Integrating Awareness Sources in Heterogeneous Collaboration Environments

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Abstract. Collaboration in heterogeneous environments involves dealing with variety of information sources that generate information that users need to be aware of. Users must be empowered to tailor the quality of awareness information. Heterogeneity of sources and media adversely affects the quality of group awareness. We propose a solution in terms of integrating the sources at the information level and provide a model for the same. We discuss our progress in designing the model, its utility and benefits. We believe that such a unifying framework can increase the effectiveness of group awareness in supporting co-ordination and execution of collaborative work.

1 Introduction

Collaboration in heterogeneous environments has become a necessity. Heterogeneity is in the plethora of applications, supported by hardware and communication infra-structure of varying capabilities. Added to this is user mobility. Awareness among such groups is essential. Many groupware applications are designed to support group awareness but often most groups use general-purpose applications not designed to support awareness. Awareness propagation is effective if the appropriate amount of information, relevant to the user's sphere of activity is delivered in an unobtrusive manner, without compromising the privacy and security constraints of the group. A key design goal of awareness systems is to empower its users with awareness characterized by a high degree of the above "quality factors".

The heterogeneity of sources and mediums that generate awareness information deeply impacts the quality factors. We examine this relation in detail, and the specific problems. As part of the solution, we propose a means to effectively integrate aware-ness information by means of an awareness model. The next section describes the effect of heterogeneity on the quality factors. Section 3 outlines the solutions. Details of our model are in Section 4, with an example. We conclude with validation steps.

2 Awareness in Heterogeneous Environments

2.1 Awareness in Group Work

Awareness has been well researched in information technology and social sciences. Gross et al. [9] provide a good comparison of both perspectives. Various forms of awareness and terminology have been defined. However we find that three aspects of awareness in general are closely related. These are *Quality of Awareness,* the *Awareness Information Characteristics* and *Awareness Sources & Mediums.*

1. Quality of Awareness: The quality of awareness impacts its role in group work coordination and execution. Quality can be characterized by factors such as:
Relevancy: How relevant is the awareness information to my sphere of work, both current and for the future (planning and coordination)? *Information Overload:* Am I aware of the appropriate amount? Am I being inundated with too much or not receiving enough? *Obtrusiveness:* How distracting is this information to my current activity? Is it interrupting my current activity? *Privacy:* Can privacy in the form of access control be established to ensure that only one with appropriate permissions is aware of classified information?

2. Awareness Information Characteristics:
Type (What am I aware of): Is this about an individual's activity or location, actions on an artifact, conversation transcript, streaming video of a meeting, or a combination of the above? *Form:* Is it text, audio, visual? *Volume (How much of it am I aware of):* Am I aware of every email exchanged by the group or just a synopsis; is it a long videoconference session? Do I receive a notification for every action taken on an artifact? *Frequency (How often do I get that information):* In a highly interactive chat session that I am monitoring, do I want to receive every line typed?

3. Sources and Medium:
Sources (Which is the information source): Email and IM messages, sensors relaying location, an artifact (actions on it), camera, microphone, user's keystrokes are all sources of awareness information, capturing various aspects of work that other users would be interested in. *Sources* impact the *Type, Form, Volume* and *Frequency.* For instance a sensor-based application will communicate awareness information only when the appropriate stimulus occurs and at the same frequency. High rate of keystrokes can result in high frequency and volume of information relayed.
Medium (How do I obtain information): Wired and Wireless networks, closed-circuit video, telephone (landlines, cellular) are all media. The capabilities of the *Medium* impact *Form, Volume and Frequency.* High bandwidth network could provide streaming video at much better quality than a dial-up connection.
Quality factors are evaluated from the perspective of the consumer of awareness and how they influence his work. Awareness Characteristics are about the information and so absolute. However the perceived quality of awareness does depend on the characteristics, which in turn are determined by Sources and Mediums.

2.2 Impact of Heterogeneity on Awareness Quality

Let us consider a scenario with three groups creating documentation independently. The team leader (TL) responsible for coordinating work among them is off-site as part of duty. Each group uses a collaborative editor, and at close of business, emails the TL their drafts. Upon review, the TL sends her comments to each group using both email and/or phone. Conflicting schedules, work commitments and lack of infrastructure keep her from joining their editing sessions. Relaying instructions at the end of the day is not very efficient. Sections in the documents depend on the content of the others. When inconsistencies are detected they have to be reworked (email is checked the next day), leading to delays. The ability to simultaneously monitor the status of three groups would be very valuable as well as knowing which parts they were working on and their decisions in the process. Even if the actual artifact being edited cannot be seen, the above "meta-information" is essential. Thus "knowing of" something can be valuable even if actual artifacts cannot be accessed. In another scenario a group in one location, needs to confer with a group at another location. They engage in video conferencing. They may record their decisions on a whiteboard. How could the TL be aware of this activity remotely without access to the video session? In other words we see the use of applications (some not designed to support awareness), running on infrastructure of non-uniform capabilities, being used in unanticipated situations i.e. heterogeneity at all levels. The TL cannot access relevant information as her capabilities limit the type, volume and frequency. Thus heterogeneity impacts the quality of awareness information and its effectiveness. We are interested in how users could control the quality factors of awareness in such environments.

3 Addressing the Impact of Heterogeneity

The approach is to integrate the various sources and mediums of awareness in a manner most suitable to the group effort. This integration has to occur at two levels.

3.1 Integrating Sources and Mediums

There needs to be mechanisms to tie various sources of information that exist in a group effort. Systems such as email servers, group editors, applications such as word processors, sensors and devices such as cameras, microphones, all generate information of different types. Consumers of this information use web browsers, hand-held devices, and applications (that are themselves sources) to obtain awareness. Communication occurs over different mediums on non-uniform infrastructure. Thus there needs to be an "Awareness Middleware" that can bind all the above together. Specific interfaces would be needed to connect the sources to the middleware making integration as easy as "plugging-in" the source. The use of non-electronic artifacts in many collaboration environments poses a challenging integration problem. The middleware and interfaces would have to conform to security, reliability and perform-

ance. Notable pioneering efforts [13], [8], [1], [2], [7] have been made to create such "awareness frameworks" for awareness propagation in groups.

3.2 Integrating Information

Different types of information generated (email messages, sensor coordinates, streaming video) have no absolute relation, though related within the context of the group's activities. They have varied source specific characteristics (Form, Volume, Frequency). These need to be woven to make the composite picture that is awareness. This integration must occur at the information level. Consumers of awareness must be able to determine quality and control it. Specifically, the implications of the awareness requirements on information integration are:

1. There must be a transformation (mapping) of the source-specific nomenclature of information generated, to the group's terminology and definitions, as users have no knowledge of the former. One way is by providing meta-tags to the information.
2. To retrieve all relevant information based on user's sphere of activity, there must be ways to relate information with respect to the common context, which is the group's work. Thus users can look for awareness information they need from their work perspective as opposed to querying about the source.
3. The integration process must be straightforward. Change in various factors is inherent in group work [4] and a simple process would help change management.
4. There must be means to express the Awareness Characteristics by which users can determine and tailor the quality factors using mechanisms such as filtration.
5. Apart from manual selection, there could be agents providing context-sensitive awareness. Mechanisms to enable such agents to match the user's profile, and work context to available information are required. This can support enhanced forms of awareness such as "intersubjectivity" ("i know, that you know, that I know")[1] .
6. Since users' capabilities to acquire awareness may not support all formats and exact artifacts, there must be means to obtain meta-information about it.
7. Obtaining awareness would begin with searching and/or browsing for it. A complete picture of information should be available to select from.
8. Historical awareness [12] of various aspects of the group's work is often essential and there must be means to retrieve such information.

Thus integration involves information transformation, relating different types and adding meta-information description to enable the above features. It is much more than creating databases, labeling and storing data. We propose a model as a basis for integration. This provides a common logical framework thereby decreasing the complexity in the integration process. Meta-information would be part of this framework.

The Awareness Frameworks reviewed emphasized awareness propagation. Sources and information were integrated in some fashion to facilitate context-awareness and user filtration. As sources to be used cannot be anticipated, our emphasis is on a generic framework. Awareness quality, simplified integration process and adaptability to changes in group work being issues of interest that we aim to address.

4 Model-Based Information Integration

4.1 The Awareness Model

Early work in modeling awareness has used spatial metaphors [3]. Medium, aura, awareness, focus, nimbus and adapter were concepts used to model and enable interaction, determining how entities behaved in virtual worlds. This was generalized to CSCW environments by a model [14] where a pool of objects and the relation between them was considered as the space. Users acting on these objects gain mutual awareness due to their interaction. Graph theory was used to express notions like strength of awareness. Another non-spatial model emphasized the effect of awareness on behavior of the objects [15]. This was based on the reaction-diffusion metaphor. Some efforts have been towards specific forms of awareness such as a model for presence awareness using concepts such as location, presentity, watcher and vicinity [6]. Another seeks to model cooperative awareness using three abstractions viz. events, places and communities [11]. Inspired by the above we borrow some of the key concepts and constructs. Our emphasis is on integrating the information sources with respect to the quality factors of awareness. Figure 1 illustrates the model.

Focus of Attention (Focus): This top-level concept represents the focus of an awareness consumer. A user's *Focus* consists of all active sources that are providing awareness. A *Source* is any entity that provides information (e.g. person, location, artifact). A *Focus* is a unified view of all its sources and the corresponding events and interactions occurring due to them (e.g. person's actions, communication, actions on an artifact). For instance the *Focus* could provide awareness about an activity in terms of email messages exchanged by the users (sources) or awareness about people entering a room, modifying an artifact and leaving. A *Focus* can shift over time. The type and number of sources win a *Focus* can change. Each *Source* has a corresponding *Medium,* which delivers information. Its characteristics dictate the quality of awareness information. Meta-information attributes describing awareness characteristics qualify the *Focus*, its *Sources* and *Medium* and are essential to determine and tailor quality. These attributes are:
Description: About what the Focus is providing.
Identifier: A unique identifier as there could be multiple Foci.
Start Time and *End Time:* Indicate the duration for which the Focus was active.
Source & Medium List: A list of sources and corresponding medium in the Focus. (Source1, Medium1), (Source2,Medium2),….. …(SourceN, Medium N).

Source: In addition to its own *Description* and *ID* fields, each *Source* entity has:
Start Time: The time the source comes within the current Focus.
End Time: The time the Focus excludes it.
Foci List: Each source element may have multiple foci it is obtaining awareness from (*Focus1, Focus 2….FocusN*) .
Information Content: This describes the information generated by the *Source*. Its attributes are:
Type: About the Information (natural language and/or keywords).

Form: Text, Audio, Video stream, others.

Frequency: How often is the source generating the information. Could be in the form of discrete notifications or continuous stream.

Total Volume: How much has been generated so far (or recorded).

Content: The actual information being generated, according to a content-specific schema depending on the source. For example, actions taken by sources, actions on artifacts, video streams, email messages and chat sessions would all be content.

Medium: Corresponding to each Source is its Medium. In addition to its own *Description* and *ID* fields, each *Medium* entity has:

Medium Specific Characteristics: A set of attributes about the specific medium. For example, the network characteristics for a wired or wireless computer network, cellular phone network or closed circuit television network would be of interest since they would indicate how much of information could be delivered and in what manner.
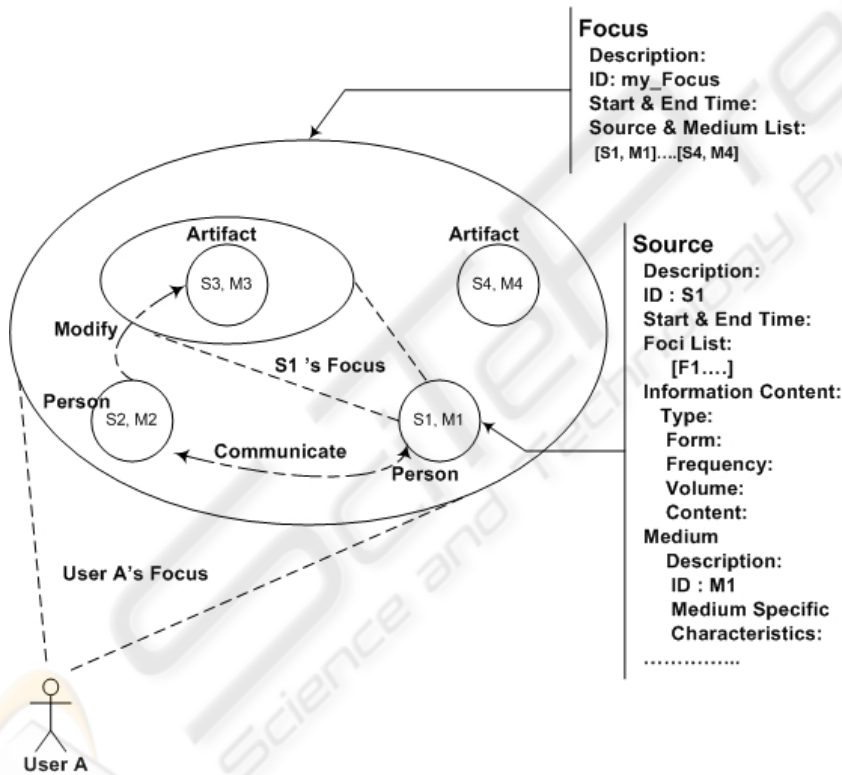

Fig. 1. Awareness Model

4.2 Levels of Awareness

An individual's *Focus* consists of the sources that are *actively* providing awareness. Users could have multiple *Foci,* each providing information about different aspects of the group's work. There are other sources that the user could access but are not cur-

rently part of his Foci. The user is aware of their characteristics but not receiving information content. This entire set of all active and potential sources is his *Source Superset,* which the user can access based on his role and access control policies. Sources outside his Superset are not accessible and invisible to him. Figure 2 illustrates this hierarchy. Finer levels could be enforced depending on the needs, what is important is that our model seeks to provide such control.

The user's view of all sources, media, and Foci in his Supersets with corresponding meta-information is his "Awareness Map", a concept inspired by [10]. On selecting an element of the map, one can zoom-in to get details about the content as well as source and medium characteristics. Such a view helps ascertaining, who else is aware of what I am aware or? Who is aware of me? intersubjectivity, and so on, which is valuable in coordination. Context-sensitive awareness sources could be added manually or programmatically based on the user's profile of work. Access control policies limiting what users can access can be established with this view. A super user would have unrestricted view of all users and their Source Supersets.
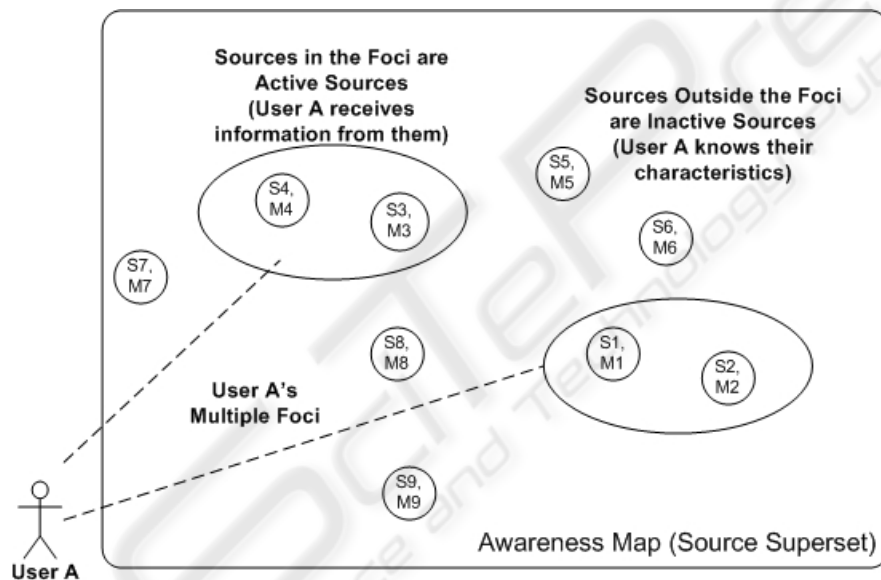

Fig. 2. Awareness Map

4.3 Illustration of Awareness Model

Figure 3 illustrates the scenario considered in section 2.2. The generic architecture of an Awareness Framework is based on our review of related work that revealed common components. Applications (sources) generate awareness information, which is communicated over certain media. They are bound to a central entity (by middleware) that manages the information flow. Application specific interfaces are necessary to connect them to the medium (very often computer networks). Users activities using these applications are of interest to other users. These consumers access this informa-

tion using applications that are bound to the framework too. In our case the central entity is the Awareness Model. We assume the collaborative editors used by the groups are physically integrated. The TL accesses the AM through a portal application. The collaborative editor is seen as one of the sources along with its characteristics in the TL's Source Superset. The TL adds it to his Focus and chooses details such as when to be notified if certain events occur in the editing session, how often and so on. This is an example of choosing the relevancy and frequency of information based on the displayed characteristics. Being on a low bandwidth connection, the TL chooses text-based notifications only. Though all events from the editing session are communicated, the AM would relay information to the TL based on her preferences. The TL being aware of the status could communicate with the groups through email/telephone/IM or even the editor application itself assuming it has such capabilities. We assume the editor communicates details such as, which changes were made by whom, when and so on making it part of the Information Content. The TL should be able to view this information as it occurs, or later. For e.g. the TL should be able to query to see all the changes made by a particular group member. The editing groups know they are connected to the AM through their Awareness Map views. They know that the TL is aware of their activities. Thus there is mutual awareness. Let us assume that one of the groups engages in a videoconference with another group as part of the process. The user TL could expand his focus to include this source if necessary. The TL may not be able to access the session but may be able to access a text transcript that is recorded and stored in the AM after the conference. The AM is not meant to be a data bottleneck; rather it is analogous to a lens over the awareness capabilities of the group bringing into focus the pertinent aspects. Users may have direct lines of communication with the source for actual data transfer.

5 Validation and Future Steps

Further work involves completing the model specification. The model will be validated with realistic collaboration scenarios and refined. Evaluating how useful the model is in enabling the users to tailor the quality factors is essential. Mechanisms used in integrating the information, displaying sources, supporting user browsing and querying based on the quality are being developed. Also providing context-sensitive awareness based on the user's sphere of activity, profile and the current state of the project is of interest. Another interest is evaluating the model in scenarios where there exists a certain level of awareness in the group, with intervals requiring a "heightened awareness" as in emergency rooms and call centers [5]. Among the multiple foci that a user has, some could diminish in "strength" when not important and others could come into prominence during such periods. The Awareness Map concept will be developed completely and a proto-type implemented.
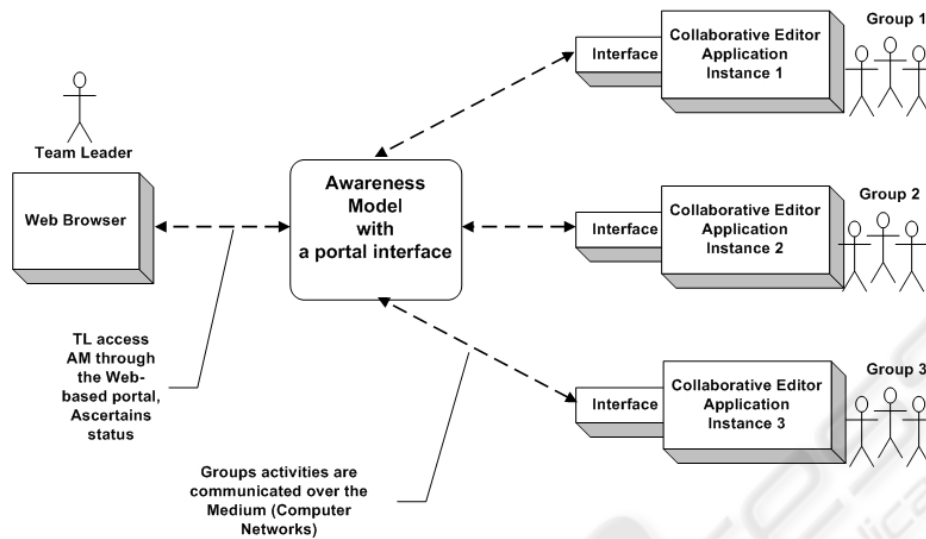
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Fig. 3. Awareness Model Illustration

6 Conclusion

Heterogeneous sources of awareness and media have a significant influence on the quality of awareness in groups. We examined the major issues in empowering users with the ability to tailor the quality of awareness and established the need for integration of sources at the information level. We proposed a generic unifying model to provide the composite picture that awareness is. We aim to demonstrate the utility of the model in tailoring awareness quality, simplifying the integration process and dealing with changes in group work.

Acknowledgements

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