Context-awareness Learning Activity Generation and its Agents in a Mobile Educaitonal Game

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Abstract - Ubiquitous learning is an innovative approach that combines mobile learning and context-awareness, can be seen as kind of location-based services, first detects user's location, surrounding context, and learning profile, and then provides the user learning materials accordingly. Game-based learning have become an emerging research topic and been proved that can increase users' motivations and interests. In this paper, we present an ongoing project of constructing a context-awareness multi-agent-based mobile educational game for on-the-job training that can provide users a series of learning activities automatically and make them interact with specific objects in the real world. The game generates learning activity for the user based on the surrounding context and the chosen theme. The user can quickly get familiar with the new environment and the job relevant objects, policies, and flows while solving the learning activities in the game.

Keywords: Context-awareness; Knowledge Structure; Game-based Learning; Multi-agent System; Situated Learning; Mobile phone

Introduction

According to Christy's data in 2008, vendors and manufacturers can produce and sell more than 32.2 millions mobile phones in a quarter of the year (Christy, 2008). Most of people in working places have at least one mobile phone, which creates a huge potential benefit to on-the-job training (OJT).

Brown and colleagues (1989) argue that students can learn specific knowledge more efficiently by interacting with situated environment (Brown, Collins, & Duguid, 1989). Many researchers use mobile devices to make students have feelings of they are living in the era or the place in which they can obtain the knowledge, e.g. the users can learn rainforest plants and ecology in Amazon River zone of a botanic garden, that is so-called mobile/ubiquitous learning (Chang & Chang, 2006; Chen, Kao, Yu, & Sheu, 2004). Some other researchers develop mobile games for educational purpose; these games not only make learners doing learning activities in specific environment such as museums and historical sites, but also make them get motivated if compared with abovementioned mobile learning systems (Wu, Chang, Chang, Yen, & Heh, 2010; Chang, Wu, & Heh, 2008)

In this research, we propose a context-aware mobile educational game under multi-agent architecture to meet three requirements existed while learning with mobile phones: (1) makes camera-embedded mobile phones be the context-aware learning platform; (2). provides users personalized contents and/or services based on their locations and surrounding context; and, (3) reduces computing power consumed by the mobile learning systems (Tan & Kinshuk, 2009).

This research aims to satisfy above three requirements by focusing on three objectives: (1) The camera on the mobile phone is used in conjunction with two-dimensional barcode scanner in other to identify where the user is by reading the information stored in the barcode; (2) the learning activities are generated automatically according to the user's location and the surrounding context, so that s/he can interact with the real-life objects representing specific knowledge/concepts and get familiar with the environment by doing the activities; and, (3) a multi-agent platform is used to design and implement a mobile game, so that different services and tasks can be divided and dispatched to different agents, and hence less computing power is consumed since not all services need to be started at the very beginning

This paper is organized as follows. In Section 2, the relevant works of different areas are introduced, such as multi-agent systems, knowledge structures, and theories needed for learning activity generation.

Section 3 describes the process of context-awareness learning activity generation in the real world. Section 4 presents multi-agent based mobile educational game design including the prototype system, goes through with a complete example to demonstrate the activity generation flow and the game-play. At the end of this paper, Section 5 makes a brief summary.

Knowledge Structure and Multi-agent Systems

In order to provide users' personalized/customized learning services, first of all, we need to know what the users want to learn and what they have already known. Knowledge structure is a good way to store the knowledge and present the concept relations that the learning materials may have. In this research, the knowledge structure which we apply is called context-awareness knowledge structure. Wu and his colleagues (2008) propose the context-awareness knowledge structure for museum learning and elementary-level botanic learning (Wu, Chang, Chang, Liu, & Heh, 2008). It has proved as a good way to store the knowledge that learning objects and materials may have. However, we want to prove that the knowledge structure can be used not only for the learning material in the specific knowledge-based area but also can be built with the learning objects of general knowledge or information.

We adapt the three layers of the abovementioned context-awareness knowledge structure according to the learning environment that our mobile game takes place, i.e. 11th floor of a university building in which new staffs and visiting scholars reside (as Figure 1 shows). Domain layer defines on-the-job training requirements as well as themes. In addition, different domains may cover same objects and characteristics. Characteristic layer is a hierarchical structure and may be associated with many domains, has root characteristics and child characteristics. Object layer represents all learning objects in the real world, e.g. workplaces, equipment, devices, forms, flyers, etc.

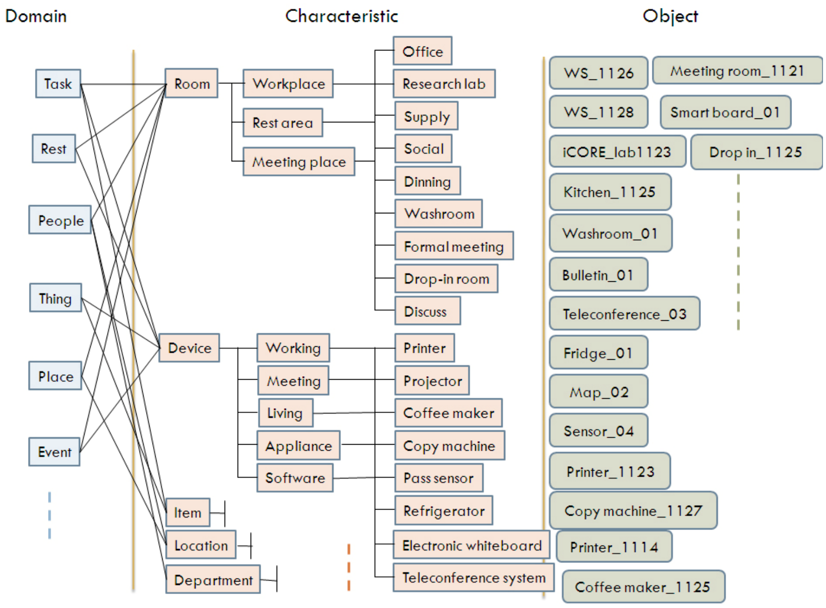


Figure 1. Partial context-awareness knowledge structure for the 11th floor of the university building.

In order to measure the common/rare degree of a learning object and learning characteristic, we take information theory into our consideration. Information theory uses logarithmic base and probability to calculate the value of a learning object/characteristic in the environment by comparing with others. Information theory is proposed by Shannon in 1948, some researchers use it to measure the importance of learning objects in the real world (Liu, Kuo, Chang, & Heh, 2008). In our research, a learning object's information value is $I(LO_i) = \log_2\left(1/P_{LO_i}\right)$, where P_{LO_i} is the characteristic probability of the learning object LO_i and $I(LO_i)$ is the information value of the learning object LO_i.

Multi-agent-based system is one of our research's objectives, designing a system with agent-based perspective makes our mobile educational game more flexible and expandable. For instance, the system can find an agent to hold user's playing data temporary if the network is disconnected and the agent asks DB Access agent doing batch update as usual after it detected the network is available again. We talk the detailed multi-agent system design for the mobile educational game in Section 4.

Context-awareness learning activity generation

In this section, we first use Chris' case to explain how the context-awareness learning activity generation process works within the proposed mobile educational game. After that, we talk the process and methodology in details.

Scenario

Chris is a scholar who visits the city learning centre of Athabasca University first time. In the learning centre, there are a lot of rooms for different purposes (e.g. working, meeting, drop-in, and dinning) and many hardware and software (e.g. printers, projectors, teleconference systems, coffee makers, banner system, and expense claim system). He might be confused about how to book a meeting room for academic discussions, install network printer's driver for printing papers to specific printer, use the facilities that the learning centre has, setup teleconference system for meetings, etc. In order to make himself get familiar with the new research environment and everything related to what he needs for doing research in the university, he downloads and installs the Context-Awareness Mobile Educational Game (CAMEG) in his mobile phone (it has built-in camera and Wi-Fi).

Players can play two roles in this game, i.e. visiting scholar and new employee. Thus, Chris chooses to play as a visiting scholar which fits what he is right now in the university. After he chose the role, he finds that several themes on his mobile screen. Chris then chooses a theme named "Life Style in ELC", because he is interesting to know the daily life of people in ELC before starting his research life here.

The game then generates a series of learning activities related to the chosen theme. These activities are not only sequential but also location-based. Each activity involves one or more learning objects including rooms, hardware, and software. With the sensor technology, every learning object can reflect messages, instructions, video streams, and hyper links on his mobile phone. Hence, he can get familiar with the environment and the facilities surround him by playing the game and doing the learning activities one by one.

Two important issues in the abovementioned scenario: (1) How to retrieve chosen-theme relevant learning objects and characteristics from the knowledge structure? (2) How to generate the learning activities and sort it into a chain? The followed section talks about the solutions of these two issues - the learning activity generating engine.

Finding/Forming a Series of Learning Activities

We describe the detailed design of the learning activity generating engine here. The activity generation process can be divided into five tasks:

Task 1: Retrieving characteristics and learning objects according to the chosen theme

Each theme is associated with a domain and multiple themes can have relations with the same domain. For example, when Chris chooses the theme - "Life Style in ELC", the theme actually associates with the domain, "Event", which covers the frequently happened events in daily works. The engine retrieves all domain relevant learning objects and characteristics from the knowledge structure.

Task 2: Filtering the irrelevant learning objects and characteristics to the chosen theme

The engine discovers the necessary root characteristics toward to the chosen theme, and then analyzes the relations among learning objects and relevant characteristics. Once again, take the "Life style in ELC" theme as example (as Figure 2 shows), the relevant root characteristics are "Room" and "Device" and the irrelevant root characteristic is "Item".

Task 3: Using information theory to weight all learning objects and characteristics

The engine uses information theory to weight learning objects according to how many theme relevant characteristics the learning objects have. For example as Figure 3 shows, the root characteristic - "Room" has three characteristics, "Workplace", "Rest area", and "Meeting place"; each characteristic has three child characteristics. Meanwhile, some child characteristics such as research lab, dinning, and drop-in room may have more than one parent characteristic, because their implicit characteristics.

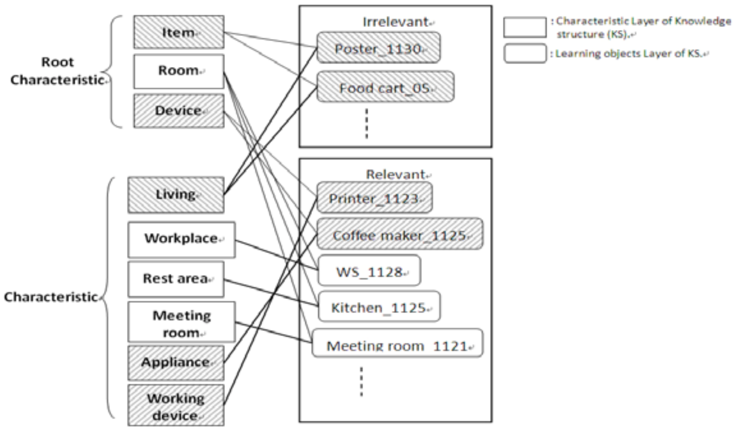
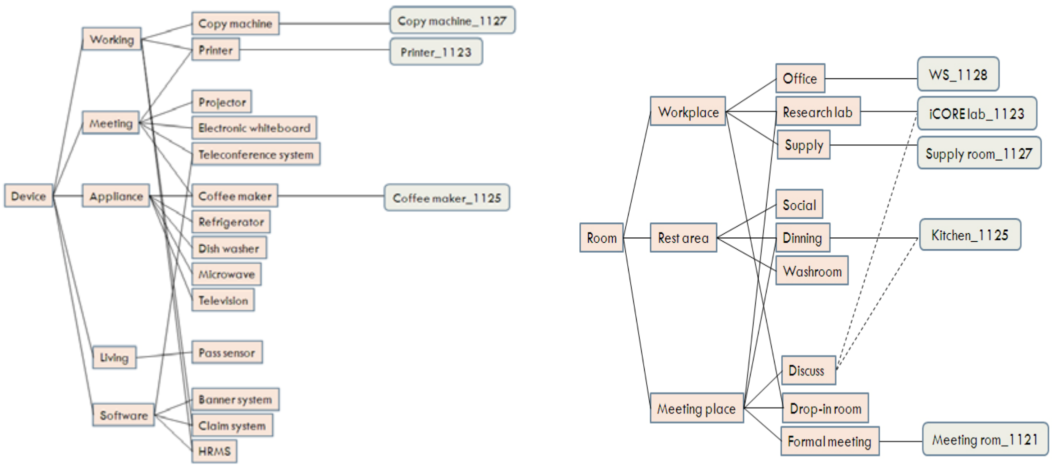


Figure 2. Relations analysis for "Life style in ELC" theme



(a) Device characteristic (b) Room Characteristic

Figure 3. Example of hierarchical characteristics

In order to weight the learning objects, the engine has to calculate the information value of all characteristics. The probability of a characteristic depends on which level the characteristic is at and how many siblings the characteristic has, for examples:

$$P(Characteristic_{Workplace}) = 1/3,\ P(Characteristic_{Meeting\_Place}) = 1/3,\ P(Characteristic_{Rest\_Area}) = 1/3$$

$$P(Characteristic_{Office}) = P(Characteristic_{Workplace}) * 1/4 = 1/3 * 1/4 = 1/12 \tag{1}$$

$$P(Characteristic_{Discuss}) = P(Characteristic_{Meeting\_Place}) * 1/5 = 1/3 * 1/5 = 1/15$$

$$P(Characteristic_{Dinning}) = [P(Characteristic_{Rest\_Area}) * 1/3]+[P(Characteristic_{Meeting\_Place}) * 1/5]$$

$$= [1/3 * 1/3] + [1/3 * 1/5] = [1/9] + [1/15] = 8/45$$

$$I(Characteristic_{Office}) = \log_2 (1/P(Characteristic_{Office})) = \log_2(1 / (1/12)) = 3.5850$$

$$I(Characteristic_{Discuss}) = \log_2 (1/P(Characteristic_{Discuss})) = \log_2(1 / (1/15)) = 3.9069$$

$$I(Characteristic_{Dinning}) = \log_2 (1/P(Characteristic_{Dinning})) = \log_2(1 / (8/45)) = 2.4919 \quad \square$$

Thus, the information value of the learning objects, $Object_{WS\_1128}$ and $Object_{Kitchen\_1125}$ will be

$$I(Object_{WS\_1128}) = I(Characteristic_{Office}) = 3.5850$$

$$I(Object_{Kitchen\_1125}) = I(Characteristic_{Dinning}) + I(Characteristic_{Discuss}) = 2.4919 + 3.9069 = 6.3988\ . \ \square$$

A learning object may have one or more characteristics. If a learning object has only one characteristic, the learning object can be seen as an object with specific function. On the contrary, the learning object may be considered as a multi-function object if it has two or more characteristics. A characteristic may have one or more child characteristics as Figure 3 shows. A learning object can be considered as a simplified object if it has characteristic which belongs to a smaller child characteristic set. Under this situation, the learning object will have smaller information value due to its characteristic has a larger probability. For examples, the probability of $Characteristic_{Office}$ is 1/12 as Eq.(1) shows. Similarly, a learning object can be considered as a diversified object if it has characteristic which belongs to a larger child characteristic set. Under such situation, the learning object will have larger information value. In this research, we assume that it is better for people doing on-the-job training with simplified objects at the beginning.

Task 4: Finding learning objects for pre-defined learning activity templates and generating activities

In the engine, we have a set of pre-defined learning activity templates stored in the database. The templates are associated with one or more learning objects and characteristics, for examples, “looking for a printer” template may associate with “$Characteristic_{Printer}$” and “having a cup of coffee in the kitchen” template may associate with “$Object_{Coffee\_Maker\_1125}$” and “$Object_{Kitchen\_1125}$”. One characteristic may associate with various objects, which means the activity can be composed from different constitutors.

The engine uses the characteristics and objects which retrieved by Task 2 to decide whether a template could be used or not. If a template requires specific characteristic(s), the engine will generate learning activities by picking up suitable learning objects which have the required characteristics. Otherwise, the engine simply generates the activity by filling the template up with the specific learning object(s) directly. At last, the engine summarizes the information values of the learning objects associated with the learning activity, which means, each learning activity has its own information value.

Task 5: Generating learning activity chain based on the information values the activities have

The engine can then sort the learning activities generated from Task 4 based on how many learning objects the activity contains and what information value the activity has. In this research, the learning activities in the chain are sorted by learning object amounts and activity information values.

The engine generates sequential activity chain with two rules, (1) the activity involves less learning object(s) has higher priority (start from simplified objects), (2) if activities involve same amount of learning objects, the activity with lower information value has higher priority. Based on the two rules, Figure 4 shows the learning activity chain for “Life Style in ELC” theme.

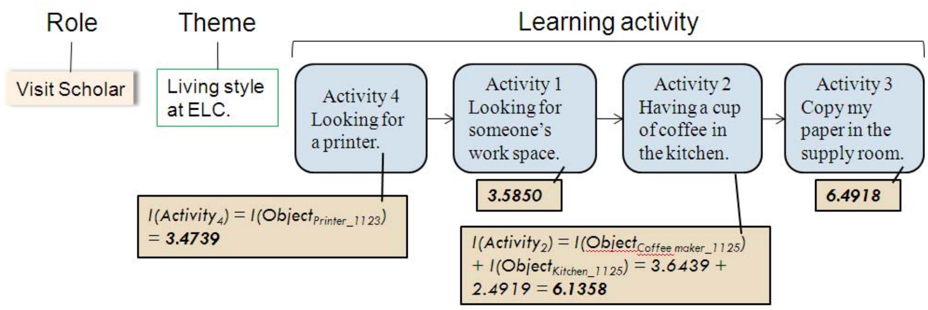


Figure 4. Learning activity chain for “Life Style in ELC”

Multi-agent Mobile Educational Game Design

Multi-Agent Architecture

In this research, we use positioning technology and two-dimensional barcode (e.g. QR code) to develop an educational game on mobile phones. To develop a lightweight, flexible, and scalable game, we take multi-agent architecture (MAA) into considerations while designing our educational game. Each agent handles simple task and listen to other agents’ requests. This collaborative working improves system’s flexibility. For instance, when Calculator cannot get location data from Location Data Collector (i.e. a GPS-enabled agent), it can send request to Activity Item Collector to enable the camera and take a photo of positioning QRcode tag as its plan B.

Multi-agent architecture not only makes different agents deal with different tasks, but also provides us an extendible way to develop further functions, for instances, we can put new agents into the game for special purpose (e.g. another calculator for a new place) or we can replace an old agent with a new and more powerful one (e.g. replace the learning activity generator with a story-teller). Figure 5 shows our MAA-based system model.

The agents in Figure 5 are responsible for specific tasks:

Player - Player agent is a bridge between the user and other agents. It acquires data from other agents such as translator and learning activity generator.

Activity item collector - The main task that activity item collector does is to scan the QR code with the camera and interpret the scanned data.

Translator - Translator can identify different language inputs and store it into database with suitable text encoding method. Translator is very useful in non-English speaking country (e.g. China, India, and Japan) and bilingual environment (e.g. English-French and Dutch-English).

Calculator and learning activity generator - The two agents accomplish the tasks for learning activity generation we talked in Section 3, calculator is charging for Task 2 and 3; learning activity generator, on the other hand, is charging for Task 4 and 5.

Location data collector - Location data collector is responsible for detecting and processing positioning data. If the location data collector is a GPS-based collector, then it gathers the GPS data and interprets the longitudes and latitudes from the data. On the other hand, if the collector is a QR-Code-based collector, it can scan the QR code and interprets the embedded information from the scanned data.

Map holder - Map holder always keeps a copy of the map where the player is playing the game in case any other agents may acquire when the network connection is no longer available. The map here in the game is the context-awareness knowledge structure.

DB access agent - DB access agent makes up the appropriate data manipulation language of SQL commands and receives the results from the database. If the network connection is not available, the agent will keep the manipulation jobs and do batch update when the network connection is recovered.

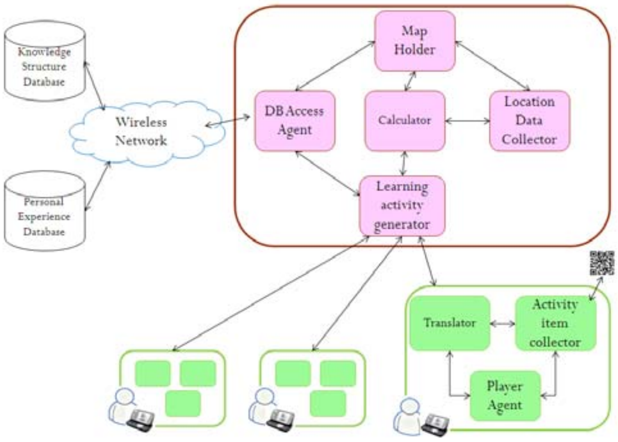


Figure 5. MAA-based system model

System Architecture

Figure 6 illustrates the relations among the agents and database. We have not considered map holder here yet because the game world is only set to the 11th floor of the university building. Nevertheless, multi-agent-based design lightens the programs, which means we could put a new agent into or replace existing agents anytime later very easily without changing the main program.

Complete Example of Game-Play

The mobile devices which host the game in our assumption are mobile phones, smart phones, and PDA as long as the devices support Java ME with the Mobile Information Device Profile (MIDP) 2.0 and have built-in camera and internet connections, it would be better but not necessary if the devices have built-in GPS. As Figure 6 shows, the system flow includes three stages: the first stage involves the player agent, translator, and DB access agent (step 1 and 2); the second stage focuses on the learning activity generation (step 3 to 7), which involves learning activity generator, calculator, location data collector, translator, and DB access agent; and, the third stage involves activity item collector, the player agent, translator, and DB access agent (step 8 and 9).

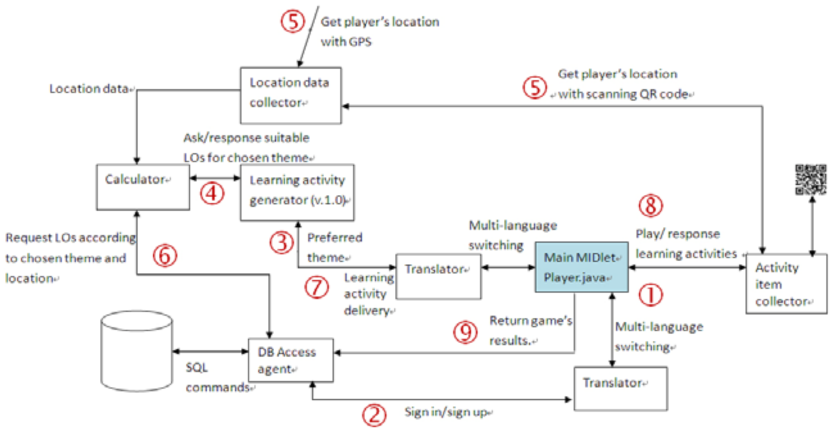


Figure 6. Relations among agents and database

Stage I. User signs in/signs up for the game

The player agent interacts with the user and helps data exchanges between the user and other agents. At beginning, the player agent first gets username and password from the user and then these data are checked by the translator (step 1 in Figure 6) to see what language encoding the data has. The player agent then sends user's username/password to the DB access agent. The DB access agent judges if the account is existed in either the game database or other system's database (e.g. our university's Moodle database). If the username/password doesn't exist, the player agent will ask the user to create an account for playing the game (step 2 in Figure 6).

Stage II. Context-awareness learning activity generation

After signed in the game, the user can choose his/her preferred role and theme as Figure 7(a) and 7(b) shows. The learning activity generator receives the choices and asks the calculator for suitable learning objects and characteristics (step 3 and step 4 in Figure 6). At meantime, the location data collector starts positioning process by using either GPS (if the built-in GPS receiver has detected) or camera (step 5 in Figure 6). Once the calculator had the location data from the location data collector and chosen theme from the learning activity generator, the calculator uses information theory to find the appropriated learning objects and characteristics and to calculate the information value for each learning object and characteristic (step 6 in Figure 6). Consequently, the learning activity generator received the learning objects with information values; it compares the learning objects and characteristics with learning activity templates and composes learning activities. The sorted learning activities are sent to the player agent (step 7 in Figure 6) to show up on the screen and to ask the user doing it as Figure 7(c) shows.

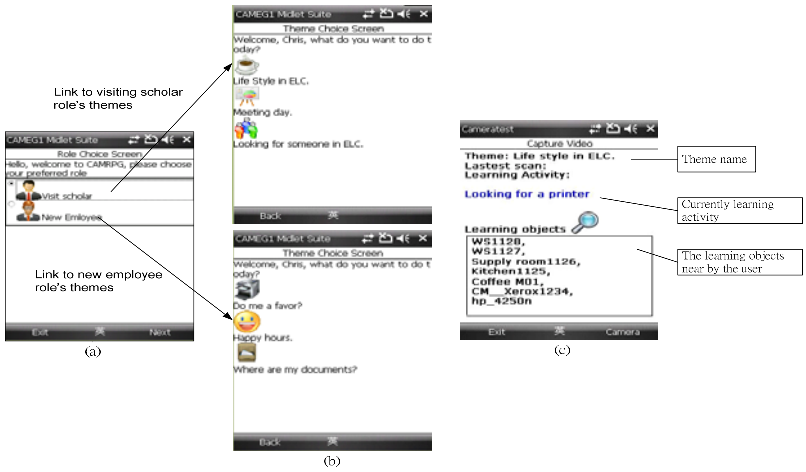


Figure 7. Screen shots of game-playing

Stage III. User does learning activities

The user starts doing the activities one by one. S/he looks for the activity relevant items (activity items for short), for examples, the coffee maker - "$Object_{Coffee\_Maker\_1125}$" and the workspace - "$Object_{WS\_1128}$". We design and set up QR codes in the environment for all learning objects. The QR code contains location data, activity item's ID, and contents such as a streaming video clip to teach users how to setup teleconference system and HTML-based instructions to teach users how to operate a copy machine. Each learning object is worth to learn when someone really needs it. Thus, once the user found the activity item, s/he can use the mobile phone to scan the QR code for collecting the item (step 8 in Figure 6), and then receive some information or knowledge. The user increases his/her understandings toward the environment and knowledge of the learning objects by doing the learning activities. The player agent will update the user's learning experience in the database after s/he has done the activity (step 9 in Figure 6). The user can see what activities s/he has done, which also means that the learning activity generator will offer him/her different activity chain with other learning objects when s/he plays next time.

Summary and Future works

In this paper, we present a multi-agent-based mobile educational game in which the kernel, learning activity generating engine, can generate context-awareness learning activities automatically. This game can help users doing on-the-job training to get familiar with new environment; to adapt new working procedures and policies; and, to learn facilities related to their jobs. The proposed game has three features: (1) it has context-awareness knowledge structure to store all learning objects and characteristics associated with the environment; (2) it can generate different learning activity chains according to user's location, chosen role and theme, and surrounding learning objects; (3) its multi-agent architecture makes itself easy to maintain and to extend.

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