

# The 5R Adaptation Framework for Location-Based Mobile Learning Systems

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## **ABSTRACT**

Utilizing the location-awareness of mobile devices in developing innovative mobile application system has attracted much attention of academic researchers and commercial application developers. Location-based mobile learning systems have taken the advantage of the mobile devices to enhance learner's interaction with the learning context. This paper presents the 5R adaptation framework for location-based mobile learning system, which takes learner, location, time, and mobile device into learning contents generation process and implements a wide-ranging adaptation in the mobile learning environment. As a result, a standard structure for adaptive mobile learning system is proposed.

## **Author Keywords**

Adaptation framework, Location-based mobile learning system, Adaptive learning, location-awareness

## **INTRODUCTION**

Over the past few years we have witnessed significant progress in mobile learning technologies and relevant enabling technologies in computing and information systems. Yet, there are still many challenging issues regarding realizing personalized adaptive mobile learning systems from various perspectives, such as information retrieval, personalized knowledge management, context-aware mobile services management, and so on (Sharples and Roschelle, 2010; Clough, 2010; Garaj, 2010). In this paper, we introduce a conceptual framework for the implementation of adaptive mobile learning systems and discuss an ontology model of the framework in which the factors of learner, location, time, and mobile device are considered in generating personalized learning contents.

The challenge of facilitating mobile learning and ensuring learners' performance depends on appropriately identifying characters of particular learner, the context of learning process and instruction, learning environment and mobile device; and presenting or generating personalized learning contents and instructions dynamically. The time based requirement makes the challenge even harder. On the other hand, predefining adaptive learning contents that might play one-size-fit-all may be costly or impossible in the dynamic mobile learning environment. In general, context-aware systems are expected to acquire and utilize information on the context of a mobile device in order to provide services that are appropriate to particular person, place, time, event, etc. These systems aim to provide context-aware access to information, communication and computation (Hong, 2009, Dey, 2001, etc.).

The semantic technology and ontology based methods are emerging as promising approaches to leverage the presentation and retrieval of dynamic context (Roy, 2010). They can play similar roles in location-based mobile learning to facilitate adaptive learning and personalized learning activities in dynamically changing environment. The challenge facing the development of location-based adaptive learning applications is the ability to deal with these contexts from learning perspective. In doing so, one of the key strategies is to identify and normalize context information based on efficient context-aware data fusion (Roy, 2010) and semantic-based context constraints using composable ontology models. The ontology-based approach uses predefined metadata models of the learning contents, learner models, context information of the learning activities, and mobile device, etc., to retrieve structural and unstructured learning materials and generate personalized, just-in-time, and location-aware learning contents or adaptive “filter” that directs mobile learner to access right contents. In general, as Mitchell, T., etc. pointed out (Mitchell, T., etc. 2009), the future impact of the semantic web will depend critically on the breadth and depth of its content. One can imagine several approaches to constructing this content, including manual content entry by motivated teams of people, convincing owners of existing databases to publish them on the semantic web, and automatically extracting structured information from the vast quantity of unstructured online text (Tom M. Mitchell, Justin Betteridge, Andrew Carlson, Estevam Hruschka and Richard Wang, 2009). In the mobile elearning application domain, we believe that the ontology-based adaptive learning contents could be generated in the similar patterns of these approaches but we want to explain a little more about the features of these approaches since detailed methods depend on specific application domain and particular requirement of adaptive mobile learning. The first approach is to create semantic learning contents manually. A second approach is to take advantage of pre-existing learning objects and to develop shareable ontologies, publishing learning objects standard, and reward mobile service system to make the learning objects widely accessible. The third approach is to develop software and knowledge retrieval mechanism that automatically identifies appropriate learning components and extracts structural knowledge from unstructured learning contents, e.g. students’ discussion forum, and structured learning contents distributed on the web. The third approach depends on so-called near-term approach and uses macro-reading strategy to deal with dynamically changing contents on which emergent socially networked mobile learning or collaborative learning may heavily depend. In our research, we use the second approach to conduct bottom-up development of the ontology for the personalized learning objectives, learning context information and proposed 5R constraint information. We also use the third approach to build and manipulate adaptive “filter” to direct just-in-time retrieval paths during the mobile learning processes. Proposed 5R constraints can be semantically presented and accessed during the automatic decision making process for generating personalized learning content “filter”.

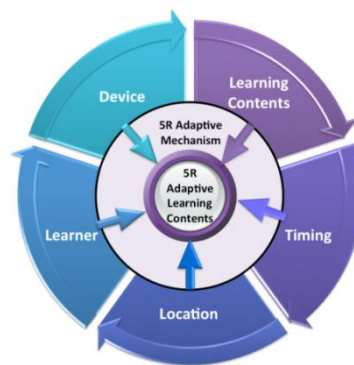
The location awareness of the mobile devices provides a distinguishing ability for mobile learning systems to interact with the learning context in mobile learning environment. Enabling the context-aware feature makes mobile devices stand out as a learning media and motivates the development and innovation (Tan et al., 2009). In this paper, the mobile learning is considered non-formal learning but is an organized and structured method of learning external to the formal learning environment. Therefore, learning contents are pre-developed and stored in the learning contents repository of the learning management system. On the other hand, mobile learning is described as learning anytime and anywhere. How to generate learning contents to accommodate when and where the learning is happening is a challenge to the learning management system. The proposed 5R adaptation framework for mobile learning system

provides a solution and a standard structure for implementing a wide ranging adaptation in mobile learning environment.

In the following section, the 5R adaptation framework will be explained, followed by the discussion on the significance of the framework. This will be followed by the description of how the 5R adaptation framework works. A scenario study will then be presented to show how to apply the framework. Finally, the paper will be concluded with the discussion on some future directions.

### THE 5R ADAPTATION FRAMEWORK

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.** This concept, proposed in 2009, aims to enrich adaptive mobile learning by taking the factors of learner, location, time, and mobile device into the adaptation process. The 5R adaptation framework, shown in figure 1, has been gradually developed to continuously enhance its mechanism by applying the 5R concept to the research on location-based mobile learning (Chang and Tan, 2010). The 5R adaptation framework imposes the adaptation constraints of the learner, the location, the time, and the mobile device on the learning contents through the 5R adaptation mechanism to generate the 5R adaptive learning contents. The intention of introducing the 5R adaptation framework is to create a standard structure for mobile learning application systems to implement a wider range of adaptation in mobile learning environment.



**Figure 1 The 5R Adaptation Framework**

**The Right Time:** The time in the adaptation framework indicates two factors, the date-time and the learning progress. The learning contents are developed and stored in the learning management system. Some of the learning contents are with date-time constraint, which means accessing the learning contents depends on when they are available, such as the contents in a lab, library or museum would be available only when these venues are open. On the other hand, learner's learning progress is considered as a time sensitive factor because it can be used as a reference for providing up-to-date learning contents to the learner. Since mobile learning can be conducted anytime, by including the time constraint into the adaptation framework, the mobile learning system is able to provide the learning contents at the right time to the learner accommodating when the learning takes place as well as where the learner is in terms of learning progress.

**The Right Location:** the location in the adaptation framework indicates the learner's current geographic location. The location-awareness of the mobile device can be employed to sense the current geographic location of the mobile learner who possesses the mobile device being used to conduct mobile learning. Therefore, in a mobile learning environment, the location-based learning contents can be implemented to enhance the contextual interaction for learners. Location-based learning contents are those learning

objects that are tied with particular locations. When a mobile learner is physically at or near a particular location, the learner could be assigned to conduct location-based learning activities, such as to visit, observe, and experience the learning objects and to complete learning tasks (fieldwork) at the location. Because mobile learning can be conducted anywhere, by including the location constraint into the adaptation framework, the mobile learning system can provide the right location-based learning contents to the learner according to where the learning takes place. The ability to provide the location adaptation in learning is the unique feature of mobile learning. The key features provided by 5R adaptation framework distinguish location-based mobile learning from traditional adaptive learning.

***The Right Device:*** the device in the adaptation framework refers to the learner's mobile device that is used to conduct mobile learning. The device adaptation is also the distinctive feature of mobile learning compared with other computer- assisted learning scenarios. In the location-based mobile learning environment, client mobile software application needs to run on the mobile device to access the mobile device's native hardware and features. The mobile devices are heterogeneous with multiple operating platforms and they have different and limited user/device interaction capabilities (Tan and Kinshuk, 2009). Therefore, it is essential to provide the right format of learning contents to the right mobile device in order to properly render the contents and to enhance the capability for the learner to interact with the learning contents. The device constraint in the adaptation framework will provide learners the best possible learning experience through mobile device.

***The Right Contents:*** the contents in the adaptation framework include learning objects, learning activities, and leaning instruction. The learning contents can be raw learning materials or pre-developed structured learning materials stored in the learning contents repository of the learning management system. The learning contents can be constructed or retrieved based on the learning objectives and outcomes, pedagogy and structure. The right learning contents will suite the learner's learning objectives and learning style, the particular time and location as well as the mobile device that is being used by the learner to conduct mobile learning. On the other hand, because the learning contents are the knowledge resource of the mobile learning environment, the learning contents generation is crucial. How to collect and develop learning contents into the learning contents repository is very important aspect in developing the mobile learning environment. The learning contents in the learning contents repository have to be properly described and tagged so that the contents could be easily constructed and retrieved by the adaptation mechanism. The physical location-based learning objects, which are either indoor or outdoor, have to be properly tagged in order for the mobile devices to sense or identify them automatically or manually.

***The Right Learner:*** the learner in the adaptation framework is the person who conducts learning through mobile device in the mobile learning environment. A learner plays the main role in mobile learning. In this 5R adaptation framework, a learner's learning profile and learning style have been taken into account in order for the learning system to identify the learner's individuality and personality among the learners in the mobile learning environment. The learner's information contains the static and dynamic data mainly including the learner's learning objectives, learning progress, learning behaviors, and learning assessment results. The data is either manually entered into or automatically collected from the learning management system before or while the learner conducts his/her learning in the mobile learning environment. The right learner means that the learning objects provided, the learning activities assigned, and the pedagogy used by the learning management system to the learner match the learner's learning profile and learning style .The learner's learning patterns and behaviors could also be used to build the learner's learning model to dynamically update the learner's personal information, to effectively analyze and predict the

learner's learning performance and outcomes, and to provide the learner with optimized and personalized learning assistance.

**The 5R Adaptation Mechanism:** the adaptation mechanism consists of the adaptive mathematic model, algorithms, and controls to process the inputs and to generate the 5R adapted learning contents for the learner in the mobile learning environment. The adaptive mathematic model is represented in equation 1,

$$C_R(i) = \mathcal{R} (C(i), (L(i), T(i), P(i), D(i))) \quad (1)$$

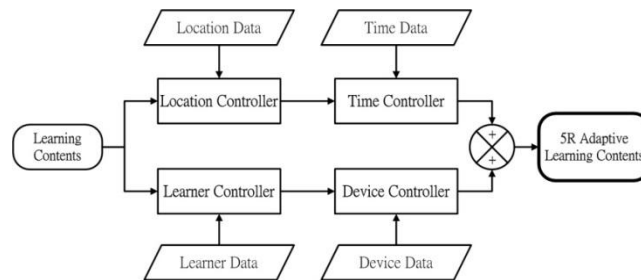
where  $C_R(i)$  is the output of the 5R adaptation mechanism representing the right learning contents,  $C(i)$  is the input representing learning contents,  $L(i)$  is the input representing the location constrains,  $T(i)$  is the input representing the time constrains,  $P(i)$  is the input representing the learner constrains,  $D(i)$  is the input representing the mobile device constrains, and  $\mathcal{R}$  is the mathematic representation. The  $\mathcal{R}$  could be varied according to the complexity of the 5R adaptation mechanism. It could be just set representation, so the output is simply an intersection set of the input learning contents set with the union set of other 4 input sets as shown in equation 2,

$$C_R(i) = C(i) \cap (L(i) \cup T(i) \cup P(i) \cup D(i)) \quad (2)$$

or it could be more complicated matrix representation as shown in equation 3:

$$\mathbf{C}_{R^{(i)}} = \begin{bmatrix} C_{R-L^{(i)}} \\ C_{R-T^{(i)}} \\ C_{R-P^{(i)}} \\ C_{R-D^{(i)}} \end{bmatrix} = \begin{bmatrix} L_1 & T_1 & P_1 & D_1 \\ L_2 & T_2 & P_2 & D_2 \\ \vdots & \vdots & \vdots & \vdots \\ L_n & T_n & P_n & D_n \end{bmatrix} \begin{bmatrix} C_{L^{(i)}} \\ C_{T^{(i)}} \\ C_{P^{(i)}} \\ C_{D^{(i)}} \end{bmatrix} \quad (3)$$

in which  $\mathbf{C}_R(i)$  matrix is one of the right learning contents, the  $4 \times n$  matrix represents the controls generated from each constraint input model or algorithm, the  $\mathbf{C}(i)$   $4 \times 1$  matrix represents one of the input learning contents, and  $C_L, C_T, C_P$  and  $C_D$ , respectively represent location, time, learner, and device properties of the learning contents. The processing model of the 5R adaptation mechanism is shown in figure 2. The processing model could be different from the one shown in figure 2, and obviously their processing performances would therefore be different.



**Figure 2 The 5R adaptation mechanism process model**

## **THE SIGNIFICANCE OF THE 5R ADAPTATION FRAMEWORK**

Traditionally adaptive learning indicates personalized teaching and learning. The learner as a stakeholder in learning is the essential focus of any education system and education technology. Adaptive education has been a very important educational method for more than two-thousand years, since at least the Confucius time. However, classroom-learning environments are typically not conducive to such adaptive education. With the development of computer technology and the Internet, eLearning or online learning has become more and more popular, allowing learning to be conducted on the individual basis. The learning contents and pedagogy can be designed to accommodate the individual learner's needs and convenience. eLearning provides a platform to implement adaptive learning approach, which can facilitate learning communication and collaboration to transform the learner from passive receptor of information to collaborator in the educational process (Paramythis and Reisinger, 2004).

Mobile learning is considered as an extended form of eLearning with its own characteristics. In the location-based mobile learning environment, the 5R adaptation framework naturally focuses on the mobile learner. The motivation of the framework is to provide mobile learners with adaptive learning contents based on their learning profiles and learning styles, additionally to adapt mobile learners' current locations, times and devices. Furthermore, a location-based learning object could be associated with different learning contents to serve different learning objectives. For example, for a historic building used as legislative assembly of a province, a learner in the history discipline could be provided with the location-based learning contents related to the building's history while a learner in political science could be offered politics related information. In the 5R adaptation framework, the same learning contents could be constructed differently according to the learners' learning styles, which could significantly impact the learners' learning performances.

It is not very common to include physical sites and objects, such as historic places, geographically and geologically interesting spots, interesting architectures, landmark buildings, and museums in course materials as the learning objects if they are far from instructor's location, even if they may be right next to where the learner is. In the location-based mobile learning environment, the learner is supposed to be mobile and the learning can be conducted anytime and anywhere, and therefore, it is possible to implement the location-based learning and to assign location-based learning activities to the learners in related sites and with objects where the learners are. In the mobile learning environment, the location-based learning contents have their location and time properties, i.e. they are tagged by location and time. One learning content can be associated with many location-based learning objects that could be physically distributed in different geographical locations. The mobile learning system is required to be able to track down where the learner is and to know which location-based learning objects are near the learner and if they are accessible at this time. Thus, the system has the capability to automatically alert the learner when the learner is approaching or is at a particular location, and then guide the learner to study with those learning objects. With the 5R adaptation framework, by knowing the learner's current location and time acquired from the learner's mobile device as well as the pre-registered information of the learner and his/her mobile device, the system can use the data as the constraint input for the 5R adaptation mechanism to retrieve or construct the learning contents from the location-based learning contents repository and to provide the right learning contents to the learner at the right time in the right location. Within the 5R adaptation framework, the learning system provides the adaptive

learning contents that not only have personalized adaptation but also have location, time, and device adaptation.

In the mobile learning environment, proper delivery of the learning contents through the mobile device has huge impact on the learner. Because of the heterogeneity and limited user interface size and functionality of mobile devices, a learner could be very frustrated by not being able to display the learning contents, such as not being able to see flash components on an iPhone, restricted layout, difficulty in the interaction with the device, and so on. Therefore, device adaptation becomes an important issue in mobile learning. The adapted learning contents lead learners to concentrate on the learning contents and to conduct their learning effectively and pleasantly. Contents presented out of context could cause huge distraction and demotivation. In the 5R adaptation framework, knowing learners' mobile device information, the system is capable to choose learning contents in the right format for the learners' mobile devices in order to greatly improve the learners' learning experiences in the mobile learning environment.

### THE IMPLEMENTATION OF THE 5R ADAPTATION FRAMEWORK

To implement the 5R adaptation framework in the location-based mobile learning environment, two critical aspects need to be considered, namely location-based learning contents creation and 5R adaptation mechanism design. In order to implement the framework, it is essential to solve the issues of how to describe or tag the location-based learning contents and how to build the relationship among the four adaptation constraints and learning contents.

**The 5R Components Ontology:** the term “ontology” in the 5R adaptation framework is used to describe the five adaptation inputs, to identify the data structures, to explicitly and formally specify their relationships, unlike the way ontology usually uses “terms” to denote the important concepts as classes of objects and “relationships” to include hierarchies of the classes (Antonious, and van Harmelen, 2008). The ontology of the 5R inputs is shown in figure 3.

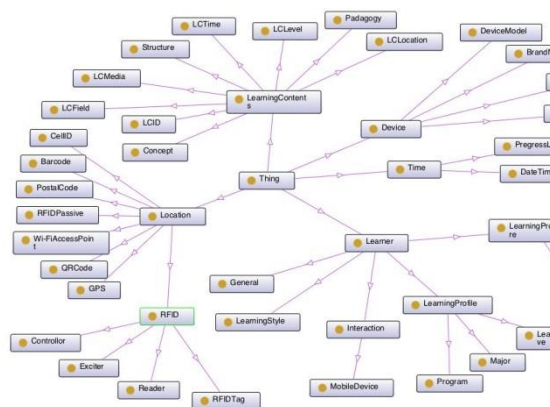


Figure 3 The 5R components ontology

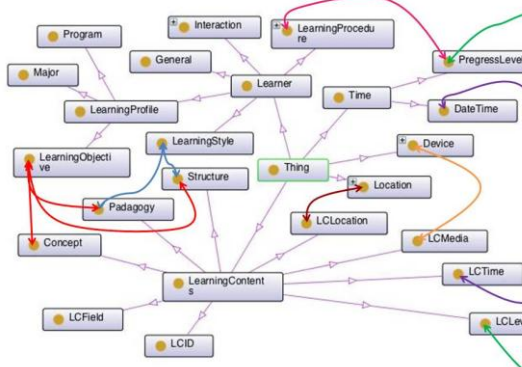
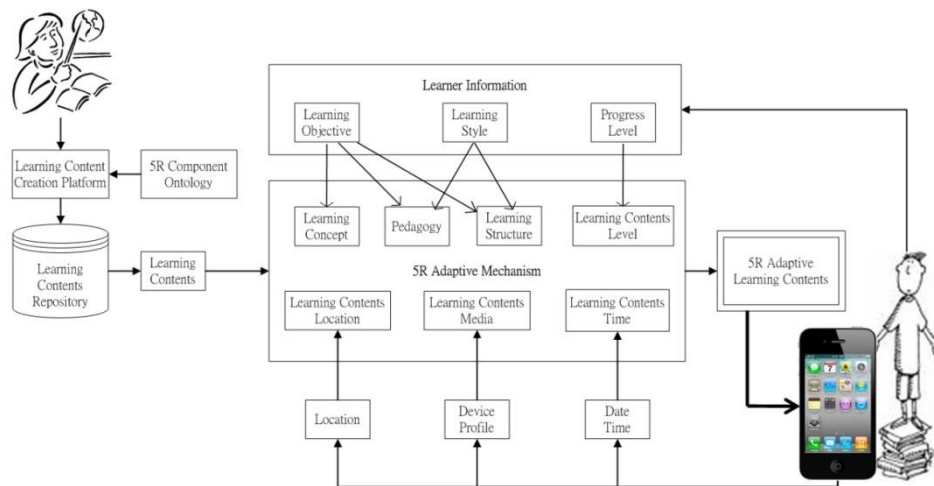


Figure 4 The 5R inputs ontology schema

In figure 3, the “Thing” represents the 5R adaptation inputs. The first layer consists of “Location”, “Time”, “Learner”, “Device”, and “LearningContents”, respectively representing the five adaptation inputs. The second layer is the further description of information or data of each adaptation input. Further extension of the hierarchies of each adaptation input in the ontology depends on whether there is enough information to describe and relate the input with other inputs in the 5R adaptation framework in order to execute the

adaptation mechanism. The ontology scheme, namely, the relationships among the adaptation inputs is shown in figure 4, which illustrates why the inputs need to be described as shown in figure 3 and how the inputs are interconnected.

**The Adaptive Mobile Learning System Architecture:** the system architecture is designed based on the 5R adaptation framework. The adaptation mechanism and process shown in figure 5 reflect the conceptual ontology schema illustrated in figure 4. In the mobile learning application system, a location-based learning contents creation platform is used for the instructors to develop location-based learning contents. The platform is designed based on the 5R input ontology that ensures all the learning contents developed to be used by the 5R adaptation mechanism. Moreover, the 5R adaptation mechanism could be viewed as a meta-architecture for the application system architecture in which different design or implementation strategies could be applied as long as the architecture and functions of mobile learning application comply with the 5R adaptation constraints and key relation models. Different applications of the 5R-constrained implementation may have different system performance, usability, maintainability, cost, and so on, but the system-level balance and optimization should be conducted to reach specific goals.



**Figure 5. The 5R adaptation mobile learning system architecture**

### THE 5R ADAPTATION FRAMEWORK APPLICATION SCENARIO

In this section, location-based mobile fieldtrip applications using visualized interaction with dynamic geospatial data are presented as a scenario for applying the 5R adaptation framework.

Understanding the concepts and mechanism of glacial processes in geomorphology study is part of learning tasks in geography course. With the help of the fieldtrip, students can better understand why glacial landscapes look the way they do, understand landform history and dynamics, and predict future changes through a combination of onsite field observations, physical experiments or analyses, and numerical modeling based on the onsite data collection, measurement and analysis model.

As illustrated in figure 6, students in the ice fieldtrip are arranged into different groups in which they conduct the field observations in specific zones around ice field, such as main glacier, medial moraine, truncated spurs, or cirques, and so on. When students enter a specific zone, the system automatically



retrieves relevant learning contents and provides location-based visualized interaction with students who observe the features of the landform, measure and collect data, and enter the data and annotation into the system via visualized fieldtrip interaction language provided in the mobile application.

***The 5R adaptation features represented in this scenario:***

*1. Location-based experiment Lab interface and visualized interaction on mobile devices*

Fieldtrip Lab experiment system is a location-aware application on mobile devices that provides students with visual language or manipulation functions to allow them to conduct all learning and experiment activities through mobile devices in the field. The conceptual architecture of the system is illustrated in figure 7.

*2. Adaptive learning content retrieval constrained by the location and ongoing fieldtrip activities*

System responds to the individual student requests based on student's learning objectives in the fieldtrip and student models, and provides individual students with adaptive content links to the course material to fit specific requirement in the fieldtrip study and experiment activities at the location with the right format matching to the student's mobile device.

*3. Visualized fieldtrip plan, real-time activity collaboration and monitoring during the fieldtrip, as illustrated in figure 6*

Visualized fieldtrip planner allows students to plan collaborative learning activities in the fieldtrip in terms of the location selection, schedule, and students' decision making for joining or disjoining pre-existing study groups or regrouping upon various learning objectives or changing fieldtrip activities in the dynamic environment. The fieldtrip process monitor allows students to observe their own activities and current locations through visualized monitor application.

*4. Dynamic annotation or blog on the visualized semantic physical object model, as partially illustrated in figure 6*

One of important tasks for the student in the fieldtrip is to collect data and do instant analysis and collaborative study using the data and course materials in the context of the trip activities. Visualized semantic physical object model represents spatial relations between the physical onsite objects and students' activities surround those objects in the semantic information so that the fieldtrip management system could real-timely track students' context in the fieldtrip and leverage the advanced functions of automatically retrieving information generated during the fieldtrip, such as current location, ongoing tasks at the location, and annotation or data collection at the location. All the interactions between the student and the mobile device and the collected data onsite are stamped by the time and the location.

*5. Real-time sharing experience between students and others who are in the field or in remote areas via visualized virtual interaction interface*

Onsite collaboration and sharing various learning activities and data collection experience between geographically distributed learners during the fieldtrip experiment process are the key features in the system. Visualized virtual interaction interface allows for retrieving available XML-based geographic annotation, adding individuals' annotation, and uploading XML-based geographic annotation into remote geographical information programs, such as Google Earth etc., and for browsing visualized fieldtrip information and real-time data from individual mobile browsers.

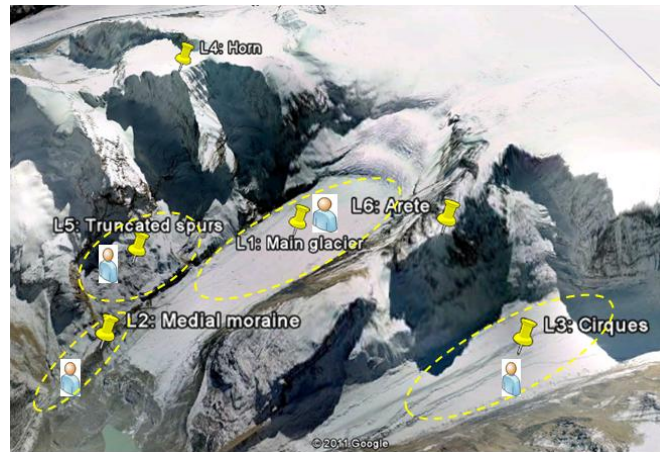


Figure 6 Fieldtrip in the different zones of the ice field

### CONCLUSIONS

This paper introduces a principle framework to leverage the application system design and implementation towards proposed 5R constrained adaptive mobile learning systems. The 5R adaptation framework could be used as a meta architecture to guide or constrain the development of a specific mobile learning system by means of particular requirement of the learning objectives, learning activities, learners' characters, the features of mobile services and environment in which the adaptive mobile learning activities conduct. The paper demonstrates how the 5R adaptation framework has been applied in our ongoing project using mobile applications for the geography fieldtrip study. The scenario illustrated in the paper extends the view on what 5R adaptation means in the mobile learning applications and how flexible it is to be realized. With the rapid development of mobile technologies, new features of mobile devices will become available to enhance the adaptation constrains and the 5R adaptation framework is also expected to evolute more and more sophisticate. In order to effective implement the 5R adaptation framework, future study should also address the 5R adaptation mechanism in order to find the optimal solutions for adaptive mobile learning.

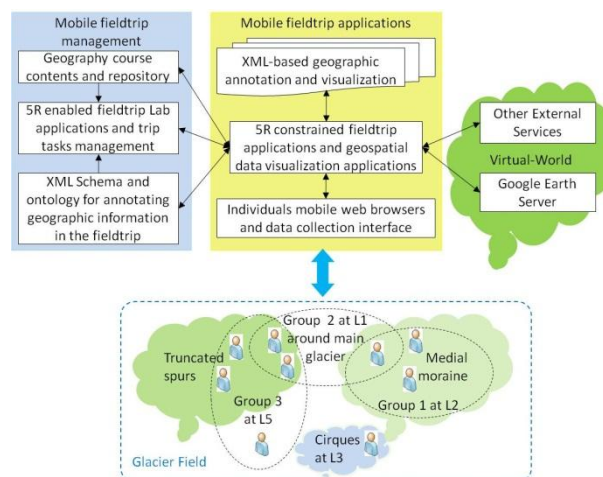


Figure 7 The conceptual architecture of the Location-based mobile fieldtrip application system

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