A Context-aware Model to Support Ubiquitous Group Decision Making

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Abstract

Due to the costs to create conditions that allow participants to meet in the same place at the same time (time, travel, etc.) the ubiquitous Group Decision Support Systems appeared allowing decision-makers to contribute with their ideas to the decision process anywhere and anytime. In this paper is proposed a model which enables decision-makers to contribute with their ideas to the decision process anywhere and anytime. It is a context-aware model which allows obtaining values of certain typical variables of the affective context (emotions and mood) and to transform those values in advises. So it enables the group reaches more easily the decision, strengthening the satisfaction of each member with the decision made. Also here are presented the architecture and mechanisms which could be used in the development of a prototype based on the presented model.

Keywords: Ubiquitous Computing, Group Decision Support Systems, Emotions, Context-aware, Multi-Agent Systems, Affective Computing

1 Introduction

The Group Decision Support Systems (GDSS) emerge with the aim of helping the decision-making groups, supporting the decision-making process. According to Detmar and Renée a GDSS can be any technology used to improve the quality of group decision-making, the assumption is that GDSS can help groups reach higher quality decisions, stimulate more equitable and useful interactions, and reduce the negative aspects of small group decision-making[44].

Aiming to satisfy all these requirements, GDSS adapts and develops through the time, incorporating new features, and modifying their architectures. Due to the costs to create conditions that allow participants to meet in the same place at the same time (time, travel, etc.) the ubiquitous GDSS (ubiGDSS) appeared allowing decision makers to contribute with their ideas to the decision process anywhere and

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anytime [19]. In addition to these available capacities, the GDSS' architectures have also suffered big changes, particularly in the use of architectures for multi-agent systems [30, 22, 47].

Recently have appeared GDSS that incorporate emotional aspects. One example is a GDSS that has been developed at GECAD (Knowledge Engineering and Decision Support Research Center) by Marreiros and her colleagues [31, 41]. In that proposal argumentative agents are used to represent the participants, and each agent is modelled with characteristics of the participant, such as personality, emotion and mood. One of the important conclusions of this work is that argumentative agents with emotions can quickly reach a consensus comparing with the non-emotional agents.

The work described in this paper presents a new model of a context-aware ubiGDSS, which allows the decision maker to use the system at anytime and anywhere. It includes a context aware model in order to understand the environment. The data collected from the environment is related to the decision maker psychological issues. This data (emotions, mood, etc) is transformed in value information according some well-known psychological models. This information allows the creation of the recommendations according to that situation. The decision maker is represented in this model by an agent who is in a community together with others decider agents. The agent is a smart agent and has a set of capacities which allows supporting his/her decision maker and seeks to improve his/her satisfaction at the end of the meeting to be as high as possible. For that he can anticipate scenarios using certain models and algorithms.

In Section 2, is presented the state of the art regarding the ubiquitous group decision-making support system and context-aware systems. In Section 3 we described the proposed model and we explain the differences between it and the systems already existent. In Section 4 is proposed an architecture that should be used and what existing works could be used to apply the model. In Section 5 we present the advantages of using the model and architecture presented in this paper. We also present the objectives we want to fulfill in the future. Finally, the conclusions on this work are drawn and the future work is discussed.

2 State of the art

The purpose of this paper is to present a model and architecture for a context-aware ubiGDSS. For this we need approach the issues of ubiquitous computing, specifically ubiGDSS, and context-aware. In this section is also presented and analyzed several existing systems.

2.1 Ubiquitous GDSS

One of the first persons to approach the ubiquitous computing was Mark Weiser [45]. Mark ”anticipates a digital world in which consists on many distributed devices that interact with users in a natural way” [45].

Ubiquitous computing is the ultimate cleavage of action from the ”here and now”. Once a digital representation of an action reaches a network, it could surface anywhere on the planet at any future time. It might not, but it might. As a result, we do not always know the contexts in which we act. A high school student may create a Web page to be viewed by other students and 10 years later discover it is being viewed by prospective employers. Understanding our context-dependent social behaviours, designed through natural selection, is crucial in identifying the limits, opportunities, and risks of context-traversing digital technologies [19].

Currently there is the interest in developing Group Decision Support Systems (GDSS) which are also ubiquitous systems. With the development of such systems it is possible the decision makers to contribute with their ideas to the decision process anywhere and anytime [19]. This allows having better experts ”present”, even when they are on the other side of the world. This approach makes sense in many areas where the decision-making is required. One of the most cited areas in literature is Healthcare since patient’s treatment involves various specialists, like doctors, nurses, laboratory assistants, radiologist, etc [7, 13].

Recent studies claim that Ubiquitous Decision Support Systems (ubiDSS) will be the next generation of Decision Support Systems [28]. Figure 1 has been adapted from the work developed by Kwon and his colleangues [28], and shows the path taken by Decision Support System.

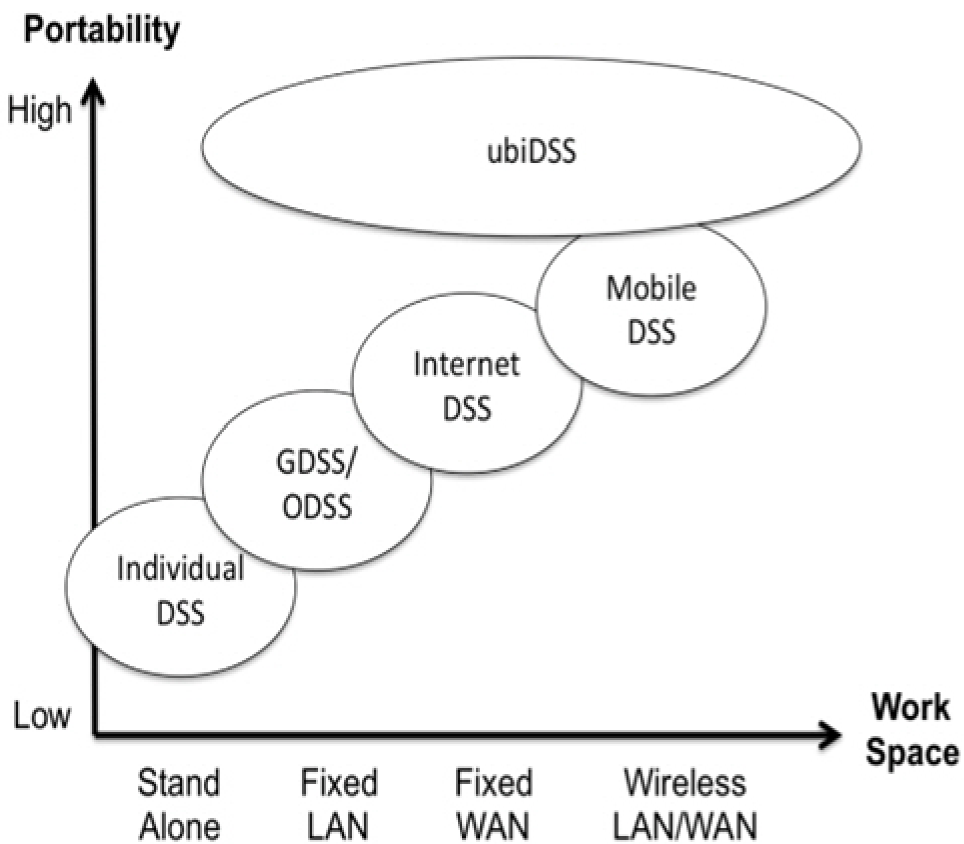

Figure 1: Locus of ubiDSS

But then, what are ubiDSS? In which ideas are they based and what needs they seek to fulfil? The ubiDSS is characterized by its ability to identify decision makers even when they are mobile, and to allow them to acquire solutions through any portable device on any workplace. As the capabilities of mobility and portability are included into DSSs, the notion of providing management-critical information or decision support anytime, anywhere can be realized [14].

There are already some examples of GDSS that support ubiquitous decision (GroupSystems software [42]; Webmeeting [39]; HERMES [26]; VisionQuest software [43]).

Webmeeting is a GDSS that supports distributed and asynchronous meetings through the Internet (ubiquitous meetings). The Webmeeting system is focused on multi-criteria problems, where there are several alternatives that are evaluated by various decision criteria. Moreover the system is intended to provide support for the activities associated with the whole meeting life cycle, from the pre-meeting phase to the post-meeting phase. The system aims at supporting the activities of the two distinct types of users: ordinary group “members” and the “facilitator”. The users of Webmeeting can access the system from anywhere through a PC and an Internet connection.

HERMES [26] is a web-based GDSS that supports argumentative discourses between group members. The agents role in this system is, for instance, to provide mechanisms to validate arguments consistency as well as to weight them. Agents in Hermes are also responsible for processes related with information search, for instance, recovering information from previous discussions.

Other very relevant topic when talking about ubiquitous computing and ubiquitous decision support activities is the context. Context underpins every process for making decision. The context mentioned in an ubiquitous computing environment is conceptualized as any useful information to characterize the situation of an entity [38]. The information indicates any place and action, or even any event caused by them. Due to the fact the information possesses users' external and internal intention, by identifying and analyzing the context, we can forecast the following events that will be confronted by users, namely decision- makers.

A work developed by Marreiros and his colleagues [17] called Agent Based Simulator for Group Decision (ABS4GD) combines an ubiDSS with human features, as intelligence and emotions. This system has the goal of supporting the decision makers and implements a multi-agent architecture. In this system each agent represents a decision maker in the system and can be used through different types of devices, being only necessary to have internet connection.

2.2 Context-Aware Systems

The information technology and communication are present in practically all of our daily tasks, making easier the realization of these tasks and thereby improving the quality of our lives [35, 2]. However, each time there is a greater need to use techniques and concepts that consider the context-aware computing. Any action or entity is linked to a context. An action cannot be described in detail because there is always implicit information [10]. An action depends on contextual parameters such as temperature or humidity of the context, which form part of the environment. However, these parameters need to be specified. Several authors have defined the word context in ubiquitous computing field, however over time this concept has evolved for more general forms. For example, one of the most recent definitions, Gillian and his colleagues [20] says that the context is all kinds of information that can be used to describe the state of an entity. An entity, according to Gillian and his colleagues [20] is a person, place or object that is important for the interaction between the user and an application. The context may be divided into several categories and in that sense Hofer his colleagues [21] makes a distinction between logical and physical context:

- *The physical context*. It refers to the general context information. This information is captured by sensors and usually updated frequently to always have a value of the current situation.
- *The logical context* is related to the physical context. It is derived from reason and process the physical context. It is more difficult to obtain, more complex and more meaningful. User's mood or the appropriateness of context specific characteristics are examples of logical context.

At this moment there are several types of context-aware applications that operate in various areas of daily life. Several projects have focused on the development of mobile guides, capable of providing relevant information to the user depending on your situation and objectives. For example Baus and his colleagues [9] describe a review of mobile tourist guides, among which are CyberGuide or GUIDE. They have also developed guidelines for museums[40, 23].

Another area of context-aware applications is the contexts of massive collection of information. Such contexts also require that the application is able to structure and organize information for further processing. For example, the objective of the project labscape [6] was to oversee and support the actions undertaken in chemistry laboratories where the amount of information that is handled is very large. Other application developed by Pascoe and his colleagues [37] is a prototype mobile application to facilitate the collection of environmental information in natural contexts.

Another type of environment for which they have developed context-aware applications are offices or workplaces. For example, the Context-Aware Office Assistant [46] is a software agent that communicates with visitors and manages user information owner. Johanson and his colleagues [25] describes the project iRoom as a meeting room that offers features such as augmented reality through screens, communication networks and other devices.

Other application environments for context-aware systems are university campuses and classrooms. For example, the ActiveCampus project [18] has a location-based mobile application that incorporates instant messaging, dynamic information and location of other peers. The project presented by Gillian and his colleagues [20] aims to create a board based on augmented reality in a classroom. Another type of applications are those that fall in a home context, mainly supporting users who are sick or limited mobility [8, 7]. Such applications can also be used in hospitals, where medical personnel to help treat patients.

Context-aware applications can also be very useful in situations of extreme danger requiring complex logistics. For example, the Siren system [24] is an application context-aware peer-to-peer that collects, integrates and distributes the data context. Also Luyten and his colleagues [29] developed a system for firefighters providing real-time contextual information to firefighters to improve the performance of its tasks.

In contexts related to transportation and logistics applications have been developed that provide context-aware information to the user based on their location and other applications that monitor the movement of objects. An example is the application that describes Meier and his colleagues [34] to support users in regard to transport infrastructure, services and traffic signals.

Another environment where context-aware applications can be useful is in sports training. In these environments, contextual services can be very useful for optimizing and motivating workouts. Currently there are applications that monitor and cycling training through mobile devices such as the application runKeeper2 [1]. Other applications such as that presented by Buttussi and Chittaro [11], oversee the conduct of training in open spaces. Also combines the use of data collected with a knowledge base to build customized models of physical training for users.

3 Proposed Model

The goal of this paper is to propose a model to a context-aware ubiGDSS. This model has as main task supporting the decision agent in the decision making process. Taking into account the ubiquitous computing objective in supporting the user regardless of location or time, an essential task is the perception of the context in which the user is immersed. The user needs to be the main actor, independently on the context. Nowadays, there are several ubiquitous systems applied to different contexts, such as, Smart Cars, Smart Homes, Health Services, etc.

The common denominator in all these contexts is the user(s) or the individual who will benefit from the ubiquitous system. Hence, in our approach the decision maker will be surrounded by sensors, which are imperceptible to him so the normal user's behavior won't be harmed. The model also includes an constant adaptation to the user context. In addition, the model aims to anticipate the user's actions, thereby increasing the automation between the user and the system.

The sensors are responsible for collecting all the data and to send it to the system. Thereby, the data is analyzed by certain models, which transform this information into important knowledge. Using this knowledge, the system is able to support the user in decision-making process. The most interesting issue about an approach like this one is the capability of considering the context, not only to support the decision process but also to improve the user satisfaction.

The users can access the system anywhere and anytime, thus facilitating the decision-making process.

As previously mentioned, the model will be used in an ubiquitous system since it can be used in any device (smartphone, tablet or laptop). In addition, the system is context-aware and takes advantage of that functionality to defend the interest of the decision maker and seeks to enhance the satisfaction with the decisions made.

As previously mentioned, the model will be used in a context-aware ubiGDSS, which main features are:

(1) To support the decision making process;

(2) To assist the decision maker anytime/anywhere;

(3) To be endowed with intelligence which allows to assist the user in discussion that he is involved;

(4) To include user's intention in process and emotional state of him;

(5) To seek to maximize the satisfaction or decrease the dissatisfaction of the decision makers using incorporated intelligence and variables collected from the context;

(6) To use natural language techniques and ontologies to present relevant in-formation in electronic boards.

The first 3 points are functionalities already existent in other ubiquitous group decision making systems. On the other hand, points 4, 5 and 6 are functionalities that do not exist in systems and models, or that are used in different contexts.

Although the first point seems a very general topic in which other topics could be included, it is related to the functionalities which a typical GDSS enables to the user. Thus the features of this model are the following: to allow defining correctly a decision problem, evaluating alternatives and attributes; to present to the group members the results already obtained; information organized as graphics or tables, to share the preferences of each participant by the group. The second point of the proposed model enables the ubiquitous systems usage at any time anywhere without major limitations regarding the device used to do it. Here the system will be an application which works in a browser and is used via internet. The third point is the one which allows the own system to support the group decision making process, and for that it looks for solutions. This way, in this model we propose an argumentation system. As have happened in point 2, point 3 presents the characteristics which can be found in the system ABS4GD previously described. Regarding point 4, we intend to obtain variables from the affective context. As seen in ABS4GD [17], to incorporate variables in the affective context is not a new thing. However, in the existent GDSS those variables are incorporated virtually, and in this model we want it to be context-aware using systems as [5, 3] which allow the decision maker to generate such variables, as emotions and mood, when he/she is sitting at the desk involved in a group decision making process. To collect using such variables is an innovation, which do not exist at this time in the literature, and also not exist as the model intends to use them in order to know and support the decision making process, but also to strengthen the decision maker satisfaction in the decision making. Using the information collected from point 1 and 4, in point 5 we intend to analyse that information in order to maximize the decision maker satisfaction at the end of the meeting. For that, it can be used a model as the one presented in [12] in which the information that this model collects is used to analyze the satisfaction. This will allow predicting the final satisfaction of the decision makers at each instant of the meeting through the information the system is collecting. Finally, the model proposed here includes the use of ontologies and techniques of analysis based on natural language to present information, statistics and graphics on issues related to the one that is being discussed by the decision makers.

In order to fulfill all points mentioned above we propose a model (Figure 2) that includes the latest features of ubiquitous decision support systems, showing mobility, adaptability and context-aware.

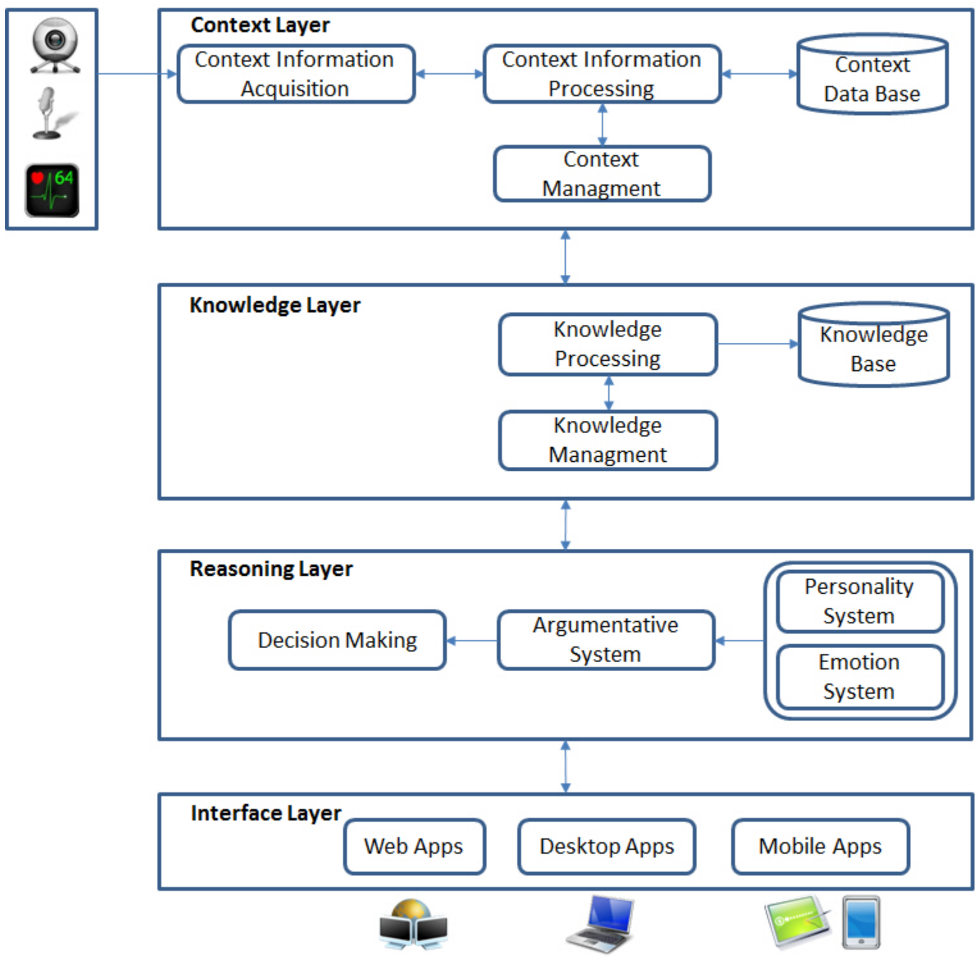

Figure 2: Model Proposed

The model presented in Figure 2 is composed by four layers that allow the collection of information, knowledge production and generation of solutions to support decision making.

The **Context Layer** has the task of collecting all the information about the environment in which the user is inserted. The collection of information is performed from sensors able to this task. This information may be about the mood and intentions of the user or about the environmental where he is inserted. The type of information varies depending on the application of this model, it is necessary to define the sensors that are best suited to each case. The context information is acquired by the Context Information Acquisition module and is processed by the module Context Information Processing module. With this, information is processed to be stored and later transformed into knowledge.

The **Knowledge Layer** has the task of transforming information into knowledge. This knowledge, in turn, allows generate solutions to support the decision making process. The function of Knowledge Processing module is to transform the information received from the context layer in knowledge. One of its main tasks is to define the problems/ideas contexts, by classifying the information shared by meeting participants (problems/ideas) in two kinds of ontologies: Domain Ontologies, which cover the domain of speech of the meeting; and in a meeting task ontology [15], contains the concepts of the meeting process. This knowledge is able to be used by the Decision Support layer through the Knowledge Management module.

The function of **Reasoning Layer** is to generate new information that will be useful to the decision maker. In this layer are three support types: is simulating the decision making process and the decision makers approve or request a new decision; or each decision maker receive arguments to support him in decision making process ; or the decision makers receive decisions/solutions from previous meetings that are relevant to the current decision context. In first case the Personality System and Emotional System modules will affect directly the Decision Making module. The system will simulate the decision making process based in arguments of each decision maker. In turn, these arguments are based in decision makers' profile. In the process of group decision-making there is always a negotiation between the various elements to reach a consensus. Thus, the system will simulate this process and show the decision to the group. In second case, the system will support each decision maker to present the best arguments. These arguments are based in decision maker's profile. In the third case by using the information on the current problem such as the ideas and problems (and the assertions associated to it) the system will be able to compute a similarity measure between the current context and other contexts in the KB in order to find relevant solutions from the past and alert the user from possible solutions already proposed in the meeting.

The **Interface Layer** is designed to provide mechanisms for users to access all information provided by the system. Given that it would a ubiquitous decision support system it becomes necessary to provide information on various types of interfaces that provide access to a user anywhere and at any time. Thus, the system is available via web interface, via mobile interface and via desktop interface.

4 Architecture

In this section is presented the way the prototype could be developed, based on the model presented here, as well as its architecture and type of physical devices required to collect data. The required proceedings to follow in order to reach the 6 points mentioned in section 3 are described.

In Figure 3 we present an agent-based architecture to enable the development of an ubiGDSS system. The delineated system is intended to support a set of users to make a decision. The community of agents is composed by several agents where each user has an agent to represent him/her in the system. Agents will be modeled with features of the decision maker, as the personality, emotions and mood. The Figure 3 shows the proposed architecture to develop a prototype.

The presented architecture (Figure 3) implement the model presented in section 3. Thus, the context, knowledge and reasoning processing are realized by each agent. These agents would be endowed with the persuasive argumentation capacity, allowing defending the interests of the decision maker they represent, and trying to convince the other agents to accept the decision maker interests. In a system like this it could be necessary to implement other types of agents, an architecture like Open Agent Architecture –OAA [4]. To undertake the argumentation process the agents could use the arguments defined by Sarit Kraus [27]. The agents could also save the historical data to use in future meetings in order to make the process more real and intelligent.

To represent in detail the knowledge present in Meetings for decision making in a group setting we use a Meeting Task Ontology (MTO) and an extension to this one, the IGMTO ontology, who specifically focuses in the Idea Generation Process [15]. These proposals reuse several established ontologies like FOAF and COBRA and all together are able to provide the specification of the meeting process and a

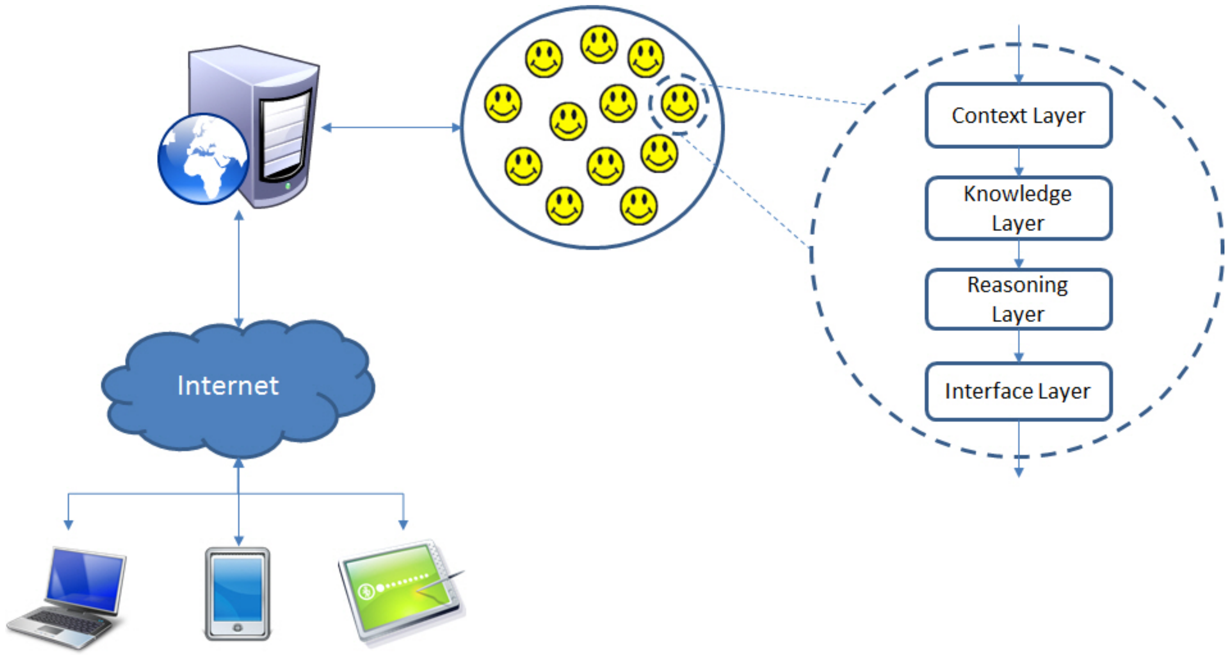

Figure 3: Architecture Proposed

link between generic ontologies (space, environment, etc) and a domain of speech ontology. To populate these ontologies is adopted the strategy proposed by Freitas [16] where the knowledge management is achieve by means of intelligent agents, which perform tasks such as building knowledge on Domain Ontologies and finding related/equal/opposite issues on indexed knowledge.

Regarding the affective context and considering only the virtual, the OCC model ,proposed by Ortony, Clore and Collins [36], could be used to understand the emotions generated by the agents during the negotiation process (argumentation) the, for a mood part could be used the PAD (Pleasure, Arousal and Dominance) model [33] and for the personality could be used the OCEAN (Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism) model [32]. To capture the personality of the decision maker and to model His/her agent with those features it could be asked to the decision maker to answer to The Big Inventory questionnaire, which allows obtaining values of each feature of the OCEAN model (also known as the five factors model). On the other hand, in order to the model to be context-aware and to take into consideration the real affective context could be used models as the chair model described in [3] or the mouse described in [5].

To evaluate the satisfaction considering every data collected by the system could be used the model of analysis of the satisfaction proposed by Carneiro and his colleagues [12], which uses every value of the variables described so far. It could also be used an agent to recognize the meeting agenda, orally or in a written, which had the responsibility of showing the information related to those topics.

5 Discussion and Future Work

The model and architecture here presented are an initial step towards the implementation of a context-aware ubiGDSS. The systems analyzed in the section of state of the art cannot fulfill three of the six points presented in proposed model section. Thus, our objective was to build a model that brings considerable advantages for a context-aware ubiGDSS. A system that applies the model presented here has the advantage of considering the logical context of the environment, for example, the user's mood or user's intention. Beyond the possibility of the user can access information easily, the satisfaction of each user is also considered by the model. Thus, the context-aware ubiGDSS we intend to develop in the future will have all these advantages, thus being an innovative system in this area.

This research is related to the themes of ubiquitous computing, context-aware and group decision support systems. It is intended to understand every advantage in the development of this type of systems. The goal is also to understand in practice the system's influence in the user and how the system is really an advantage and not a threat to the privacy. In order to develop the prototype of the model presented in this paper, it is required certain equipment which usually is in decision making rooms: a network with internet, computers, projectors, devices with sensors to capture variables of the affective context, servers and screens.

The evaluation of the models like the one proposed in this document is a very difficult task. Besides that, it is one of the main problems that researchers face when working in this area. To evaluate the quality of a model or prototype of a group decision making system is also not a trivial task. To conclude that with a certain model the group will quickly reach a decision, a consensus, do not necessarily means that the mode is better than others. To understand the advantages of a GDSS model or prototype is required to evaluate the system usability, and also to understand the satisfaction reached by the decision makers (users) according to the results obtained by using the system.

The fact to conclude that a particular model with the group you will quickly come to a decision, a consensus does not necessarily mean that the model is better than others. To realize the benefits of a particular model or prototype of a GDSS is then necessary to evaluate the usability of the system, as well as to realize the satisfaction achieved by the decision makers (users) with the results obtained using the system.

6 Conclusions

In this paper is presented a new model to support context-aware ubiquitous group decision process. The model presents features in order to be sensitive to context and to support the decision maker anytime and anywhere. Besides that, the model takes advantages from those features, seeking to enhance the quality of the decision and the satisfaction of every group member with the decision made. In this paper we present a possible architecture to this model, using intelligent agents, where each participant is assisted by a decision agent that is modelled according participant profile.

In the future we intend to start developing a prototype which implements the described model in order to understand the results reached by it. It will be studied the difference between the satisfaction of the decision makers and the alternative obtained by this prototype and it will be compared with other context-aware ubiGDSS. The comfort and usability that a prototype like this can cause in the users will also be studied.

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