An Integrated Context Model: Bringing Activity to Context

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ABSTRACT

This paper presents ongoing research on context modelling. A review of past research in context awareness shows that researchers have defined and classified context differently. This leads to different views of context amongst different researchers. Moreover, existing context definitions and classifications are ambiguous and therefore it is difficult to carry them forward into design and implementation work. The main aim of this research is to provide a context model that covers key elements of context that researchers should take into account in their designs. Moreover, the relationships between elements are provided by this model. The model provides researchers and practitioners with an integrated point of reference for considering the elements of context and their relationships. This model can then be used as a framework in their implementation of context aware systems.

Keywords

Context model, context awareness, activity theory, ubiquitous computing

INTRODUCTION

Users are now living in a ubiquitous computing environment. They are able to access information or use computing services while they are doing their everyday life activities. As a result, the user's attention may be divided between several simultaneous activities and devices. Moreover, as computing devices become smaller, their interfaces are becoming smaller to disappearing. These problems make user interaction with the devices more difficult.

Researchers have tried to solve the problem by improving user interaction by exploiting information relating to users, devices and environments, through the notion of context awareness. Context awareness plays a key role in reducing the user's explicit input.

In order to use context in developing context aware applications, the notion of context has to be well understood. In the past, researchers have defined context in different ways to better understand context. However, throughout the context awareness literature, having a clear understanding of context in a complete, concise and unambiguous way remains a challenge. It is difficult to define the important elements in context from previous work, as different researchers have different points of view of context. For the most part, past context aware projects have utilized only isolated subsets of their context, such as a location or a device's state. A truly context aware system requires a holistic approach that takes into account the wide range of interrelated types of context and the relationships amongst them. As a precursor to implementing such systems, we need an approach to modelling context that takes account of this complexity.

Our research addresses the issues of modelling context, defining the relationship between the elements in a context model and explaining the use of our context model in the design and implementation processes.

Our goal is to be able to provide an operational context model and use it to build a context aware system that it is easy to use by reducing explicit input from the user.

This paper is structured as follow: first we review context classification systems and examples of related projects. Secondly, a potentially valuable approach to developing a comprehensive context model and framework is described with an example. Thirdly, our conclusions and future work are discussed.

DIVERSE DEFINITIONS OF CONTEXT

Researchers have tried to define the elements of context via diverse context definitions and classifications. The differences and similarities of elements that make up context as described by different researchers are discussed in this section and shown in Table 1.

The columns in Table 1 are extracted from the elements that researchers have tried to classify as part of their context. The rows show different approaches from different researchers.

<table>
<tr><th></th><th>Location</th><th>Conditions</th><th>Infrastructure (Computing Environment)</th><th>Information on User</th><th>Social</th><th>User Activity</th><th>Time</th><th>Device Characteristics</th></tr>
<tr><td>[Benerecetti et al. '01]</td><td colspan="2">Physical Environment</td><td></td><td colspan="2">Cultural Context</td><td></td><td></td><td></td></tr>
<tr><td>[Schmidt et al. '99]</td><td colspan="3">Physical Environment</td><td colspan="3">Human Factor</td><td>X</td><td></td></tr>
<tr><td>[Lieberman and Selker'00]</td><td>User Environment</td><td>Physical Environment</td><td>X</td><td>User Environment</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>[Hull et al. '97]</td><td></td><td>Physical Environment</td><td></td><td>X</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>[Chalmers and Sloman'99]</td><td>X</td><td></td><td>X</td><td></td><td>X</td><td>X</td><td></td><td>X</td></tr>
<tr><td>[Lucas'01]</td><td colspan="2">Physical Environment</td><td colspan="5">Information context</td><td>X</td></tr>
<tr><td>[Schilit et al'94]</td><td colspan="2">Physical Environment</td><td>X</td><td colspan="2">User environment</td><td></td><td></td><td></td></tr>
<tr><td>[Dey and Abowd'99]</td><td>X</td><td></td><td></td><td>Identity</td><td></td><td>X</td><td>X</td><td>Identity</td></tr>
<tr><td>[Chen & Kotz'00]</td><td colspan="8">Active/Passive</td></tr>
</table>

Table 1 Context classification systems

In the first row of Table 1, Benerecetti et al. [1] have classified context into physical context and cultural context. The physical context is a set of features of the environment. Cultural context includes user information, the social environment and beliefs. Schmidt et al [14] have extended Benerecetti et al's classification into three dimensions, the physical environment, human factors and time. Human factors are the same as the cultural context. Time was added because it is an important facet of context that has a significant impact on people's behaviour. Time also enables the context model to represent the history of context, which has influence on understanding about user's current and future action.

Lieberman and Selker [10] ignored time and classified context in terms of the physical environment, the user environment and the computing environment. In this case, the user environment includes the user's location and is treated separately from the physical environment. Lieberman and Selker treat the computing environment as a separate entity here because they believe that information such as network availability can be of interest to the user and related computing devices. Hull et al [7], Lucas [11] and Chalmers and Sloman [2] argue that characteristics of the device itself, such as screen size and input device, are also of interest to the user and system. They have therefore defined device characteristics as one element of their context classification. Chalmers and Sloman have also added user activity into their context classification. However, they have ignored time and other user characteristics.

Dey et al. [4] took a slightly different approach to classifying the context as they provide a top level classification system, which includes four types of context: location, identity, time and activity. Dey et al. claim that these are primary types of context, that is, they can be used to refer to other secondary context. For example, identity could refer to anything from users to other objects. However, there is no clear separation between device and user.

Existing context classification systems typically aim to define the elements of context needed to reason about the users. This is to have a better understanding of the user's intention. Chen and Kotz [3] introduced a classification system with a completely different aim. Context is classified depending on how it is being used in the application: active and passive. Active context is one that influences the behaviours of an application. Passive context is relevant but not critical to an application.

THE ONGOING FRAMEWORK

The main aim of our work is to develop a context model that takes into account the elements that influence users' intentions. This context model will then be used as a framework in developing the context aware system. In this paper, the approach and current context model are presented.

Motivations

As seen in Table 1, researchers have various views of what elements should be taken into account as part of context. These views are both partial and overlapping, covering both similar and different elements. There is no single context model that all researchers can refer to so that they can have the same understanding of context. Therefore our first motivation is to produce an operational context model that provides an understanding of the key elements needed to understand users' intentions.

Another problem is that in the implementation process, context aware applications have utilized only isolated subsets of their context, such as a location or a device's state, e.g. [12]. There has been little research exploring the relationships between different elements of context and how these relationships can affect the efficiency of context aware applications. These relationships are important in order to use context to represent the world of the user and to help the system better to understand the user's activities and intentions.

Moreover, modelling these key elements and their relationships should ameliorate the difficulties of expanding the system later. If we know what are the possible elements and their relationships, during the earlier design stage we know how to prepare for these elements and relationships to be added to the system at any time during the development.

Approach

The context model will be used to help in understanding of what and how the elements have influence on users' intentions in doing their activities. There are many approaches to analysing and understanding human activity or tasks, such as Activity Theory [6, 13] and Task Analysis [5, 8]. For the purpose of defining elements in a context model and attempting to relate existing partial classification of context, we have developed an approach based on Activity Theory. There are three main reasons for using Activity Theory. First, it provides a simple standard form for describing human activity. It acknowledges that we, as fellow humans, cannot fully understand the full moment-to-moment richness of other humans' activities, states, goals and intentions. But we do manage to interact and to interpret others' actions with an enormously higher degree of success than any existing context-aware computer based system. Hence, in attempting to produce better context-aware systems, it is neither possible nor necessary to model all the richness of human activity. To make progress from the current state of the art, we propose that a sufficiently comprehensive context classification may be developed using the relatively simple standard form offered by Activity Theory that covers the key elements influencing human activity.

Secondly, it takes into account the concepts of tool mediation and social environment, which are important in the ubiquitous computing world. This is because in ubiquitous computing, users are allowed to use different computing devices, both physical and virtual. Moreover, the users can use computing services anywhere and anytime which means that they use the services in different social environments. The social environments and tools are important elements that have an influence on users' intentions in doing activities.

Finally, Activity Theory models the relationships amongst the elements. Therefore it can be a useful way to model the relationship between each element in a context model.

Activity Theory Background

Activity Theory was developed by Russian psychologists Vygotsky, Rubinshtein, Leont'ev and others beginning in the 1920s [9]. Activity Theory is a philosophical framework used to conceptualize human activities. In 1987 Engeström [6] proposed the triangular structure of human activity as shown in Figure 1.

The main components of this model are:

Subject: Information about the individual or subgroup chosen as the point of view in the analysis.

Tools: Information about tools, which can mean either psychological or physical tools.

Community: Information about individuals or subgroups who share the same object as subject.

Division of labour: The division of tasks between members of the community.

Rules: Explicit or implicit regulations, norms and conventions that constrain action or interaction.

Object: Target of the activity within the system.

Outcome: The result from transforming the object.

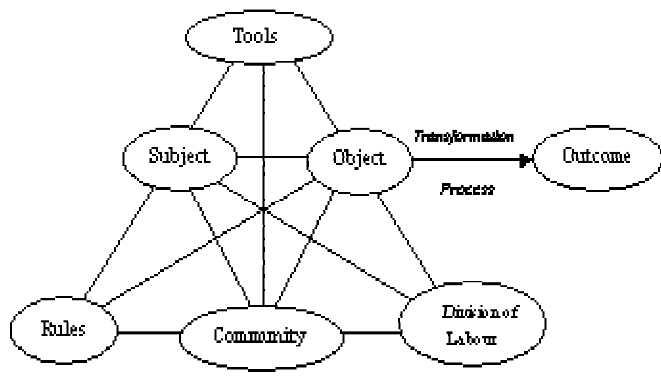

Figure 1 Triangular structure of human activity.

Activity Theory describes and relates key elements that influence human activity. Activity Theory considers that any two elements in the model are mediated by another element. For example, the relationship between subject and community is based on rules and at the same time the tools have influence on how the subject meets the object.

From Activity Theory to Context Model

Applying Activity Theory to provide a context model that covers all possible contexts in a ubiquitous computing world is not a simple process. From Table 1, time is an important element of context as it allows the system to keep records of the context of each activity in the past. This past context has a strong influence on users' intentions in doing their next activity as the user may take past experience into account in determining what they are going to do in the future. Therefore we add time as another dimension to the Activity Theory model in order to

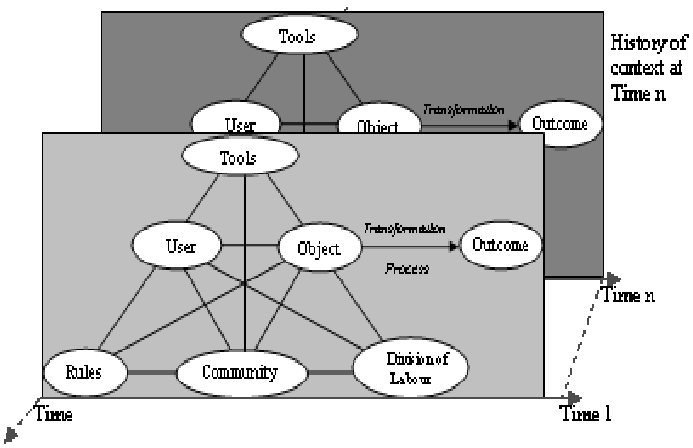

Figure 2 Context model from Activity Theory.

represent context as shown in Figure 2. Time in this case is information such as date and time of day when a particular activity is completed.

Therefore we propose the context model illustrated in Figure 2. The elements in the context model can be described as follows:

User: Information about the user that the system is interested in and her physical environment that has influence on her activity, including user's current location, action, device and timetable.

Tools: Tools those are available in the public space and their availability, including device characteristics, public services and computing environment such as network liability.

Rules: Norms, social rules and legislation within which the user relates to others in her community.

Community: Information about people around the user (in both physical and virtual environments) that may have an influence on her activity.

Division of Labour: Roles of user in that situation including who can perform which tasks to the object.

Object: User's intention and objective. The system uses all the elements above to decide about user's intention or objective.

Time: This is a time in a particular situation when an activity occurs. The activity in this case is when the system reacts to context to support the user.

From Context Model to Reasoning Context

From Figure 2, we can see that the model groups the context into eight main categories. In each category, there are further levels of context. In the category of tools, for example, its second level will be virtual or physical tool. The next lower level is a specific type of the tool such as its identity (network's name, blackboard's or printer's name). The lower levels will provide the characteristic of the specific tool, for example its network availability or its location. Each level of context category has its own reasoning process to form the information for the upper level. This depends on the design.

Figure 3 shows an example of context at different levels in the Tools category. It shows the information about the tools available in the current user's environment.

After the information at lower levels has been determined, each category is analysed based on its characteristics that have been derived from lower levels of context in the category. For example to predict the next activity of the user, the model considers what tools are available to the user in the community that s/he is currently in, what is his/her role in the community and what are the rules in that community.

This context model allows the designers to build their reasoning model for the context aware system by grouping the information from any types of sensor into these levels and categories of context. With this model, the information from one sensor can be used in different levels or categories of context as well. The reasoning model is completely separated from the sensor implementation.

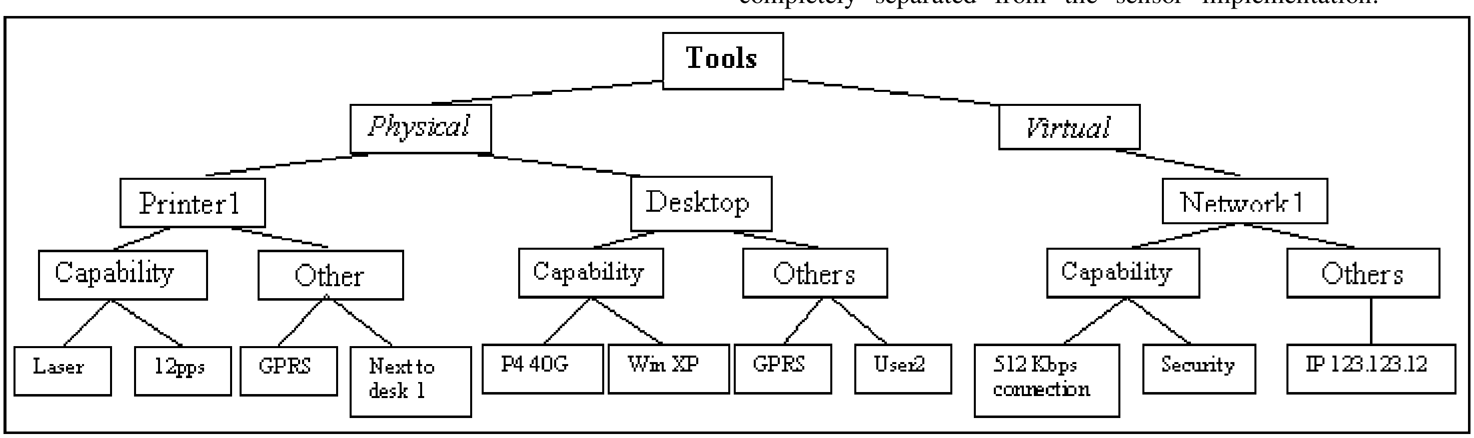

Figure 3 Example of different levels of context in Tools Category of context model.

Therefore, the researchers can add any new sensors to the system and it will not affect the reasoning process.

Moreover, this model suggests to the designers what elements that should be taken into account in making decisions about the user but it does not mean that the designers have to use all the elements. The model also allows the designers to be aware of what other elements can be added to the system in the future.

Current Work

As discussed above, the context model has the possibility of being a framework for implementing a context aware system. However, the model is still in its infancy. Development of a context aware system based on this model is required in order to evaluate and revise the model to cope with the complexity of context. At this stage of the project, we are developing scenarios that context aware systems should support in which users have to deal with multitasking in a ubiquitous computing environment. From these scenarios, the context aware system will be implemented using the context model as a framework. This should allow us to discover its strengths and weaknesses.

CONCLUSIONS AND FUTURE WORK

Our purpose is to use context awareness to improve usability for ubiquitous computing users who have to perform multiple simultaneous tasks. However, the previous definitions and classifications of context are unclear, as different researchers have different definitions and classifications. There is no clear and unified understanding of context. This leads to ambiguity in design and implementation.

In this paper, we have outlined a comprehensive context model that includes the key elements of context that have an influence on a user's diverse activities in a ubiquitous computing world. We hope to identify the relationships between each element in the classification so that these relationships may be applied during the development of a context aware system. The example in this paper shows that the context model has potential to be used as a framework in developing the context aware system. The model provides developers with an idea of what elements should be taken into account as context and the relationships between the elements.

In our future research, the proposed context model will be used as a framework in an implementation of a context aware system. This will allow us to evaluate the model. Therefore the next step in this research is to find suitable scenarios in which a context aware system will be of real use for users who are dealing with multitasking in ubiquitous computing environments. We will implement the context aware system based on these scenarios.

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