Location-Based Augmented Reality for Mobile Learning: Algorithm, System, and Implementation

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Abstract: AR technology can be considered as mainly consisting of two aspects: identification of real-world object and display of computer-generated digital contents related the identified real-world object. The technical challenge of mobile AR is to identify the real-world object that mobile device's camera aim at. In this paper, we will present a location-based object identification algorithm that has been used to identify learning objects in the 5R adaptive location-based mobile learning setting. We will also provide some background of the algorithm, discuss issues in using the algorithm, and present the algorithm empowered mobile learning system and its implementation.

Keywords: Augmented Reality, Object Identification, Location-Based Adaptive Mobile Learning

1. Introduction

Mobile devices have become ubiquitous in today's learning. Now with the emergence of new functionality in mobile devices, mobile learning can be conducted in more innovative fashion. From the pedagogical perspective, the advantages of mobile learning could not be fully exploited and demonstrated if the mobile learning is only conducted by using the mobile browser to access learning contents without using the native functions and features of the mobile devices. There are more and more location-based mobile applications from location-based information services to location-based games and then location-based ubiquitous learning [Benford, et al. 2005 and Hwang, 2006]. In recent years, mobile devices with built-in Global Positioning System (GPS) receivers and A-GPS services are becoming increasingly popular. Utilizing a mobile device's location awareness capability within mobile learning applications has now become a reality [Tan, et al, 2010]. One of the emerging research emphases is to utilize the location-awareness functionality of the mobile devices to further strengthen mobile learning. Previous research [Patten, et al, 2006 and Michie, 1998] have also indicated that the combination of location-awareness and a contextual learning approach can enable learners to better construct meaningful contextualization of concepts.

Furthermore, location-based e-learning provides a personalized learning experience and helps in keeping the learners engaged in the learning activities and enhancing their effectiveness. For example, in terms of ubiquitous learning applications, [Chen, et al, 2007] proposed a personalized context-aware ubiquitous learning system with ability to exploit appropriate context based on learners' location, leisure learning time, and individual abilities to adapt learning contents towards learners for promoting the learning interests and performance. As early as 1950, situational learning approach for language learning [Homby, 1950] indicated that context is an important factor in the learning process and it can enhance learners' learning interest and learning effectiveness. These examples suggest that meaningful knowledge is constructed primarily when the learning process integrates with social culture and life-context.

Augmented Reality (AR) has become a popular display and interactive technique in the past few years. It can be defined, as a technique is to display virtual contents superimposed upon real-life objects. On the other hand, the location-based adaptive mobile learning is to provide adaptive learning contents to particular learner according to the learner's location where the real-life context is used as learning objects. To employ mobile devices to interact with real-life learning object in a context-awareness mobile learning environment, Mobile Augmented Reality (MAR) is introduced. The first generation of MAR using context-awareness was based on laptops and mainly used location information as a context [Höllerer, et al, 1999 and Bauer, et al 2001]. Later on, the convergence of context-awareness and MAR started to shift to lightweight platforms such

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as PDAs, Ultra Mobile Personal Computers (UMPCs) and mobile phones [Henrysson and Ollila, 2004]. Then most of the researches were focused on using a domain knowledge and behavior model to improve interactions in MAR.

Ubiquitous learning offered through the Mobile Augmented Reality Systems (MARS) requires well-engineered system/software architecture in order to deliver on-demand instructional services. Target applications generated from the architecture require instructional capabilities for understanding individual learning strengths while tailoring empirically evaluated pedagogical techniques to enhance learning performance. In order to significantly impact learning, a MARS e-learning tool needs to consistently measure learning progress and continuously update information about the learner for the duration of the learning interaction. Hence, a MARS e-learning tool may continually process learning data associated to a given context for a given learner.

In this research, Augmented Reality is considered as an emerging content display technique that can improve and enhance learning content presentation as well as interaction between learners and learning contents associated with location-based real-life learning objects (RLO). To apply AR technique for the learning, the major technical challenge is to identify real-life objects (the realities). In order to tackle the technical issue, this paper presents a Location-Based Object Identification Algorithm that we proposed and have implemented in a mobile learning application. The algorithm aims to identify the real-life learning objects by matching the tagged location information of the RLOs with the current location and orientation of the mobile device. Furthermore, the algorithm also provides the guidance capability to navigate learner to the right RLO among the nearby RLOs for learning. A real-life learning object is a real-life object used as a location-based learning object in the location-based mobile learning setting.

A location-based adaptive mobile learning application, called Multi-Object Identification Augmented Reality (MOIAR) has been developed to apply AR technique into mobile learning application. It is empowered by the Location-Based Object Identification Algorithm to identify the real-life learning objects in the mobile learning setting. The implementation of the mobile learning application has proven the usability and the practicality of the Location-Based Object Identification Algorithm, To improve the learning content adaptability, the MOIAR also utilizes the 5R adaptive mechanism, which not only provides adaptive learning contents but also assists real-life learning object identification (Chang & Tan & Fang, 2010). The 5R adaptation concept for location-based mobile learning is stated as: at the right time, in the right location, through the right device, providing the right contents to the right learner (Tan, et al, 2011).

In this paper, we will review the related work following by this section. Then in section 3 we will present the Location-based Object Identification Algorithm in detail. In section 4, we will give a location-based mobile learning scenario study where the MOIAR application is used at the Legislative Assembly of Alberta as a real-life learning object to show usability and effectiveness of the algorithm. Finally this paper will be concluded with discussion of future works.

2. Related Work

In Augmented Reality, markers are often used in the environment due to their low setting up cost and robustness (Rohs, 2004). However, it is an invasive solution since objects have to be tagged with these codes. On the other hand, emerging tracking systems offer various ways to identify objects in the real world. They range from the well-known Global Positioning System (GPS) to GSM, GPRS and UMTS systems, which enable identification and location of mobile phones within an area of influence (Kalkbrenner & Koppe, 2002). Radio frequency identification systems (RFID) enable non-contact reading of transponders equipped with a worldwide unique identification number (Ferscha, 2002). The emerging wireless sensors network (WSN) systems enable the tracking of mobile devices that are connected to the network through a wireless network card (Ferscha & Beer & Narzt, 2001).

There are many positioning approaches (GPS, WLAN, GSM, transponders, indoor positioning systems, etc.) and orientation identification methods (digital compass, accelerometer, gyros, etc.). They provide all types of tracking information and support different location identification systems. For instance, an active sensing system is able to determine its current position and/or orientation by itself. Built-in A-GPS receiver and digital compass on a mobile phone enable the mobile phone to be able to detect its current position and direction.

Augmented Reality (AR) has the ability to combine digital media/information and augment the physical world. This ability to fuse digital media within the physical world gives way to the potential for AR learning which creates the ideal conditions for locative, contextual and situation-based learning scenarios. Prior research has concluded that the incorporation of various sensors provides new ways in which we are able to interact with the world around us [Nokia Research Centre, 2009]. Furthermore, the tools (software) and technologies (hardware) are more evenly distributed and are at our disposal to deploy mixed reality learning scenarios that deliver rich and immersive AR content which could potentially re-shape how individuals and groups approach learning and education.

Majority of the prior research about applying AR into education has indicated that the intuitive interaction of AR has greatly improved learning efficiency, motivation, and overall performance. For example, [Chen, et al, 2010] proposed a novel game-based English learning system with context-aware interactive learning mechanism which can appropriately provide a corresponding game-based English learning scene to the learner's handheld device based on the learner's location context. The proposed system aims to construct a mixed reality game-learning environment that integrates virtual objects with real scenes in a university library. The preliminary experimental results reveal that the proposed learning mode provides likely benefits in terms of promoting learners' learning interests, increasing learners' willing to learning English. A research [Liu, et al, 2007] constructed a learning system called HELLO (Handheld English Language Learning Organization). It consisted with 2D barcode and handheld AR that has 3D animated virtual learning partner (VLP) over the real world. The student can complete the context-aware learning process by talking to the VLP and to learn in the designed game-based pedagogic scenario to improve students' English level. Another research [Juan & Beatrice & Cano, 2008] presented an AR system for children of the Summer School of the Technical University of Valencia for learning about the interior of the human body. In addition, they presented two AR interactive storytelling systems that use tangible cubes for the same students as mentioned above to learn with the 8 different ends of the Lion King story [Juan & Canu & Gimenez, 2008]. [Wagner and Barakonyi, 2003] proposed a piece of educational software that uses collaborative AR on fully autonomous PDAs running the application which is laid out as a two player AR computer game, together with an optical marker-based tracking module to teach learners the meaning of kanji symbols. [Kaufmann, 2003] developed a collaborative AR application, called Construct3D, specifically designed for mathematics and geometry education. Construct3D is based on the mobile collaborative AR system "Studierstube" within the greater context of immersive virtual learning environments.

3. Location-Based Object Identification Algorithm

3.1 The MOIAR Overview

AR provides an excellent learning interface in a mobile learning application. The learner's view is augmented with digital information at the correct geographic location, thus providing an intuitive way of presenting such information (Reitmayr & Schmalstieg, 2003). In this paper, the MOIAR application focuses on identifying location-based outdoor real-life learning objects. The MOIAR aims to not only provide the learning contents but also allow learners to interact with the Real-life Learning Objects (RLO) in the simplest and most intuitive way. The MOIAR can also provide learning contents that are adapted and personalized to learners through AR display. In the MOIAR, a mobile AR client application running on a mobile device that is equipped with a built-in A-GPS and a digital compass is used as the tracking device and the learning terminal. The mobile device can continuously track a learner's movement without the need for external references. Sometimes it may be assisted with secondary sensors such as motion sensors (accelerometers) and rotation sensors (gyroscopes). Further, with the implementation of AR and mobile device's location awareness and mobility, the MOIAR has the potential to eliminate some of the learning limitations and disadvantages that exist in the traditional learning. Figure 1 shows the MOIAR application system architecture diagram.

3.2 Location-Based Object Identification Algorithm

In the MOIAR application, AR is used to display digital learning contents related to the real-life learning objects by superimposing upon the video stream of real-life object on the mobile device's screen. This means that the learner carrying the mobile device has to be at a location that is nearby the real-life object, and the learner has to face the mobile device's camera lens towards the real-life object, so that the contents can be seen superimposed upon the real-life learning object on the screen. To display the right learning contents on the real-life object, the MOIAR has to be able to identify the real-life object i.e. to find which the location-based learning object stored in the database of the mobile learning application match with the real-life object; then the 5R adaptive mechanism will generate right learning contents superimposing on the object.

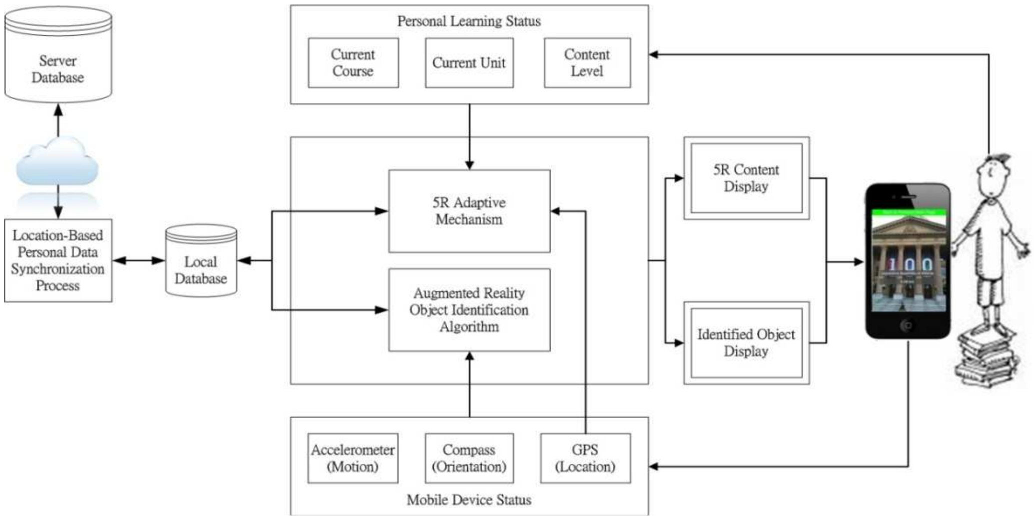


Figure 1: The MOIAR system architecture diagram

The idea behind the location-based object identification algorithm for mobile Augmented Reality is based on location-awareness of mobile devices and known geographic coordinates of location-based learning objects in the location-based mobile learning environment. The MOIAR mobile application first obtains the current geographic coordinates of the mobile device acquired by the built-in A-GPS sensor. The MOIAR then uses the geographic orientation information to obtain the absolute orientation, which is detected by the built-in digital compass. On the other hand, each location-based learning object predefined and stored in the database has been tagged with its geographic coordinates. When the learner with the mobile device approaching into a pre-configured distance toward a real-life learning object, the MOIAR application will find the object then calculates the relative distance and orientation between the mobile device and the real-life object, which is accomplished by the location-based object identification algorithm.

In fact, in the outdoor learning environment, the locations of real-life objects used as location-based learning objects are known and fixed. When the learner carrying a mobile device is standing nearby a real-life object, it is easy and would make sense for the learner to change his/her current orientation to face the camera lens to the real-life object. Particularly when the object is located in an open space, which means there are no other objects close by or right next to it, the learner can walk around the object as long as he/she is close enough or nearby the object's location, and has mobile device facing the object. Hence, the mobile device's orientation related to the real-life learning object becomes very important.

The location-based object identification algorithm utilizes the concept of the Relative Orientation that will be discussed later in this section. This algorithm also uses two-dimension geographic coordinate information, namely latitude and longitude, to calculate the distance between the learner and the real-life objects. The mobile device's digital compass can get the angle between the mobile camera face and the true north, and then the algorithm can calculate out the angle between mobile camera face and the real-life object. Both of the angles are then used to decide whether the identification tags and the 5R adaptive learning contents should be displayed on the screen or not.

3.2.1 Distance Between Mobile Device and Real-life Learning Object

In the MOIAR mobile learning environment, there could be multiple real-life learning objects related to the learner at a particular location. In order to effectively utilize the limited screen space on the mobile device, as well as to provide the 5R adaptive learning contents, only a certain number of real-life object identification tags and contents should be displayed at the place and time. In the MOIAR application, only objects that match the learner's personal learning profile and status are included into the AR data model as Objects of Interest, and the real-life object identification tags of only those objects may be displayed on the screen at the right location. In fact, in the MOIAR learning environment, learner could be nearby and see several real-life learning objects in different views at one location. However, the learning contents are displayed on the screen only for the real-life learning object that the learner's mobile device's camera lens is pointed to within the pre-configured distance range.

Hence, the relative object identification algorithm is designed to compute the orientation subtended from the learner's current location to each real-life learning object at the location. The MOIAR utilizes two coordinate systems to implement the algorithm. The first coordinate system is the original geographic coordinate systems, known as the Polar coordinate system, which utilizes the latitude, longitude, and the North Pole based orientation. Based on the Polar coordinate system, each real-life learning object's location is indicated as (ϕ_o, λ_o) as a known parameter, which is predefined and stored in the RLO data model. The learner's current location is indicated as (ϕ_m, λ_m) as a sensor parameter. The subscript "o" and "m" represent respectively real-life learning object and the mobile device (i.e. refers to the learner's current location). Firstly the algorithm is to compute the distance, D from the learner's current location to each real-life learning object. The calculation is based on the Spherical Law of Cosines is shown in formula (1):

$$D = R * \arccos [\sin\phi m * \sin\phi o + \cos\phi m * \cos\phi o * \cos(\lambda o - \lambda m)] \qquad (1)$$

The ϕ_o and ϕ_m indicate their latitudes of the learner and the real-life learning object, the λ_m and λ_o indicate their longitudes, and the R is the radius of the earth in meter. In the formula, R is a constant, R=6.371 X 10^6 meters. The geographic coordinates of the learner are acquired from the GPS receiver of the mobile device, and real-life learning object's geographic coordinates are stored in the database of the MOIAR application system. The latitude and longitude coordinates have to be converted into Radian if their unit of measure is in degree. Based on the difference of the distances from the real-life learning object to the learner, the real-life objects are filtered out if they are not within a pre-configured distance range from the learner's current location.

3.2.2 Orientation Between Mobile Device and Real-life Learning Object

The orientation of the mobile device defines the angle between the mobile device camera lens and the real-life learning object, which is one of calculation criteria for the content display. For example, the learner might be standing on the different side of the real-life learning object, which would require the learner to turn the camera lens to a different direction in order to get the right content to be displayed on the screen properly. As mentioned above, the mobile device's current Azimuth, each real-life leaning object's Azimuth, and the angle subtended between the two Azimuths, are the critical elements to accomplish this algorithm. The mobile device's current Azimuth is indicated as θ_m, which is also a sensor parameter and is measured in Radian, discussed in the later paragraph. Another coordinate system is the MOIAR coordinate system that based on the Cartesian coordinates, which computes the Azimuth of the each real-life learning object that is subtended to the learner's current location and the North Pole. In the MOIAR coordinate system, the learner's current location is indicated as the coordinate origin.

The MOIAR coordinate system contains two key variables, ϕ and λ. They respectively indicate the computed west to east axis and north to south axis variables that are subtended from the learner's current location to each real-life learning object at the location. The formula (2) for calculating the [$\Delta\phi$, $\Delta\lambda$] is shown as follows:

$$\Delta\phi = \phi o - \phi m \qquad (2.1)$$

$$\Delta\lambda = \lambda o - \lambda m \qquad (2.2)$$

After [$\Delta\phi$, $\Delta\lambda$] is computed, which indicates the new coordinate variable between the real-life learning object and the learner's current location, the Polar coordinate system is then conceptually converted into the MOIAR coordinate system, which utilizes the learner's current location as the coordinate origin. As mentioned above, in order to identify the right real-life object and display the right content when the learner is facing the mobile device on the right orientation to each real-life learning object, and to further guide the learner regarding which direction to face the camera lens, the Azimuth of the learner's current orientation and the Azimuth of each real-life learning object is computed. The concept of the Azimuth in the MOIAR coordinate system is shown in figure 2 and the computing formula to further calculate the Azimuth θ_c is presented as follows:

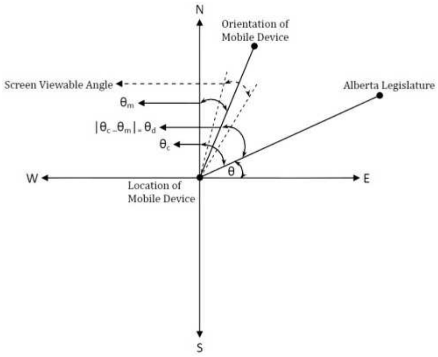


Figure 2: The concept of the MOIAR coordinate system in the algorithm

$$\tan\theta = | Yc / Xc | \quad (3.1)$$

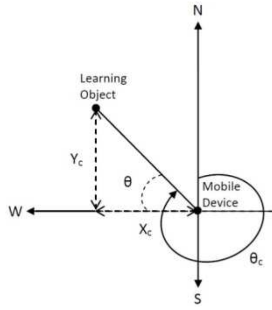
$$\theta = \tan^{-1} | Yc / Xc | \quad (3.2)$$

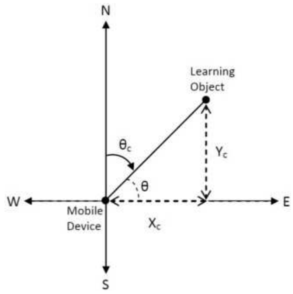
$$\theta c = 90^{o} \text{ or } 270^{o} \pm \theta \quad (3.3)$$

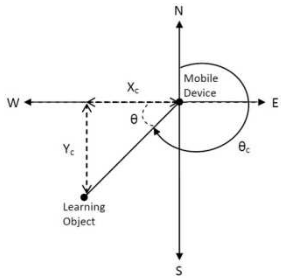
In the MOIAR coordinate system, the angle between the line from the coordinate origin to the North Pole and the line from the coordinate origin to [Δϕ, Δλ] refers to the Azimuth of real-life learning object represented as θc. In order to compute θc, the angle θ between the learner, the real-life learning object, and the Δϕ axis have to be computed first by using the Tangent Trigonometric Functions. Further, according to [Δϕ, Δλ] that locates the quadrant in the MOIAR coordinate system, the complete Azimuth θc will be found. When Δϕ is positive and Δλ is positive, it means the real-life learning object is located in the first quadrant and θc will be 90° + θ. When Δϕ is positive and Δλ is negative, it means the real-life learning object is located in the fourth quadrant and θc will be 90° - θ. When Δϕ is negative and Δλ is negative, it means the real-life learning object is located in the third quadrant and θc will be 270° - θ. When Δϕ is negative and Δλ is positive, it means the real-life learning object is located in the second quadrant and θc will be 270° + θ. Table 1 displays different cases when Azimuth θc is located in each quadrant.

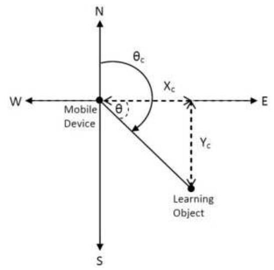
The Object Identification algorithm proposed and implemented in this paper is for the MOIAR application to effectively identify the real-life learning objects based on the calculated Azimuth and the subtended angle, whatever the learners' current location and orientation are, and whenever learners change them. Unlike prior AR learning applications that require learners to stand within a certain distance from the object or focus the camera lens in front of the optical marker, the MOIAR application lets the learners walk around the real-life learning object and still see the identification tags and the adaptive learning contents, as long as the camera lens is facing the real-life learning objects. Further, the MOIAR can also guide the learner to other real-life learning objects located with the object identification tags. Also, the 5R adaptive mechanism tailored the learning contents according to the learner's learning status and the mobile device's current location status. Comparing the MOIAR approach developed in this research with prior mobile AR learning research applications, most of the prior applications can only provide learning contents based on the textbook or tailored to the object itself. The MOIAR system can not only identify the objects of interest but also provides the contents of interest. The 5R adaptive mechanism helps the learners in constructing more meaningful knowledge because the learning process and learning contents are integrated with societal culture, life-context, and personal learning preferences.

Table 1. Azimuths in different quadrants of the algorithm

<table>
<tr><td colspan="2">Mobile Device Coordinate</td><td colspan="2">Mobile Device Coordinate</td></tr>
<tr><td>-</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td colspan="2">RLO Coordinate</td><td colspan="2">RLO Coordinate</td></tr>
<tr><td colspan="2">North West: Second Quadrant


$\theta_c = 270° + \theta$</td><td colspan="2">North Ease: First Quadrant


$\theta_c = 90° - \theta$</td></tr>
<tr><td colspan="2">Mobile Device Coordinate</td><td colspan="2">Mobile Device Coordinate</td></tr>
<tr><td>-</td><td>-</td><td>+</td><td>-</td></tr>
<tr><td colspan="2">RLO Coordinate</td><td colspan="2">RLO Coordinate</td></tr>
<tr><td colspan="2">South West: Third Quadrant


$\theta_c = 270° - \theta$</td><td colspan="2">South East: Fourth Quadrant


$\theta_c = 90° + \theta$</td></tr>
</table>

Once Azimuth θ_c is computed, the last step is to compute the subtended angle. The subtended angle is computed according to the difference between Azimuth of the learner's current orientation, which is sensed by the built-in digital compass on the mobile device, and the Azimuth of each real-life learning object θ_c. Further, the object identification algorithm can determine whether the object identification tags and the 5R adaptive contents of the object should be displayed on the screen or not, according to the formula (4) below:

$$\theta d = |\theta m - \theta c| \leq R \text{ (ex: } R = 5^{o}) \qquad (4)$$

In the formula (4), θd refers to the angle difference between the Azimuth of the learner's current location and each real-life learning object. Variable R refers to the Rule in the algorithm that is used to determine the error band for displaying the object identification tags and the 5R adaptive contents. The reason to compute θd as an absolute value is that the MOIAR system should display the object identification tags and the 5R adaptive contents no matter whether the real-life learning object is on the left side or right side of the learner. For example, if θm is 45° and θc is 40°, the original θd is $+5^{o}$, which means the object is slightly left to the learner. On the other hand, when θm is 45° and θc is 50°, the original θd is -5^{o}, which means the object is slightly on the right side of the learner. If we set the rule as 5°, after computing θd with an absolute value, the object identification tags and the 5R adaptive contents would be displayed in both cases.

4. The MOIAR Implementation

This section describes how the MOIAR works in the research environment created for the purpose of demonstration through a scenario study. There are three students in this scenario. Will is currently enrolled in the English program, and he is taking course 604 "Traveling English" and he is on unit one with knowledge level one. Jimmy is currently enrolled in the Politic program, and he is taking course 704 "Politic Science" and he is on unit one with knowledge level one. Alex is currently enrolled in the Architecture program, and he is taking course 804 "Introduction to Architecture" and he is on unit one with knowledge level one. The real-life learning object is the Alberta Legislature building.

4.1 Learner Authentication Interface

The learner authentication interface contains two parts of information, the personal learning profile and status and the learner's current location. The screen shots are shown in figure 3. The MOIAR mobile client application shows to the learners the courses and units that they are currently learning with the MOIAR application, the knowledge level of the learning contents that they will be getting, and their mobile device's current GPS location information.

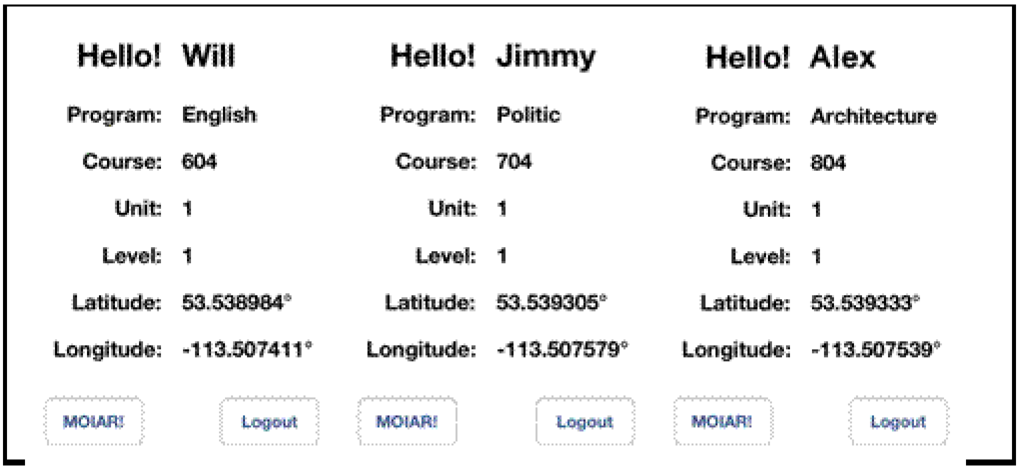


Figure 3. Personal learning profile and status

4.2 Location-based Reality Learning Object Identification

When the learner clicks the MOIAR button, the application will launch the object identification process powered by the Location-based Object Identification Algorithm to start identifying the real-life learning object around the learner's current location and display identification tags of the location-based learning objects as shown in figure 4.

The screenshot (4 - A) shows that the MOIAR application successfully identified one of the real-life learning objects, the Alberta Legislature Building, with the object's name and the distance displayed upon the screen. The screenshots (4 - B) and (4 - C) display different identification tags at the same location according to their orientations and motions. In screenshot (4 - B), the learner was standing in front of a house that is located at the address 2422 111B Street, where the house was 0.02 km away from the learner. When the learner faced to the house right next to it, the tag shows the neighbor house's address, the distance from the learner is now shown as 0.03 km (screenshot 4 - C). The houses are predefined and stored as a real-life learning object in the database. Further, when there are more than one object in the camera view, the MOIAR mobile application will change the size of the object identification tags according to the distance; the closer the object is to the learner, the bigger the tag will be.

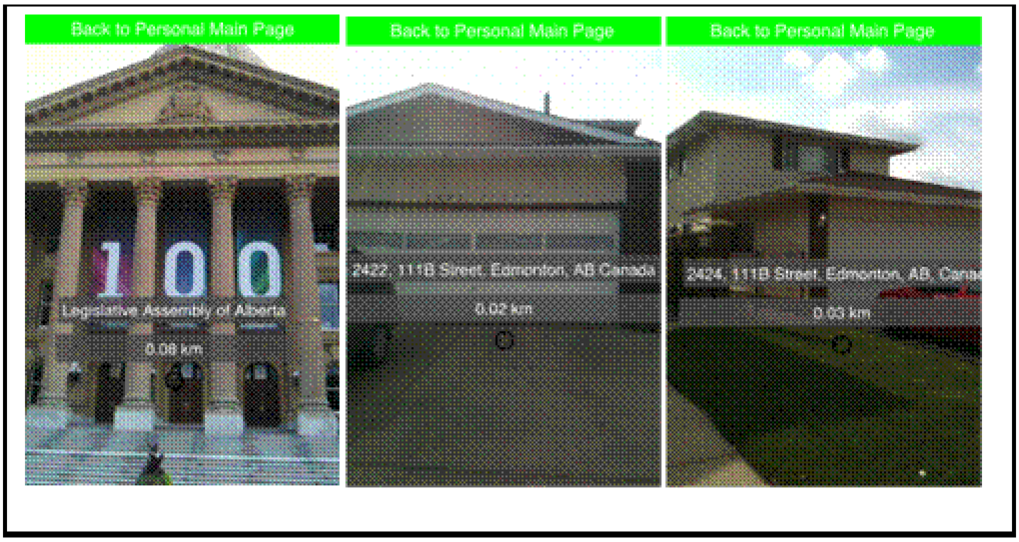


Figure 4: Location-based learning object identification tags

4.3 The 5R Adaptive Learning Contents

The object identification tags are touchable buttons, and the learner has just to click the tags to get the detailed learning contents. The MOIAR application can identify multiple learning objects at the same time, but the screen space on the mobile device is limited. So it is better to display only the object identification tags at first because the learners do not need to see the contents until they are right in front of a real-life learning object and are ready to learn. Figure 5 shows different location-based learning contents superimposed on the real-life learning object, the Alberta Legislature building adapted to their personal learning profiles and statuses of three learners. There are three parts of contents in the content view. The first part on the top shows the name of the learning object; the second part below shows the learner's current personal learning status, and the third part shows learning contents. As shown in figure 5, screenshot (5 - A) is tourist information of the Alberta Legislature Building for the course "Travelling English". Screenshot (5 - B) shows the political history of the building for the course "Political Science". The last screenshot (5 - C) gives the design and architectural of the building for the course "Introduction to Architecture"

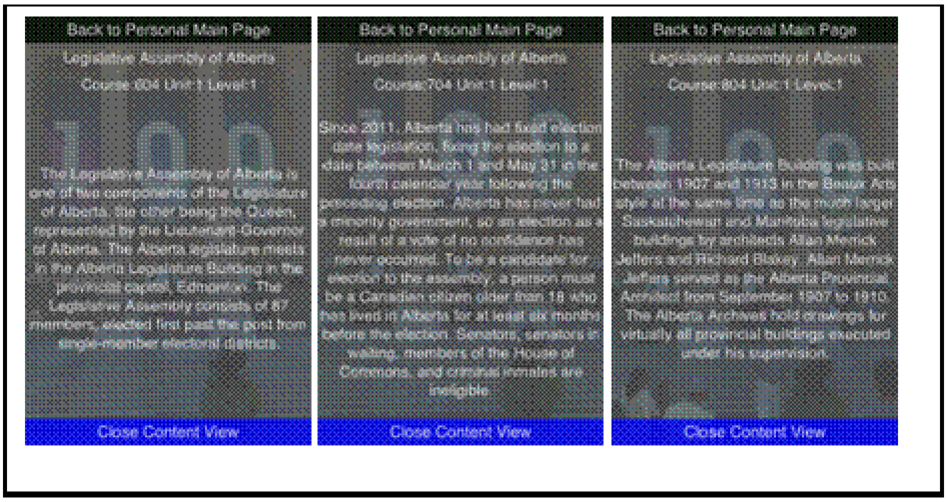


Figure 5: The 5R adaptive location-based learning contents superimposed on the real-life learning object

5. Conclusion and Future Work

The Location-based Object Identification algorithm presented and implemented in this paper is for the MOIAR mobile learning application to effectively identify the real-life learning objects based on the learners' current location and orientation and real-life learning object's location information. The MOIAR application allows the learners walk around the real-life learning object and still see the identification tags and the adaptive learning contents, as long as the camera lens is facing the real-life learning objects. Further, the MOIAR can also guide the learner to from one real-life learning object to others marked by object identification tags. The 5R adaptive mechanism can tailor the learning contents according to the learner's learning profile and status and the mobile device's current location. The MOIAR application can not only identify the objects of interest but also provide the contents of interest. The 5R adaptive mechanism helps the learners in constructing more meaningful knowledge because the learning process and learning contents are integrated with societal culture, life-context, and personal learning preferences.The focuses of this research are on the algorithm development and its implementation to support using AR technique in location-based mobile learning setting. Further research should be on how the AR technique enhances the mobile learning application and how the MOIAR has impacted on the learners in the mobile learning setting.

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