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An Activity Awareness Visualization Approach Supporting Context Resumption in Collaboration Environments

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Abstract. In the research on Computer Supported Cooperative Work, activity awareness is considered a key feature for the coordination of users' activities. We propose a model for the visualization of recent activity awareness information organized at two abstraction levels: (a) the upper level, represented as a tag cloud, provides a general view of the degree of activity occurred in the user's collaborations. (b) the lower level is a detailed view of the occurred events, structured on the basis of the user's activity contexts. The results of a user study show that the adoption of the proposed solution is preferable over a standard awareness space providing a direct access to complete awareness information.

Keywords: activity awareness support, workspace awareness, collaboration environments, Web 2.0.

1 Introduction

The research on groupware and Computer Supported Cooperative work describes awareness support as a key feature for collaborative environments, in order to enable users to maintain an up to date view of their collaborations. In particular, [1] introduces the *activity awareness* concept to represent "the awareness of project work that supports group performance in complex tasks".

Activity awareness support involves notifying the user about many different types of information, concerning collaborators, artefacts to be manipulated, actions performed by others, pending tasks, etc. Thus, a major issue to be addressed is that of preventing the user from being overloaded by an excessive amount of data to be inspected (i) while (s)he operates in the collaboration environment, and (ii) every time (s)he resumes the state of an activity context; e.g., after having been out of office for some time.

The risk of overloading users was evident in former collaboration environments; e.g., see [2]. However, nowadays it is even more problematic, as private and corporate users are increasingly using online services to carry out their activities by exploiting the ubiquitous environment offered by the Internet [3, 4]. Therefore, for each user, the number of private and shared activity contexts to be handled in parallel, and the amount of awareness information to deal with, are much larger than before.

In order to support an efficient resumption of the state of the user's collaborations, we propose a two-level model for the visualization of recent awareness information which provides a synthesis of the evolution of the user's activity contexts, from which the details of the occurred events can be retrieved on demand. The idea is that of enabling the user to quickly understand the degree of activity occurred in her/his collaborations in order to decide whether some of them deserves to be inspected in detail. For this purpose, we have designed the higher visualization level as a tag cloud (the Awareness Cloud) whose nodes

- represent activity contexts and users, depicting the level of occurred activity in the selected time interval by means of their relative size in the cloud;
- are direct links to projections of the awareness space handled by the collaboration environment, focused on specific activity contexts/users. These projections form the lower visualization level and support a direct access to recent awareness events from particular perspectives.

These two views complement the thorough information provided by standard awareness spaces by enabling the user to access information incrementally and in a focused way.

We conducted an experiment with end users to assess how people interacted with these views. The results revealed that, in terms of improved users' performance, our designed Awareness Cloud represents an added value to an awareness space structured on the basis of the user's activity contexts because it helps users to quickly access the information required to answer specific information needs.

In the following, Section 2 presents our visualization model. Section 3 describes the user study we carried out and discusses its results. Section 4 compares our proposal to the related work and Section 5 concludes the paper.

2 Presenting Recent Activity Awareness Information

The provision of awareness information is challenging: on the one hand, push technologies can be employed to notify users about the occurred events, e.g., via Instant Messages or e-mail. However, they can generate interruptions possibly having a disruptive effect on users' attention and emotional state [5]. On the other hand, as discussed in [6], users acknowledge notifications as disruptive, yet opt for them because of their perceived value in providing awareness. Moreover, as reported in [7], users are observed to frequently switch among different activity contexts, with a consequent effort in resuming the state of the contexts they enter.

One way to address the trade-off between keeping users up-to-date about the evolution of their collaborations and interrupting them is the provision of an incremental access to awareness information. In fact, this solution gives a flavor of what has happened in the users' activity contexts and supports a quick access to the details they need, on demand. The visualization model we propose follows this approach and is thus proposed as an awareness layer to be superimposed over a standard awareness space, in order to provide views on such space, focused on the recent past and on specific information needs. As such information is not enough to reconstruct the complete history of a collaboration, our visualization model assumes the existence of a separate awareness

space presenting the long-term event history. See [8] for a proposal of how such a space could be organized.

2.1 Context-dependent Management of Awareness Information

For each user of a collaborative environment, the awareness events to be visualized concern actions performed by her/himself, or by her/his collaborators, while they use the business services integrated in the environment. In order to support a structured, context-dependent presentation of information to the user, our visualization model makes two main assumptions:

- The user's activity contexts are explicitly modeled, as well as the collaboration groups associated to such contexts.
- The awareness events generated by the services integrated in the collaboration environment are classified in their reference activity contexts, so that they can be managed in a structured awareness space reflecting the user's collaborations and private activities.

Fig. 1. Awareness cloud of a user of a collaboration environment (user utntest1@gmail.com).

As described in [9, 10], we represent the user's private and shared activity contexts at different granularities, considering the following types of contexts:

- *Collaboration sphere*: this is a thematic group, similar to a virtual community, used to keep in touch with each other. For instance, the "family" sphere could be defined to keep track of the communication concerning the user's family.
- *Activity frame*: this is a more or less structured project, which a user can define in order to collect artefacts of interest around a topic and manage activities aimed at reaching a goal, possibly in collaboration with other users. For instance, an activity frame could represent a work project aimed at preparing a conference paper.
- *Task*: this is used to specify and carry out the execution of an activity, possibly shared with other users; e.g., writing a section of the above mentioned conference paper. A task may include artefacts to be manipulated and can have a deadline. Tasks are created within activity frames and can be related to each other according to partial order relations, in order to coordinate the execution of complex activities.

[9] and [10] present a framework for the development of user-centered service clouds supporting an explicit management of contexts and the consequent classification of awareness events. The visualization model proposed here builds on that architecture but could be applied to a different one, as long as it guarantees the association of awareness events to actors and contexts.

2.2 Two-level Presentation of Awareness Information

We propose to visualize the recent activity awareness information for a user in the Awareness Cloud. This is a tag cloud which shows the degree of activity occurred in the user's private and collaboration contexts during the time interval selected by the user.

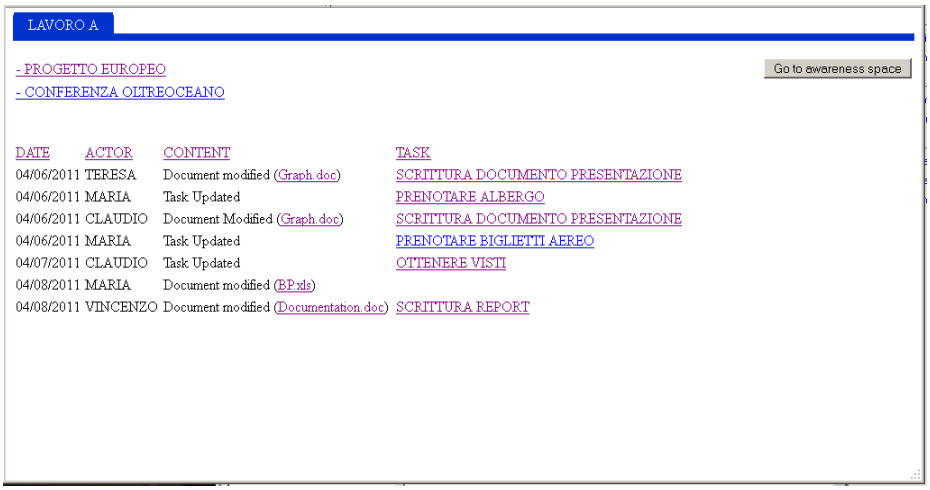

Fig. 2. Detailed views on awareness information concerning context "LAVORO A".

As shown in Figure 1, the Awareness Cloud for a user U is organized as follows:

- The nodes represent four types of entities: *user* nodes are associated to U's collaborators; e.g., see node CLAUDIO. *Collaboration sphere*, *activity frame* and *task* nodes are associated to the user's collaboration spheres, activity frames and tasks, respectively. For instance, node LAVORO A represents a collaboration sphere.
- The relative size of each node in the cloud represents the degree of activity in the selected time window and depends on the number of associated awareness events that have been collected in the collaboration environment. Specifically, user nodes visualize the degree of activity of the represented users *within* U*'s activity contexts*, as the operations performed by users in other contexts cannot and must not be disclosed to the user. The other types of nodes summarize the degree of activity occurred in the contexts they refer to.
- The user can specify the starting and end time of the interval for the generation of the cloud in order to visualize the evolution of her/his activity contexts along time.

Moreover, a "catch up" button enables the user to refresh the cloud by setting the starting time to the current time. This is useful when the user is not interested in the recent event history any more.

Thus, for each user, a dynamic awareness cloud is generated, which reflects the activity contexts (s)he engages in and the selected time interval.

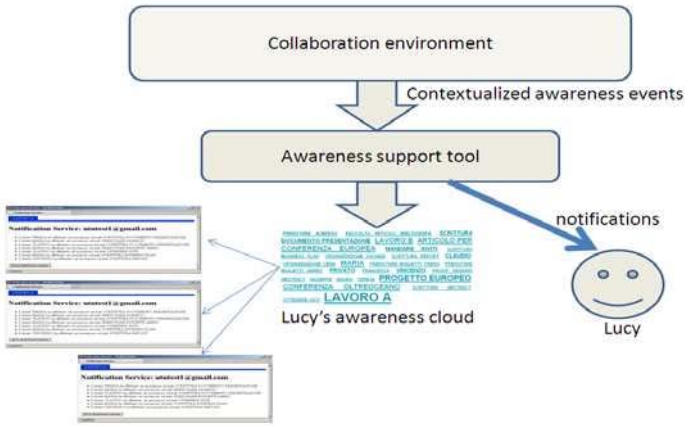

Fig. 3. Architecture of the collaboration environment supporting activity awareness.

Each node of the cloud is linked to a view on the main awareness space of the collaboration environment which shows the related awareness events in detail. Each view is indeed a projection of the awareness space, focused on the context represented by its source node in the Awareness Cloud and on the time interval selected for the generation of the cloud. Specifically, the page linked to a user node displays the list of events describing the actions performed by the represented user. Moreover, the page linked to an activity context node displays the list of events occurred in that context.

Figure 2 shows the event history associated to node LAVORO A of the awareness cloud: in order to support the navigation of events, these can be sorted by date, actor, content and task (in fact events are managed as structured objects, with features, within the collaboration environment. Notice that, if the context associated to a view includes any nested contexts (in this case, PROGETTO EUROPEO and CONFERENZA OLTREOCEANO, which are two activity frames defined within the LAVORO A collaboration sphere), the page includes links which the user can follow in order to visualize the events concerning such nested contexts. Thus, the projections on the awareness space are hierarchical.

It should be noticed that the cloud includes a maximum number of 40 elements to be visualized at each time because, as discussed in [11], a cloud with too many tags can be puzzling and hard to read. Should more than 40 elements be eligible for visualization, those with least elements would therefore be dropped. The user can however personalize the cloud by suppressing nodes in order to avoid the visualization of users

and/or activity contexts (s)he is not interested in. Moreover, we are extending the cloud generation model in order to allow the user to specify high-priority nodes, associated to users and/or contexts which the user wants to monitor with particular attention. Such nodes will not be dropped from the cloud and will be depicted in a different color for easy identification.

We integrated our visualization model in a collaboration environment developed by exploiting the Personal Cloud Platform (PCP) [9], which supports the development of customized collaboration environments by integrating heterogeneous software components in order to answer specific functional needs. Figure 3 shows the overall system architecture and highlights the generation of the Web pages according to our proposed model (integrated in the Awareness Support Tool of the environment). The PCP enables the user to specify her/his collaboration spheres and to synchronize heterogeneous business services accordingly. Moreover, it offers the Collaborative Task Manager (CTM, [10]) for the management of activity frames and tasks and for the classification of the awareness events generated by the user's actions in the related activity contexts. The CTM offers a User Interface which enables the user to interact with business services (e.g., to create or manipulate artefacts) within a specific activity context and to classify awareness events in the appropriate activity contexts.

3 Tests

3.1 Description

We conducted an experiment to evaluate the impact of the introduction of the Awareness Cloud on users' experience. We wanted to test a hypothesized causal relationship between the introduction of the Awareness Cloud on top of an awareness space structured on the basis of the user's activity contexts (henceforth, context-aware awareness space) and people's performance during a task.

Our research question was *"Does a context-dependent tag cloud modify the level of performance of the users with an activity awareness space?"*. If the answer is positive, which case can give best results?

Hypothesis (Ha): The introduction of a custom tag cloud to enhance a context-dependent activity awareness space (i.e., an awareness space structured on the basis of the user's activity contexts) will improve users' performance on an awareness information seeking task, in terms of execution times and number of errors.

Sixteen volunteers participated as participants in this experiment (10 men and 6 women). All participants were students or staff within the University of Torino and performed the test for free, without any reward.

The experiment had a single-factor, between-subjects design. Two treatments were applied - one experimental treatment and one base-case control treatment. The experimental treatment consisted in a context-dependent activity awareness space enhanced with an Awareness Cloud, while the context-dependent awareness space alone was reputed as the base-case.

Each treatment condition was considered as an independent variable. Participants' performance was considered as a dependent variable and was calculated considering

two objective measures: number of committed errors and time needed to complete the task. Participants were divided into two groups of eight people, and each group received one single treatment. Such design was aimed at preventing side effects such as practice and fatigue. Users were also given two questionnaires: one before the task, the other after task completion. The first questionnaire was meant to evaluate users' background about collaborative applications. The second questionnaire was meant to evaluate users' opinion on the adopted User Interface solution.

The experimental task was designed as an information recovering and comprehension one, simulating a typical, asynchronous reception of awareness information in a collaboration environment. Users in both groups were briefed about their scenario before the beginning of the task: as participants of three different collaboration groups, they had received awareness information regarding other users' activities, that was still to be read. Such information was collected in a structured list (the activity awareness space), where each event-related element was organized on the basis of its originating activity context; the recent activity awareness consisted of 13 events. Users were then asked to answer six questions, whose answers could be found by navigating the events. Questions 1, 2 and 4 were general, quantitative oriented ones, such as "who is the most active user in a certain task"; questions 3, 5 and 6 were more specific, as for example "list every task and collaboration sphere a certain user is involved in".

All participants used the same activity awareness space for this purpose. The only difference between the two treatments was the presence (or the absence) of the Awareness Cloud, combined with the visualization of recent events. Users within the experimental treatment group could therefore access particular "projections" of the awareness space by clicking on the corresponding node of the Awareness Cloud. Each user was also given information about the nature of their (simulated) collaborations, such as names of collaboration groups, projects, tasks and involved users. Such instructions were available to participants as a reference throughout the whole experiment. Each participant was engaged in testing activity for a period of about 15 minutes.

3.2 Results and Discussion

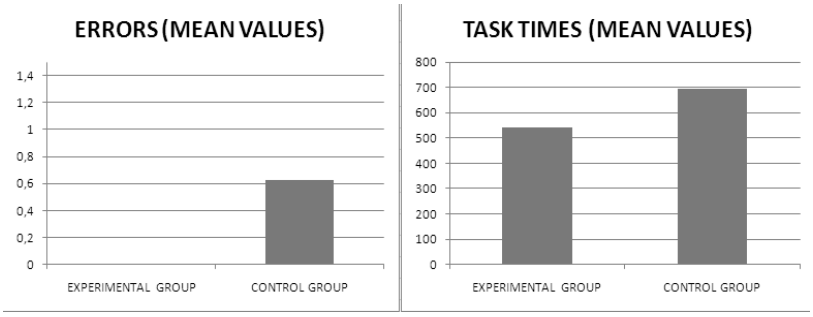

Fig. 4. Test results.

The first questionnaire was aimed at measuring the level of practice each user had with collaborative applications, within two different environments: workplace and private life. Each user could choose between four non-decreasing levels of practice, ranging from 0 to 3. Results showed no significant difference in the level of practice each user had with collaborative applications in both environments.

Figure 4 shows the results of the user tests. The figure is split in two parts, and both parts show mean values for the two treatments: the values are referred to the number of errors and execution times (in seconds) respectively, and are defined on the y-axes; the x-axes identify the treatment group.

We used an unpaired Welch's t-test (which does not assume equal variances) to analyze collected data. An alpha level of 0.05 was used to make decisions of significance. We found a significant effect either for number of errors ($t = -2.38$, $p = 0.049 < 0.05$) and for execution times ($t=-3.15$, $p = 0.011$), that lead us to reject null hypothesis of no difference between the treatments, and to accept our hypothesis: the introduction of the Awareness Cloud lead to an improvement of users' performances.

In the second questionnaire we asked users to evaluate their own experience with the User Interface they operated with: awareness space plus Awareness Cloud for experimental group, awareness space alone for control group. Each user could choose between seven non-decreasing levels of satisfaction, ranging from 0 to 6. The experimental group expressed a mean value of 5,81 for their UI (st.dev = 0,55), while the control group expressed a mean value of 5,31 (st.dev = 1,02).

The results of this experiment revealed that the introduction of the Awareness Cloud significantly improved users' performance, in terms of times of execution and number of errors. First-hand observations of participants behavior in this experiment lead us to grasp two aspects that may explain these results:

- The Awareness Cloud proved itself as very easy to understand and to use, and showed a good level of integration with the awareness space. Indeed, the users of the experimental group were left free to choose arbitrarily whether to adopt it or not, but every one of them (even those who did not know what a tag cloud was) opted for its use since the first question.
- The Awareness Cloud allowed users to express fast and precise queries by clicking on the desired nodes, with a User Interface that was valued as "practical, good and interesting". Navigating into the awareness space in isolation did not prove itself as immediate and error-proof as the Cloud: users of the control group who did not commit errors tended to spend more time doing their tasks, probably due to the need of verifying their choices with more accuracy.

Users indicated as a major drawback of the Awareness Cloud the fact that it made hard to spot nodes with a very low density of events: while it could be much faster to identify high density elements (specifically, groups of users and highly active tasks), those written with the smallest font (such as low activity tasks) might get lost among the crowd. This aspect is typical of a tag cloud [11] but could be addressed by supporting a personalized configuration of the cloud, based on the user's interests. Specifically, we plan to enable the user to configure the Awareness Cloud by specifying which elements (s)he wants to monitor with most attention. When the cloud is generated, such elements

will then be displayed with a different color (e.g., red instead of traditional light blue) and would never be omitted when the cloud is too large.

4 Related Work

Most groupware and project management tools only offer standard awareness spaces which show the list of occurred events organized by collaboration group; e.g., BSCW [12]. Other systems, such as CANS [13], support the presentation of awareness events in different formats (such as lists and tables), but events are classified by group/shared directory. Furthermore, [14] proposes a radar view of awareness events, which are only classified by source application.

In [2], AwarenessMaps are proposed to provide the members of shared workspaces with an overview of users and documents: "the PeopleMap shows an array of pictures of active users fading out over time; and the DocumentMap provides a schematic overview of the structure of a shared workspace and indicates recent changes." Moreover, [15] introduces a pictorial representation of incoming e-mails (Info-Lotus), divided in groups and sub-groups in order to represent conversation threads. Our proposal makes a step forward in this direction by visualizing the recent awareness information at different granularity and abstraction levels. The *granularity* aspect concerns the generality of the activity context to be considered and is motivated by the fact that users engage in different types of collaborations, such as thematic groups (e.g., small or large virtual communities), more or less structured projects, and specific tasks. The *abstraction* aspect enables the user to receive a synthesis of the evolution of her/his activity contexts and to select the contexts to be inspected in detail.

Recently, the research about collaboration in online communities has focused on activity awareness in order to inform users about who is active in the topics of interest of the community, which kind of contribution has been provided, and similar. For instance, [16] proposes a "star" view of users, aimed at showing their degree of activity in the community. Moreover, [17] proposes a visualization of activity awareness in CiteULike, which exploits radial time bands to show the time period during which the user/group activity (or the activity on a topic) has occurred. Our proposal differs from those works because, besides modeling individual users and groups, we model the user's activity contexts. Specifically, the visualization we propose enables the user to assess the state of her/his collaborations or to focus on aspects, such as a particular task.

5 Conclusions

This paper has described a visualization model supporting the incremental access to activity awareness information in a collaboration environment. Our model presents the awareness information at different levels of detail in order to provide the user with a general view on what has recently happened in her/his collaborations, and enable her/him to retrieve detailed information on specific activity contexts. A user study showed that the adoption of the proposed solution is preferable over a standard awareness space providing a direct access to complete awareness information.

Before concluding, it is worth mentioning that the model presented in this paper is the first step towards the development of an adaptive awareness support service enabling users to receive a personalized view of the information they need, depending on their interests and activities. In fact, the current model for the generation of the Awareness Cloud is only based on the user's activity contexts and on the selected time interval for the visualization of information. Personalized clouds could be generated by enabling the user to explicitly select "high-priority" contexts (as proposed in Section 2), but also by tracking the user's interests across activity spaces along time, and by dynamically configuring the Cloud in order to focus it on the most relevant ones; e.g., see [18] for a similar approach applied to notification management. In our future work, we plan to extend our awareness model towards the provision of adaptive workspaces which tailor both the presentation of information (e.g., awareness information) and their services to the dynamics of the collaboration activities carried out by users; e.g., see [19].

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