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Abstract. Mobile Groupware Systems employ devices such as PDAs and cellular phones to explore the opportunities that mobile technologies grant for cooperative work. However, due to the physical constraints related to these devices, such systems must adapt the content of information to user's context. This adaptation usually takes into account user's location and device. As for the users of Groupware Systems, mobile users need to be aware of what is going on inside the group in order to better perform their own activities. This refers to the notion of awareness support, which stands for the knowledge a user has about the group itself and her/his colleagues' activities. In this paper, we propose a context-based awareness mechanism for mobile Groupware Systems. This mechanism takes into account both the user's physical and organizational context in order to filter the awareness information and to deliver relevant information to mobile users.
Keywords. Context-aware computing, adaptability, awareness support, mobile computing, computer supported cooperative work.

1 Introduction

Groupware Systems are usually conceptualized as software systems that allow computer supported cooperative work. For some years, Groupware Systems, such as BSCW[2], have been using the Web in order to provide a world wide access to their users. With the massive introduction of web-enable mobile devices, such as laptops, PDAs and cellular phones, users of this kind of devices can access the system virtually everywhere. The use of such mobile devices leads to a new generation of Groupware System, called here *mobile Groupware System*, which are Groupware Systems intensely accessed through mobile devices.

However, the use of mobile devices introduces several technical challenges. Specially, systems should carefully select and adapt the information to be displayed (as well as the supplied services) to the physical constraints of these devices (limited display size, power and memory capacity…). Obviously, a system cannot deliver the same (amount of) information to a mobile device that it delivers to a fixed device (a desktop, for example). It has to select a reduced set of information to be delivered and to adapt the presentation of this content to the target device (for instance, to transform XHTML files into WML files, or to debase the quality of a video sequence). Moreover, since the user of such devices may move and change of device, this adaptation process should take into account her/his current context (where she/he is,

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[2] http://bscw.gmd.de/

which device she/he is using, etc), in order to better cater the information for this mobile user, *i.e.* to determine which information is relevant, which media types can be used, etc.

Therefore, the ability to detect the context characterizes the so-called *context-aware systems*, whose premises include that the computing device should be aware of the user's circumstances and should be able to interpret any interaction in an appropriate manner [13].

Context-aware systems usually adopt a notion of context limited to the physical aspects, such as the user's location or device (see [2] as an illustration). However, a mobile user is often involved in some cooperative process. And, as any other user of a classical cooperative environment, a mobile user should be aware of what is going on inside the group in order to build a sense of community [15]. This means that mobile Groupware Systems should provide their users with an awareness support adapted to their mobile situation. Awareness support in Groupware Systems refers to the knowledge a user has and to her/his understanding of the group itself and her/his colleagues' activities, providing so a shared context for individual activities in the group (e.g. [5] and [11]). This notion of awareness is often neglected by context-aware systems, which ignore the organizational context of the cooperative work. This organizational context is related to the activities, the status and the composition of the group, a knowledge usually supplied by awareness support in Groupware Systems.

However, a selection of the information is necessary for mobile users because awareness support may generate too large amounts of information, and because the constraints of these mobile devices impede the presentation of all available information. We believe that mobile Groupware Systems should take into account both the physical and the organizational context of the user in order to filter the available awareness information and to reduce it to a restricted set of relevant pieces of information that can be physically handled by the mobile device.

In this paper, we propose a context-based awareness mechanism which uses a description of the current user's context. This description integrates, on the one hand, the concepts related to the notion of awareness (definitions of group and role, activities and work process, etc.) and, on the other hand, the concepts related to the user's physical context (location, device…). We use an object-oriented representation in which the concepts are represented by the means of classes and associations. We aim at managing asynchronous Groupware Systems, such as systems managing group calendar, messages and shared repository (a shared workspace). We assume that those systems are composed by many components (for access control policy, for communication facilities, etc.) which are connected and communicate with each other (and possibly with other instances on remote sites). We consider awareness mechanism as one of such components, and we propose a filtering process that exploits the context representation mentioned above to better select the awareness information delivered to mobile users.

This paper is organized as follows: first, we introduce some work related to adaptation (Section 2). Second, we discuss the notion of awareness (Section 3). Then, we present our proposed description of the mobile user's (Section 4), and describe the filtering mechanism based on this description (Section 5), before we conclude (Section 6).

2 Context and Adaptation for Mobile Users

The development of software applications for mobile devices involves several technical challenges, which makes adaptation crucial for the usability of such systems [7]. In this context, many researches deal with the adaptation of multimedia and web-based information content to mobile devices. These works usually take into account the technical capabilities of the client device, and adapt the content of the information to be delivered, by transforming the original content so that it can be handled and displayed by the device (see, for example, [17] and [10]).

Additionally, some works adapt the content by filtering it according to the physical context of the client device. The notion of context which is used includes aspects concerning the device itself and also aspects such as the user's location and time (see, for example, [2], [13] and [12]).

Our approach also relies on the selection of the content delivered to the user considering her/his current context. However, we differ from other works on context-aware computing by considering the user's context from two points of view organizational and physical. In fact, the organizational context, as much as the physical context, plays a critical role in shaping an action, and also in providing people with the means to interpret and understand action [4].

The coupling of this two types of context allows to evaluate what is relevant for a mobile user, and thus, to select the available information for her/him. On the one hand, users of mobile Groupware Systems are involved in a cooperative process and are particularly interested in information related to this process. They are more particularly interested in events related to their work context, *i.e.* events that can lead them to take better decisions and/or to increase their capacity to decide [3]. On the other hand, by using mobile devices, users have to cope with several restrictions inherent to the limited capacity of their devices (particularly the reduced display capacity). In our approach, we try to represent and explore the organizational and physical context in order to filter the awareness information in a suitable way for mobile users.

3 Adaptation Needs for Awareness Support

The term *awareness* has a large meaning in the Computer Supported Cooperative Work (CSCW) community and is actually used in very different situations [11][18]. Generally, awareness refers to actors' taking heed of the context of their joint effort, to a person being or becoming aware of something [18]. However, this definition is too vast to be used for a Groupware System, so we adopt a more concise one, which defines awareness as “an understanding of the activities of others, which provides a context for your own activity. This context is used to ensure that individual contributions are relevant to the group’s activity as a whole and to evaluate individual actions with respect to the group goals and progress” [5].

There is, in the CSCW community, a consensus about the importance of the awareness support for cooperative work (see, for example, [18] and [6]). Awareness represents the knowledge about a group involved in a collaborative process, its activities, status and evolution [8]. Relying on an awareness support, users can coordinate and evaluate their own contributions considering the whole group evolution. Such an awareness support can be seen as an implicit coordination

mechanism [16]. Indeed, if the members of a team are kept aware of their project status and activities, then they are able to communicate (exchange information) with each other and to coordinate themselves. Then, this knowledge refers to the organizational context in which the cooperative work takes place.

However, as stated by Espinosa et al. [6], the functionalities of an awareness tool have to meet the informational requirements of the tasks performed by the users. Otherwise, awareness support can turn out to a distraction.

For users who access Groupware Systems through a web-enabled mobile device, the delivered information should also comply with the material constraints of their device as well as their changing location. Consequently, information delivered to a mobile user should be limited to the one which is relevant for the work he/she performs, but also it should cope with her/his location and be formatted according to the capabilities of the client device. This is why information has to be adapted to the organizational and physical context of a mobile user interacting with a Groupware System. In order to adapt the awareness information to such mobile users, a Groupware System has to rely on an adequate representation of the notion of context which it can consequently use for adaptation purposes. In the next section, we describe the representation of the notion of context we propose to be exploited by the awareness mechanism.

4 An Object-Oriented Context Representation

In order to create a useful representation of the user's context at a given moment, we restrict this representation only to aspects that we consider as essential for an awareness mechanism embedded in a mobile Groupware System. A special emphasis is put here on how it is used by mobile users. However, this representation could also be used by other components of the Groupware System, those in charge of the presentation of information, for example.

There are, in the CSCW literature, several propositions of user's context representation. For instance, Leiva-Lobos and Covarrubias [9] consider a threefold context for cooperating users: spatial, temporal and cultural. The spatial context contains shared artifacts found in both the physical and the electronic space. The temporal context refers to the history of past cooperative activities and to the expected or future ones. The cultural context gathers users' shared view and practices (*i.e.* the community practices). Similarly, Allarcón and Fuller [1] describe the work context using the following entities: the content (*i.e.* tools, shared objects, etc.), the process (*i.e.* activities and their calendar) and the users themselves. In addition, these authors define the notion of the user's electronic location as an entity of the user's context.

Synthesizing these works, we have identified five viewpoints which compose the notion of context we propose: *space, tool, time, community* and *process*. These viewpoints correspond to main concepts of the context representation. The space viewpoint refers to the concept of physical *location*. The tool viewpoint concerns the concepts of physical *device* and *application*. The time viewpoint points to the concept of a common *calendar* the group shares. The community viewpoint refers to the composition of the community of users, including the concepts of *group*, *role* and *user*. Finally, the process viewpoint concerns to the *process* (workflow) performed by the group, including the concepts of *activity* (task) and *shared object* (an object handled by the group).

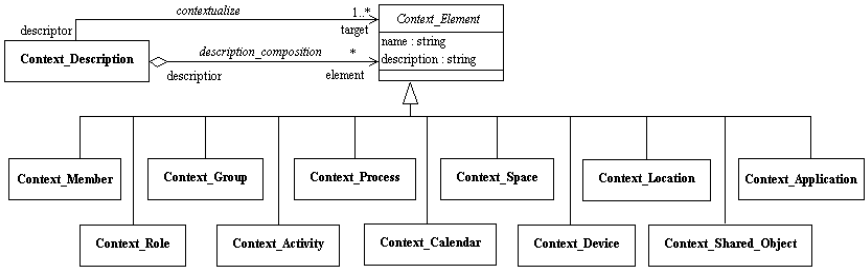

Fig. 1. The context description and the basic elements of the context representation[3].

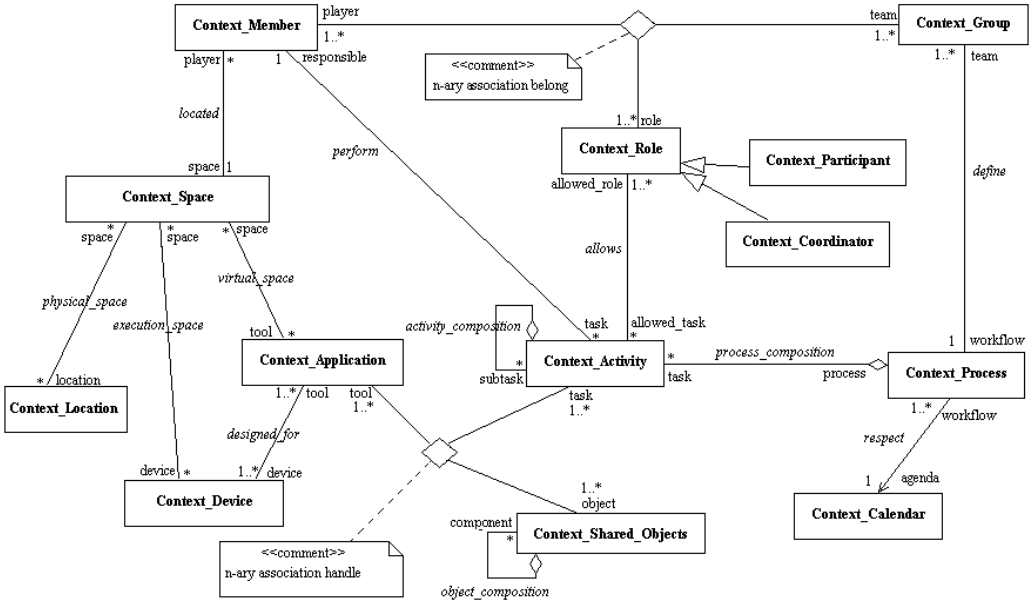

Fig. 2. The associations among all elements in the context representation.

We consider these concepts as the most relevant ones when defining a mobile user's context for a cooperative environment. Fig. 1 presents an object-oriented representation (using UML) of this notion of context. In this diagram, the concepts listed above (user, group, role, location, etc.) are represented by classes (*member, group, role*…) and the relations that hold between them by associations.

The context description is seen as a composition of the elements mentioned above. It is then represented by a *context description* class, which is a composition of these *elements*. In addition, this description is linked to another element for which it describes a specific context. For instance, the context of a user (here, called *member*) who is currently accessing the system, or the context in which an application can be executed.

[3] Please note that in the rest of the paper we omit the "Context_" prefix for readability.

As shown on Fig. 2, the basic elements which form the context are related to each other, defining associations between the corresponding concepts. Thus, a *member belongs* to the group through the *roles* she/he plays in this *group*. We also consider that each group *defines* a *process* (or adopt a predefined one). This process *respects* a given *calendar* and is *composed* by a set of *activities* (or tasks, also composed by subtasks). A *role allows* the execution of one or more activities (which may be possibly executed by other roles). Each activity is *performed* by a member and *handles* a set of *shared objects* (composed by other objects) through a set of applications, which are *designed* for specific devices. A *member* is located in a certain *space*, which is composed by a *physical space* (the physical *location* of the member), by a *virtual space*, corresponding to the *application* that is accessed, and by an *execution space*, including the *device* employed.

The classes and associations of this context description form the schema of a knowledge base which allows to describe the context of a mobile user accessing a Groupware System. Then, the awareness mechanism can exploit this context representation to better cater information delivered to the user. At a given moment, the context information concerning a user is represented by instances of the classes and associations of this knowledge base. These instances are aggregated into a context *description* instance, which represents, completely or partially, the context related to a specific element. For instance, a *context description* instance may refer to the context of a user currently accessing the system, including instances describing this member, her/his roles, the activities she/he is performing, and possibly her/his location. It may as well partially describe the context, including only instances referring to the space (location, device, and application) and ignoring all information about the activities and the group process.

In order to build these instances, we assume that the Groupware System has a component which detects the current user's context and dynamically creates the corresponding context description. For mobile users, this component has to determine the physical location of the user (through GPS technology or estimation based on signal strength, e.g. [2] and [12]) and to discover what are the characteristics of the client device, and to identify the user and the activities she/he is performing. Frequently, this component is not able to determine all the elements of the context representation. For example, when the Groupware System integrates a workflow component, it can determine easily what activities (tasks) a user is working on. Otherwise, it is very difficult for the context detection component to determine them, and it may ask the user for some help (as suggested by [13]) or omit this information in the context description. This omission means that the system does not have enough knowledge to represent these elements, and then can make no assumption about them.

We have implemented this representation using the AROM system [14]. AROM is an object-based knowledge representation system, which adopts classes/objects and associations/tuples as main representation entities. This object-oriented representation can be easily adapted for different Groupware Systems using the specialization mechanisms proposed by the AROM system. For instance, the Groupware system designer may define new subclasses of any context elements (such as the “Participant” and “Coordinator” classes in Fig. 2), even for the root element of the proposed class hierarchy (the *element* class). In addition, the use of the AROM system allows to perform queries such as: "is a user currently using a given device?", or "is a user in a specific location?". This corresponds to ask if the instances representing such device or location belong to the current user’s context description. In the next section,

we describe how an awareness mechanism can take advantage of this context representation.

5 A Context-Based Filtering Process

We consider the awareness mechanism as a component of the mobile Groupware System. This component able to analyze users' activities, as well as those performed by other components (for instance, a workflow component), in order to collect information that could be relevant to the group members and enhance the group's performance (for instance, the information about a deadline, a meeting, a document that is available, a colleague that is on-line, etc.).

In this work, we exploit the context representation presented above to perform the information, using an event-based awareness mechanism. In other words, we assume that all the awareness information is carried by events. We assume that events are defined by the Groupware developer and that each event contains useful information for the group members about a specific topic. Additionally, we define the concept of *general profile* (see Fig. 3), which represents the preferences and the constraints that the system should satisfy for a given element (group member, role, device…). For group members, this concept specializes in *preferences*, which describes the preferences of the user concerning the awareness information delivery. For devices, it specializes in *characteristics*, describing the capabilities of the referred device. These profiles may typically define conditions under which events (and, consequently, information) should be delivered, as well as its quantity (maximum number of events or Kbytes supported). The *characteristics* profiles can be represented using the CC/PP[4] reference. The *preferences* profiles may indicate a priority order for the events, the time interval that is suitable for the user, and other conditions related to the context description (for instance, if the current device is a given one, or if a given activity has been performed).

As an illustration, let us introduce an example considering a mobile Groupware System which has shared repository and synchronous/asynchronous communication features. In such a system, a user may define a *preference* profile indicating events related to some modifications made on a report that she/he is writing, to the availability of the other group's members or to the group's deadlines. In addition, she/he may associate to this profile a time interval, specifying that she/he is interested only in events performed last week or which should occur during the next one (such as a deadline). In fact, we consider that each group member can define for herself/himself a set of profiles and the circumstances in which these profiles should be applied, as explained later in this section.

In order to perform the context-based filtering process, we associate each *context description* instances with each *event* instance, with a *general profile* instance, or with an active user. This reflects the fact that *i)* events are (or should be) produced in a certain context, *ii)* at least, one *context description* instance describing the circumstances in which a profile can be applied is associated with this profile, *iii)* once a mobile user accesses the system, she/he is doing so through a specific context, which is identified by the system and represented by a *context description* instance as

[4] http://www.w3.org/Mobile/CCPP/

well. The Fig. 3 presents the associations between events, profiles and the classes defined by the context representation (see Section 4).

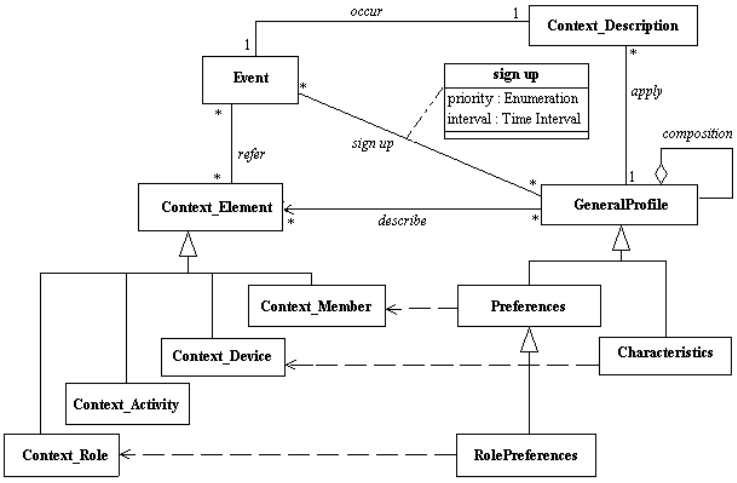

Fig. 3. The application of the context representation to the awareness mechanism[5].

The proposed filtering process is performed in two phases, using the *context description* instances associated with the group member and the general profiles in order to perform the selection of the suitable events for this member. In the first phase, the awareness mechanism selects the profiles (preferences or characteristics) that are applicable to the current member's context description. Then, in the second phase, it applies the selected profiles to filter the available events. We consider that each group member can define circumstances, through a *context description* instance, in which each profile can be applied.

The first phase, profile selection, is performed by comparing the content of the *context description* instances of both, user and profile: if the *context description* instance of the profile has the same content or is a subset of the current user's *context description* instance, then this profile can be applied. We consider that the *context description* instance and its associations with other instances define a graph, where the nodes represent the instances and the edges between them represent the tuples in which these instances are involved. Thus, a context C is a sub-context of a context C' whenever the graph corresponding to C is a subgraph of the graph corresponding to C'. For instance, a user may define a profile that is applicable only when she/he is working on an activity which concerns the referred report and when she/he is working on a desktop device. This means that this profile is not selected when she/he is working on her/his PDA, even if she/he is involved in one of these activities. This is because of the context description of this profile does not match the user's context description (it does not include the node referring to the PDA device, so it is not a subset of the user's context description). On the other hand, if the same user defines a second profile including, as context element, an instance referring to this PDA device

[5] The prefix "Context_" is used to distinguish between the elements of the context representation and those of the awareness mechanism.

(*i.e.* a profile for the situations in which she/he is using it), this profile is selected in this situation. In addition, individual elements of the user's context may have in turn their own profiles, which are also taken into account in the selection process (for instance, the device employed by the user may have a *characteristics* instance associated with it that will be considered).

Once all applicable profiles are selected, the second phase begins. Here, the awareness mechanism compares the conditions associated with these profiles to the information carried by the set of available events. Then, among the available events, the awareness mechanism selects only those which correspond to (*i.e.* match with) the conditions expressed by the profiles, that is the ones which are considered as relevant for the user's context. This matching can be achieved in different ways. We propose to perform it gradually, respecting the order in which they have been selected. This means that, for each profile, the filtering process selects the event instances corresponding to the event types signed up by the profile, and then it applies the conditions expressed on this profile.

For instance, let us consider a user who has two selected profiles: one including the event type corresponding to the colleague's availability (called "on-line" event type), and another including the event type related to a particular group's activity ("activity X" event type). Additionally, each profile expresses an extra condition: a time interval condition (colleagues available right now) for the former profile, and a context condition (the event must handle a given shared object) for the latter. Using these profiles, the filtering process will select only the instances of these two event types ("on-line" and "activity X") which correspond to the expressed conditions (the time condition for the instances of the first event type, and the context condition for the instances of the second one). The process will ignore other instances that do not correspond to these event types, neither to these conditions. Furthermore, the context condition is expressed as a context description instance. Its evaluation is performed by comparing it with the *context description* instance associated with each event instance (through an operation similar to the one used to select the profiles). The time condition evaluation exploits the *interval* attribute of the class-association *sign up* between the classes *Event* and *General Profile* (Fig. 3).

The result of such a filtering process should be a reduced set of events that will be delivered by the Groupware System to the mobile user (possibly, after the application of other adaptation components that should adapt the presentation of the selected information to the capabilities of the current device).

6 Conclusion

This paper presents a context-based filtering process for awareness mechanisms in mobile Groupware System, which relies on a context representation, described using an object-based knowledge model. This context representation differs from other works by combining two points of view (organizational and physical context), as well as by using an object-oriented representation. This representation has been implemented using the AROM system, and we are now performing preliminary tests, considering more particularly the subset relation between context description instances. We are also implementing the filtering process, using a framework for awareness support called BW [8]. We expect to perform more practical tests with mobile users through a test application, a cooperative game especially designed for

this purpose. Through these tests, we expect to evaluate the effective impact of our proposition for mobile users and the usefulness of this mechanism by the users.

In addition, we expect that these practical tests will show more about the scalability of this proposition. Preliminary tests are promising since the AROM system seems able to handle large amounts of instances. Finally, considering the filtering process, its scalability and adaptability depend mainly on the profile definition. The process proposed in this paper presents some limitations (*e.g.* the user has to predefine the conditions of the profile application and the conditions for the events selection), and we intent to improve this definition on the future.

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