Attentive Office Cubicles: Mediating Visual and Auditory Interactions Between Office Co-Workers

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ABSTRACT
We designed an office cubicle that automatically mediates communications between co-workers by sensing whether users are candidate members of the same social group. The cubicle regulates visual interactions through the use of privacy glass, which can be rendered opaque or transparent upon detection of joint orientation. It regulates auditory interactions through noise-canceling headphones that automatically turn off upon co-orientation.

Author Keywords
Social Geometry, Group Interaction, Attentive Interfaces.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces: Input devices and strategies.

1. INTRODUCTION
Sensing the availability of users for interruption is an increasingly important topic of Human-Computer Interaction. Knowledge about a user's interruptability has been applied in a wide range of applications, from regulating mixed-initiative dialogue in speech interaction [5] to determining the cost of notifications by messaging devices [4]. Knowledge about participation in group activities provides an important contextual indicator for a person's interruptability. This is because users engaged in group interactions, such as when speaking to an audience, are less likely to be available for outside communications. Conversely, social orientation of users is also useful for determining when users *are* interested in communications. According to Frolich [3], during face-to-face interactions, users are likely to orient themselves towards each other before initiating a conversation. Indeed, the conveyance of information about the co-orientation of participants has been shown to be beneficial to the regulation of turn taking during teleconferencing and computer supported cooperative work [11]. There is a significant body of research on determining joint attention between users by measuring speech activity and eye gaze patterns [10]. In this paper, we show how the use of simple measures of geometric data provided by body orientation and grouping of participants [8] can be used to deduce focus of attention in office environments.

We designed an office cubicle that automatically mediates both visual and auditory interactions between office workers by sensing whether they are candidate members of the same social group. The cubicle regulates visual interactions through the use of privacy glass, which can be rendered opaque or transparent upon detection of joint orientation. It regulates auditory interactions through the use of noise-canceling headsets programmed to become transparent to ambient sound upon co-orientation.

2. BACKGROUND
The interruptive behaviour of technologies used in office environments has become an important topic of study. The Attentive User Interface (AUI) paradigm [6] tries to address the problem of managing user attention by measuring and reasoning about the attention of the user for devices and tasks. The Attentive cellphone [10] is an example of a mobile AUI that used eye tracking and speech activity measures to determine when a user is engaged in a conversation. To preempt interruption, the phone communicates user engagement estimates to people in its contact list. AUIs have also been deployed in optimizing teleconference meetings. E.g., the GAZE-2 video conferencing system measures where participants look in order to communicate who is talking to whom during remote meetings [6]. There are, however, few examples of applications of systems that measure participant attention in order to manage co-located meetings. Stiefelhagen [8] developed a system that tracked head orientation of participants using computer vision and a neural network. Studies show that head orientation can be used as a good indicator of gaze direction, with an error of less than 15 degrees [8].

3. THE ATTENTIVE OFFICE CUBICLE
Problems of managing attention between co-workers are particularly acute in cubicle farms, where many users share the same workspace. In order to avoid distraction, cubicle workers may opt to wear noise-canceling headsets. Such headsets cancel out auditory distractions from co-workers and allow workers to focus better on their tasks. However, the use of noise-canceling headsets places serious constraints on office collaborations by reducing co-worker awareness of the environment. Our attentive cubicle system addresses this problem by automatically mediating auditory and visual communications between co-workers on the basis of information about their social-geometrical relationships.

3.1 Tracking Social Geometry
Our system deploys a vision-based motion tracker to determine head orientation and co-orientation of individuals: their Social Geometry (see [2] for more details). We used fiducial markers placed on the each participant's head to ease motion capture and recognition. In our setup, a camera is located in the ceiling of the

Figure 1. Attentive Cubicle in opaque mode.

Figure 2. Attentive Cubicle in transparent mode.

room, serving as a stationary sensor monitoring the moving subjects. To find the fiducial markers in the image, we adapted the ARToolKit [1]. The ARToolKit is a software library for augmented reality applications that can be used to calculate camera position and orientation relative to fiducial markers in real time. We adapted the ARToolKit to allow tracking of multiple moving targets from a stationary camera. Our system uses fiducial markers that can be distinctively recognized by the framework, and that are tilt independent and asymmetric. The use of unique identifiers allowed support for identification of individuals. It also allows robustness to movements in and out of the camera's field of view. Movements are tracked parallel to the camera plane with a resolution of 320 x 240 pixels. Our sample rate is in the order of 4-5 frames per second for up to eight tracked individuals.

3.2 Hardware

Our prototype cubicle's walls were constructed using a special translucent material called Privacy Glass™ [9]. Privacy glass consists of a glass pane with an embedded layer of liquid crystals. When powered off, the crystals are aligned randomly, making the glass appear frosted and opaque (see Figure 1). When a voltage is applied, the liquid crystals in the glass align, allowing light to go through the pane, thus rendering the glass transparent (see Figure 2). When the privacy glass is opaque, cubicle workers cannot be seen by others, and are not distracted by visual stimuli from outside their cubicle. When the privacy glass is transparent, a cubicle worker can interact visually with workers on the other side of his cubicle wall. We augmented the privacy glass with a contact microphone to allow our system to detect knocks by co-workers on the pane. These knocks inform the system of a request for attention of a person inside an opaque cubicle.

3.3 Attentive Headphones

Each attentive cubicle worker wears a noise-canceling Bose™ headset augmented with a fiducial marker and a microphone (see Figure 2). Headsets are also augmented with a circuit that allows noise-cancellation to be switched on or off, and the signal from the microphone to be presented to the headset speakers. When the headset is turned off, this allows wearers to hear normally. When a headset is turned on, all ambient sound is attenuated by –20 Db, allowing a wearer to work without auditory distractions. Headsets within our office environment are tracked by our computer vision engine through overhead cameras mounted in the ceiling. For each tracked individual, the geometry engine reports information about potential communication partners to that individual's EyeReason server (see [5,6] for more detail), as given by the ID of the fiducial marker. The EyeReason server controls the setting of the headset of the associated individual, as well as the transparency of the privacy walls of a cubicle entered by that individual. The scenario played out in the accompanying video illustrates how the attentive cubicle can aid co-workers in managing distractions in noisy environments. In a typical scenario, a user inside a cubicle is working behind his computer system (see Fig. 1). The computer vision engine detects he is not engaged in a co-located social interaction and attenuates outside noise, rendering the cubicle wall opaque. A co-worker knocks on the glass pane to ask a question. Upon detection of the knock, the cubicle worker's headset is temporarily turned off. When the cubicle worker wishes to be disturbed, he orients himself towards the wall (see Fig. 2). The computer vision system detects the co-orientation of co-workers on either side of the wall and renders the wall transparent, allowing normal visual and auditory communications between the two co-workers.

4. CONCLUSIONS

We presented an office cubicle that automatically mediates communications between co-workers by sensing whether they are candidate members of the same social group. The cubicle regulates visual interactions through the use of privacy glass, which can be rendered opaque or transparent upon detection of joint orientation. Auditory interactions are regulated through noise-canceling headphones that automatically become transparent to ambient sound upon co-orientation.

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