Learning in an Ambient Intelligent Environment

Towards Modelling Learners through Stereotypes

Anders Kofod-Petersen* — **Sobah Abbas Petersen*** — **Gunhild Griff Bye*** — **Line Kolås*,**** — **Arvid Staupe***

* *Norwegian University of Science and Technology, 7491 Trondheim, Norway*

{anderpe,sap,gunhildg,linek,staupe}@idi.ntnu.no

** *Nord-Trøndelag University College, 7729 Steinkjer, Norway*

line.kolas@hint.no

ABSTRACT. *Ambient learning is an area that combines mobile learning, situated learning and context awareness, where the learners wish to learn anytime, anywhere and anyhow. The context of ambient learners is dynamic and they tend to engage in short bursts of learning, where the learning content must be adapted to the dynamic nature of their learning needs. One of the challenges of supporting such learners is the development of learner models that could be used to define the learning resources at any point in time. In this paper, we have considered stereotype modelling as a means of modelling ambient learners so that the learning resources could be quickly and efficiently adapted to the learner.*

RÉSUMÉ. *L'apprentissage diffus est un domaine qui combine l'apprentissage mobile, l'apprentissage situé et l'attention au contexte, et où les apprenants souhaitent apprendre à n'importe quel instant, n'importe où, et de n'importe quellle manière. Le contexte des apprenants diffus est dynamique et ceux-ci tendent à s'engager dans de courtes explosions d'apprentissage où le contenu de ce qui doit être appris doit être adapté à la nature dynamique de leurs besoins en apprentissage. Un des challenges pour aider de tels apprenants est le développement de modèles d'apprenants utilisables pour définir les ressources à tout instant. Dans ce papier nous considérons le stéréotype modelé comme un moyen de modeler des apprenants diffus de sorte que les ressources d'apprendre puissent être adaptées à l'apprenant.*

KEYWORDS: *Ambient learning, Context awareness, User modelling, Mobile learning.*

MOTS-CLÉS : *Apprentissage diffus, Attention au contexte, Modélisation de l'utilisateur, Apprentissage mobile.*

1. Introduction

Advances in ubiquitous and mobile technologies have facilitated learners to continue their learning outside their classrooms, when and where they desire. Recent research has shown that learners desire to continue their learning processes outside of their classrooms and combine learning with leisure (Thornton *et al.*, 2005) or learn spontaneously, in response to recent, current or imminent situations, but without any time being set aside for it (Eraut, 2000). Learning paradigms have evolved from distance learning to e-learning to mobile learning (m-learning) and ambient learning. Mobile learning denotes learning that is conducted while the learner is on the go or when the learner is mobile (Sharples *et al.*, 2005). Hence, when the learner is outside the classroom and classroom hours, the learner is mobile and needs access to the learning resources such as books, literature and people. The term ambient learning (Amb, 2004) has been used to bring together the concepts of mobile learning (learning anytime and anywhere) and situated learning (Lave *et al.*, 1991), where the learner's current situation and learning context are considered.

The IST Advisory Group in European Union (ISTAG) defines ambient intelligence as human beings surrounded by intelligent artefacts, supported by computing and network technology embedded in everyday objects. More importantly, the environment should be aware of the presence of a person, perceive the needs of this person and respond intelligently to them in a relaxed an unobtrusive manner (Ducatel *et al.*, 2001). To respond to the needs of the user, there is a need for a user model.

When using systems that require user models to adapt their services some considerations as to the nature of these models and the domain in question must be made. In domains where the user group is highly homogeneous, canonical user models are likely to be the best option, whereas in domains where the user group is highly heterogeneous specific user models are likely to be the preferred option. We have earlier suggested an ambient intelligent architecture and implementation where a one-to-one coupling between the system instance and the user exists (Kofod-Petersen *et al.*, 2005a). In this case the system builds an implicit user model over time, by storing experienced situations as cases and utilising case-based reasoning as the means of achieving context-awareness, thereby adapting its behaviour to the user's idiosyncrasies.

We have previously suggested how to use an ambient intelligent system in a mobile collaborative learning domain (Petersen *et al.*, 2006a). The number of users in ambient intelligent systems may potentially be very large and diverse than in more controlled settings such as hospitals (Kofod-Petersen, 2006; Kofod-Petersen *et al.*, 2006). In this case, an extensive modelling of the domain is likely to prove unfeasible. Thus, some explicit user model is required. The work presented here expands on the use of stereotype modelling as a means of realising an explicit user model in an ambient intelligent setting presented in Kofod-Petersen *et al.* (2007).

Several pedagogical and psychological theories deal with issues such as a learner's level of competencies, his capabilities and relationship to society. The work presented here takes it origin from Bloom's taxonomy of cognitive domains (Bloom, 1956), and utilises Gardner's theory of multiple intelligences (Gardner, 1985), Dreyfus' stages of proficiency (Dreyfus, 1998) and Hofstede's framework for assessing cultures (Hofstede, 2001) for constructing stereotypes in the tradition of Rich (1983), in the ambient learning domain.

The rest of the paper is structured as follows: First, the background on ambient intelligence and ambient learning is described. This is followed by an overview of mobile collaborative learners, how user modelling can benefit an ambient learning domain, our interpretation of context, and finally an overview of the three theories used for constructing stereotypes. Secondly, the existing ambient intelligent framework is briefly presented. Thirdly, stereotype modelling is presented as well as the use of the three theories and how they are mapped into stereotypes and corresponding facets. Finally, an outlook on future work concludes the paper.

2. Background

2.1. *Ambient Intelligent Environments and Ambient Learning*

To achieve ambient intelligent environments, several different paradigms and technologies must be integrated. The concept of ambient intelligence has been described as humans being surrounded by intelligent interfaces supported by computing and networking technology that is embedded in everyday objects such as furniture, clothes and the environment (Ducatel *et al.*, 2001). We see ambient intelligence as a combination of a number of paradigms (Petersen *et al.*, 2006b): ubiquitous computing (Weiser, 1991), pervasive computing (Satyanarayanan, 2001) and artificial intelligence (Russel *et al.*, 2002). The ubiquitous computing aspect addresses the notion of accessibility of the technology, where the technology and connectivity is available through everyday objects that are in the user's environment. Artificial intelligence techniques provide the context awareness to establish the user's needs and the appropriate response and the pervasive computing aspect supports the architectural aspects to realise the situation.

Ambient Learning has been described as having access to learning resources anytime, anywhere and anyhow. The main distinguishing features of ambient learning are multimodal broadband access to learning resources, context management and content integration (Amb, 2004). The main objective of ambient learning is to provide a pragmatic, easy to use personal learning environment, allowing anytime, anywhere, anyhow access that is being adapted to individual needs and to high quality learning material (Paraskakis, 2005). Learners are provided contextualised learning resources that are adapted to the current context and the situation and accessing existing knowledge catalogues and e-learning sources composes the learning resources.

A combination of technologies is often required to obtain the appropriate set of learning services that are required. An example of blended technologies in learning is described in Morken *et al.* (2005), where an interactive shared display in combination with email, Short Message Service (SMS) and other applications are proposed for collaboration among teacher trainees during their practice period. In Fallakhair *et al.* (2005), they describe the combined use of interactive television with SMS for language learners while watching TV.

2.2. *Mobile Collaborative Learners*

Language learning is one area where the learner has the need to complement the classroom learning with experiences outside of the classroom. In language learning, there is a strong component of informal learning that takes place outside the classroom through interactions with the society that complements and reinforces the formal learning that takes place in classrooms. Learners often experience situations where they would like to continue their learning processes as they go about their daily lives and while they are mobile. An exploratory study of language learners' use of technology has shown that learners desire to combine learning with leisure and entertainment (Thornton *et al.*, 2005). For example, a TV program may stimulate them to learn new words in a particular subject area or they may feel the need to learn the appropriate usage of a word or a phrase that appears in a conversation. Other areas where the learners are mobile as a part of their studies include teacher trainees, where they are required to acquire teaching practice in a school and medical students who are required to do an internship at a hospital before they are qualified as doctors.

Learning as a social activity has been the discussion of several books and articles (e.g. (Wenger, 1998) and (Lave *et al.*, 1991)). Many scholars agree that learning is most effective when it takes place as a collaborative rather than an isolated activity and when it takes place in a context relevant to the learner (Godden *et al.*, 1975). In our work, a socio-constructivist approach to language learning is considered where learning is supported by collaboration and the interaction with others (Vygotsky, 1978). In collaborative language learning, the social construction of knowledge occurs through the learners' interaction with other learners, teachers and various communities that support the learning process. Similarly, conversation has been identified as an important aspect of learning where learning is considered as a continual conversation with other learners and teachers (Sharples, 2005). This is particularly important in language learning where the learning is strongly influenced by situations (Ogata *et al.*, 2005) and culture (Tang, 1999). It is important for a language learner to learn in an appropriate cultural context and to interact with communities that exist in the cultural setting and practise the language with native speakers, fluent speakers and peers. A learner that is mobile and collaborates with other people as a part of her learning process is a mobile collaborative learner.

2.3. *User Modelling*

User modelling is done in learning systems to provide personalised learning resources to the learner. Personalisation of learning systems is often based on making them context-aware, where the definition of context has varied from the location of the learner (Hsieh *et al.*, 2007; Kuo *et al.*, 2007) to learner's leisure time and individual abilities (Chen *et al.*, 2007). According to Dey (2001), context is defined as any information that can be used to characterise the situation of an entity. Thus, information that is required to provide personalised learning resources to a language learner, i.e. the user model can also be considered as a part of the context of the learner.

The main parameters that have been used to model a user or the profile of a user in the literature are the user's name, gender, age, address, skills and experience level and interests. In the case of a language learner, the native language of the learner and the other courses that are taken by the learner can be useful (Markiewicz, 2006). In the mobile learning domain, context is viewed as dynamic, as being continually constructed through negotiation between communicating partners and the interplay of activities and artefacts (Syvänen *et al.*, 2005). Unlike the context for traditional learning, the context for mobile learning evolves according to the interactions of the learner. Thus, factors that have to be taken into account in user modelling, in addition to the learner's individual profile, include the evolution of the behaviour of the learner, the variables affecting the learning such as the social aspects and the uncertainty of the domain or the learning environment such as something happening unexpectedly (Viola *et al.*, 2007).

In Chen *et al.* (2007), personalisation is considered as similar to context awareness where the context of a language learner is defined as the learner's location, learning time, e.g. around Christmas time, learning abilities and leisure time. In their application, the learner's location is considered the most important parameter. In another application, the user model is just a part of a multi-modal approach to personalisation, where the user model describes the learner's personal data such as name, gender and address and the learner's interests and experiences is a part of the personalisation (Paredes *et al.*, 2005).

In Liu *et al.* (2005), they propose moving from user modelling to person modelling or cultural modelling by recommending suggestions to the user based on something other than domain-specific knowledge. They have used the concept of an InterestMap, where they conduct social data mining on web-based social networks to map people's interests and social and cultural identities (e.g. book lover, rock musician). Using this approach, they claim that better models of the person can be constructed which can be used to make recommendations for the user.

2.4. *Context*

Humans use an abundance of more or less subtle cues to define the context. A human, as any agent, is situated in the environment (Brooks, 1991), and is even inseparable from the environment (Gibson, 1979). Humans are also able to perceive their environment through a variety of sensors, such as sight, smell and touch, as well as capable of a large degree of flexibility in interpretation of these sensors. Thus, humans are capable of reasoning about perceived information and using this information as context when assessing situations and ultimately deciding how to behave in certain situations. However, as humans are individuals, context and situation assessment is subjective and can be regarded as collective*tacit* (Polanyi, 1964) knowledge (Brézillon *et al.*, 2001); that is, knowledge regarding assessment of situations belongs to somebody and is not shared, objective or public.

Artificial intelligence has historically been closely connected to formal logic. Formal logic is concerned with explicit representation of knowledge. This leads to the need to codify all facts that could be of importance. This view stands in stark contrast to the views advocated by people such as Polanyi, who argue that no such objective truth exists and all knowledge is at some point personal and hidden (tacit). Since context is an elusive type of knowledge where it is hard to quantify what types of knowledge are useful in a certain situation and possible why, it does not fit very well with the strict logical view on how to model the world. According to Ekbia *et al.* (2001), this has led to the fact that context has largely been ignored by the Artificial Intelligence community.

The ability to appreciate the environment and thus adapt to this is, within ambient intelligence, referred to as being context aware. One of the major challenges in context awareness is the lack of a common agreement on what context really constitutes. Dey *et al.* (2000) describe the different definitions of context available in the literature. The authors distil the different uses into a very flexible definition:

> Context is any information that can be used to 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.

Parallel to the analysis by Dey and Abowd, Chen *et al.* (2000) investigate the use of context in several available systems. Some of the investigated work was overlapping, thus they unsurprisingly arrived as quite similar definitions. In accordance with tradition in pervasive computing Dey *et al.* (2000) attempted to extend their *functional definition* of context into a domain independent *structural definition* by defining some parameters as always being context. When parameters *a priori* are being defined as always being context it leads us down the objective-truth path of *Episteme* (Aristole, 350 BCE). Brézillon *et al.* (1999), among others, argue that a particular kind of knowledge can be considered context in one setting and domain knowledge in another, or in their own words: " . . . knowledge that can be qualified as 'contextual' depends on the context!" (Brézillon *et al.*, 1999, p. 7). Thus, defining a set of parameters as always being context is contrary to the concept of context.

2.5. *Learning Interfaces*

Personal learning environments (PLE) are considered to be the future e-learning system, but there is still not a common understanding of what the term PLE means (Johnson *et al.*, 2006). One interpretation of a PLE could be to create an ambient intelligent environment based on stereotype modelling. A PLE must take into consideration that the learners are heterogeneous.

When working in domains with heterogeneous user groups it is necessary to find and describe the important factors that dintinguish different users. In order to achieve learning in an ambient intelligent environment, this is of course an integrated part of the construction of user models. There are numerous contributions in the literature of the pedagogical and psychological fields trying to describe the learner. Bloom's taxonomy for the cognitive domain (knowledge) has been an important contribution, and consists of six categories (starting from the simplest behaviour to the most complex); knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). There are taxonomies for the affective domain (attitudes) (Krathwohl *et al.*, 1964) and the psychomotor domain (skills) (Dave, 1970; Harrow, 1972; Simpson, 1972), in addition to revised taxonomies for the cognitive domain (Anderson *et al.*, 2001).

In the pedagogical field, there have been several attempts to describe a student's learning style. Coffield *et al.* (2004) have identified 71 models of learning styles, among which 13 were categorised as major models. Howard Gardner's theory about "multiple intelligences" provides a contribution to the discussion about who the learner is. In this theory, he defines eight different intelligences (Gardner, 1985). The idea is that all persons have eight intelligences, but that some intelligences are better developed than others. The eight different intelligences are:

1) Visual / spatial intelligence: The ability to visualise and make mental maps. Persons using mind maps are using this intelligence.

2) Verbal / linguistic intelligence: The ability of reading, writing and communicating with words. This intelligence is well developed among writers, journalists, speakers etc.

3) Logical / mathematical intelligence: The ability of logical thinking and performing calculations, and for abstract thinking. Mathematicians, engineers and lawyers have often developed this intelligence well.

4) Bodily / kinesthetic intelligence: The ability of body coordination and conscious use of own body and hands, an ability typically well developed among athletes, dancers, actors and craftsmen.

5) Musical / rhythmic intelligence: The ability of singing, playing, composing and having a good musical ear, usually found among composers, conductors and musicians etc.

6) Interpersonal intelligence: The ability of understanding people and communicating, usually well developed among competent diplomats, charismatic leaders and

among "persons that people like".

7) Intrapersonal intelligence: The ability of understanding our "self".

8) Naturalistic intelligence: The ability to recognise and classify elements / patterns of the natural world.

Where Gardner talks about different intelligences, Dreyfus (1998) separates students across different levels of proficiencies. Dreyfus argues that five stages of proficiency describe the way students moves from the novice stage, via advanced beginner, competence and proficiency to expertise. Each stage has some unique characteristics and students at each stage have different needs, such as a novice requiring models, rules and prescriptions, while an advanced beginner starts to utilise experience. With competence, the student uses plans to achieve goals, proficiency will allow a student to gradually replace theory connected with skill with situational discrimination. Finally, expertise allows a student to not only correctly identify what needs to be done, but also to see how the goal is achieved. Kolås (2005) have demonstrated how "multiple intelligences" and proficiency stages must be orthogonally combined in an attempt to achieve personalisation of e-learning interfaces.

Cultural differences influences the way we collaborate in general and with regards to learning in particular. Hofstede (2001) describes a framework for assessing cultures that builds on the assertion that all humans act based on inherent patterns. These patterns consist of mindsets, feelings and potential act-patterns. Hofstede uses an analogue to programming computers that is known as *software of the mind* (Hofstede *et al.*, 2004). Humans act on a set of mental assumptions consisting of values, rituals, heroes and symbols. The latter three can be comprehended and to a certain degree affected by an outsider or society as such. This insight led to Hofstede's five cultural dimensions:

1) Power Distance Index: The extent to which the less powerful members of organisations and institutions (like the family) accept and expect that power is distributed unequally.

2) Individualism vs. Collectivism: The degree to which individuals are integrated into groups.

3) Masculinity vs. Femininity: The distribution of roles between the genders.

4) Uncertainty Avoidance Index: A society's tolerance for uncertainty and ambiguity.

5) Long-term vs. Short-term Orientation: Thrift and perseverance versus respect for tradition, fulfilling social obligations and protecting one's "face".

3. Existing Framework

The work presented here builds upon an existing framework for ambient intelligent applications. This framework assumes a layered perspective on ambient intelligence (Kofod-Petersen *et al.*, 2006). Figure 1 depicts the functional system architecture, where the system *perceives* the environment, including the person; is *aware* of an ongoing situation and responds by being *sensitive* to the context.

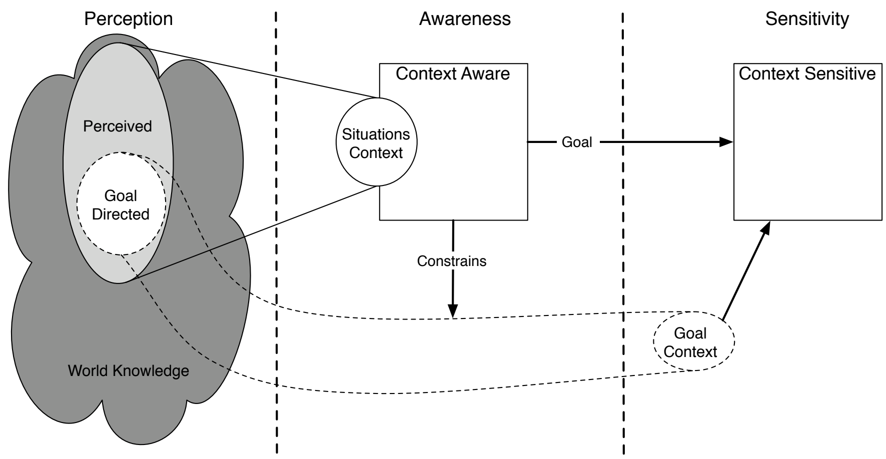

Figure 1. *Functional System Architecture*

The existing implementation employs context in two different manners. In initially uses a *Context Middleware* solution to perceive the environment (Kofod-Petersen *et al.*, 2005a). This middleware aggregates environmental information into a syntactic coherent structure that is transmitted to the awareness part, as the *Situation Context*. This context contains all available information in the environment, both from sensors in the physical environment and digital available information such as the stereotype user model proposed here.

Currently, case-based reasoning is used to classify an ongoing situation (Kofod-Petersen *et al.*, 2005a). All available information is used as the *findings* in a case, and the case-based reasoning engine retrieves cases matching this input. Once a suitable case has been retrieved, the goal of the situation is extracted. This goal is transmitted to the *Sensitivity* layer, which is responsible for responding to the user's needs. The goal extracted also constraints the context available to the sensitivity layer by selecting which information is relevant for achieving the goal.

The sensitivity layer acquires the goal from the awareness layer. Each goal is matched to an existing task-decomposition-tree. These trees are currently hand-coded, with one tree corresponding to each possible goal. These trees contains the tasks required to achieve the goal. These tasks are structured in a directed acyclic graph, where the leaf-nodes correspond to actions that are solvable (Gundersen *et al.*, 2005). Each task corresponds to any number of actions, which in the current implementation is executed by agents. The agents capable of performing each action are gathered based on availability and capability; that is, the *Goal Context* describes the environment in such a way that this layer can select appropriate agents. Once the goal has been achieved, the solution is returned and the user is informed about the solution.

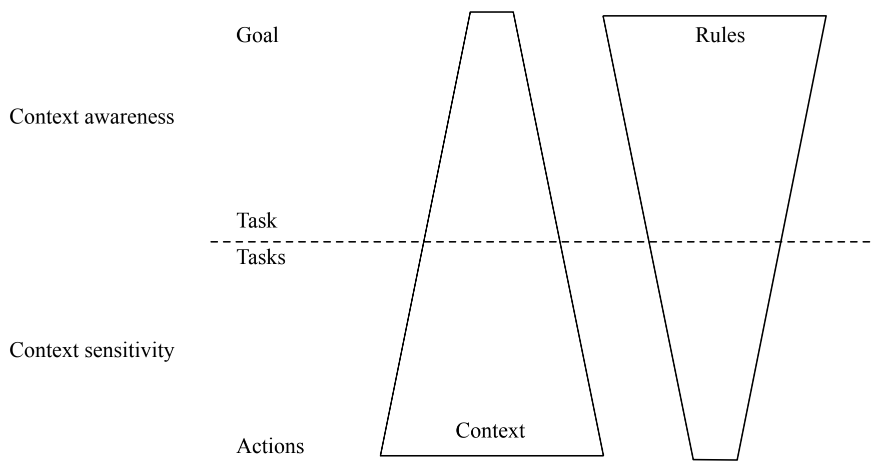

Figure 2. *Level of Contextualisation*

This dual use of context influences the level of contextualisation across the architecture. Figure 2 depicts the relationship between the use of rules and context across the functional architecture shown in Figure 1.

Initially, the case-based reasoning system can, to some degree, be perceived as a rule-based system with very large rules. A case's findings can be viewed as a problem's antecedent and its solution as the consequence. However, they differ in several important ways: *i)* rules are patterns, whereas cases are constants; *ii)* rules are retrieved based on exact matching, where cases only require partial matching; *iii)* rules are small, independent, and consistent pieces of domain knowledge, cases can be large chunks of potentially redundant domain knowledge. Thus, when retrieving the goal for a situation, and thereby implicitly the top-most task, context still plays a part in the awareness layer.

The relationship between rules and context is also important when investigating the sensitivity layer. Here, the initial selection of a task tree is largely governed by rules, supplemented with context; whereas, the selection of action is mostly governed by available context and less by rules.

The stereotype user model proposed here is an integrated part of the system's knowledge model. With the addition of this model, the knowledge model now contains six different areas all interconnected in a multi-relational semantic net (Aamodt, 2004; Kofod-Petersen *et al.*, 2005b; Kofod-Petersen *et al.*, 2006). Functionally, the stereotype user model does not differ in any way from the rest of the knowledge model. Knowledge contained in the stereotype user model is used as context in both ways shown in Figure 1. Initially, it is used to guide the case-based reasoning process in classifying an ongoing situation, that is deciding on which goal the student is to achieve. Following Figure 2, knowledge about the user is used as findings in the case-based reasoning process. Secondly, the relevant parts of the user model are used as the goal context when deciding upon the specific tasks that will satisfy the goal.

4. Stereotype Modelling

As aforementioned, an explicit user model has not been a focus in our work so far. However, as the nature of the mobile learner dictates that our system moves from a subjective perspective on the world and its user to a more objective view, an explicit user model is required. The work presented here suggests the use of stereotype modelling in the tradition of Rich (1983) as the means of constructing a user model.

A stereotype contains characteristics of the user, and may contain conditions that represent important characteristics, which for instance can indicate that the users belong to a given group. One advantage of stereotypes is that they are easy to build. This property is important in an ubiquitous environment since the users change over time. If the system is slow when generating the user model, there is a risk that the user will not use the system.

The specific user model, known as the *User Synopsis (USS)* in Rich, contains a specific model for each of the individual users. This model is a summary of the different stereotypes that are found relevant for the user. In addition to the facets, values and rating triplet, each tuple also contains a justification; that is the name of the stereotype that has supplied the specific triplet.

Stereotype are ordered in a directed acyclic graph in a "generalisation of" hierarchy. The root node of the graph contains the most general stereotype and the leaf nodes the most specific. Each of the stereotypes contain a set of *facets* with a *value* and *rating*. Following Rich, each of the facets' values are in a linear scale ranging from -5 to 5, where a positive value indicates that the stereotype is positive to the facet and a negative value indicates that the stereotype is negative to the facet. The ratings range from 0 to 1000 indicating the degree of certainty in the facet-value pair.

4.1. *Gardner's Stereotypes*

As described earlier, Gardner is concerned with the different intelligences that a person exhibits. The work presented her applies this theory to construct a set of possible stereotypes. Gardner (1985) argues that there are eight different intelligences and each individual is strongest in three of them. That is, each of the intelligences corresponds to a stereotype and a user will fit into three of these (see Table 1).

Stereotypes	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

Table 1. *Stereotypes and facets from Gardner*

When the user is mapped to the stereotypes, measurements acquired through questionnaires are mapped from a scale of 0 to 100 to the -5 to 5 scale employed by Rich.

When investigating the different intelligences or stereotypes suggested by Gardner, we can observe the concepts used to described them. By analysing these concepts a list of possible facets has been constructed (see Tabel 1.)

The facets of a *spatial intelligent person* are *images*, *shapes* and *3D-spaces*, based on a person's capability of conjuring up mental images and transforming them, working with shapes and navigating in three-dimensional spaces. *Write*, *speak* and *mnemonic* are the facets of a *linguistic intelligent person*. The first two facets are based on a person's abilities to read, write and speak. In addition to the directly linguistic abilities, the mnemonic potential is high. This ability maps to the facet *mnemonic*. The facet *logical* represents the ability of logical thinking of a person with a *logical-mathematical intelligence* and the facet *numbers* represents the ability to do calculations and understand numbers. The facet *physical* represents good physical condition and the fine control over ones body. Further, the facets touch and feeling are two very important facets for a *bodily intelligent person*. *Rhythm*, *musical* and *sound* are the facets of a *musical intelligent person*, who exhibits a good understanding of rhythm, as well as the ability to understand musical patterns and the ability to appreciate and make use of sound. The facets *human contact*, *communication* and *cooperation* are based on *interpersonal intelligent person's* abilities to understand communication and people, which make them good at cooperation and human contact. The facets of an *intrapersonal intelligent person* are *self-reflection* and *self-discovery*, based on a good understanding of himself; he will be aware of and reflect on himself. The *naturalistic intelligent person* is good at recognising and classifying patterns in nature. The two important facets for this type of persons are *natural contact* and *natural communication*.

4.2. *Dreyfus' Stereotypes*

As described earlier, Dreyfus (1998) states that every user finds himself in only one of the five stages at any given time. Each of these stages contains some characteristics about the user. When investigating the different stages as described by Dreyfus, we can map the concepts describing each stage into suitable facets. The stereotypes and corresponding facets are shown in Table 2.

Stereotypes	**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 Dreyfus*

The facets *recognise* and the important ability to *remember* the rules he has been taught represents the capabilities of a novice. When a person has acquired some experience in handling real situations, he will advance to the advanced beginner stage. This stage is described by a person's ability to still *recognise* context-free characteristics and further the person's ability to *interpret* situations and *note* patterns and/or discrepancies. Competence is the stage where a person begins to be able to formulate plans and select perspectives that reduce the possible aspects. This leads to the person being able to *reason* about and *understand* situations. Since the person now sees that choices lead to results, he will also have an *emotional involvement*. As a person's experience increases beyond competence, proficiency is achieved. Two important facets accompany proficiency: *situational discrimination* and the ability to *see goals* that must be accomplished. Finally, an expert knows what to do and how to do it. The two facets that describe an expert are to *see goals* and to *achieve goals*.

4.3. *Hofstede's Stereotypes*

Hofstede describes the cultural dimensions that affect the behaviour of both societies and other organisations. In particular, he describes a framework that consists of five dimensions. Each of these dimensions are modelled as a stereotype, each measurement will be in the range 0–100 and are mapped to the -5 to 5 scale. Each of the five stereotypes with their corresponding facets are shown in Table 3.

The facets of the *power distance index* are the amount of *respect* a pupil shows to his teacher. This ties in with the second facet *discipline*, which deals with how well behaved a person is, for example the behaviour of a pupil in class. Finally, pupils in a society with a *high power distance* tend to be *teacher dependent*. The facets of Dreyfus' second dimension, individualism, are based on that in a very individualistic

Stereotypes	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

Table 3. *Stereotypes and facets from Hofstede*

society, people tend to be *independent*, have *individual desires* and *talk actively*. The masculinity dimension deals with the values traditionally ascribed to males or females. Here, the facets describe how much a person enjoys *attracting attention* and the level of *competition*. Further, the desire to achieve *attainment* and show this to others is an important facet. Finally, the level of desire for *success* can, according to Hofstede, be based on gender. A person in an environment with a high *uncertainty avoidance index* has the characteristic of being *uncertain*. Further, uncertainty can lead to fear, uneasiness and worries about unspecified objects leading to *angst*. Finally, the facets of the *long-term orientation* deal with the perspective of the person involved. People in an environment with high long-term orientation have a *persevering behaviour*. This type of behaviour is evident when a person is patient and does not require instant gratification. Another characteristic often associated with a long perspective is a person's desire to *save money*.

5. Towards Implementation

We are currently implementing a module for acquiring the necessary knowledge to construct a user model based on the stereotypes presented here. The implementation will primarily use online questionnaires as a means of acquiring knowledge of a student. However, this approach requires immaculate attention to details since questionnaires have many pitfalls (Robson, 2002).

The first time a user registers in the system, some information is required from the user. Initially, some general information must be supplied, such as gender, date of birth, nationality, school, class and interests. In addition, information related to Dreyfus' stages is required. This contains the proficiency level of the user in the different subjects that are related to the user's school class. Finally, a small test that gathers information related to Garder's multiple intelligences and Hofstede's dimensions must be filled in. As the user fills in the forms, the user model is updated. After this initial user model, the system is left with the responsibility of updating the user model continuously, depending on the user's activity.

Gardner's theories on multiple intelligences, Dreyfus' proficiency stages and Hofstede's cultural dimensions provide us a means of using stereotype modelling to map the user model so that the system could respond quickly. However, there are some open issues, in particular the question on how to acquire the knowledge necessary for representing a student is largely unanswered. With regards to Gardner's multiple intelligences, existing (online) tests are available and his theory already influences the existing school systems; with regards to Dreyfus, the specific stage a student is currently in can either be acquired from the student's teacher or through methods employed in intelligent tutoring systems. Thus, we do not anticipate significant problems when acquiring this part of the user model. Hofstede's dimensions have been criticised for not being applicable to individuals in the sense that the model might be correct for the general population but not for specific individuals. We are currently working on how to incorporate Hofstede's model into the other models.

The task model contains information about subjects, goals and tasks that are registered in the system. The subjects are related to the school and the class that the user is registered in. The tasks are related to the subject and to different proficiency levels and intelligences. The user has the possibility to select a subject and look at the tasks related to his user model. The user has the possibility to solve these tasks based on a sequence of actions that are related to the user's stereotype modelling. As the user is able to solve tasks, the proficiency increases and the goals are achieved.

6. Conclusion and Future Work

An ambient intelligent system does not necessarily have the privilege of being able to conduct a conversation with the user. More often the primary interface between the system and its users are behavioural interfaces. Here, users can observe the results of the system through its behaviour and influence the system through their behaviour. Likewise, the system can observe the effects of its behaviour by observing its users' behaviour, thereby reasoning on the success of its behaviour. Thus, to adapt the specific user model, the system has to monitor the users' behaviour and look for triggers that might reinforce the existing user model, or in case of unexpected behaviour, adapt its model of the specific user to include previously non-important stereotypes. This paper discusses the use of stereotype modelling to create quick and appropriate user models in an ambient learning environment.

We have presented how three different theories on learning and social systems can be used to construct well founded stereotypes for an ambient learning environment. Gardner's theories on multiple intelligences gives us the possibility to model the properties of a learner. It not only influences the type of tasks relevant for the learner by enriching the context used to select tasks, but also how they are presented (Kolås *et al.*, 2007). Dreyfus' proficiency stages allows us to decide the level of competence of a learner, thus further improving task selection. Finally, Hofstede's cultural dimensions is particularly useful when dealing with cooperation between both human and artificial actors.

We are currently evaluating our approach using some students from a secondary school in Trondheim. Initially, the students were asked to fill in a questionnaire regarding their expectations about mobile collaborative learning. Each student is provided an Apple iPod Touch with which they can access the Wireless Trondheim environment. The students are required to register themselves on the system and then go through some steps to define their user model. The students are prompted for information about their learning preferences that reflect the models from Gardner, Dreyfus and Hofstede and the input is them mapped to a stereotype model. Based on the user model that is created, the students are then presented some tasks that they could perform. The current implementation of the system is intended to validate our approach of creating user models based on stereotypes and does not utilise a case base. At the end of this exercise, the students will be asked to fill in another questionnaire regarding their experiences with the system as well as their view on the usefulness of the system.

Finally, the theoretical foundation presented here, along with the existing ambient intelligent system is currently being merged to construct an ambient learning platform to be tested in the Wireless Trondheim project (Andresen *et al.*, 2007).

Acknowledgements

Part of this work has been supported by Accenture Innovation Lab Norway and the MOTUS2 project, funded by the Norwegian University of Science and Technology.

7. References

Aamodt A., " Knowledge-intensive case-based reasoning in Creek", *in* P. Funk, P. A. G. Calero (eds), *Advances in case-based reasoning, 7th European Conference, ECCBR 2004, Proceedings*, p. 1-15, 2004.

Amb, " Ambient Learning (eTEN 510749)", 2004. http://www.ambientlearning.net/ambient/Home.asp.

Anderson L. W., Krathwohl D. R. (eds), *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*, Longman, 2001.

Andresen S., Krogstie J., Jelle T., " Lab and Research Activities in Wireless Trondheim", *Proceedings of IEEE International Symposium on Wireless Communication Systems*, IEEE Computer Society, p. 385-389, 2007.

Aristole, " Nicomachean Ethics, book IV", , Available in translation from the Internet: http://classics.mit.edu/Aristotle/nicomachaen.html, 350 BCE.

Bloom B., *Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain*, Longmans, Green, 1956.

Brézillon P., Pomerol J.-C., " Contextual knowledge sharing and cooperation in intelligent assistant systems", *Le Travail Humain*, vol. 62, n° 3, p. 223-246, 1999.

Brézillon P., Pomerol J.-C., “ Is Context a Kind of Collective Tacit Knowledge?”, *in* W. Prinz, M. Jarke, Y. Rogers, K. Schmidt, V. Wulf (eds), *Proceedings of the Seventh European Conference on Computer Supported Cooperative Work*, Kluwer, Bon, Germany, p. 23-29, September, 2001.

Brooks R. A., “ New Approaches to Robotics”, *Science*, vol. 253, p. 1227-1232, 1991.

Chen C. M., Li Y. L., Chen M. C., “ Personalised Context-Aware Ubiquitous Learning System for Supporting Effective English Vocabulary Learning”, *Proceedings of the International Conference on Advanced Learning Technologies (ICALT 2007)*, IEEE, Niigata, Japan, 2007.

Chen G., Kotz D., A Survey of Context-Aware Mobile Computing Research, Technical Report n° TR2000-381, Department of Computer Science, Dartmouth College, 2000.

Coffield F., Moseley D., Hall E., Ecclestone K., “ Learning styles and pedagogy in post-16 learning. A systematic and critical review”, *in* E. Popescu, P. Trigano, C. Badica (eds), *Proceedings of the 7th IEEE International Conference on Advanced Learning Technologies*, IEEE Computer Society Press, 2004. http://www.lsda.org.uk/files/PDF/1543.pdf.

Dave R. H., “ Psychomotor levels”, *in* R. J. Armstrong (ed.), *Developing and Writing Behavioral Objectives*, Educational Innovators Press, 1970.

Dey A. K., “ Understanding and Using Context”, *Personal and Ubiquitous Computing Journal*, vol. 5, n° 1, p. 4-7, 2001.

Dey A. K., Abowd G. D., “ Towards a Better Understanding of Context and Context-Awareness”, *CHI 2000 Workshop on The What, Who, Where, When, Why, and How of Context-Awareness*, April, 2000.

Dreyfus H. L., “ Intelligence Without Representation”, 1998, http://www.class.uh.edu/cogsci/dreyfus.html.

Ducatel K., Bogdanowicz M., Scapolo F., Leijten J., Burgelman J.-C., ISTAG Scenarios for Ambient Intelligence in 2010, Technical report, IST Advisory Group, 2001.

Ekbia H. R., Maguitman A. G., “ Context and Relevance: A Pragmatic Approach”, *Lecture Notes in Computer Science*, vol. 2116, p. 156-169, 2001.

Eraut M., “ Non-formal Learning and Tacit Knowledge in Professional Work”, *The British Journal of Educational Psychology*, vol. 70, n° 1, p. 113-136, 2000.

Fallakhair S., Pemberton L., Griffiths R., “ Dual Device User Interface Design for Ubiquitous Language Learning: Mobile Phone and Interactive Television (iTV)”, *Proceedings of IEEE International Conference on Wireless and Mobile Technology for Education (WMTE)*, 2005.

Gardner H., *Frames of Mind: Theory of Multiple Intelligences*, Basic Books, 1985.

Gibson J. J., *The Ecological Approach to Visual Perception*, Houghton Mifflin, 1979.

Godden D. R., Baddeley A. D., “ Context-dependent memory in two natural environments: on land and underwater”, *British Journal of Psychology*, vol. 66, n° 3, p. 325-331, 1975.

Gundersen O. E., Kofod-Petersen A., “ Multiagent Based Problem-solving in a Mobile Environment”, *in* E. Coward (ed.), *Norsk Informatikkonferance 2005, NIK 2005*, Institutt for Informatikk, Universitetet i Bergen, p. 7-18, November, 2005.

Harrow A. J., *A taxonomy of the psychomotor domain*, David McKay Co., 1972.

Hofstede G., *Culture’s consequences: Comparing values, behaviors, institutions and organizations across nations*, Saga Publications Inc., 2001.

Hofstede G., Hofstede G. J., *Cultures and Organizations: Software of the Mind*, McGraw-Hill, 2004.

Hsieh H. C., Chen C. M., Hong C. M., " Context-Aware Ubiquitous English Learning in a Campus Environment", *Proceedings of the 7th International Conference on Advanced Learning Technologies (ICALT 2007)*, IEEE, Niigata, Japan, 2007.

Johnson M., Liber O., Wilson S., Sharples P., Milligan C., Beauvoir P., " Mapping the future: The personal learning environment reference model and emerging technology", *in* D. Whitelock, S. Wheeler (eds), *The Next Generation: Research Proceedings of the 13th Association for Learning Technology Conference*, 2006.

Kofod-Petersen A., " Challenges in Case-Based Reasoning for Context Awareness in Ambient Intelligent Systems", *in* M. Minor (ed.), *8th European Conference on Case-Based Reasoning, Workshop Proceedings*, Ölüdeniz / Fethiye, Turkey, p. 287-299, September, 2006.

Kofod-Petersen A., Aamodt A., " Contextualised Ambient Intelligence through Case-Based Reasoning", *in* T. R. Roth-Berghofer, M. H. Göker, H. A. Güvenir (eds), *Proceedings of the Eighth European Conference on Case-Based Reasoning (ECCBR 2006)*, vol. 4106 of *Lecture Notes in Computer Science*, Springer Verlag, Ölüdeniz, Turkey, p. 211-225, September, 2006.

Kofod-Petersen A., Mikalsen M., " An Architecture Supporting implementation of Context-Aware Services", *in* P. Floréen, G. Lindén, T. Niklander, K. Raatikainen (eds), *Workshop on Context Awareness for Proactive Systems (CAPS 2005), Helsinki, Finland*, HIIT Publications, p. 31-42, June, 2005a.

Kofod-Petersen A., Mikalsen M., " Context: Representation and Reasoning – Representing and Reasoning about Context in a Mobile Environment", *Revue d'Intelligence Artificielle*, vol. 19, n° 3, p. 479-498, 2005b.

Kofod-Petersen A., Petersen S. A., " Learning at your Leisure: Modelling Mobile Collaborative Learners", *in* A. Kofod-Petersen, J. Cassens, D. B. Leake, S. Schulz (eds), *Proceedings of the 4th International Workshop on Modeling and Reasoning in Context (MRC 2007)*, n° 112 in *Computer Science Research Report*, Roskilde University, Roskilde, Denmark, p. 25-36, August, 2007.

Kolås L., " Variation and Reusability in E-learning: not Compatible?", *in* G. Richards (ed.), *E-learn 2005 Proceedings*, 2005.

Kolås L., Staupe A., " A Personalized E-learning Interface", *in* M. P. Kazmierkowski, J. Modelski (eds), *Proceedings of the IEEE Region 8 Eurocon 2007 Conference*, IEEE Computer Society, 2007.

Krathwohl D. R., Bloom B. S., Masia B. B., *Taxonomy of educational objectives: Handbook II: Affective domain*, David McKay Co., 1964.

Kuo R., et al, " Delivering Context-Aware Learning Guidance in a Mobile Learning Environment based on Information Theory", *Proceedings of the 7th International Conference on Advanced Learning Technologies (ICALT 2007)*, IEEE, Niigata, Japan, 2007.

Lave J., Wenger E., *Situated Learning: Legitimate Peripheral Participation*, Cambridge University Press, 1991.

Liu H., Maes P., " InterestMap: Harvesting Social Network Profiles for Recommendadtions", *Proceedings of Beyond Personalisation, IUI'05*, San Diego, USA, 2005.

Markiewicz J. K., Personalised and Context Sensitive Foreign Language Training supported by Mobile Devices, PhD thesis, Norwegian University of Science and Technology, 2006.

Morken E. M., Divitini M., “ Blending mobile and ambient technologies to support mobility in practice based education: the case of teacher education”, *Proceedings of the 4th world conference on MLearning MLearn 2005, Cape Town, South Africa*, 2005.

Ogata H., Yoneo Y., “ Knowledge Awareness for a Computer-assisted Language Learning using Handhelds”, *International Journal of Continuous Engineering Education and Lifelong Learning*, vol. 14, p. 435-449, 2005.

Paraskakis I., “ Ambient Learning: A New Paradigm for e-Learning”, *in* A. Méndez-Vilas (ed.), *Recent Research Developments in Learning Technologies*, Formatex, 2005.

Paredes R. G., Ogata H., Yano Y., Martin G. A. S., “ A Multi-model Approach for Supporting the Personalisation of Ubiquitous Learning Applications”, *in* H. O. et al. (ed.), *Proceedings of the 3rd IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2005)*, IEEE, Tokushima, Japan, 2005.

Petersen S. A., Kofod-Petersen A., “ Learning in the City: Context for Communities and Collaborative Learning”, *Proceedings of the 2nd International Conference on Intelligent Environments (IE06)*, The Institution of Engineering and Technology, Athens, Greece, July, 2006a.

Petersen S. A., Kofod-Petersen A., “ The Non-accidental Tourist: Using Ambient Intelligence for Enhancing Tourist Experiences”, *in* L. Camarinha-Matos, H. Afsarmanesh, M. Ollus (eds), *Proceedings of the 7th IFIP Working Conference on Virtual Enterprises*, vol. 224 of *IFIP International Federation for Information Processing*, Springer Verlag, Helsinki, Finland, September, 2006b.

Polanyi M., *Personal Knowledge: Towards a Post-critical Philosophy*, N.Y.: Harper & Row, 1964.

Rich E., “ Users are Individuals: Individualizing User Models”, *International Journal of Man-Machine Stuides*, vol. 18, p. 199-214, 1983.

Robson C., *Real world research: a resource for social scientists and practitioner*, Blackwell, 2002.

Russel S. J., Norvig P., *Artificial Intellignece: A Modern Approach*, 2nd edn, Prentice Hall, 2002.

Satyanarayanan M., “ Pervasive Computing: Vision and Challenges”, *IEEE Personal Communications*, vol. 8, n° 4, p. 10-17, August, 2001.

Sharples M., “ Learning As Conversation: Transforming Education in the Mobile Age”, *Proceedings of the Conference on Seeing, Understanding, Learning in the Mobile Age*, 2005.

Sharples M., Atylor J., Vavoula G., “ Towards a Theory of Mobile Learning”, *Proceedings of mLearn 2005*, Cape Town, South Africa, 2005.

Simpson E. J., *The Classification of Educational Objectives in the Psychomotor Domain. The Psychomotor Domain*, Gryphon House, 1972.

Syvänen A., et al., “ Supporting Pervasive Learning Environments: Adaptability and Context Awareness in Mobile Learning”, *in* H. O. et al. (ed.), *Proceedings of the 3rd IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2005)*, IEEE, Tokushima, Japan, 2005.

Tang R., “ The Place of "Culture" in the Foreign Language Classroom: A Reflection”, *The Internet TESL Journal*, 1999.

Thornton P., Sharples M., " Patterns of Technology use in Self-directed Japanese Language Learning Projects and Implications for New Mobile Support Tools", *Proceedings of the International Workshop on Wireless and Mobile Technologies in Educations (WMTE)*, 2005.

Viola S. R., Giretti A., Leo T., " Learners' Profiling by Data Driven Approaches", *Learning Technology Newsletter*, vol. 9, n˚ 2, p. 11-13, 2007.

Vygotsky L. S., *Mind in Society*, Harvard University Press, Cambridge, MA, 1978.

Weiser M., " The computer for the 21st century", *Scientific American*p. 94-104, September, 1991.

Wenger E., *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, 1998.