A context awareness architecture for facilitating mobile learning

Peter Lonsdale, Chris Baber, Mike Sharples, Theodoros N. Arvanitis
University of Birmingham
Electronic, Electrical, and Computer Engineering, Birmingham, B15 2TT
{p.lonsdale, c.baber, m.sharples, t.arvanitis}@bham.ac.uk

Abstract

The MOBIlearn project (EU IST-2001-37187) aims to support a wide range of services and applications for learners using mobile computing devices such as phones, PDAs, and laptops. The display limitations of these devices mean that it is crucial to deliver the right content at the right time. One way of doing this is to use contextual information to derive content that is relevant to what the user is doing, as well as where and how they are doing it. We present an object-oriented, feature-based architecture for a context awareness subsystem to be implemented within the MOBIlearn project, and consider the implications involved in the use of such a system for mobile learning.

Keywords: context awareness, elearning, mobile computing, mlearning

1. Mlearning in MOBIlearn

MOBIlearn is a worldwide European-led research and development project exploring context-sensitive approaches to the application of mobile technology to informal, problem-based and workplace learning. The MOBIlearn system will deploy a generic mobile learning architecture based on subsystems that interact through web protocols to provide relevant and timely learning content and services.

Context management is a key subsystem that delivers content appropriate to the learner’s goals, situation and resources. Context awareness is a highly desirable feature for mobile computing devices – for a recent review see Chen and Kotz (2000), and some examples of current projects include Kolari (2003) and Chalmers et al (2003).

People on the move need information relevant to their location and immediate needs. The display capabilities of mobile devices are restricted when compared to desktop alternatives and the mobile communications channel may have limited bandwidth, so the subsystem must match the content to the available display and communications and also to the learner’s needs and preferences. It is also important for a mobile device to provide services (such as collaboration tools) and user options (such as interaction preferences) that are appropriate to the situation of use.

1.1. Context awareness for mlearning

Context awareness in MOBIlearn is implemented as a context awareness subsystem (CAS) that selects content reflecting the requirements of a specific individual and then presents this content with minimal user effort.

There are two potential advantages for this approach:

1. The need to define search terms and perform content search is reduced.
2. The system is usable whilst the person is engaged in other activity.

The usefulness of this approach has already been demonstrated by Bristow et al (2002) who showed that simple sensor input indicating user status could provide effective context dependent content provision. For example, a user walking past the library sees a
link to the library homepage on a head-up display, and if they stand still they are presented with a brief version of the page itself. If they then sit down, they see the page in full.

In broad terms, the aim of the CAS is to provide a means by which users of mobile devices can maintain their attention on the world around or the task at hand, whilst providing timely and effective computer support. The CAS provides a mechanism by which relevant content can be selected, filtered, and passed to the user. Users can then either look at the content or select other content from the filtered set.

MOBiLearn aims to provide users with a rich and flexible learning experience, and as such “content” is to include not only learning objects or materials per se but also resources, services, and options that might be relevant to the learner in their current context. For instance, other learners themselves might constitute resources in a learning environment, and users should be offered the opportunity to make contact when appropriate. By including services, we aim to address the need to make learning content available from a variety of sources, and not limited to the content set available immediately to the user in their current location.

Numerous examples exist of varied uses of different elements of contextual data but there is no over-arching architectural approach. What we are concentrating on for MOBiLearn is developing a re-usable architecture that can be used for a wide range of applications and scenarios. This is in line with the general MOBiLearn aim of producing a reference architecture for mobile learning that affords flexible re-use and application to a wide range of mobile learning scenarios. Our aim is to produce a simple, yet powerful, approach to building context aware applications that non-expert users can easily customise for their own needs.

1.2. Scenarios of use

Development of content and delivery mechanisms within MOBiLearn is based around the development of learning scenarios in three key areas, namely MBA students, museum visits, and health care/first aid provision. All of these areas provide rich contexts of use that can be used to determine what content is appropriate for a given user at a given time. For example, MBA students travelling on the train can be given a quick multiple choice quiz that downloads quickly to their mobile phone; art history students following a study guide around a museum can be offered relevant content whenever they stop in front of specific art works; and a first-aider in the field can be given just-in-time advice by a device that is able to respond to the severity of injury, distance to the nearest medical facilities, and the experience of the person administering the first aid.

1.3. Approaches to context awareness

A survey of the current literature concerning context-aware computing indicates that there are two main approaches to building context-aware artefacts. The technologically driven approach is focused on what capabilities can be provided by the available hardware and software. For context aware applications, this is usually a case of determining what data can be obtained through sensors and what processing can be carried out on that data by the available devices – see Want et al (1992) and Abowd et al (1997) for some examples.

Conversely, the application driven approach concentrates on what capabilities are required by a particular learning application or context of use, including the requirements of the user(s) themselves. Some examples relevant to this alternative approach can be found in Lueg (2002) and van Laerhoven (1999).

We aim to reconcile these two approaches by maintaining an awareness of current technical capabilities and limitations as well as taking into account the needs of learners in the scenarios for which we are developing. This means that we are aiming to provide learners with a flexible context awareness system that can react to their needs as anticipated by authors, publishers, and developers, and also to their direct input should the need arise. One of our primary assumptions is that the system could fail or make an erroneous judgement at any time, and that users need to have the opportunity to influence and correct the system.

1.4. Describing context

Our starting point in a definition of context is to identify the purpose of the context we are interested in. For MOBiLearn, the purpose is learning, specifically learning on mobile devices, and so our approach to describing context and applying this description to produce a usable software architecture is based on this focus. Figure 1 shows the basic hierarchy for our description of context.

Instead of a rigid definition, our intention is to provide a hierarchical description of context as a dynamic process with historic dependencies. By this we mean that context is a set of changing relationships that may be shaped by the history of those relationships. For example, a learner visiting a museum for
the second time could have his or her content recommendations influenced by their activities on a previous visit.

<table>
<thead>
<tr>
<th>Context</th>
<th>What's going on over time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context State</td>
<td>Elements from the Learning and Setting at one particular point in time, space, or goal sequence</td>
</tr>
<tr>
<td>Context Substate</td>
<td>Elements from the Learner and Setting that are relevant to the current focus of learning and desired level of context awareness</td>
</tr>
<tr>
<td>Context Feature</td>
<td>Context Feature</td>
</tr>
</tbody>
</table>

_Figure 1: context hierarchy_

A snapshot of a particular point in the ongoing context process can be captured in a _context state_. A context state contains all of the elements currently present within the ongoing context process that are relevant to a particular learning focus, such as the learner’s current _project_, _episode_, or _activity_ (see Vavoula and Sharples, 2002).

A _context substate_ is the set of those elements from the context state that are directly relevant to the current learning and application focus, that is to say those things that are useful and usable for the current learning system.

_Context features_ are the individual elements found within a context substate. Each feature is atomic and refers to one specific item of information about the learner or their setting.

Implementing context awareness within our architecture is a matter of deriving a context substate and using the context features contained within it to determine what content might be appropriate.

2. Context Awareness Architecture

The basic representation of how the context awareness system functions as part of the MOBIlearn content delivery system is illustrated in Figure 2. A learner with a mobile device is connected to a content delivery system, which in turn is linked to the context engine. The mobile device passes contextual information obtained from sensors, user input, and user profile to the context subsystem which then compares this metadata to the content metadata provided by the delivery subsystem and returns a set of content recommendations. These recommendations are then used by the delivery subsystem in determining which content to deliver to the learner.

_Figure 2: context awareness in action_

The basic cycle of operation of our context awareness system is as follows:

1. _input_ – of context metadata.
2. _construction_ - of context substate.
3. _exclusion_ - of unsuitable content.
4. _ranking_ - of remaining content.
5. _output_ – of ranked list of content.

The CAS comprises a set of software objects called _context features_ that correspond to real-world context features relating to the learner’s setting, activity, device capabilities and so on to derive a _context substate_, as described above. Data can be acquired through either automated means (e.g. sensors or other software subsystems) or can be input directly by the user. This context substate is used to perform first _exclusion_ of any unsuitable content (e.g. high resolution web pages that cannot be displayed on a PDA) and then _ranking_ of the remaining content to determine the best _n_ options. This ranked set of options is then _output_ to the content delivery subsystem.

The sections below explain the operating principles underlying the context features, beginning with an outline of the kinds of metadata we anticipate using in the system, followed by a description of the context feature software objects that perform the context processing.
2.1. Use of Metadata

The primary purpose of CAS is to perform intelligent matching between metadata on learning materials, services, and options (content metadata) and metadata on the learner and their setting (context metadata). By looking for content metadata that matches the metadata of the current context, the system can make recommendations about what content is appropriate.

![Diagram of context awareness and metadata](image)

**Figure 3: context awareness and metadata**

This process is illustrated in Figure 3 – context metadata from the learner and their setting is matched to content metadata drawn from the set of available learning materials, options, and resources.

There are two crucial prerequisites for the successful completion of this process. Firstly, available content must be appropriately marked-up with a suitable metadata schema. Secondly, the system must have access to relevant metadata about the context, i.e. the learner and their setting.

2.2. Acquiring content metadata

For our first prototypes we are anticipating the use of a metadata schema being developed as part of a PhD at the University of Birmingham by Chan. This schema is based on the draft IEEE Learning Objects Metadata schema (IEEE 1484.12.1-2002, 2002) and includes extra elements appropriate to our approach to context and our desired level of context awareness.

Work is underway to build a database of content suitable for the MOBIlearn project, and it is anticipated that the learning content management subsystem will handle this content and all associated metadata, making it available to other architecture components as required.

2.3. Acquiring context metadata

We have identified two main aspects of the learner’s context, namely their **setting** (including physical location, objects and people in close proximity, and available resources) as well the **learner** themselves (including their current activities, goals, and learner profile).

**Setting metadata**

Any context aware application or service depends on being able to obtain contextual information from the user’s environment or **setting**. For the MOBIlearn system, we anticipate relying on both automated input from sensors and other software, and on input from the user themselves as to their state and the state of the world.

Some possibilities for automated input include the use of location data derived from tracking a device within a wireless LAN, and the use of infra-red or RF (radio frequency) tags to signal the proximity of nearby objects. Wireless network tracking is becoming an increasingly feasible option with the availability of software such as Ekahau’s Positioning Engine (see www.ekahau.com) which can use wireless LAN signals to locate a device to within a few metres, and RF tags are also looking promising as a way of implementing cheap and robust object identifiers. Also, since many handheld devices now feature Bluetooth technology as standard, this is another way in which RF technologies could be used for identification and communication purposes within a context aware application framework.

**Learner metadata**

The learner or user also forms part of his or her own context, and we anticipate the use of contextual metadata relating to both the user’s **status** (including their current goals and activities) and their learner profile.

User status is perhaps the most difficult aspect of context to acquire through automated means, but it is not impossible. Bristow has demonstrated the use of simple accelerometers to detect whether a user is sitting, standing, or walking. Information of this sort could easily be used to tailor information displays.

**Student or learner modelling** approaches aim to add user-adaptivity to the component(s) of a learning environment by adapting i) the selection and form of information to be presented; ii) the content of problems and tasks; and iii) the content and timing of hints and feedback (see Jameson, 2003 for more details). In this way learner modelling seeks to use information about the user and their experiences to guide content delivery. This approach to context awareness is relevant to MOBIlearn, and we anticipate a use for models of this sort within the context awareness subsystem.
Aspects of the learner to which a learner model can respond include the following:

- The learner’s knowledge of the current topic area, including knowledge acquired before use of the current system
- The learner’s learning style, their motivation, and their general way of looking at the topic area
- Details of the learner’s current processing of a particular problem

The underlying assumption to the use of learner modelling is that the use of this kind of information can help make the learner’s experience more effective and enjoyable, and this assumption appears to be borne out by the research in this area (for example Corbett, 2001, cited in Jameson, 2003).

Clearly there are ethical issues to consider when gathering detailed information about users – this issue is discussed further in Section 3.

2.4. Context features

The context awareness subsystem comprises a set of software objects called context features that respond to features of the real-world context to provide an ordered list of recommended options.

Types of context features

Context features are either excluders or rankers. Items of content that are deemed entirely inappropriate for the current context are excluded. That is to say they are removed from the list of recommended content and not subject to any further consideration. Content remaining in the list after the exclusion process is then ranked according to how well it matches the current context. The ranking process simply increments the score of each item of content that has metadata matching the stimulus values of any particular context feature. The size of the increment depends on the salience value of the context feature doing the ranking. Individual context features can have their salience values changed so that they exert more influence on the ranking process. Any individual context feature can be de-activated at any time so that it has no effect on the exclusion or ranking processes.

A context feature has a set of possible values, and an indicator of which value is currently selected. It is also possible for context features to have multiple sets of possible values, with the current active set being determined by the current value of another linked context feature.

Linked context features

Each context feature responds to only one metadata tag and performs either an exclusion or ranking function. To achieve more complex filtering of content, context features can be linked together so that their function (i.e. their stimulus and response values, their salience, and whether they are enabled) can be dependent on the state of other context features. For example, we might choose to have a context feature that excludes content based on its file-size – such a context feature should be active if the learner is using a low-bandwidth connection, but it should remain quiescent if there is a high bandwidth connection available. By creating a context feature which responds to bandwidth availability and allowing it to control the status of the context feature that responds to file-size, we can easily create a pair of context features that respond to a more complex context. The linking process is transparent to the user and to individual context features, so long chains can easily be created to cope with complex situations.

Output

The ordered list of ranked items of content is passed to delivery subsystems for use in determining exactly what content should be made available to the user. In this way, the context awareness subsystem has no way of specifying exactly what is made available – the system is intended to only make recommendations to the system and to the user.

2.5. Integration with MOBIlearn system

The overall aim of the MOBIlearn project is to produce a reference architecture for delivering learning content to users of mobile devices. The context awareness subsystem represents an essential part of that architecture, but ultimately it is dependent on other subsystems to fulfil the goal of providing the user with a rich and effective learning experience. As the CAS is responsible for recommending learning content to be delivered to users, there are clear interdependencies between the CAS and the content management system which is responsible for handling the content database, accepting recommendations, and then making appropriate content available to the user.

The CAS will also have intimate links with an adaptive human interface (see Vainio and Ahonen, 2003), intended to provide a usable, functional interface on a variety of devices.
Users must be able to inspect, understand, and modify the context model at any time.

Additionally, given our aim of providing recommendations about not only content per se but also relevant services and options, the CAS will also be linked to a collaborative learning system.

Content delivery itself will be handled mainly by a learning content management subsystem that will maintain a repository of available learning content along with any associated metadata. The content delivery subsystem and the CAS will function in tandem to deliver contextually relevant content to the learner.

3. Ethical Issues

Clearly, the gathering of contextual data could involve the use of information that is personal and private to the users involved. Such information needs to be gathered with the consent of users, and must be stored securely so as to prevent misuse by third parties.

There are five main questions to ask when considering the ethical implications of the use of contextual data:

1. What information do we obtain?
2. How do we obtain it?
3. What do we use it for?
4. What risks are there in doing this?
5. What do users think about it?

Data being gathered without users being aware of this is part of our learning solution but unfortunately also part of the larger problem of ethical gathering and application of user data.

There are specific international guidelines and legislations that address concerns about the gathering and use of such data, and we will defer to the recommendations set out in such documents in our use of contextual data.

The following issues are of concern:

- **Informed user consent:** users must be made aware of what data is being gathered and what it is being used for, and this consent should be ongoing in the sense that users are kept informed for the whole time they are using the system and have the right to change or withdraw their consent at any time. They should also be made fully aware of the security risks of this data being gathered, stored, and used.

- **Control:** where consent has been given for the gathering and use of contextual data, users should be given information, access, and control over data.

- **Security:** it will be our responsibility to ensure that any gathered data is stored securely, available only to necessary parties, and to prevent the misuse of data by third parties

Particular security problems arise when information is stored on computers other than the user’s own. We must ensure that as little info as possible is used, i.e. only the essential minimum, and that it is held securely so as to be accessible only within the MOBilearn system.

Some useful work addressing these issues has already been described in Rainio (2000) and the intention within MOBilearn is to follow-up such work and ensure that we adhere to any relevant guidelines and legislation.

4. Current status and work in progress

The CAS is currently implemented as a prototype demonstrator in Java. The prototype illustrates the operating principles of the architecture as a standalone demonstrator.

The next steps for the MOBilearn context awareness subsystem involve linking the CAS prototype to sensors that can provide real-world context features on a mobile device such as a tablet PC or PDA. As we move towards integrating the CAS with the rest of the MOBilearn architecture we are exploring implementation methods such as Web Services Architectures (see Booth et al., 2003) to achieve flexible integration of the relevant components.

The CAS prototype will be evaluated as a standalone context aware application by asking users to perform a set of simple information retrieval tasks in mobile contexts. The results of these evaluations will inform the next phase of our design.

5. Acknowledgements

This research is supported by the European Commission’s 5th Framework Programme on Information Society Technologies, project no. IST-2001-37187, MOBilearn: Next-generation paradigms and interfaces for technology supported learning in a mobile environment exploring the potential of ambient intelligence.

We would like to gratefully acknowledge the contributions of non-author project partners to the work reported in this paper. More details of the MOBilearn project can be found at http://www.mobilearn.org.
6. References


