Supporting Pervasive Learning Environments: Adaptability and Context Awareness in Mobile Learning

Antti Syvänen* Russell Beale Mike Sharples Mikko Ahonen* and Peter Lonsdale

**University of Tampere*
{antti.syvanen;mikko.ahonen}@uta.fi

University of Birmingham
{r.beale;m.sharples;p.lonsdale}@bham.ac.uk

Abstract

In the mobile learning context, it is helpful to consider context awareness and adaptivity as two sides of the same coin. The purpose of the adaptivity and context awareness is to better support a variety of learners, given that they may have very different skills and motivations to learn in varying contexts. The recent research on adaptivity and context awareness has turned towards supporting pervasive environments and this is coupled with the increasing trend in seeing learning environments from an informal learning perspective. Introducing mobility to learning in a meaningful way emphasizes the role of the contextual factors, and learning as an informal activity. In this paper are presented experiences of developing an adaptive and context aware mobile learning system, with examples of other systems underlining the development towards supporting pervasive learning environments. We then consider approaches for the future development of systems supporting pervasive learning environments.

1. Introduction

The European Union 5th Framework IST research and development project MOBIlearn (2002-2004) developed a generic, adaptive system that supports learner groups in mobile, informal learning situations. It is a component-based architecture, which has modules dedicated to context awareness and adaptivity, as well as content provision. It has been extensively trialled in three very different scenarios: within an art museum, on a Master of Business Administration (MBA) course and first-aid training scenarios. The major goal of the adaptive and context aware systems is to support a variety of learners, e.g., their skills and motivation to learn, and the context of learning itself. The recent development of mobile adaptivity in learning has focused towards building systems that are both location aware and use an open learner model for consultation by a student, and away from an intelligent tutoring system in which the learner model was generated [1].

Learning taking place in mobile uncontrolled environments is mostly informal. This places constraints to the location awareness and learner modeling through finding and anticipating typical tasks in different contexts becomes harder [2]. In addition, the changing context and bandwidth limitations affects the availability of tools and services. According to Livingstone [3] the supporting and recognition of incidentally-initiated and irregularly-timed learning is difficult in informal learning activities. This is the case especially in the mobile contexts of use, as the changing context emphasizes the informal nature of learning activities. Activities are not bound to only one specific environment e.g. classroom, nor are the activities prestructured. Concerning such learning activities Goodyear [4] has stated "there may be good reasons for allowing and perhaps encouraging learners to create their own ‘learn places’, configuring the physical resources available to them in ways they find most comfortable, efficient, supportive, congenial and convivial". The goal of adaptive, context aware mobile learning systems should be to support this goal by making it as easy to achieve as possible.

In this paper, we discuss the adaptivity and context awareness modules of the Mobilearn system as strategies to provide support for the learner in mobile contexts, as steps towards a successful pervasive learning environment. In addition, other examples of evolving pervasive learning environments are presented. In the conclusions future research questions and activities are presented concerning the development of pervasive learning environments.

2. Pervasive learning environments

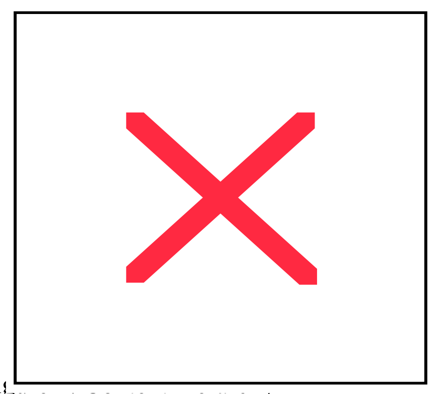
According to the findings of an earlier study it has been proposed that one clear characteristic of mobile learning is seeking information more freely from different domains (both from physical and virtual) and constructing knowledge based on information from different contexts [5]. According to Jones and Jo [6], any setting in which students can become totally immersed in the learning process can be seen as a ubiquitous learning environment. Pervasive computing takes part in an experience of immersion as a mediator between the learner's mental (e.g., needs, preferences, prior knowledge), physical (e.g., objects, other learners close by) and virtual (e.g., content accessible with mobile devices, artefacts) contexts. Where these contexts overlap and form a single entity is addressed here as a *pervasive learning environment*.

In the future, as the technology advances and miniaturization reaches its height point the technology will "disappear" or at least become more transparent and less noticeable. This is to be aspired with ubiquitous [7] and wearable computing [8]. Ubiquitous computing suggests that information technology should be embedded in the physical environment whereas wearable computers are trying to merge information technology into clothes. Different researchers use a variety of terminology to discuss systems in this area; for example, "pervasive computing", "context-aware computing" or "augmentation of the real world", are similar strategies for contributing to the effort of coupling digital and physical world [9, 10, 11]. This paper deals especially with adaptivity and context awareness as approaches for supporting pervasive learning environments.

3. The MOBIlearn system

As part of the MOBIlearn project, the University of Birmingham has developed an *interactional* model of context. By contrast with a data-driven approach, in which data from sensors are integrated to trigger services, the interaction-driven approach examines what interactions are appropriate for a particular context of use. We view context as being continually constructed through negotiation between communication partners (including humans and interactive technology) and the interplay of activities and artefacts. This dynamically-changing construct can be explicitly represented as a dynamic data structure and used to determine relevant content and services[12]. The changing relationships may be shaped by the interaction history. For example, a learner visiting a city for the second time could have content recommendations influenced by their activities on a previous visit, or their current path through the city could create an evolving history that influences which services to offer or prioritize. This approach has a number of advantages. Firstly, it ensures that context is much more than location. Secondly, it can be used to guide effective choices and propose future actions, rather than simply acting as a filter on information.

The systems architecture for the MOBIlearn context subsystem (Figure 1) represents context as a *dynamic process of interaction, with historical dependencies*. For example, visitors to a gallery create context by interacting with the paintings, the gallery space, and other visitors. Their current context is influenced by previous visits, routes and activities. A *context state* is a snapshot of a particular point in this ongoing process of generating context through interaction. A context state contains all the elements of context process that are relevant to a particular activity focus, such as the person's current goals, and social and physical resources. A person may at any one time be engaged in a number of simultaneous activities that relate to a single goal or project, and they may have several ongoing projects with sets of associated goals and activities. A *context substate* is the set of those elements from the context state that are directly relevant to support of the current task and activity and that can be explicitly modeled. Lastly, *context features* are the individual, atomic elements found within a context substate and each refers to one specific aspect of interaction in context (for example, the current location, the time, the closest exhibit, or another person within communication range).



Fi

In the MOBIlearn context subsystem, contextual information is represented as XML documents and Figure 2 shows the flow of data between components. Contextual metadata is either acquired automatically (from sensors or other software subsystems), or constructed from patterns of existing context data, or input directly by the user. This metadata is integrated to form context feature objects (CFOs) that represent the user's setting, current and previous activity, device capabilities and so on to derive a context substate.

This context substate is processed to first exclude any unsuitable content (for example high-resolution web pages that cannot be displayed on a PDA) and to then rank of the remaining content to determine the best options. The ranked set of options is sent to the content and services subsystem to activate appropriate content, services or interface presentations to the user. CFOs are created at run-time from a set of definitions provided by the designer of the context-aware experience for which the system is being employed. These definitions specify values for the parameters such the relative salience values for different CFOs and the links between them. To achieve more complex interactional modeling of content, CFOs can be linked together so that their function can depend on the state of other context feature objects. Link objects are used to send either the values of context features or the time they have held that value to other context features. Criteria associated with each link determine what action should be taken.

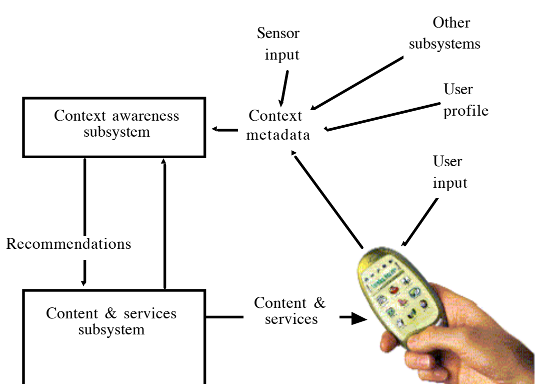


Figure 2: Data flow for the context system input directly by the user.

For the MOBIlearn project, the University of Tampere has developed an adaptive user interface system. In the MOBIlearn learning system the adaptivity was designed in relation with the context awareness subsystem. The adaptive user interface subsystem received data from the context awareness subsystem and this contextual, presence and device information was utilized to optimize the user interface for a PC, a mobile phone and a PDA. Although many user interface adaptation possibilities (like user's browsing history) were not utilized in the final system, the aim was to build a dynamic type of adaptive learning system. Essentially, the context system takes in the environmental and other contextual information and calculates the salience values for a variety of context feature objects: the adaptivity system takes this data and uses it to produce the most effective representation of the information for the current context – for the device, user, and task in question.

When adaptive and pervasive learning environments are designed, there are several issues that support the learning. Based on the work of the MOBIlearn project, the following recommendations were formulated as examples to be considered in the design process of an adaptive and pervasive learning environment:

- Organizing the information provided to the user according to the availability for cooperation (students), advice (experts, instructors) and groups available at a given moment
- Supporting the communication between users by providing tools, such as the news groups and chats, that are presented to the user by their current popularity in the learning community (placing first the most popular, or the most relevant to the learner according to the profile, at any given moment).
- Encouraging users to cooperate and affiliate by pushing the information when relevant opportunities occur. Actions by the system are guided, for example, by the information related to a group-based modeling that takes into account each user's evident interest in certain piece(s) of information.
- Offering information according to the patterns, preferences, interests or goals perceived by the system but not necessarily perceived or stated (in settings) by the learner.
- Providing multimodal information (pictures, sound, text, notion maps, etc.) according to a learning style of the learner.
- Adjusting automatically contrast/sounds according to the physical qualities of the environment (louder system sounds in noisy environment etc.)
- Understanding Multiple User Interfaces requirements and providing different functionalities for each device (PC, Mobile Phone, PDA). A single learner often uses many devices for different purposes.

Note that the combination of context and adaptivity does not simply alter the appearance of the interface, or filter the information presented: it can also prioritise communication channels, encourage cooperation, and adjust information modalities.

4. Approaches to future development

The recent development on providing context awareness and adaptivity in mobile learning has been done in terms of location awareness and open learner modeling. Earlier systems such as Mobi-Timar and My Chameleon illustrate this approach. Mobi-Timar supports access by homecare workers to non-critical information such as scheduling and patient data, and supports communication between homecare workers. My Chameleon provides easy 'one click' access to applications, tasks, files and documents needed by the user, according to their current location. My Chameleon is being used by university students. [2]

At the University of California, San Diego (UCSD), researchers have developed an advanced wireless campus network, called ActiveCampus, and made experiments with tools for community-oriented ubiquitous communication. The UCSD ActiveCampus explores wireless location-aware computing in the university setting. ActiveCampus Explorer supports several location aware applications, including location-aware instant messaging and maps of the user's location annotated with the dynamic hyperlinks to getting in contact with nearby students. [13]

Analysis of the use of ActiveCampus has revealed many aspects to be considered in building a campus-wide pervasive learning environment, e.g. the relevance of proximity in social computing, and the willingness to share location information with others. The students' willingness to share location with other students and even unknown ones suggests promise to location-aware social computing. The finding that students were more likely to message each other when they are closer than average is as well interesting, suggesting that relative location is a relevant context factor in community-oriented computing. [13]

Smart Phones are a promising platform for developing pervasive computing and as such they could be ideal for supporting pervasive learning environments. However, the main function of the Smart Phone is as a device for and thus any activity being supported with a Smart Phone must inherently support interaction and communication between people. A pervasive learning environment should then be supported with contextual social navigation in order to assist, even emphasise, the cooperation between the learners. It is logical to assume that in the future adaptive and context aware learning systems should gather input from the users social context as well and adapt to it accordingly. The findings from several different systems developed at the University of Birmingham [14] and the findings of the ActiveCampus experiments have illustrated this as a promising approach to future development.

5. Conclusions

The above systems presented here were designed to support pervasive learning environments. However, it can be argued that if these types of activities are most meaningfully supported with mobile technology, should all mobile learning materials and virtual learning environments be evaluated through their support to pervasive learning environments?

It is important to further elaborate what pervasive learning environments should be like in the future and how they could be supported. This should be taken into account in the earliest design process stages.

What is the negative effect of pervasiveness? To avoid extensive cognitive load and time management problems, should user have an option to define availability and accessibility profiles for herself? We are interested to find out how to define profiles for online and offline use. Which adaptivity and contextual features the learner should be allowed to adjust and which features should be handled automatically? How do we handle security and privacy issues, in situations when the environment, and potentially other users around, can know a lot about our current state of understanding and our personal preferences. It is clear that this is a rich area for exploration and further research, with platforms suich as Mobilearn offering a generic approach on which to conduct further experiments and longer-term trials.

6. References

[1] Bull, S. User Modelling and Mobile Learning. User Modeling 2003: 9th International Conference. Springer, Berlin Heidelberg, 383-387, 2003. Available from: http://www.eee.bham.ac.uk/bull/papers-pdf/AH04.pdf

[2] Sharifi, G., Deters, R., Vassileva, J., Bull, S. and Röbig, H. Location-Aware Adaptive Interfaces for Information Access with Handheld Computers. In W. Nejdl & P. de Bra (eds.), Adaptive Hypermedia and Adaptive Web-Based Systems: Third International Conference. Springer, Berlin Heidelberg, 2004. Available from: http://www.eee.bham.ac.uk/bull/papers-pdf/AH04.pdf

[3] Livingstone, D. Exploring the Icebergs of Adult Learning: Findings of the First Canadian Survey of Informal Learning Practices. NALL Working Paper #10-2000. Ontario Institute for Studies in Education, University of Toronto, 2000.

[4] Goodyear, P.M. Environments for lifelong learning: ergonomics, architecture and educational design. In J.M. Spector, and T.M. Anderson (eds.), Integrated and holistic perspectives on learning, instruction and technology: understanding complexity. Kluwer Academic Publishers, Dordrecht, 1-18, 2000.

[5] Syvänen, A. Evaluating Mobile Learning in a Comprehensive School. In J. Levonen, T. Järvinen and S. Kaupinmäki (eds.), Tuovi 2: ITK '04 tutkijatapaamisen artikkelit. Tampere University Press, Tampere, Finland, 189-199, 2005.

[6] Jones, V. and Jo, J.H. Ubiquitous learning environment: An adaptive teaching system using ubiquitous technology. In R. Atkinson, C. McBeath, D.

Jonas-Dwyer and R. Phillips (Eds), Beyond the comfort zone: Proceedings of the 21st ASCILITE Conference, 468-474, 2004. Available from http://www.ascilite.org.au/conferences/perth04/procs/jones.html

[7] Weiser, M. The computer for the twenty-first century. Scientific American, September, 94-104, 1991.

[8] Starner, T., Mann, S., Rhodes, B. and Levine, J., Augmented Reality Through Wearable Computing. M.I.T. Media Laboratory Perceptual Computing Section Technical Report No. 397, 1997.

[9] Banavar, G., Beck, J., Gluzberg, E., Munson, J., Sussman, J., and Zukowski D., An Application Model for Pervasive Computing. Proceedings of MobiCOM 2000: The 6th Annual International Conference on Mobile Computing and Networking. ACM Press, Boston MA, 266-274, 2000.

[10] Lonsdale, P. and Beale, H. Towards a dynamic process model of context. Proceedings of Ubicomp 2004 workshop on Advanced Context Modelling, Reasoning and Management, 2004. Available from: http://www.cs.bham.ac.uk/~rxb/Online%20papers/ubicomp-lonsdale.pdf

[11] Wellner, P., Mackay, M., and Gold, R.ComputerAugmented Environments: Back to the Real World Introduction to the Special Issue. Communications of the ACM, 36(7), 24-26, 1993.

[12] Beale, R. and Lonsdale, P. Mobile context aware systems: The intelligence to support tasks and effectively utilise resources," presented at Mobile Human-Computer Interaction - Mobile HCI 2004, Glasgow, 2004.

[13] Griswold, W.G., Shanahan, P., Brown, S.W., Boyer, R.T., Ratto, M., Shapiro, R.B., and Truong, T.M. ActiveCampus - Experiments in Community-Oriented Ubiquitous Computing. IEEE Computer, 37(10), 73-81, 2004. Available from: http://www-cse.ucsd.edu/~wgg/Abstracts/ac-handhelds.pdf

[14] Beale, R. Supporting social interaction with the smartphone – designing pervasive systems, IEEE Pervasive Computing, April-June 4(2), 35-41, 2005.