TeleEye: An Awareness Widget for Providing the Focus of Attention in Collaborative Editing Systems

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Abstract. Awareness is the knowledge about present and past group's activities and it is a relevant issue for cooperative work. There are many devices that supply awareness information in synchronous collaborative editing systems. However, the current awareness devices have restrictions to both accomplish effective awareness and show the focus of attention identifying the exact place of the participants' attention. This paper presents an awareness widget for synchronous collaborative editing systems called TeleEye that provides information about the localization of the participants' attention during a collaborative session by means of eye tracking.

Keywords: awareness, attention, eye tracking.

1 Introduction

The CSCW (Computer Supported Cooperative Work) area has many goals including the exploration of the necessary means to accomplish effective awareness in group work. One of the means used in this exploration is the search for new awareness devices that provide information on the participants' actions and the sense of presence during group work.

The devices used to provide awareness information in Collaborative Editing Systems (CES) allow the participants to obtain knowledge of the group activities to know what happened, what is happening and what will happen, and also to provide details about the work and the group. However, the current awareness devices have restrictions to accomplish effective awareness and are not able to inform the exact place where the participants' focus of attention is during group work. The restrictions include the need of explicit actions to provide awareness, the effort required to obtain awareness and the need to occupy additional space of the shared workspace.

Being able to know the participants' focus of attention is important to preserve the smoothness of the group work and also contributes to communicate the participants' actions under current execution. Moreover, the awareness of the attention plays a key role in any form of cooperation, since the abilities to know, recognize and understand someone's attention are a major aspect of human interaction and communication.

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According to Yarbus [19], a person's gaze direction is one of the factors that identify his focus of attention. Motivated by this assertion, we investigate how the gaze direction can be used to improve awareness in CES.

The goal of this paper is to present an awareness widget that provides information about the place of visual attention based on the detection of gaze direction. This paper also presents a comparison between the proposed widget and the current visual awareness widgets used in CES.

The rest of the paper is organized as follows. Section 2 describes the current awareness devices used in CES to provide information of the participants' actions and the sense of presence during group work. Section 3 presents four eye-tracking mechanisms used to detect the user's point of regard. Section 4 details the proposed awareness widget used to obtain information about the place of visual attention based on the use of an eye tracking mechanism. In the Section 5, we make a comparison of the proposed widget with some visual awareness devices discussed in Section 2. Finally, Section 6 presents the conclusions, comments and future work.

2 Awareness in CES

The support of group work in CES is a necessary factor to create a common context among the participants. This context prevents that a specific participant feels isolated of the group, thus blocking his contributions and distancing himself from the work being accomplished. Pinheiro et al. [13] define awareness as the supply of common context to the participants of a group. Awareness is also the understanding of past activities while knowing what happened, what is happening and what will happen as well as the knowledge of the group participants' and the work to be done [13].

In CES, awareness is responsible to provide the sense of presence and actions of the group to remote participants. This means that awareness allows each participant of the group to coordinate and organize his work, since he has information that allows the understanding of what the others are doing. The awareness also provides the opportunity to both enhance communication, either informal or not and support the social protocol used while the work is being produced.

When the group is working to complete a task, it is common to expect actions being made to objects placed in a workspace shared by the groups' participants. The objects and the shared workspace are important elements that affect the performance of the group as a whole because the cooperation and the interactions among the group occur through the manipulations of the objects. The awareness of what is happening in the shared workspace is called workspace awareness and it is similar to the perception that a participant has of each other and the work when they are sitting around a table during physical meetings. Workspace awareness is defined as the up-to-the-moment understanding of another person's interaction with a shared workspace and involves knowledge about where others are working, what they are doing, and what they are going to do next [9].

The sense of presence of the participants is the most traditional type of awareness information provided by the CES. This information leads to the current state of the participants and their activities, since the knowledge of who is active facilitates the identification of who is working, where the work is being made and if it is being made simultaneously or concurrently. Because of what can be inferred by the sense of presence it is closely related to the workspace awareness regarding the knowledge of who and where the participants are interacting with the group, and it is an essential type of information that can be used during group work.

The information about the sense of presence and workspace awareness is provided by awareness devices that show details about the individual actions of the participants. The devices offer the opportunity to understand the meaning of the actions and can be used to coordinate activities and enhance the communication. In CES, the visual awareness devices that provide information about the sense of presence and workspace awareness are called awareness widgets and are designed as elements of the user interface.

Fig. 1 shows six awareness widgets. They are: (i) Telecarets; (ii) Telepointers; (iii) Multi-user scrollbars; (iv) RadarView; (v) Read and Write Shadows and (vi) FishEyeView. Although the widgets presented in Fig. 1 does not form a complete list of awareness devices used in CES, they are traditionally mentioned in the literature of the CSCW area.

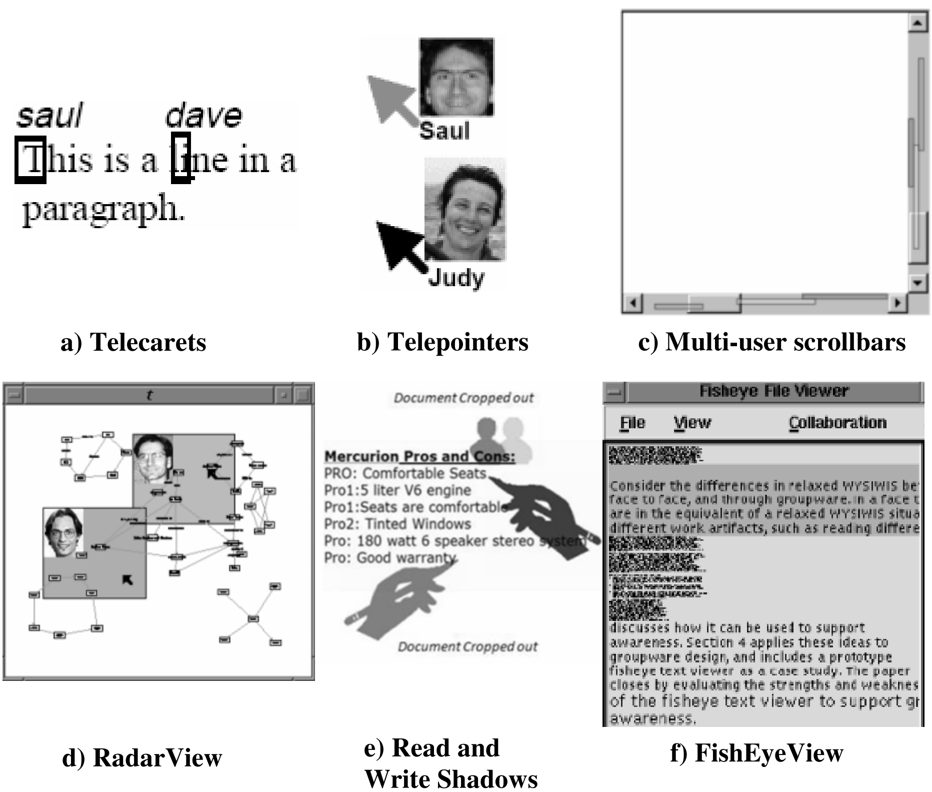


Fig. 1. Awareness widgets: a) Telecarets [6], b) Telepointers [5], c) Multi-user scrollbars [10], d) RadarView [7], e) Read and Write Shadows [15] and f) FishEyeView [4]

Telecaret [6] is an awareness widget that shows the area around the caret used in collaborative text editing. Every time a user edits the text, select a character or navigates among the words the caret's position is automatically replicated to the other participants of the collaborative session by means of a visual cue called Telecaret. With this widget the participants can see the exact position of the user's caret showing to them where in the text the user is working at the moment.

Using the same concept of Telecaret, Telepointer provides the remote position of the cursor used to represent the movements of the user's mouse pointer in the shared workspace. Telepointer can also show semantic information that identifies the current action being executed [5] by changing the form, the color or the image used in the cursor.

Multi-user scrollbars are awareness widgets created from the traditional horizontal and vertical scrollbars used in graphical user interfaces that are based on the windows metaphor. Those widgets show the visible part of the shared workspace that can be seen by each user through the visualization of individual view-ports in small colored rectangles added to the scrolling area of the widget. Multi-user scrollbars are included in the MAUI (Multi-User Awareness User Interface) [10] toolkit, which is a set of individual components designed to provide awareness information in CES. The toolkit has many components, however only the Multi-user scrollbars provide information about the sense of presence and workspace awareness at the same time.

RadarView [7] is a widget that displays a miniature view of the shared workspace. This widget presents the location of each user's view-port superimposed in the miniature allowing the group to see which part of the workspace is visible to each user. Every modification made to the objects contained in the shared workspace is immediately visible using RadarView, which also shows the position of the user's Telepointers. It is also possible to use RadarView to navigate through the shared workspace by changing the position of the user's view-port.

Read and Write Shadows [15] are widgets that provide read and write awareness during collaborative text editing, respectively. The write shadow widget indicates the exact place where the user is editing the text and is represented by the icon of a right hand placed near the last changed character. The right hand icon is filled with a color that identifies the user and is presented as a left hand icon in the shared workspace of the other users. The read shadow widget indicates the part of the text that the user is reading and is pictured by the icon of the user's silhouette filled with the user's color positioned in the part of the text that is visible to the user, i.e. the paragraph that is visible on the screen.

FishEyeView [4] is an awareness widget that changes the visualization of the shared workspace modifying the size of the objects contained in the document, such as words in a text or drawing elements in a diagram. When a user is located in a specific place of the document, named focal point, every object near this point has its sizes increased while other objects that are far from the focal point have their sizes reduced. With this visualization the users see the shared workspace distorted, since the objects near the focal point become bigger and the objects far from the focal point become smaller.

RadarView and FishEyeView are not the only widgets that provide the sense of presence and workspace awareness by a modified visualization of the shared workspace. Gutwin and Greenberg [8] present the dragmag view, a virtual magnifying glass that increases the size of all objects placed on a chosen point. The two-level view, also presented by Gutwin and Greenberg, superimposes RadarView allowing the user to see an overview of the workspace, with the details view of the magnifying class, allowing the user to see the details of objects. This visualization combines two layers of information in the same window.

The information about the sense of presence and workspace awareness is not provided only by visual awareness widgets. Gaver [3] proposed the use of different audio cues to represent the actions and types of activities done by the users in the objects of the shared workspace. Another example of audio used in CES to provide awareness is found on the project Kansas [16] in which activity sounds were used to indicate the distance and location of user's actions by changing volume and direction.

All the awareness devices discussed so far allow the users of a CES to obtain information about the sense of presence and workspace awareness aiming at reproducing the real world interaction found in physical meeting. Whereas they provide valuable awareness information, they are not able to inform the exact place where the participants' focus of attention is during group work. This focus of attention is part of the concept of gaze awareness [9], which is defined as the specific place of the shared workspace where the users are looking at.

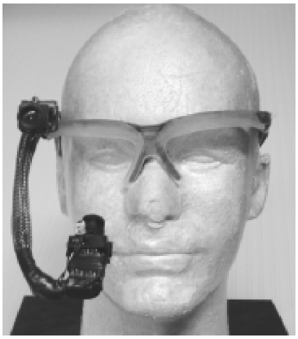
The connection between the focus of attention and the place where a person is looking at is presented by Yarbus [19]. By conducting psychological experiments and studying its results, Yarbus provided evidence that the user's point of regard, which can be calculated by the projected trajectory of the gaze direction, is one indicator of his focus of attention. Based on this assumption, the gaze direction can be used to indicate the exact place containing the user's current focus of attention.

However, the CSCW literature contains few studies about the focus of attention based on the direction of gaze, probably because of the needed requirements to set up an eye tracking mechanism that detects the eye position. One of these studies is presented by Vertegaal and Ding [18], in which the authors discuss how to simulate the eye contact found in physical meetings. This study evaluates a system composed of an eye tracker and a video conference to support the collaboration during specific tasks. The authors concluded that the eye contact simulated by the system increased in 46% the performance of the tasks completed. Nevertheless, in that study the authors did not investigate the direct focus of attention of the users in order to provide awareness information.

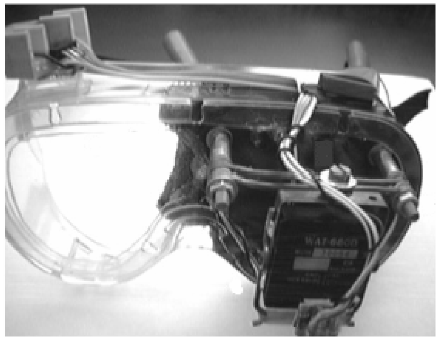
3 Eye Tracking Mechanisms

The developments of mechanisms that track the eye position and detect the gaze direction have been evolving from many years. One of the main motivations to develop this technology is the possibility to improve the interaction capability of people with physical disabilities, allowing individuals that can only move the eye use the computer and have better communication with other people.

There are mechanisms that allow the human interaction with computers based on the detection of face and eye movements and using techniques provided by photo-and video-oculography, which allows the detection of the user's iris from images and real-time video. Fig. 2 presents four examples of eye trackers that represent the state of the art to detect gaze direction.



a) Portable eye tracker



b) MCMO prototype

c) REGT prototype

d) Tobii eye tracker

Fig. 2. Examples of eye tracking mechanisms: a) Portable eye tracker [11], b) MCMO prototype [2], c) REGT prototype [1] and d) Tobii Eye tracker [17]

The eye tracker proposed by Li et al. [11] is a portable mechanism based on open software and hardware that can be built from low cost components. It is composed of two cameras embedded in a pair of glasses and connected to a laptop inside a backpack. This mechanism has the estimation error for the point of regard of one degree of visual angle.

In order to facilitate the interface with the computer for people with motion disabilities that cannot speak and can only move the eyes, Foggiatto [2] proposes the MCMO (Mouse Controlled by Eye Movement) prototype, which is composed of an infrared camera inserted in the place of the left eye lens of a pair of glasses. The author did not provide data about the degree of visual angle error of this mechanism, however empirical experiments presented by the author suggest that the users adapted very fast to the mechanism and were able to properly communicate and to use a computer when using the mechanism.

Coutinho and Morimoto [1] propose a REGT (Remote Eye Gaze Tracking) prototype, which is an eye tracking mechanism that allows head movement without losing track of the eye's position. The mechanism uses a camera that is placed in front of the user with a set of infrared light in its optical axis. This mechanism has also motion engine that move the camera according to the position of the user's head, which is tracked by a classifier algorithm. To use the mechanism it is required to attach four infrared lights in the four frontal corners of the monitor in order to create a polygon that illuminates the user's iris. According to the authors, the average gaze estimation error of the mechanism is between 0.91 and 2.4 degrees of visual angle.

Tobii eye tracker [17] is a commercial product that detects the gaze direction as a complete solution. The mechanism has the format of a 17 inch CRT monitor and contains an infrared camera bellow the front screen. Among other features, Tobii eye tracker allows the user to wear glasses and contact lenses, supports head movements in a 30x15x20 cm space, transmits in real time the position of the eye's coordinates on screen via a TCP/IP connection and has the estimation error of less than one degree of visual angle.

The recent decrease of costs in devices that capture video, such as webcams, and the advances of the Computer Vision area motivated the development of unexpensives eye trackers. However, the current approaches based on webcams still lack precision and require many enhancements before they can be used in real eye tracking applications. We hope that in a near future the mechanisms reach a state where they are economically viable and technologically acceptable.

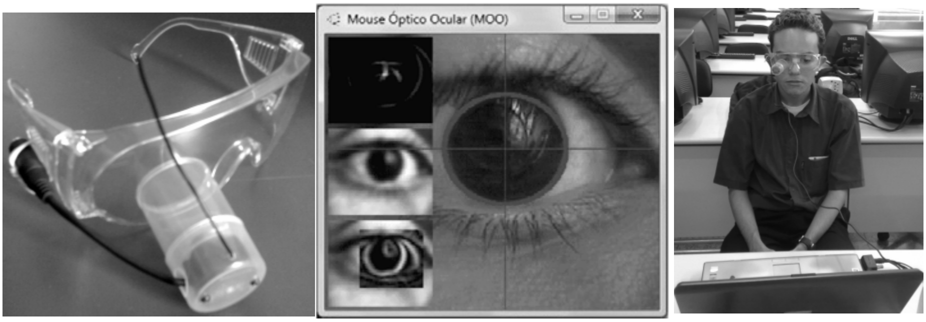
4 An Awareness Widget for Providing the Focus of Attention Using the User's Point of Regard

The eye trackers presented have the goal to find the user's point of regard or the estimation of his visual line of view using eye tracking techniques. With this information, the mechanisms map the approximate position of the eye to coordinates of the screen after a calibration phase. Most of the mechanisms require that the user keeps looking at fixed points in the screen for a short period of time. Once the calibration phase is completed, the mechanism is ready to provide the coordinates of the screen where the user is looking at in real time.

Having the coordinates of the point on the screen that the user is looing at, it is possible to display an icon to provide a visual feedback to the user in order to facilitate the navigation on the screen. However, for the proposed awareness widget the coordinates of the screen that show where the user is looking at must be presented only to the others participants of the collaborative session and not to the user that is generating the coordinates. This setting will provide the sense of presence and workspace awareness to the remote participants that are using the CES.

After the evaluation of the existing eye trackers we decide to develop an awareness widget that does not depend on any specific eye tracker. The proposed awareness widget is called TeleEye and is based on the existing Telepointer and Telecaret implementations that provide awareness information of the mouse pointer and the text caret positions, respectively.

A prototype of TeleEye was implemented in an existing CES in order to evaluate the feasibility of this awareness widget. The CES chosen was CoArgoUML [12], a CASE (Computer Aided Software Design) tool modified to support the synchronous collaborative modeling of UML (Unified Modeling Language) diagrams. Aiming to test TeleEye, a home made eye tracking mechanism was assembled using a video



a) MOO hardware **b) Iris detection application** **c) Wearing MOO**

Fig. 3. Eye tracking mechanism used to test TeleEye: a) The MOO hardware, b) Screenshot of the iris detection application and c) An user testing the MOO

capture device that was mounted in front of the right eyeglass lens of a pair of plastic safety glasses. This prototype is called MOO (Ocular Optical Mouse) and uses an algorithm that detects circles based on the Hough Transformation. However, the MOO is not able to compensate user's head movements because it is fixed on the face and does not have the ability to detect background movements. The MOO hardware, the application that detects the user's iris and a user wearing MOO is shown in Fig. 3.

Although the eye tracking mechanism built does not provide precise estimation of the gaze direction, it was a suitable alternative to test TeleEye's prototype. Fig. 4 presents Telepointers and TeleEyes for two modelers, A and B, in their shared workspace during collaborative modeling of a Class diagram.

Fig. 4 shows an example in which TeleEye can be used with Telepointer. In the upper shared workspace of Fig. 4 the modeler A sees the Telepointer icon of the modeler B as a black cross placed on the left side, near the Binding class. The TeleEye icon of the modeler B, depicted as a circumference with the name of the modeler on the upper left side, is placed between the relationships connecting the abstract class *ModelElement* and the class Dependency.

Modeler B, whose shared workspace can be seen in the lower part of Fig. 4, sees a dark gray cross that represents the Telepointer icon of modeler A placed on the lower right side near the Abstraction class. Modeler B also sees the TeleEye icon of the modeler A depicted as a dark gray circumference placed on the center, near the Binding class.

In the scenario presented in Fig. 4 it is reasonable to assume that alhtough the mouse pointer of the modeler A is placed on the lower right side near the Abstraction class, the focus of his attention probably is in the Binding class, since he is looking at that class. The base for this assumption is the fact that TeleEye identifies the focus of attention of the modeler whereas Telepointer indicates the likely place of the next or previous mouse position. Likewise, the focus of attention of modeler B probably is in the relationships between the abstract class *ModelElement* and the class Dependency, because his TeleEye icon is near those relationships, and he is not focusing his attention in the empty space bellow the *ModelElement* class where his mouse pointer is placed.

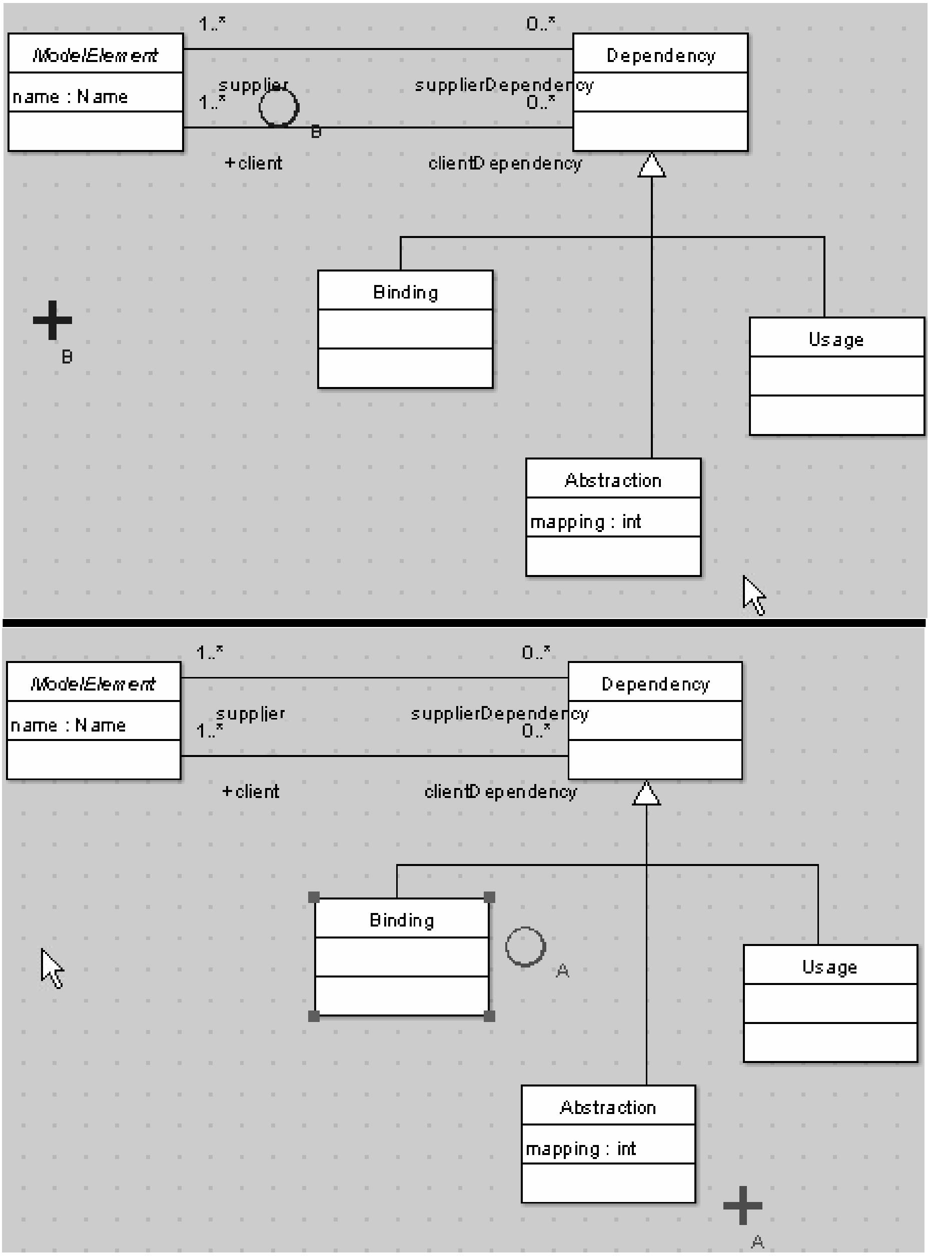


Fig. 4. Shared workspaces, Telepointers and TeleEyes of two modelers, A and B, on a collaborative modeling session of a Class diagram in CoArgoUML. The upper workspace is the user A screen and the lower workspace is the user B screen.

Another example in which TeleEye can be used is during the explanation of details in a collaborative session. While one participant explains the details of a specific part of a shared document he can be aware of where is the visual focus of the other participants through the TeleEye icons. He can check if they are paying attention in the visual details being explained or not. With this information the participant that is explaining the details can take an action to have the attention of the group. In this scenario TeleEye provide an important information for the group coordination.

TeleEye can also be combined with other awareness widgets to enhance the sense of presence and workspace awareness. For instance, TeleEye can replace Telepointer when a participant stops moving his mouse for a specific period of time. Another possible combination of awareness widget is to insert the TeleEye icon inside the miniaturized view of RadarView, providing information about the focus of attention in any place of the shared workspace.

5 Comparison of Awareness Widgets

This section presents a comparison of the awareness widgets discussed in Section 2 and TeleEye based on the affordance of the sense of presence and workspace awareness. We claim that a comparative analysis of the objective features can provide a base for the evaluation of TeleEye as a visual awareness widget.

The comparison between the visual awareness widgets and TeleEye is based on the three awareness principles proposed by Sasa et al. [15], which are: (i) The first principle, labeled *No Explicit Actions*, states that the awareness widget must automatically gather information about the user; in particular, the user must not be required to perform explicit actions to provide awareness to the observer; (ii) The second principle, labeled as *Least Effort*, states that the awareness widget must minimize interpretation difficulties compared to other competitive tools; in particular, the observer must be able to obtain awareness of the user with the least effort; (iii) The third principle, labeled as *No Additional Space*, states that the awareness widget should be in-place; that is, it should not occupy additional screen space. The adherence to these three principles is the first three criteria used in the comparison of the visual awareness widgets.

A fourth criterion, we call *Attention Focus*, is used in order to compare how the widgets provides the sense of presence and workspace awareness through the indication of the focus of attention. Only the widget that shows where the user's focus of attention inside the shared workspace is compliant with this criterion. Table 1 shows the comparison of the awareness widgets and TeleEye based on the four criteria. The comparative values for all the widget with the exception of TeleEye were obtained by Sasa et al. [15], which compares the existing widgets with the Read and Write Shadows according to the three awareness principles.

The comparison presented in Table 1 shows that TeleEye is the only widget that complies with the four criteria used in the comparison. However, it is important to stress that all the awareness widgets provide information about the current user action or the view-port in shared workspace that the participant is working on, but only TeleEye can identify the exact place of the participant's focus of attention.

Table 1. Comparison of the visual awareness widgets

Widget	No Explicit Actions	Least Effort	No Additional Space	Attention Focus
Telecarets		✓	✓	
Telepointers		✓	✓	
Multi-user Scrollbars		✓		
RadarView	✓	✓		
FishEyeView, Dragmag View and Two-level View	✓		✓	
Read and Write Shadows	✓	✓	✓	
TeleEye	✓	✓	✓	✓

The criterion *No Explicit Actions* indicates that Telecarets, Telepointers and Multi-user Scrollbars widgets requires explicit actions from the user to provide awareness. The actions are the pressing of the keyboard's keys that change the text caret's position, the mouse movements that change the mouse pointer and the scrolling actions that change the coordinates of the user's view-port, respectively. The eye movement is not classified as an explicit action since the user must naturally move his eyes while working with the computer.

The *Least Effort* criterion indicates that the widgets FishEyeView, Dragmag view and Two-level view require a considerable amount of effort to obtain awareness of the users. The reason for such effort is due to the fact that the understanding and comprehension of the information from a distorted shared workspace require more cognitive effort than the effort required in normal shared workspace, assuming that the users are not accustomed to work in a distorted workspace.

The criterion *No Additional Space* classified the widgets Multi-user Scrollbars and RadarView as widgets that occupy additional screen space. As presented in Section 2, RadarView requires a window to display the miniaturized view of the shared workspace. Multi-user scrollbars demands the space occupied by the scrolling area and elevator components of this widget.

6 Conclusions, Comments and Future Work

In this paper, we propose a visual awareness widget named TeleEye that provides information about the sense of presence and workspace awareness. The goal of TeleEye is to show the location of the participant's attention during a collaborative session by means of eye tracking. Using an eye tracker it is possible to find a reasonable accurate region on the screen that the user is looking at, which is calculated by the projected trajectory of the gaze direction.

The awareness devices used to obtain information about the sense of presence and workspace awareness in CES were presented, followed by a brief description of their use in order to contextualize TeleEye. In order to better understand how to capture the focus of attention, the paper discusses the technology and the characteristics of some eye-trackers available to detect the gaze direction.

We also compare TeleEye with other visual awareness widgets. The comparison indicates that TeleEye is the only awareness widget that does not require (i) explicit actions to provide awareness, (ii) extra effort to be used, and (iii) additional screen space. Besides it can also identify the location of the participant's focus of attention. However, one important limitation is that TeleEye can only be used with an eye tracking mechanism that detects the gaze direction.

Future work includes the evaluation of TeleEye with users in a collaborative application in order to assess the effectiveness of visual awareness widget. The study could also include comparison of usage of widgets discussed in this paper. The user study can also provide valuable information on how the participants communicate and coordinate their activities when they know where is the focus of attention of each participant of the group.

We believe that a significant contribution of TeleEye is its integration with the HCI (Human Computer Interface) area, which opens new opportunities to use non standard input devices to provide awareness information during collaborative work. More specifically, TeleEye provides a new environment to test and evaluate how eye tracking mechanisms can be used when more than one individual obtain information provided by the widget, i.e. see the patterns of the user's eyes movements, find the locations that capture the visual attention and even discover if the user is looking at the CES or not, which may indicate that the collaborative work might be doing concurrently with another task.

The awareness widget presented in this paper provides a novel approach to obtain additional awareness, the focus of attention, in collaborative sessions. With the new awareness information provided it is possible to enhance the coordination and communication of actions between the participants of collaborative sessions, giving them awareness information similar to the ones found in physical meetings.

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