information to be serviced is recommended based on the context-aware information fit for each learner's preference and intelligent recommendation service for learning is guaranteed in ubiquitous environment.

This module, based on learner profile and learning content data, recommends content each learner prefers. A plethora of learning content is stored in personalized mobile devices. Each learner prefers personalized lists of content estimated based on personal preference to random lists of much content. Learner's preference is contained in the learner profile where learners' preference is kept. The preference profile is variable and contains each learner's current preference for media content. In this learner content recommendation module, data mining technique is used to provide useful information for each learner out of a pile of scattered data. The overall schematic of this system is in Fig. 4.

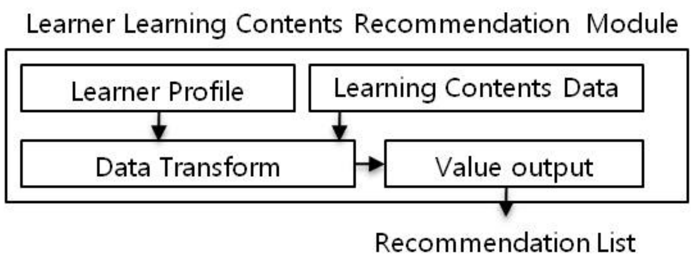

Fig. 4. Learning content recommendation module

The system's data sources are learner profile and content meta data. The learner profile keeps learner's preference for the meta data. The content consists of meta data describing the content of photos. The two data sources undergo a conversion process, where the data transforms into the types applicable to the system. The processed data are largely transformed into contextual data and content information. The transformed data estimate values with the similarity measurement. Data estimated using the similarity measurement recommend learning content, considering learner's preference, in the order of magnitude of values.

4 Results and Implementation of the System

To test the performance of the proposed system, the effectiveness and usability are measured here[18]. The effectiveness of retrieval is usually measured by the following two quantities, recall and precision:

$$recall = \frac{relevant_{set} \cap retrived_{set}}{relevant_{set}}, \quad precision = \frac{relevant_{set} \cap retrived_{set}}{retrived_{set}} \tag{2}$$

Let us assume that $relevant\_{set}$ represents the set of relevant learning objects and $petrived\_{set}$ represents the set of retrieved learning objects.

Table 1. Environment of System Development

OS	android 2.2 Froyo
Language	Java JDK, android SDK
Database	SQ Lite
Mobile Device	galaxy tab

Table 1 shows the environment needed to develop the intelligent context-awareness learning system based on mobile AR.

To test the system performance, an experimental group of 30 learners are set. The learners are asked to move a certain distance randomly while using the service and the extent to which information suitable for learners is recommended in the context recognized is measured and evaluated. As seen in Table 2 regarding the result of the experiment, the proposed method of learner information and personal preference performs better in precision than conventional to use characteristics approaches.

Table 2. Experiment result

Method	Precision	Recall
Collaborative Filtering	70	70
Content-Based Filtering	80	76
Proposed Method	82	66

According to Nielsen's definition on usability, a high usability refers to low mental burden on account of easiness to learn and remember, high effectiveness in use, high subjective satisfaction and low error rates. Among 10 heuristic assessment items Nielsen suggested, the items that are meaningful for comparison with conventional systems[19] are chosen. 5-point scale is applied to each assessment question.

Table 3. Comparison of two systems

items	MLLAS[19]	Proposed System
Visibility of system status	3.17	3.75
Match between system and the real world	3.20	4.35
User control and freedom	3.15	3.80
Consistency and standards	3.12	3.78
Recognition rather than recall	3.07	3.84
Flexibility and efficiency of use	3.14	3.40
Aesthetic and minimalist design	3.21	4.05

The significant difference in assessment values regarding the item, "Match between system and the real world", implies that AR technology ensures that real-life environment and the content on mobile devices are not discrete, inducing learners to further interest and immersion. Compared to previous learning systems using mobile devices, the proposed mobile device has a relatively large screen and superior system performance, resulting in higher satisfaction in general.

Fig. 5 is a screen on a learner's device showing relevant shops around the learner's current location. Here, instead of shop names, business types are showed. Horizontally, the center is approximately within 50m from the learner's current location, and the higher the location on the screen, the farther the real distance. If there are relevant business types behind the learner, their locations are marked below the horizontal center. General business types are marked in white; favorites are marked in green; and frequent visits are marked in red. The compass at the upper left corner on the screen is based on north and south SE, and indicates 134 degrees north, 36.20.54.78 latitude and 127.24.58.68 longitude. Fig. 6 is a screen turning up on pressing 'clinics and hospitals' and shows English conversation used in the sector.

Fig. 5. Result Screen

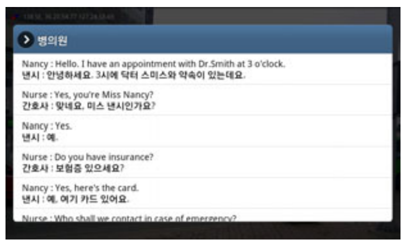

Fig. 6. English Conversation Screen

5 Conclusion

The present study aims to design and implement an intelligent context-aware learning system based on mobile AR that is possibly to provide a learning environment using common mobile devices only. The proposed learning system overcomes the issues of mobile devices including the limited screen size by using the Galaxy Tab. It is an intelligent context-aware learning system using learners' context-aware information gained from mobile devices as well as users' profile information.

To extend the application of the proposed intelligent context-aware learning system based on mobile AR developed here, subsequent studies need conducting as follows. First, to enable learners to use the developed system more easily and conveniently, a program need be developed to register and manage locations they want. Second, study efforts should be made to re-use existing mobile content on the proposed system. Third, further studies must be performed to build diverse learning content applicable to the proposed system.

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