Gaze-based awareness in complex healthcare environments

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ABSTRACT
Medical staff work in collaborative environments and require information regarding workmates, patients and resources as well as data related to the completion of ongoing tasks. Healthcare systems provide a large quantity of information and current applications usually involve the simultaneous use of many different devices. A system might monitor several patients, provide alerts and warnings as well as information on pending tasks, and many other demanding workloads. It is therefore an open question whether a professional is able to attend a rehabilitation process involving technology and still be able to remain aware of all notifications provided by different devices. In this paper, gaze-based awareness is presented as a natural evolution, through current technology, of the common awareness concept. The key concept consists of considering users' gaze as fundamental to personalizing the way to subtle notify users about changes on unattended screens. To this end, different levels of subtlety of notification are considered based on where the user is looking together and the user's work conditions. We present a realization of gaze-based awareness using a real healthcare system named Ubi4health in which this awareness has been considered an essential element during development.

Categories and Subject Descriptors
H.5 [**Information Interfaces and Presentation**]

General Terms
Design, Human Factors.

Keywords
Awareness, Healthcare, Context-awareness, Collaboration, Gaze-based.

1. INTRODUCTION

Endsley [1] defined awareness as "knowing what is going on", in other words, it is the user's perception of their colleagues' activities and the state of resources. Such information is essential to complete any collaborative task require knowledge about the colleagues' situations, resource location, task evolution, etc. Consequently, awareness is an essential factor to be considered in healthcare systems due to the collaborative level of most medical staff tasks. They need to be aware of the state of the work environment to a greater or lesser extent based on their role.

Healthcare environments involve complex situations for medical staff. Specifically, the need to control a large amount of data related to current and future tasks requires being aware of changes and new circumstances. In addition, conditions worsen if the employee has more than one device in their working environment (e.g. the interface of the application used is distributed across three monitors, see Figure 1).

The circumstances described present healthcare centers as interesting environments in which to consider and apply the concept of awareness as an essential element in deployed systems. Given the necessity of notifying changes and updates of information of interest, users' gaze is an essential factor. This element offers a useful source to know where a user is looking. Then, a system can identify the information the user has seen or not seen, which means the system has the capacity to notify the user of new information when applicable. This gives rise to a remarkable type of awareness, which is referred to as *gaze-based* [2] *awareness*. Basically, this awareness can be considered as the information needed by users to complete their tasks in a computer system and provided in a personalized way. Depending on what the user has visually perceived, the system can attract the user's attention with additional notification methods.

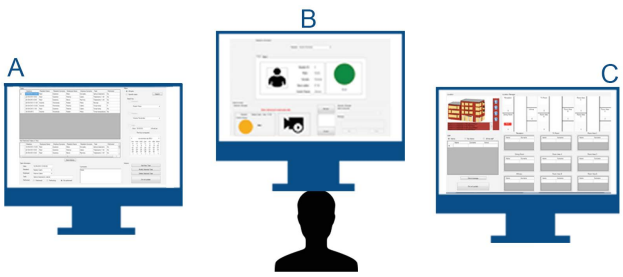

Figure 1. Working environment with three screens through Ubi4health desktop application

Ubi4health [3] is an integrated solution deployed in healthcare centers. The system provides a range of features from task management to a context-aware [4] system of alert notification, including a complete rehabilitation assistant. The system presents a complex scenario that requires medical staff to control people attending machines and performing auxiliary tasks. The system uploads any data related to the evolution of the process related to patients. This stored information is analyzed in order to show notifications, alerts, etc., to the employees through a multi-display

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system. To this end, Ubi4health has been developed taking into account gaze-based awareness.

This paper provides a brief description of how gaze-based awareness is provided and also the proposed methods whereby the related information can be shown. In order to show a concrete scenario, Ubi4health illustrates how to consider the presented awareness in a real healthcare scenario.

2. AWARENESS CONCEPT AND GAZE-BASED DEVICES

Awareness has been studied in different environments whose common element is collaboration. In this way, awareness has been analyzed as a concept in the existence of collaborative systems. In 2002, Gutwin and Greenberg [5] made one of the first major analyses of awareness. Their study considers users working collaboratively through real-time distributed groupware systems [6] (to allow people to work or play together at the same time but from different places). This work defined workspace awareness as "*the up-to-the-moment understanding of another person's interaction with a shared workspace*". The main contribution is to show how this awareness is useful for users in collaborative activities: to coordinate action, manage coupling, talk about the task, to anticipate others' actions, and find opportunities to help one another.

Other work focuses on the analysis of awareness in specific but everyday collaborative environments. Greenberg and et al. [7] described the key role that awareness plays in the home. People living together also form a collaborative environment. In this case, interpersonal awareness is defined [8] as "*the awareness information and mechanisms necessary to satisfy people's real need and desire to know about each other*".

Regarding healthcare, awareness has been studied in specific environments where specific collaboration is needed. An example is shown in the analysis made in residential care homes [9]. In these environments each employee may be aware of specific information in relation to the tasks he has to perform: information about colleagues' tasks, information about residents and the state of the resources to be used. As a result, a new type of awareness is described, RCH awareness which is defined as "*the information about colleagues and resources needed by RCH employees to perform their tasks*".

Current technology allows us to take a step forward in the information given to users in collaborative environments. The awareness needed by users can be provided and notified based on their gaze. The users can obtain information about the environment, colleagues and resources in a personalized way. Previous awareness studies have focused on the information needed in several environments but they did not consider user gaze as a good opportunity to personalize that information.

The authors use Diff Displays technology [2], which is a technology designed to manage people's inattention in multi-display environments. Diff Displays uses computer vision to detect whether a user is looking at a display or not. Unattended displays are dimmed and intelligently visualize changes in display content in a subtle and nonintrusive manner. The gaze-based awareness concept presented in this paper, is explained through this technology and a complex healthcare system, Ubi4Health, in which it is developed.

3. GAZE-BASED AWARENESS IN HEALTHCARE

The working environment atmosphere and setup for medical staff are complex factors in task performance. Much information needs to be controlled and analyzed or many changes have to be identified to react accordingly. In addition, current technology provides users with applications in which the interface requires the use of two or more devices at the same time. These conditions require a high degree of concentration in users to be aware of all the relevant information. Therefore, gaze-based awareness is an essential element when developing healthcare systems as in Ubi4Health.

Ubi4Health is a solution to monitor all the information needed by medical staff during their work. Awareness has been a key element in its development. As a result, the information needed is shown in different ways based on where the user is looking, what they are doing and the urgency of notifying their own information.

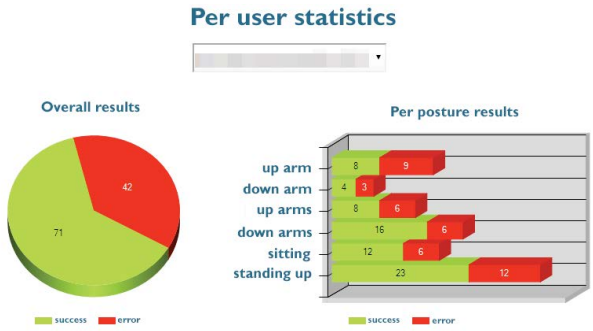

Figure 2. Information about patients in Ubi4health

The information provided to generate gaze-based awareness or any other type of awareness in a healthcare environment focuses on the four main axes. Each of them represents the related needs of medical staff provided by the different components of Ubi4health:

- *Users*: information about who is using the system. It shows workers, patients, residents and external people (e.g. residents' family). This information is useful to show who can help with each user's task at a specific moment or pending tasks.
- *Tasks*: information about colleagues' tasks concerning each user task and also, related patients. The relationship between such tasks can be of dependence or help. The dependence relation indicates that one task requires the results of another task or the resources used. The help relation indicates that other tasks are similar and then can be used to solve doubts or problems. In addition, each user should obtain information about their tasks and patients. For example, Figure 2 shows how Ubi4health offers information about the evolution of patient to users who are rehabilitators.
- *Location*: information about colleagues, patients, residents and resources location. This information is essential in order to establish users' needs in the surrounding environment. Figure 3 shows how Ubi4health offers information on employees' location.

- *Resources*: information about resources, that is, the situation of resources. Current state indicates if the resources are available, being used, who used them and their location.

The user's gaze allows us to go a step further by taking into account what information should be considered for any awareness in healthcare. Specifically, gaze gives powerful feedback to be able to personalize awareness based on what the user has visually perceived. The information can be shown and notified in a specific way if the user has not visualized it. For example in a setup like Figure 1, when an update happens in the center screen while the user is looking at the left screen, the related information will be marked in order to be underlined when the user returns to the center screen. In essence, this information notified to healthcare users in different ways based on their gaze, constitutes a particular and useful awareness: *gaze-based awareness.*

Any system considering gaze-based awareness needs to track the eyes of the users in order to react accordingly. The way to work with the gaze is not an obstacle due to current technology as a number of research works demonstrate [10]. In Ubi4health, Diff Displays [2] has been the way to track where the user is looking. Diff Displays is a system that is able to track the display the user is looking at by using a web camera in a multi-display environment. Specifically, the detection procedure is based on a server offered by Diff Displays to which Ubi4health is connected. The server is constantly sending information that indicates whether the user is looking at a specific display. The information supplied by the server is configured so as to know, second by second, if the user is looking at a particular screen. Obviously in the case of having more than one screen, the server must be run for each one. When configured, the server constantly sends information related to the user's gaze so that it can be read by the application requiring it.

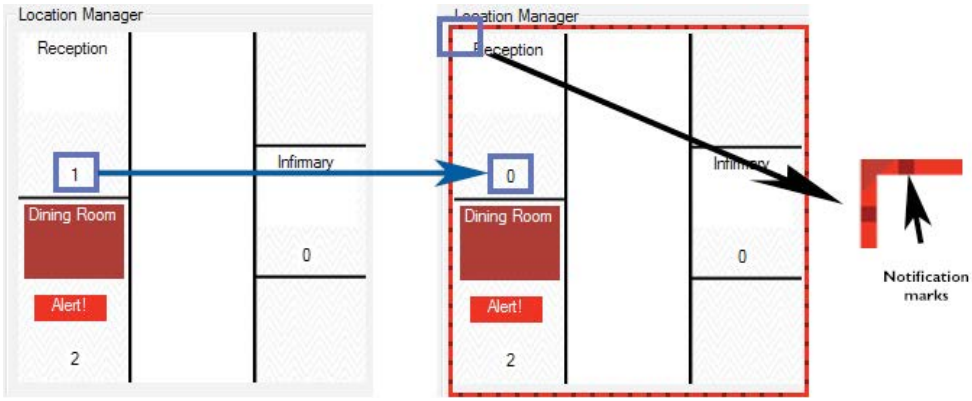

Figure 3. Notification about changes in employees' location in Ubi4health

3.1 Subtlety Requirements

The analysis of this awareness generates a set of implications related to the level of interruption when notifying changes. Healthcare environments involve tasks in which the level of concentration ranges from high (the user can be interrupted) to light (totally interruptible). However, in other circumstances the concentration level is less important than the urgency of the information to be notified, such as an alert related to attending immediately to a patient. These conditions involve the need to consider different levels of subtlety when showing changes, that is, the information the users have not perceived on a non-visualized screen.

The way the changes are shown to the user will depend on the environment created by the developer for healthcare applications. Each environment will offer certain conditions and requirements which involve an adjustment of the level of subtlety of the information the user receives regarding changes. Consequently, a set of modes has been defined to specify the level of subtlety of information regarding a change:

- *Disruptive*: the user is alerted and current activity is disrupted.
- *Intrusive*: the user is alerted and we can expect their gaze to be directed at the location of the change but they can freely continue their current activity.
- *Subtle*: the user is alerted, attention is attracted but their gaze is directed at the location of the change.
- *Unnoticeable*: the user is alerted so subtly that if they are not paying full attention they may not notice the change signal.

Ubi4health considers the disruptive, subtle and unnoticeable levels when notifying awareness to the user. The first one is essential to alert employees when an emergency arises and the user's conditions are adequate. To this end, Ubi4health shows the notification in the alerts screen. If the user does not look at that screen during ten seconds, the system moves the content of the alerts screen to the one the user is looking at. Therefore, the user is totally interrupted when required by the circumstances. The subtle level is used when a change appears on the screen the user is not looking at and is of considerable importance. For example, Figure 3 shows the way to notify new employees located on a floor. This can be useful in order to reorganize tasks to be performed in that location. Finally, the unnoticeable level corresponds to general updates through Ubi4health system.

4. CONCLUSIONS

Medical staff has to manage a large amount of data and related tasks. Healthcare systems may provide users with information about the current state of the environment in order to facilite their work. This information is named awareness. It includes the

current situation of colleagues, the location of resources needed, patient progress, etc.

Current technology generates complex applications in which users have to manage all the information provided in several devices. This situation situation complicates the way the user can undestand and be aware of all the important information, alerts, notifications, etc. In this way, classic gaze-awareness needs to evolve in order to improve how the user is aware of the given information provided.

The analysis of user gaze allows us to know where they are looking and consequently, what information has not been visually perceived. Accordingly, this paper describes gaze-based awareness as a natural evolution of the common awareness concept. The explanation focuses on Ubi4Health, a complex healthcare system, in which the concept has been essential during development.

The main feature and contribution of gaze-based awareness is the way users are notified of the appearance of new information they have missed. Specifically, Ubi4Health uses diffDisplays technology to detect where the users are looking by analyzing their gaze. In addition, taking into account the existence of different user work conditions and concentration needs, the present awareness system involves four levels of notification: disruptive, intrusive, subtle and unnoticiable.

5. ACKNOWLEDGMENTS

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