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Technical Feasibility of a Mobile Context-Aware (Social) Learning Schedule Framework

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ABSTRACT

The purpose of this paper is to show the technical feasibility of implementing their mobile context-aware learning schedule (mCALS) framework as a software application on a mobile device using current technologies, prior to its actual implementation. This process draws a set of compatible mobile and context-aware technologies at present and can be used as a reference point for implementing generic mobile context-aware applications. The authors' mCALS framework retrieves the learner's location and available time contexts via the built-in learning schedule (i.e., electronic organizer) on a mobile device. These contexts together with the learner's learning styles and knowledge level (on a selected topic) are used as the basis for the software application to suggest learning materials that are appropriate for the learner, at the time of usage. This retrieval approach eliminates the use of context-aware technologies and the need to directly request the user to enter context information at the time of usage. The authors develop a fully functional prototype of this framework for learners to plan their individual as well as social learning activities amongst one another to make their individual learning processes collaborative and as a way to enhance individual and social learning experiences.

Keywords: *Context-Aware, Context-Aware Technologies, Mobile Context-Aware Learning Schedule Frameworks (mCALs), Mobile Learning, Technical Feasibility*

1. INTRODUCTION

The aim of our study is on mobile learning (hereafter, abbreviated as m-learning) and mobile social learning, particularly learning in different locations and under various contextual situations, from the perspective of university students, individually or collaboratively with others. We initially derived and designed a theoretical *mobile context-aware learning schedule (mCALS) framework* (Yau, 2011) from an extensive literature review. The objective of the framework is to recommend appropriate learning materials to students based on their current locations and circumstances. The framework uses a learning schedule (i.e. the built-in electronic organiser on mobile devices) to record learners' study-related and unrelated events, as well as information regarding the events (including the location, start and finish times) are stored. Subsequently, this information is used to inform the location and available time a student has for learning/studying at specific points in time. Additionally, a number of factors are taken into consideration for the

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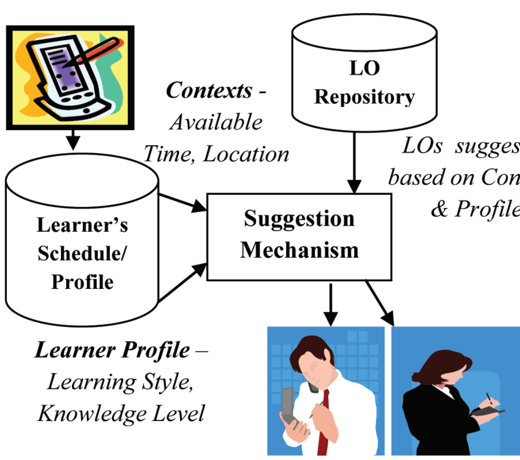
recommendation of appropriate learning materials to students. These are the student's learning styles, knowledge level, concentration level, frequency of interruption at that location and their available time for learning/studying. The suggestion mechanism suggests to learners appropriate learning materials from the learning object (hereafter, abbreviated as LO) repository within our framework, for learning at that length of time and type of location. We propose that this learning schedule retrieval approach can be 1) a successful self-regulated learning strategy as the act of pre-planning of studying events can be motivating for self-regulated learners to carry out their studies; 2) an effective method for eliminating the use of context-aware technologies and the need to directly request context information from users, at the time of usage; and 3) a successful environment in which to facilitate social learning opportunities. Figure 1 shows the conceptual model of mCALS.

In order to determine the potential deployment of the framework as an m-learning application by intended users, we carried out six feasibility studies. First, a pedagogical study was conducted using interviews to explore together with students (a) what their learning requirements were when studying in a mobile environment, (b) whether the framework could potentially be used effectively to support their studies and, (c) using this user-centred understanding, refined user requirements of the framework. Second, a diary study was conducted where we collected data and analysed the usability feasibility of the framework by (a) determining whether students could plan their daily schedule ahead and keep to it, (b) ascertaining which learning contexts were important and, (c) establishing which learning materials were appropriate under which situations (Yau, 2011). The results from our completed diary study suggested that participants were mostly in their planned locations as the planned and actual locations had matched entirely. There were discrepancies between the planned and actual start and finish times, suggesting that the actual available time of a learner may not always be retrieved accurately. In the light of this, we propose to use the retrieved location and available time as default values which will then be verified by location-detecting technologies and by the learner. More precisely, two verification methods can be added to strengthen our framework – 1) GPS and Wireless LAN technologies to verify the learner's location, and 2) a request for learners to confirm whether the retrieved available time is accurate.

Two validation studies relating to the framework were also conducted. The first one was an online experiment utilizing Java LOs.

Figure 1. Conceptual model of mCALS

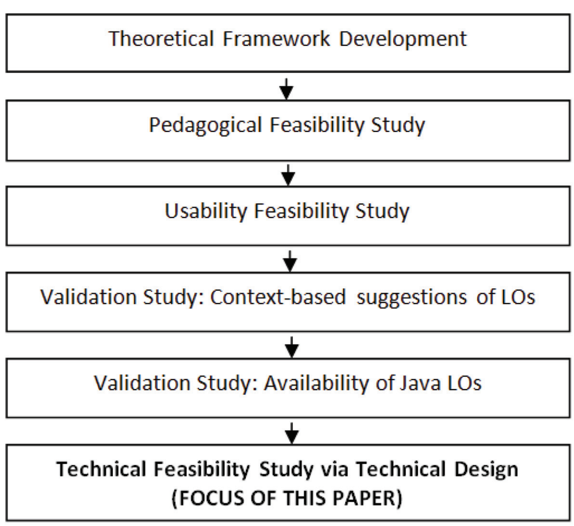


Participants of this study were suggested appropriate LOs to study with, based on their amount of available time, current motivation level for learning and their proficiency level of Java. The second validation study was an investigation into high-quality Java LOs available in the public domain (Yau, 2011). Finally, a technical design of the framework was carried out to determine whether the framework at present could realistically be implemented using current mobile technologies. This paper presents the results of this technical feasibility study, which offers a fast approach to demonstrate that our framework is implementable, without the substantial resources required to actually implement and deploy such a mobile software application. If the application were to be implemented, it may also very quickly be out of date in one or two years' time, given the fast development of computer technologies. Figure 2 shows the studies conducted for designing and evaluating mCALS. Note that all phases of the studies have been completed, and can be found in Yau (2011).

The data analyses of the three feasibility studies and two validation studies show that (a) a learning schedule approach is successful to an extent in obtaining location and available time information to indicate accurate values of these contexts, (b) different learners may require different personalization strategies when selecting appropriate learning materials for them in mobile environments, and (c) the mCALS framework is particularly well-suited for self-regulated students. The validation studies show that 1) the proposed suggestion rules are effective in recommending appropriate materials to learners in their situation, in order to enhance their learning experiences, and 2) there is a sufficiently large number of high-quality LOs available in the public domain that can be incorporated for use within our framework. Finally, the development of mCALS has been considered from three perspectives – *pedagogical, usability* and *technical*. These perspectives consist of critical components that should be considered when developing and evaluating m-learning software applications.

This paper reports the results of the final phase, the technical feasibility study. The structure of the paper is as follows. The technical feasibility study is introduced in section 2, and the potential individual component technologies are discussed. In section 3 we examine how the component technologies can be integrated together to form an implementation of mCALS,

Figure 2. The studies conducted to design/evaluate mCALS



and section 4 is devoted to a discussion of how the mCALS framework supports social learning activities. In section 5 we conclude and offer suggestions for future work.

2. TECHNICAL FEASIBILITY STUDY AND COMPONENT TECHNOLOGIES

In order to establish whether our framework is technically feasible, and how it might be used to create social learning opportunities, we examined four components of the framework:

- Calendaring technologies for the learning schedule;
- Location verification technologies;
- Learning object and learning style support for learning contexts;
- Learning systems supporting suggestion rules.

Consideration was then given to how these components can be integrated together into the framework implementation, and the framework can then be extended for creating social learning opportunities.

2.1. CALENDARING TECHNOLOGIES FOR THE LEARNING SCHEDULE

Our proactive approach of using a learning schedule is a simple and effective technique for retrieving a learner's location and available time, via their built-in electronic diary on mobile devices. Currently, most Windows CE-based, Apple Mac-based and Linux-based mobile computers, smartphones and PDAs contain built-in electronic diaries/calendars; these diaries can also be used and accessed offline. Online diaries can also be accessed via the web, for example, through Microsoft Outlook 'web access' features or using a web calendar such as Google Calendar. Events stored on the latter calendar can also be synchronised with Microsoft Outlook, Apple iCAL and Mozilla Sunbird calendar applications. A read-only version of Google Calendar can also be viewed offline.

The Microsoft Office Outlook Mobile calendar application can be installed on most Windows-based mobile phones or computers. If necessary, calendar events stored on the desktop or laptop computers can be synchronised to the mobile device (and vice versa), via the mobile network, a wired or wireless connection. Outlook Mobile is compatible with Windows Mobile 5.0 and 6.0 and works on both touch and non-touch screen mobile phones or devices.

Palm Pilot, Psion, and Timex Data Link Watch were found to be popular personal organisers (Brown & Crawshaw, 1998), and an investigation of PDAs for the use of electronic diaries was conducted by Drury (1999) showed that the Psion Series 5 PDA was useful for users who require additional office applications, the Franklin REX PRO was useful for users who wished to simply replace their paper-based diary, and the 3COM Palm Pilot III was suitable for users who were in-between these two scenarios. Whilst these are now old technologies, it is useful to note that richer calendaring is an established functionality of mobile devices.

A user's location and available time at a particular point in time can easily be retrieved from the learner's events stored on any of the calendar applications built into or installed onto mobile devices, such as those mentioned above. Users would include for each of their events the following information – geographic location, type of location, time start, time finish and nature of the event.

Via the standard Microsoft Import/Export (from and to vCal/iCal) feature, Outlook calendar applications can automatically convert events information into iCalendar format (and vice versa), this format is known as .ics or .ical format. Note that vCal was the standard used prior to iCal. This feature also enables calendar events (or calendar-based data) to be easily sent to other users via email and the receiver can easily accept or decline the proposed events. An add-in for Microsoft Outlook, for example SyncWiz, gives additional benefits such as allowing Outlook calendar events (and contacts) to be exported, imported, backed up and synchronised to other mobile, desktop and/or laptop computers.

Overall, the purpose of the iCalendar format is to provide compatibility for capturing and exchanging calendar and scheduling information between events stored on a calendaring and scheduling application (such as Personal Information Manager (PIM) or a Group Scheduling product) and other applications. The iCalendar format is a suitable exchange format between different applications or systems because it is defined in terms of MIME content type. iCalendar objects can be exchanged via several transports - such as SMTP, HTTP, a file system, desktop interactive protocols, point-to-point asynchronous communication, wired-network and unwired transport (Dawson & Stenerson, 1998).

In order to illustrate how the location and time available at a particular point in time can be retrieved from users' events, the following example of an iCalendar object is given in Box 1.The code illustrates an event occurring on 14 August 2011, 09:00:00 until 09:59:59, and taking place at University Campus in a lecture theatre.

The iCalendar Core Object Specification (Ibid) is primarily used for providing a standard capturing means for calendar events, to-do and diary/journal entry information. Additionally, it can be used to convey free/busy time information as well as allowing iCalendar object methods to be defined. Such a method is a set of usage constraints for an iCalendar object. Dawson and Stenerson (1998) identified a number of methods that can be defined to carry out certain tasks such as a) to request an event to be scheduled, b) reply to an event request, c) send a cancellation notice for an event, d) modify or replace the information of an event, e) reply to a free or busy time request and so on.

An open source Python library for parsing iCalendar data was constructed by Max (2006). The class method Calendar.from_string() can be used to parse the text representation of the calendar data in order to create a Calendar instance with their attributes described in the input data. When a Calendar object had been instantiated, the walk() method can be used to process each attribute in the calendar event. In order to access individual attributes, the getitem() API can be used (Hellman, 2007). The script in Box 2 written in Python for retrieving a learner's location and their available time has been adapted from (Ibid).

2.2. Location Verification Technologies

To counter against the possibility that learners are not adhering to their schedules entirely leading to the retrieval of their current locations and available times being inaccurate, two additional methods have been incorporated into our framework:

1. Location-verification methods, using context-aware sensor technologies such

Box 1.

```
BEGIN:VCALENDAR
VERSION:2.0
PRODID:-//hacksw/handcal//NONSGML v1.0//EN
BEGIN:VEVENT
DTSTART:20110814T090000Z
DTEND: 20110814T095959Z
GLOCATION: University campus
TLOCATION: Lecture theatre
SUMMARY: Lecture
END:VEVENT
END:VCALENDAR
```

Box 2.

```
from icalendar import Calendar, Event
cal_data = Calendar.from_string(open('events.ics', 'rb').read())
//For parsing the text representation of calendar data, as described above.
for event in cal_data.subcomponents:
if event.name == 'VEVENT':
print 'GEOGRAPHIC LOCATION:', event['GLOCATION']
print 'TYPE OF LOCATION:', event['TLOCATION']
// The above 2 lines obtain both the geographic and type of locations of the event, then outputs them.
getCurrentTime () = currentTime
availableTime = event['DTSTART'] – currentTime
print availableTime
// The above 3 lines obtain the current point in time and the start time of the learner's next event to determine their available time, which is then outputted.
```

as GPS, or a location-based positioning technique such as Wireless LAN, can be used for retrieving and verifying the location of a learner. A GPS receiver can detect the appropriate outdoor locations and the Wireless LAN positioning technique can detect both indoor and outdoor locations using a wireless network connection. The location information is used to alert the system when and if the retrieved and scheduled location does not match and for identifying the learner's actual location in order to confirm whether they are keeping to their schedule.

2. A user-verification method i.e. an interactive approach for requesting users to confirm that their available time was accurately retrieved. This prompts the user at the beginning of a learning session to check and/or indicate whether their available time that that tool had retrieved was accurate, and this information is used to update the schedule, if necessary. When necessary, the user is asked to input their available time into the system.

2.2.1. Overview of Various Technologies Used for Location-Tracking in Different Applications

GPS receivers have been used by several researchers including Fithian *et al*. (2003), Ogata and Yano (2004a; 2004b), Ryu and Parsons (2008), and Gil (2012) for detecting the location of learners. Note that GPS may not always be reliable and accurate especially when recording travelling GPS data, such as when students travel from location A to location B (Kochan *et al.*, 2006; Gil, 2012). Our work did not consider transition periods as important, only the location and available time of a learner at the beginning of their learning session is important. This assumption is based on our extensive literature review and our interview data results (Yau, 2011) that learners may not always want materials to be altered if there is a change in their learning situation.

The Wireless Local Area Network (WLAN) positioning technique can be used for location-tracking and retrieval in indoor as well as outdoor environments, where signals can be retrieved from the wireless network being accessed. The location of a learner can be implied by the access point or station that they are connected to (Li et *al*., 2006). This technique was used in the language learning, butterfly-, and bird-watching applications of Chen *et al*. (2007, 2002 and 2004) respectively. In the first application, a WLAN was used to detect the location of a learner in the playground of a school environment for the suggestion of English vocabulary learning. In the latter two applications, a WLAN was not used for positioning learners but rather for transmissions to be sent to and from learners and the instructor. A WLAN card built-in or inserted into a laptop computer functioned as the local server, and learners each using a PDA equipped with WLAN acted as clients. Transmissions were sent wirelessly to and from the learner's PDAs and the local server for immediate information retrieval concerning the butterflies and birds being observed.

The WLAN positioning technique can be implemented with minimum effort, as modern mobile devices have built-in wireless access capability and the common availability of WLANs within educational institutions. The signal strengths of WLAN contribute to their accuracy as a positioning technology (Li *et al*., 2006).

In the GUIDE visitor and context-aware m-learning applications (Cheverst *et al.*, 2000; Chen *et al*., 2007), two methods were used – a location-tracking method (such as WLAN) and direct request from the users. In the latter application, learners could make corrections to their locations using a default list of locations supplied by the system. This method was also used in the work of Cui and Bull (2005).

A separate Bluetooth GPS device such as *GlobalSat BT-338* can be attached to the mobile device, such as in the work of Ryu and Parsons (2008). This is done by setting up a Bluetooth connection between a Bluetooth GPS receiver and a Pocket PC; and can be used as a substitute in those mobile devices which do not have a built-in GPS receiver i.e. the older and less expensive mobile devices models.

Types of locations (such as library, lecture theatre), as opposed to their geographic co-ordinates, can be hard-coded for location-tracking and stored in a database or SQL server. The position of a learner can then be located on the university campus map. The server can be accessed using a mobile network; the one that researchers of this work (Ibid) had deployed was Vodafone New Zealand. To relate the contextual information and the location data, a Microsoft SQL server was used and Microsoft Visual Studio 2005 was used to implement each component of the software to enable the location-tracking (Ibid). A prototype using locations defined by semantic markers associated with specific geographic positions was developed by Fithian *et al*. (2003) by replacing geographic co-ordinates with names or types of locations such as movie theatre.

Mobile devices and physical environments which were equipped with RFID writers and tags respectively can be another method of location-retrieval (Wu *et al.*, 2008; Ogata and Yano, 2004a; El-Bishouty *et al*., 2010). In the JAPELAS application (Ogata and Yano, 2004a), the implementation of their system consisted of six models – *Learner, Environmental, Educational, IR Communication, Location Manager* and *Polite Expressions Recommender*. In their Environmental model, the rooms which were used for the application were stored and can be detected by the Location Manager using either RFID tags or GPS. RFID tags were attached to indoor environments, and more precisely, to the entrance door to a room. The researchers used GPS for location-tracking of learners in outdoor environments.

In the TANGO and Chinese Language Learning applications (Ogata and Yano, 2004a; Chen and Chou, 2007), the use of their RFID reader/writer was attached onto a Compact Flash memory card which was then slotted into the memory slot of their PDA. The RFID tags could read/write within a 5 cm distance. Retrieval of the device's location was also made available using Wireless LAN. In the evaluation experiment of Chen and Chou (2007), they had attached RFID writer tags onto different parts of the walls within a classroom to represent different underground stations in Taipei.

These four main technologies described in this section are all technically feasible to deploy, as is clear from the projects we have referred to. However, each has both pros and cons, and none is the optimal solution.

- GPS is a mature and reliable technology, but does not generally work indoors.
- Wireless LANs are also reliable and provide sufficient accuracy, but are not often available outdoors.
- RFID tags can provide extra semantic location information, but require substantial

effort to set up and also require mobile devices to be physically close to the tags.
- Hard-coded co-ordinates have the same benefits as RFID tags but are likely to be less flexible to manage.

Our framework can therefore be strengthened by combining the use of GPS and Wireless LAN technologies and interactive user input, since GPS and Wireless LAN are reliable and easily implementable methods for outdoors and indoors respectively and can be accessed by receivers already contained in most mobile devices without further programming or configuration. Most modern mobile devices have built-in GPS receivers attached, and if this is not the case, a Bluetooth GPS can be easily attached to the device to achieve the same capability. Likewise, most modern mobile devices have built-in WiFi. Within our university, a strong wireless connection is available in most of the departments and buildings as well as in a number of social and administrative buildings (University of Warwick, 2012), and this supports our claim that a WLAN can be used successfully to retrieve the location of a learner located within these buildings.

2.3. Learning Object and Learning Style Support for Learning Contexts

Our framework incorporates Java LO and a LO typically includes a set of rich metadata for describing which learners are appropriate for that object. Six advantages of constructing learning materials as LOs were identified (Yau, 2004), as follows.

- *Flexibility* of learning materials since LOs were initially designed to be used in multiple contexts.
- Metadata tags facilitate *ease of updates, searches* and *content management*.
- **Customization:** A personalized learning experience for each individual learner is easier to be constructed due to the modularity of LOs.
- **Interoperability:** LOs are compatible for use within different applications.
- **Facilitation of competency-based learning:** Since metadata tags describe each LO, learners are able to fill their gaps in knowledge by searching for appropriate objects to learn.
- The *value of content* is increased each time they are used since additional costs of new design and development can be avoided with acts of reuse.

Information about the suitability of LOs for learners based on their learning styles and knowledge levels can be stored in the learning object metadata, and information about a learner's learning styles can be obtained via an initial questionnaire and/or proficiency tests to ascertain their knowledge level. For example in the work of Lee *et al*. (2005), they had defined a Java LO ontology for allowing different learning strategies and/or paths to be utilized (for example, a number of topic prerequisites were specified) and as a result facilitated adaptive learning.

In the context of introductory Java programming, the difficulty level of each topic of was established in Yau (2004). This was based on a large number of students' perceived difficulty levels within basic Java; in the order from easy to difficult, the nine topics were *comments, assignment, expressions, if-statements, input-output, arrays, methods* and *classes*. Given that a learner's knowledge level in introductory Java was known, this information can be used to ascertain which Java LO would be appropriate for them.

LOs are usually stored in global learning object repositories. Repositories are usually built on a client/server architecture employing brokerage services and provide peer-to-peer access to the local repository of the LOs. For example, 1) *Codewitz* (www.codewitz.org) was an international project which created many LOs for learning programming contained in their so-called *Material Bank* repository, 2) *Merlot* (www.merlot.org) contained 34020 learning objects in disciplines including Biology, Business, Engineering, History, Mathematics, Psychology and World Languages, and 3) *CAREO* (careo.prn.bc.ca) contained 994 learning objects.

Different LOs standards have been established by different standards initiatives such as the Learning Technology Standards Committee (LTSC) (IEEE LTSC, 2005) which created the *Learning Object Metadata (LOM)*, Dublin Core Metadata Initiative (www.dublincore.org) which created the *Dublin Core Metadata (DCM)*, the Instructional Management System Global Learning Consortium (www.imsglobal.org) which created the *IMS Learning Resource Metadata (LRM) Specification* and Advanced Distributed Learning (www.adlnet.org) which created the *Sharable Content Object Reference Model (SCORM)*. Common between each of these standards/specifications is the promotion of LOs to be exchangeable across any web-based learning systems. SCORM was written in order to store and catalogue and retrieve Shared Content Objects (SCOs) within and from different web-based intelligent learning environments, and to promote SCORM-compliant Learning Management Systems (Ibid).

The learning styles and knowledge levels contexts can be deployed into our framework through the utilization of Learning Object Metadata for describing LOs (IEEE LTSC, 2005). We propose that additional metadata tags can be added to the IEEE LOM specification so that suitable LOs can be fitted to the criteria of m-learning students and so that LOs can be easily searched and selected for different situations. An extension to LOM and IMS Learner Information Profile (LIP) Standards has been proposed by Chan *et al*. (2004) to cover mobile and informal learning scenarios. The necessity for this proposal was to include these forms of learning in the current usage of LOM and standards alike, as the LOM had been previously designed to aim at web-based learning using desktop and/or laptop computers.

Their proposed Mobile Learning Metadata (MLM) (Ibid) comprises of 3 top level classifications – Learning Object, Learner and Settings (describes the context state of the learning environment such as the location of the learner or LO). The Learner classification is then divided into two sub-categories – *Learner Profile* (contains static information about the learner and their preferences) and *Learner Model* (contains dynamic information relating to the learner's knowledge and learning history. Conceptually, the relevant LO is located by the context-aware engine of an m-learning system using the information provided by the Learner and Setting classifications by accessing the metadata of the LO. Information within the Setting classification is generation dynamically to describe current values of context information. Corresponding to their MLM (Ibid) learning styles (or learning preferences) are described in 2.1.2.2 in the Learner Profile of the MLM (as per IMS LIP), knowledge level is described in the Learner Model of the MLM, which is currently works-in-progress. The amounts of available time context which apply in both of our framework designs can be inferred using the duration attribute described in 1.4.7 of LOM and MLM which state the duration of time the LO is required to take for completion. (Please refer to Chan *et al*. (2004) for 2.1.2.2 in the Learner Profile and 1.4.7 of MLM).

Bradley *et al*. (2009) have also examined extensively various techniques of how to design LOs appropriately to fit onto the screens of mobile devices. Specific LOs in introductory Java programming have been created and a Java LO ontology (Lee *et al*., 2005) was created to facilitate different learning paths and strategies for different learners; hence creating different Java learning courses and is a reusable and sharable ontology. Java LOs are also widely available from LO repositories such as Codewitz (see above).

2.4. Systems Supporting Suggestion Rules Learning

In this section, we present a brief overview of technologies (including mobile devices, operating systems and programming language used for implementation) of related applications.

Toshiba Genio-e PDA with Pocket PC 2002 operating system, and Visual C++ 3.0 were used in the JAPLEAS and TANGO projects (Ogata & Yano, 2004a). The same technologies were used in the Knowledge Awareness Map (Ogata and Yano, 2004b) with the addition of a server program implemented with a Java servlet via Tomcat. The TANGO prototype was constructed using a server-client architecture; the server implemented with a Java servlet and each client i.e. learner uses a Toshiba Genio-e PDA with Pocket PC 2002, equipped with Personal Java (a Java edition for mobile and embedded systems). Note that usually software applications can be implemented, compiled and tested on desktop and/or laptop computers, and then synchronised to be run on a compatible version of the programming environment on mobile devices.

A Ubiquitous-Learning System for the Japanese Polite Expressions (ULSJPE) (Yin *et al*., 2010) was developed based on the JAPELAS application (Ogata and Yano, 2004a). The improvement made included the ability a) to obtain the learner's location automatically, either via their personal schedule or using GPS or RFID technologies, and b) to upload the learning records of learners to the server, which are then transmitted and shared by other learners. A data server-client architecture prototype using Embedded Visual C++ 4.0 was implemented; the data and client server configuration was implemented on a desktop computer and a Pocket PC 2003 respectively. The Data server consists of four components – *Location manager* (manages the scheduled, GPS and RFID location data), *Learner Info manager* (facilitates for learners the retrieval and reading of learning records of other learners), *Education manager* (facilitates the retrieval and reading of learning materials) *and the Server communication* (manages the communications with the mobile devices). The Client server consists of three main components – *Learner-module* (contains learner information which is entered by the learner before using the system), *Environmental-module* (provides location information about the areas where learning is being conducted using schedule, GPS and RFID location methods, and the *Educational-module* (manages learning materials i.e. Japanese polite expressions). Based on a set of rules for polite expression of the Japanese language, the Polite Recommender Manager selects appropriate expressions for learners based on each different situation.

In the system architecture of the context-aware English vocabulary learning application (Chen *et al*., 2007), the Context Analysis agent analyzes a combination of factors including the learner's location, learning requirements and preferences (including leisure learning time), then the English Learning Materials searching agent searches and selects appropriate learning materials to students based on these factors. The application begins to sense the location of the learner when they select the 'learning by context' button within the application. The positioning result is then shown which users have the possibility of correcting, if necessary, via a constructed list of locations.

Embedded Basic 3.0 and Visual C++ were used for constructing the Chinese Language Learning System (CLLS) (Chen and Chou, 2007) on a HP IPAQ with Pocket PC 2003. It consisted of three components – location detection, learning materials and record/play function.

Microsoft Visual Studio 2005 was used for the construction of the client-server architecture of the location-aware learning reminder application (Ryu and Parsons, 2008) on a HP IPAQ 6700; one of its main functions was to direct users to various lecture theatres as new students were often unaware of where these were. The user's current position is represented on the screen map of the application and a path to their selected position is displayed to direct them to requested locations on campus. The user's location, movement and any rotation are synchronized with the map. Their next destination can also be selected from their course calendar and the path to the location appears on the map. The authors noted that a major challenge was related to the privacy protocols imposed by the university to store student's data, however, consent of each student was obtained. A MySQL Server database was used for storing locations (such as latitude, longitude, campus and type of location) and students' information (such as name) and networked with the PDA server, the purpose of which is to provide contextual information to students in the locations they are situated in. PDA clients access the server via the wireless network and also have GPS receiving capabilities.

To implement our framework, a mobile device possibly with a Windows-based operating system can therefore be used, together with a programming environment such as Microsoft Visual Studio .NET Compact Framework, Visual Studio, Basic or C++ for Pocket PC. The capabilities of Visual Studio .NET have been extended to create, utilize and debug applications suitable for use on Pocket PC and Windows-based devices. A rich subset of the full .NET framework is supported by the .NET Compact Framework, whilst still capable for the use on resources-constrained mobile devices; features include rapid development and comprehensive class libraries (Microsoft, 2003).

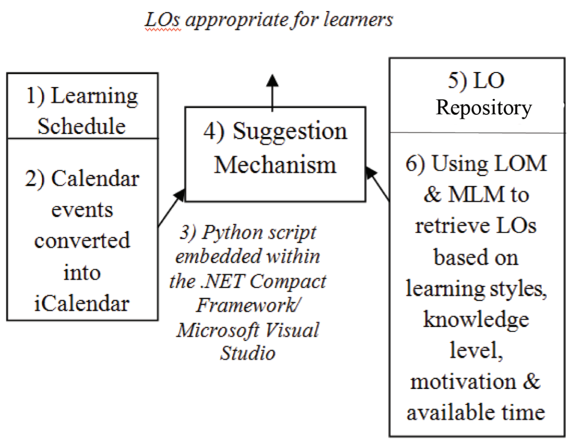
Microsoft SQL database server can be used for allowing information in our *Student* and *Learning Object Repository* databases to be stored, and transmitted to other system components such as to the suggestion mechanism. A set of suggestion rules can thus be integrated successfully into our suggestion mechanism within our framework, and these rules can be written using any programming languages and can be embedded within the .NET Compact Framework programming environment.

3. TECHNOLOGY INTEGRATION

In the previous section, we surveyed the current technologies which might support the four components of our framework, and for each component identified, each of those technologies were both feasible and practical. In this section, we demonstrate how the various components of the framework can be incorporated together successfully using current mobile and context-aware technologies, as shown by Figure 3 in which the various components are labelled and explained.

1. GPS and Wireless LAN: These options can be switched on to detect the location of the learner when outdoors (using GPS technology) and indoors (using wireless LAN positioning technique), as discussed in 2.2
2. Learning Schedule and Calendar Events: Most modern mobile devices have built-in learning schedules and the calendar events can be converted with minimal effort into iCalendar format, as was established in 2.1
3. The Python script presented in 2.1 for retrieving the location and available time information from the calendar events is embedded, compiled and run within the .NET Compact Framework programming environment/Microsoft Visual Studio. This programming environment supports any object-oriented and visual programming languages and has extensive class libraries and functions readily available (Microsoft, 2003). Microsoft Visual Studio is an Integrated Development Environment and supports the .NET Compact Framework.
4. The suggestion mechanism is used to store a set of suggestion rules embedded in Personal Java; this is compatible for use within mobile applications, as was discussed in 2.4. Additionally, research conducted by Meawad and Stubbs (2006) showed that at the time of writing there were almost 250 million Java-enabled mobile devices on the market and by 2006 there would be an expected increase of 1 billion Java-enabled devices. Currently, there may be over 10 billion on the market (Howard, 2010).
5. A Java LO repository such as Codewitz or Java LOs created by Lee *et al*. (2005), Leeder *et al.* (2004) and Chalk & Qi (2005) can be incorporated into our framework, as established in 2.3. A database server such as Microsoft SQL is usually used for storing and retrieving these objects and these repositories are usually built on a client/server architecture (Yau, 2004); database servers such as SQL Server Compact Edition are compatible for use on mobile devices.

Figure 3. System architecture showing compatibility of various components



6. Learning objects use metadata tags written in XML, eXtensible Markup Language, which is a system for storing and exchanging information on the web for describing information about the objects. XML is a platform-independent language; its files are compatible for use within any web-based system and data can be transmitted between many incompatible formats. Wireless Markup Language (WML), a subset of XML, can be used to create content to be displayed on mobile devices (Yau, 2004).

4. EXTENDING THE FRAMEWORK TO SUPPORT SOCIAL LEARNING ACTIVITIES

Our framework can be used as a tool for arranging collaborative social learning meetings/activities with peers and these can be held either remotely, or in person, depending on the geographical locations of the learners. Each individual learner has a schedule which can be made public and can be shared amongst his/her peers, and vice versa. New learning activities can be slotted into the schedule and take place virtually via the mobile devices, or physically in person. With the new capabilities of the Internet and computing technologies, the direction that the mCALS framework will aim toward is to provide social learning for students. Additional features that can be incorporated into the framework include social networking functions, for example, which identify learners of the same interests or other contexts and when they have free time to meet together for learning. Precise instances of potential intended social learning activities using our framework are:

- A mechanism can be used to identify the same interests, location and/or other contexts of users (such as same or similar level of knowledge on a particular topic, similar learning style). Users can recommend and add other users as peers based on similar identified interests such as for the learning of Java, or similar available times that they have so that they are able to meet either virtually or physically. One of the intended outcomes of this function of our framework is to increase social interactions amongst learners and in order to gain the associated benefits of collaborative social learning.
- If a learner is unable to attend to a meeting, he/she may suggest other users to attend this. Meetings (such as for solving a particular learning task) can be recorded and made available for the community to access; comments and reviews can also be added by members of the community.

A blog can be kept for encouraging and promoting social activities. A community of similar interests/contexts can be set up in this way to promote collaborative social learning.

Social learning appears to be very beneficial for students for increasing their learning effectiveness and enhancing their learning experiences. However, this needs to be more widely tested, as in our framework; we will test this as part of the future work. A comparison can be made between the learners who learn individually with our framework, and those who learn socially with other students also using our framework. Limited research on context-aware social learning applications has been conducted since this is still a very new field. Some examples of related work on context-aware social learning research/applications are:

- A recommendation mechanism proposed by Huang *et al*. (2010) aims to support collaborative learners to carry out mobile computer-supported collaborative learning activities including the sharing of knowledge and a space where learners can interact with one another.
- Yang & Chen (2008) discussed the methods in which social network-based system can be used to support interactive collaboration in knowledge sharing over peer-to-peer networks. Their aims were to overcome two current challenges in knowledge sharing – 1) finding the relevant knowledge and, and 2) finding relevant collaborators to interact with.

5. CONCLUSION AND FUTURE WORK

In this paper, we addressed several issues relating to the technical feasibility of our mCALS framework, and also for extending it for creating social learning opportunities. We first discussed the feasibility of implementing our proactive retrieval approach via learning schedules, available through the use of built-in electronic diaries contained within modern mobile devices. To counteract the possibility that learners may not adhere to their planned schedules, two methods can be incorporated to strengthen our framework – location-tracking via technologies such as GPS and Wireless LAN and user-verification which request users to confirm the available time retrieved by the system, and update if necessary. In summary, mCALS is a framework in which appropriate learning materials (in the form of learning objects) can be recommended to learners based on their learning contexts (location, available time, knowledge level). The learning schedule component within the framework is original in the context-aware mobile learning field as well as the recommendation mechanism itself, incorporating the different contexts and recommendation of Java learning objects.

We provided an overview of the technologies, including mobile devices, operating systems and programming languages used for implementation of related research works on mobile learning systems. Finally, we concluded with a set of technologies appropriate for the implementation of our framework for use on a mobile device. A system architecture has been constructed to demonstrate the compatibility between the different technologies used within the different components of the architecture, and explanations of these were presented. Our future work includes the real implementation of our framework and a technological evaluation of it to be taken place with university students within our institutions, as well as extending our framework to include collaborative learners for conducting social learning in order to increase individual and social learning experiences and effectiveness. The social aspect of the framework and the benefits this will bring to learners will then form the focus of our future works.

The contribution of the research presented in this paper is the establishment of a proactive approach (described in 2.1) for retrieving learners' locations and available time contexts via the use of a learning schedule for use within context-based or context-aware m-learning software applications. The underlying design mechanism of the learning schedule approach is simple and the learner is responsible for recording and conforming to their learning schedule (i.e. diary or planner on a mobile device). The proposed advantages of this approach include making a learner's learning status or situation throughout the day known to the mobile device via the learning schedule. The learning schedule approach has the potential a) to eliminate the use of context-aware technologies, b) to tackle inaccuracies and unreliability in location-tracking technologies and c) to overcome technological constraints of memory limitations on mobile devices for operating additional location-tracking programs.

The learning schedule approach has been partially successful in accurately retrieving the learners' contexts, as demonstrated by the findings of our diary study. Participants in this study were asked to keep a (learning) diary for two days and details of their learning sessions for these two days. The recorded time and location details in the learning sessions were then verified against the information in the original diary to determine how closely the planned and actual locations and available amount of time were. The findings showed that a learner's planned and actual location is more likely to match than their available time (Yau, 2011). The framework could in principle retrieve a learner's location and available time contexts from the learner's schedule. Appropriate recommendations of materials suitable for students in their learning situation can be made using the established suggestion rules. The retrieval of learning contexts from students' learning schedules appears to be more effective for students who are more self-regulated. The approach appears to be a successful technique for students to self-motivate and manage their studies. In order to strengthen the framework, we have proposed using additional GPS and WLAN technologies and a direct request method from users to ensure that their location and available time contexts are accurate.

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