IMPLEMENTING A CONTEXT-SENSITIVE MOBILE LEARNING SYSTEM

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ABSTRACT

As learning moves beyond the classroom and into everyday life, the supporting technology must be able to adapt, not only to the situations in which learners wish to learn but also their particular style of learning. Modern learning paradigms, such as mobile and ambient learning embrace adaptation through context-sensitivity. Context-sensitivity allows systems to carry out their main functions, whilst still adapting their behaviour. A user's idiosyncrasies are important contextual information that must be handled. The work presented here demonstrates how Dreyfus' level of competence, Gardner's multiple intelligences and Hofstede's cultural dimensions can be used as a basis for modelling users through stereotypes, and further how a context-sensitive mobile learning systems can use this to adapt its behaviour when assisting learners. It shows how an implementation of such stereotypes and details initial functionality testing.

KEYWORDS

Mobile learning, user modelling, context.

1. INTRODUCTION

Advances in ubiquitous and mobile technology have facilitated learning outside the classroom, where and when desired. Technology now allows learners to access recourses and interact with their peers and teachers while being mobile. This mobility heavily influences the development of suitable learning system. Many learners wish to continue their learning in response to ongoing situations without time being specifically set aside for it [Eraut, 2006] or combining it with leisure [Thornton et al., 2005].

The flexibility of modern learning paradigms, in particular mobile learning [Sharples et al., 2005] and ambient learning [eTEN, 2004], fosters a closer look at making the corresponding systems context-sensitive. Learning can be claimed to be situated [Greeno, 1998]. Some of the most important contextual information in mobile learning systems is the competence of the users and their style of learning. Constructing a system that is sensitive to this type of information requires a user model. The type of user model is dependent of whether the user group is highly homogeneous or heterogeneous. In the former case the easiest solution is using canonical user models, whereas in the latter specific user models are likely to be preferred. With respect to the specific learning styles, mobile learning appears to be leaning towards the use of a specific user model. However, specific user models can often be a time consuming, both in modelling and run time.

The work presented here argues that the use of stereotype user modelling is a promising approach for constructing feasible general, yet sufficiently specific user models. We take our departure from the work by Rich [1983] on stereotype modelling, which we attempt to ground in learning and social theories from Dreyfus [1998], Gardner [1984] and Hofstede [2001].

The rest of the paper is structured as follows: First, the relevant background is described. Then, an overview of our design and implementation is presented. This is followed be a running example from our initial testing of the system. Finally, the paper is concluded and some pointers to future work are presented.

2. BACKGROUND AND RELATED WORK

The idea of ubiquitous computing [Weiser, 1991] is an important influence when dealing with mobile learning. As computers fade into the background, the focus shifts from the computer to user activities. Yoshida [2006] states that a characteristic of ubiquitous learning is that anyone can learn anytime, anywhere, and for any purpose. These qualities are also relevant for mobile learning, where a mobile learning system must focus on learning across situations. This is also argued by Sharples et al. [2005], who tell us that learners might gather their ideas and learning resources in one place, and then applies them in another. A mobile learner's efficiency is affected by the system's ability to be: learner centred, knowledge centred, assessment centred, and community centred [Barnsford et al., 2000]. All in all, a mobile learning system must adapt to its users, and not vice versa. Adapting to a user requires some knowledge of the user and the user's context. We adhere to the definition by Dey and Abowd [2000], who states that: "Context is any information that can be used that characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves."

One important aspect of context is the user. The main approach for adapting a system to a user is through user modelling. Rich suggested the use of stereotype modelling for adaptive systems [Rich, 1983]. A stereotype contains characteristics ascribed to the user that fits this particular stereotype. The main advantages of using stereotypes are the fact that they are easy to build and quick to use. These properties are highly desirable in a ubiquitous computing environment, where users might change over time.

A system using stereotypes must include information on the stereotypes themselves, and the characteristics for each of those. The latter is referred to as *facets*. Each facet represents a certain quality and is coded with a value ranging from -5 to 5. Each facet has a certainty assign, ranging from 0 to 1000. This rating tells us how certain that the system is about the value assigned. Thus a high value tells us that the users is very interested in the particular facets, while a high rating tells us that we are very certain of the rating.

Stereotypes are traditionally structured in a directed acyclic graph (DAG), where the root node is *any-person*, which contains all facets with a value around 0 and a very low rating. As we traverse the DAG downwards the stereotypes become more precise. When all the stereotypes have been constructed the specific user model, known as a *User Synopsis*, can be build. For each facet the value and rating are assign the average for each of the stereotypes that matches the user in question.

Often stereotypes are defined by simplifying subjective perception on what aspects one can ascribe to a certain group of people. However, as we aim to build well functional adaptive systems, we should diverge from a very strict view on stereotypes and attempt to ground them in existing theory. One approach that demonstrates how construction of stereotypes can be grounded in theory is described in Kofod-Petersen et al. [2008] where Dreyfus' stages [Dreyfus, 1998], Gardner's multiple intelligences [Gardner, 1984], and Hofstede's cultural dimensions [Hofstede, 2001] are used to construct stereotypes.

3. DESIGN AND IMPLEMENTATION

The system presented here falls in the category of Personal Learning Environments (PLE). PLEs are considered the future for e-learning, yet no common understanding of the term PLE exists [Johnson et al., 2006]. Our interpretation of a PLE is to create an ambient intelligent environment, where user profiling is achieved through stereotype modelling. In brief, the system presented here is based on handheld devices connected through a wireless LAN, which also facilitates positioning. The main purpose is to supply students with tasks, related to their curriculum, that are relevant to them and connected to their physical location. In addition, the system can facilitate cooperation between peers by suggesting potential partners based on the students in question, other students near by, and the task in question.

The initial implementation uses the infrastructure supplied by Wireless Trondheim [Andresen et al., 2007]. The system is accessible through a standard web browser, using Java Server Pages (JSP) and Cascading Style Sheets (CSS). The handheld client of choice is the Apple iPod Touch.

The work presented here focuses on the way the user profiles are handled. As described above, user profiles are represented through stereotypes, and in particular by grounding them in three different theories: Dreyfus' stages, Gardner's multiple intelligence, and Hofstede's cultural dimensions.

Dreyfus' stages describes five stages, where every learner finds himself in only one of these at any give time [Dreyfus, 1998]. Each stage contains some characteristics about the user, which describes the approach to problem solving. By examining the description supplied by Dreyfus, each stage can be mapped into a set of suitable facets. The stereotypes and corresponding facets are shown in

Table 1. Stereotypes and facets from Dreyfus

Stereotype	Facets
Novice	Recognise, remember
Advanced beginner	Interpret, note, recognise
Competence	Reasoning, understand, emotional involvement
Proficiency	Situation discrimination, see goals
Expert	See goals, achieve goals

Table 2 Stereotypes and facets from Gardner

Stereotype	Facets
Spatial intelligent	Images, shapes, 3D-spaces
Linguistic intelligent	Write, speak, mnemonic
Logical-mathematical intelligent	Logical, numbers
Bodily intelligent	Physical, touch, feeling
Musical intelligent	Rhythm, musical, sound
Interpersonal intelligent	Human contact, communication, cooperation
Intrapersonal intelligent	Self-reflection, self-discovery
Naturalistic intelligent	Natural contact, natural communication

(Tables 1-3 are adopted from Kofod-Petersen et al. [2008]).

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Gardner's multiple intelligences describe eight different intelligences that a person can exhibit. Gardner [1984] argues that each individual is strong in three of those. Applying Gardner's theory to stereotype modelling results in a set of stereotypes with corresponding facets, see .

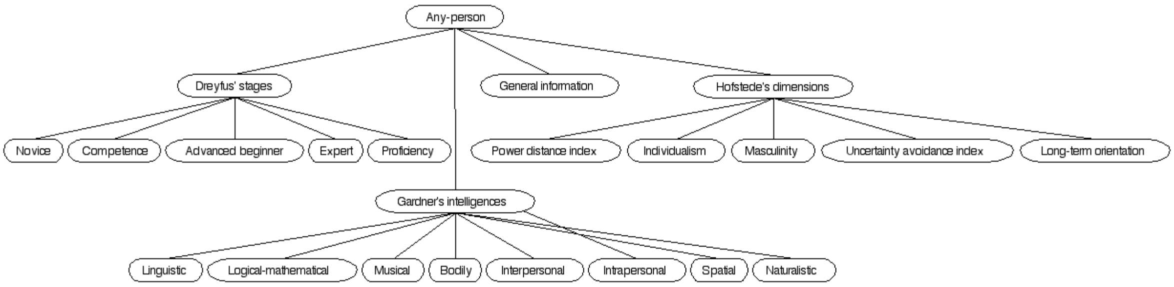
Finally, Hofstede's dimensions describe the cultural dimensions that affect the behaviour of societies and organisations [Hofstede, 2001]. Table 4 describes the stereotypes and facets acquired from Hofstede.

Table 4 Stereotypes and facets from Hofstede

Stereotype	Facets
Power distance index	Respect, discipline, teacher depended
Individualism	Independent, individual desire, talk active
Masculinity	Attract attention, competition, attainment, success
Uncertainty avoidance index	Uncertain, angst
Long-term orientation	Persevering behaviour, save money

Following Rich, the stereotypes are organised into a hierarchy (Figure 1). As aforementioned, the root node is *any-person*. The stereotypes for each of the three theories are organised one level below any-person. Contrary to the original work by Rich, there are not many levels in this tree. This follows from the usage of the three theories, where it is impractical and even counter productive to separate further.

Figure 1 Stereotypes hierarchy



In addition to the stereotypes, the tasks that the user is to carry out are modelled in accordance with the different facets described above. By relating the task descriptions to the stereotypes the system is capable of selection appropriate tasks for each user. It is important to note that only the stereotypes from Dreyfus and Gardner are used to actually describe and select tasks. As Hofstede's dimensions revolve around social structure, the stereotypes resulting from Hofstede are used to select appropriate and near by students for cooperation. Therefore the stereotypes arriving from Hofstede will only be touched upon briefly.

There are five levels of competence in Dreyfus and eight intelligences from Gardner. To ensure a well functioning system, it is important that each student is assigned tasks that are relevant. Thus, to have one task that fits all combinations of Dreyfus and Gardner, a minimum of 40 tasks are required. However, as one of the purposes of this system is to adapt to specific users, more tasks are better.

Finally, adapting the user model is carried out in two ways: calculating level of competence, and values and ratings for the multiple intelligences. The level of competence is easily calculated by measuring if the user is capable of solving the tasks presented.

With respect to the different intelligences, the system will randomly ask the user if he felt that the presentation of the task was appropriate. Initially, the system will have a high variance in calculation of the values for each facet. As a function of the number of questions answered, the system will gradually modify the values with a lower and lower variance. This approach counters any wrongly chosen intelligence in the beginning, while making the values more and more stable as time progresses. The rating is calculated by looking at the average historical feedback resulting in the *totalVariance* as shown in . The rating is the calculated using

Equation **1** Total variance

$$totalVariance = \sum_{0}^{numberOfFeedbacks} |\, numberOfThisFeedback \bullet feedback - average) \,|$$

Equation 2 Rating

$$rating = \left(\frac{totalNumberOfFeedbacks}{totalNumberOfFeedbacks + totalVariance + 1} \right) \bullet 1000$$

. This approach makes the rating more and more stable over time.

Equation 1 Total variance

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Equation 2 Rating

$$rating = \left(\frac{totalNumberOfFeedbacks}{totalNumberOfFeedbacks + totalVariance + 1} \right) \bullet 1000$$

4. TEST AND EVALUATION

The initial test revolves around testing if the adaptation of the user model works correctly. Therefore, only three students were selected. The participants started off by registering on the web page, where they answered the questions for the system to select the corresponding stereotypes. After registering the participants moved downtown and into the area covered by Wireless Trondheim. In addition to the registration, 200 tasks were prepared all within in area of first year mathematics for upper secondary school. To investigate if the participants' user model changes over time, the log files can be investigated to see how the values and ratings change. To illustrate the system's adaptation we will investigate the changes in participant 49's (P49) user model.

Initially P49 answers that he fits into the *novice* stage from Dreyfus' stages. After answering the questions related to Gardner's multiple intelligences the system can generate the relevant values and ratings.

Table 5. Participant 49's intelligences

Intelligence	Value	Rating
Linguistic intelligence	3	416
Logical-mathematical intelligence	2	445
Musical intelligence	4	461
Bodily intelligence	1	418
Spatial intelligence	3	520
Interpersonal intelligence	2	445
Intrapersonal intelligence	2	461
Naturalistic intelligence	5	532

Table 6. Participant 49's dimensions

Dimension	Value	Rating
Power distance index	0	363
Individualism	2	444
Masculinity	0	500
Uncertainty avoidance index	2	363
Long-term orientation	1	500

shows the final values and ratings after answering all the multiple intelligences questions.

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The system suggests that the user is strongest in *naturalistic intelligence*, *musical intelligence* and *spatial intelligence*, thus activating these stereotypes. Following the questions regarding Gardner's multiple intelligences, the user answered the questions concerning Hofstede's dimensions. shows the values and ratings calculated after these questions.

The user model, or User Synopsis (USS) in the word of Rich [1983], is the sum of Dreyfus' stages, Gardner's multiple intelligences and Hofstede's dimensions.

To investigate if the user model changes over time, as a response to the user's interaction with the system, we have to look at the state of the user model after the experiment is done, in particular with respect to the preferred intelligences. By investigating log files from the systems, we can continue to follow participant 49 around as he interacts with the system.

The first task is presented to the user as he enters the main shopping mall in the centre of Trondheim. The task is chosen in such a way that it reflect the user's three main stereotypes: naturalistic, musical and spatial. The user is further asked to report whether or not he likes the presentation of the task (not the task itself). The user solves the task, yet reports that he is not satisfied with the presentation. Due to the nature of the task, the *Intrapersonal* value is increased with one, to 3, and the rating is adjusted accordingly to 516. Even with this increase the three preferred stereotypes remain the same.

After the initial task the user is presented with more tasks that match the three main stereotypes. As the user solves the tasks the competence level is potentially increased, and when the user fail to solve a task the level is potentially decreased.

Five tasks later, the user is again asked to verify the presentation. This time the user is not satisfied with the presentation and the *Intrapersonal* value is again affected. This time the value is decreased with one, down to 2, and the rating is adjusted to 482. As before, the three preferred stereotypes are unaffected.

Six more tasks are presented to the users before the next question on presentation. This task is designed to test the *naturalistic* value. The users is again dissatisfied with the presentation, thus the value of naturalistic is decreased with one, down to 4, and the rating down to 450. Again the three main stereotypes remain unaffected.

The following task is again accompanied by a question on the presentation. This task affects the *interpersonal* value, which as a result of the answer is increased to 3 with a rating of 482.

Three more tasks are presented until another question on the presentation. This time the answer confirms the *intrapersonal* value. The value is kept at 2, however the confidence, or rating is increased to 508.

After the next two tasks, the user's answer to the question increases the *intrapersonal* value by one, and the rating to 528.

The user is now done and has completed 18 tasks, of which 17 of were different, and one was repeated in the beginning and end. The total time used, including registration was one hour, eight minutes and twenty eight seconds. As described above, the system has continuously modified the values and ratings of the user model. Table 8 shows the final distribution of values and ratings after this short experiment, as well as the original ones.

Table 8 Comparison of original and adapted values and ratings

Intelligence	Old value	Old rating	New value	New rating
Linguistic intelligence	3	416	3	416
Logical-mathematical intelligence	2	445	2	445
Musical intelligence	4	461	4	461
Bodily intelligence	1	418	1	418
Spatial intelligence	3	520	3	520
Interpersonal intelligence	2	445	3	482
Intrapersonal intelligence	2	461	3	528
Naturalistic intelligence	5	532	4	450

If we investigate Table 8 we can most values and ratings are unaffected. Yet, *Interpersonal* and *Intrapersonal* has increased in both value and rating. Where as, the values and ratings for *Naturalistic* have decreased. In other words, the system has reasoned that the user in question is more interpersonal than originally assumed, from 2 to 3, and it is slightly more confident in this value, from 445 to 482. The same is true for intrapersonal, which has increased from 2 to 3, and the confidence from 461 to 528. Finally, the system has gathered that the user is less naturalistic than originally assume, with a decrease from 5 to 4, however it is less confident in this assumption, the rating has decreased from 532 to 450. These changes have lead to the fact that one of the three preferred intelligences has changed. The original preferred spatial intelligence has been changed to intrapersonal.

Even though it is evident that there have been some changes to the values and ratings, as well as the preferred stereotypes, this experiment was quite brief. It is worth underlining that the more time the system has the better the user model will be.

5. CONCLUSION

The work presented here has demonstrated how it is possible to apply theories on learning as an integrated part of a user model. The system developed applied the five level of competence from Dreyfus to select the level of difficulty of tasks presented to the user. It further used Gardner's multiple intelligences to present tasks in a suitable manner. Finally, Hofstede's cultural dimensions have been prepared to allow the system to select suitable tasks for cooperation, but have yet to be used.

This is ongoing research, and as such has some challenges that are currently unaddressed. The fact that cooperation has yet to be tested has already been mentioned. Further, the test described here only shows that the system is actually functioning. It is important to test this system on a larger scale, where both the functionality and perhaps more importantly the usability can be thoroughly tested. Finally, we argue that the ability to handle user modelling in these types of systems is of high importance. Therefore, it is important to investigate the inclusion of further contextual information, beside those presented here and location, in this type of user model.

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