Interaction Mediate Agent Based on User Interruptibility Estimation

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Abstract. In recent years, the scope of users receiving information from information systems has been increasing. However, the timing of interruption is not controlled in most of these systems. In this paper, we propose a secretary agent to mediate interactions between users and others. The agent estimates user interruptibility from PC operation records and head motions. Moreover, the agent requests interaction from others by controlling the avatar's gaze, joint attention, and mutual gaze on the basis of the interruptibility. We confirmed the usefulness of the mediation based on the estimation of user interruptibility.

Keywords: interruptibility, estimation, human–agent interaction, application switching.

1 Introduction

In recent years, the scope of users receiving information from information systems has been increasing with the popularization of the Internet and ubiquitous computing environments. Although the frequency of interruptions from systems such as mail alerts, instant messaging tools, and software agents has been increasing, the timing of such interruptions is not controlled in most information systems. Previous studies [1] have indicated that frequent interruption without considering the user's status fragments the user's work time and decreases productivity. Therefore, automatic status estimation and ambient interruption methods are expected to assist in avoiding unintended interruptions.

One potential method for estimating a user's online status is by monitoring PC operations or by using sensors [2-6]. However, these physical activity indices do not capture all instances of the intellectual activities that should not be interrupted, because intellectual activities do not always have observable outputs. Another approach is to estimate the breakpoint of a task [7, 8]. At the breakpoint, the user's interruptibility is expected to increase instantaneously. However, this approach requires task-structure analysis to determine the interruptibility level of the breakpoint.

We considered focused application switching (AS) as a breakpoint in PC work. Our experimental results demonstrated that the interruptions at AS are significantly more acceptable than those during continuous work. Finally, we proposed a user interruptibility estimation method for AS timing [12].

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In this paper, we propose a secretary agent to mediate interactions between the user and other users or systems, in order to start accepting interactions with others, based on the interruptibility estimation method. The agent gently requests interactions from the user by using gazing actions (joint attention and mutual gaze) and leads the user to confirm the request on his/her own. We experimentally confirmed the usefulness of the agent for estimation and mediation between users and others.

2 Related Studies

2.1 Estimation of User Business/Interruptibility

There are several related studies regarding user-status estimation by various techniques; e.g., counting the keystrokes or mouse clicks and using various sensors placed in the work space or on the users [2-6]. These methods are expected to adequately estimate the user's status when the status has observable physical activity indices. However, intellectual activity such as deep thinking has no observable output. Moreover, it is practically difficult to place various sensors on the user or in the work space.

On the other hand, some studies have reported a relationship between interruptibility and breakpoints [7, 8]. At a breakpoint, the user's interruptibility is expected to increase instantaneously even if the work requires intellectual activity. Furthermore, it has been suggested that the kind of the breakpoint affects interruptibility. However, this method requires an analysis of the task structure to determine the level of the breakpoint. Multi-tasking during PC usage is also a potential difficulty in the application of the task-structure based method. Therefore, it is still a challenge to distinguish the level of interruptibility at a breakpoint.

Moreover, the interruptibility expression must be intuitive in order to reduce the user's cognitive load. Some studies have examined ambient awareness using nonverbal information. Movements of the head, face, and body were determined to be effective in expressing nonverbal behavior [9]. The expression of interruptibility using nonverbal information through an avatar appears promising for the intuitive recognition of a user's status.

2.2 Study of Application Switching for User Interruptibility Estimation

We used focused application switching (AS)—transition of the active application window—as a breakpoint in PC work [12]. AS is considered to be the user's intentional switching of the working space or working target. Therefore, the user's concentration at AS is expected to be instantaneously weakened compared to that during continuous work. Moreover, AS commonly and frequently occurs in PC work and is easily detected. Thus, AS offers scope for information presentation with less risk of task disturbance.

To examine this assumption, we experimentally collected and analyzed PC operation records and subjective interruption evaluation logs. Experimental results demonstrate that interruptions at AS are significantly more acceptable for users than those during continuous work ($p < 0.01$, t-test).

Therefore, we analyzed the relationship between interruptibility scores and the indices calculated from the operation records, which were expected to reflect the interruptibility at AS. Finally, we defined the estimation rule on the basis of co-occurring indices at the same AS, and decided to judge the interruptibility using three levels in a way similar to the previous works, for practical utility. Figure 1 shows the experimental results of the interruptibility estimation using our proposed method. The results demonstrate that the proposed estimation method allows information systems to reduce the risk of serious work disturbance due to interruptions.

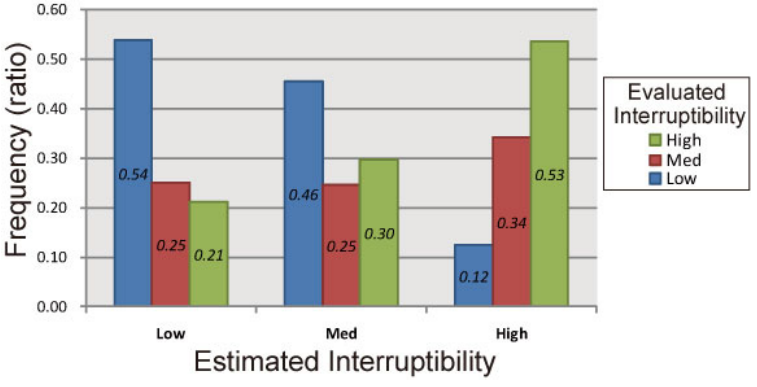

Fig. 1. Results of interruptibility estimation using three levels

3 Secretary Agent

We proposed an interaction initiation method with acceptable timing by using an agent to mediate the interaction based on the user-interruptibility estimation. In this section, we explain the concept of agent mediation and details of agent architecture.

3.1 Concept of Interaction Initiation by Agent's Mediation

The above analysis indicates that interruptions at AS are significantly more acceptable for users than those during continuous work. Based on this analysis, we proposed the interruptibility estimation method. This method provides a controlling interruption timing that is useful to initiate interactions without causing problems of disturbance from online users or other information systems. However, as the estimation has an error, there is a risk of unintentional disturbance. Therefore, we need to consider a method that is robust against estimation errors.

Interruptions by pop-up windows or sounds may seriously disturb the user's work. Therefore, an ambient and natural presentation of the interruption is necessary to enable the busy user to not respond until a break [9-11]. Moreover, it is difficult to predict a highly interruptible time. Therefore, assistance from the information system is needed for smoothly starting the interaction at a high-interruptibility period.

In this research, the secretary agent estimates user interruptibility and receives interaction requests from a user or system in bulk. After receiving the request, the agent

starts to convey it at a high-interruptibility period by using an ambient presentation. The presentation is based on actions in human daily life, "wait and see how the interaction partner works." In particular, the agent gently presents the request to the user by gazing actions and leads the user to start the interaction. Therefore, the agent's mediation causes a shift of positions between the interrupter and the interrupted user.

Figure 2 shows an example of dialog initiation by the secretary agent. The dialog initiation has the following steps:

1. **Request dialog:** If user A wants to start a dialog with user B, A sends a dialog request to B's agent through his/her own agent via the network. Then A awaits a message from B while doing his/her own work.
2. **Start appeal:** The dialog request by A is sent to the secretary agent of B, and the agent starts to present the dialog request unobtrusively by using gaze controls, joint attention, and mutual gaze. The agent continues to appeal to B according to his/her interruptibility.
3. **Notice:** If B notices the appeal and decides to start a dialog with A, B sends an instant message using the system to A. On the other hand, B is allowed to not respond to the request until a break, because A is doing his/her own work and is not able to recognize whether B has not noticed the appeal or is ignoring the request.

3.2 Overview of the Secretary Agent

Figure 3 shows the architecture of the secretary agent. The developed agent consists of two main functional components, the user's interruptibility estimation component and the request appeal component.

The interruptibility estimation component monitors the user's PC operation activity and head position using a web camera and then estimates user interruptibility using three levels based on our proposed method [13]. The estimated interruptibility is used to control the intensity of an appeal using a CG avatar. The request appeal component expresses the existence of an interaction request from others by the joint attention and

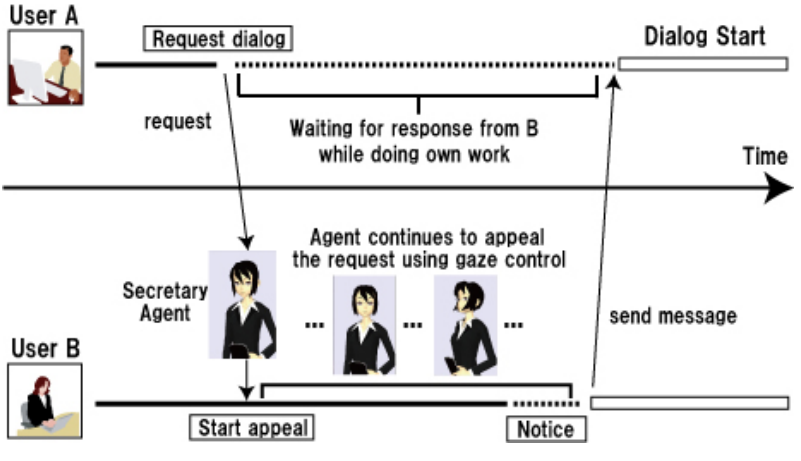

Fig. 2. Example of dialog initiation by the secretary agent's mediation

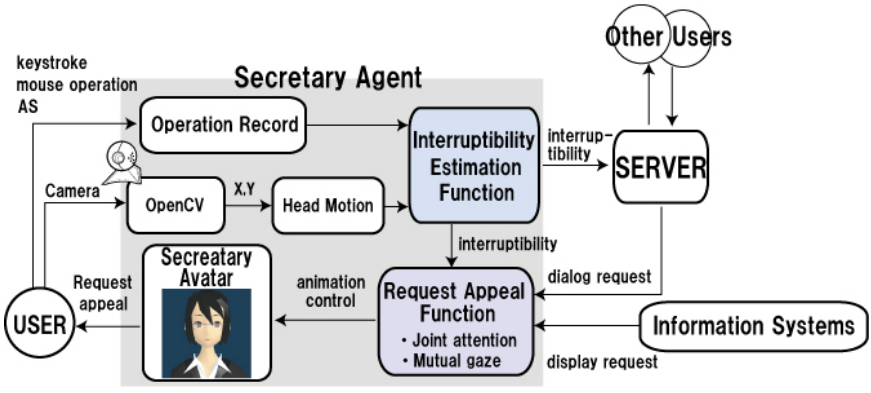

Fig. 3. Architecture of the secretary agent

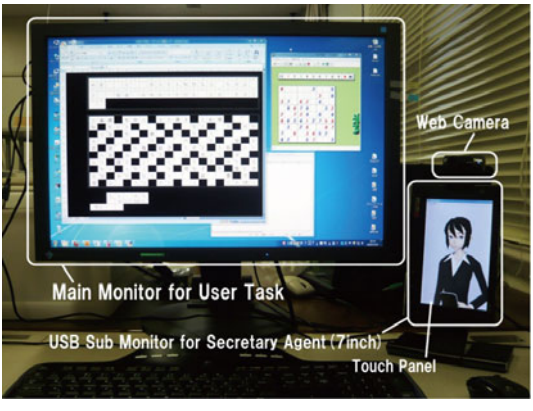

Fig. 4. Example of user environment

mutual gaze motions. The presentation strength and timing of the request are modified on the basis of the estimated interruptibility in order to attain pleasant and acceptable dialog initiation.

Figure 4 shows an example of user environment using the secretary agent. In this study, we propose using a USB sub-monitor to display the agent. Moreover, a web camera, which is used to capture the user's head position, is set up at the top of the sub-monitor. This not only improves the practicality, because it does not encroach upon a user's working area, but also reinforces the weak awareness of software agents. Moreover, a sense of intimacy and reliance on the agent are achieved easily because of the continuous interaction with the agent existing at the same location. We expect that a positive impression of the agent reduces the adverse effect due to the estimation effort.

Function I: User interruptibility estimation

The agent estimates the user interruptibility at AS timings in three levels based on our proposed method [13]. One difficulty in the previous research was that there were

insufficient opportunities to interrupt at high interruptibility, only twice an hour. Therefore, in this study, we developed a method to estimate the interruptibility even during continuous work (not application switching: NAS).

To improve the accuracy of the estimation and to expand the estimation range of the target work, we considered using the user's head motion because it tends to reflect the user's motivation toward the current work [14]. To recognize the user's head motion, the agent captures the user's image using the web camera, and then detects the user's facial position and motion using OpenCV.

Function II: Ambient appeal of interaction requests

The agent presents a specific interaction request by using both joint attention and mutual gaze.

- **Joint Attention:** If the partner is in the NAS state, the agent occasionally observes the user's active window, which might be the user's current work space. The agent then appeals that the requested user is interested in the partner.
- **Mutual Gaze:** On the partner's AS, the agent gazes at the user who might be sitting in front of the monitor. At the time of AS, the interruptibility of the user will be reduced temporally, and so the agent uses a stronger presentation of the request, "face to partner," to influence the user to talk.

User interruptibility continually changes during the user's task. Therefore, the intensity of the appeal should be changed according to user interruptibility, or else the appeal would easily disturb the user's concentration even if it was ambient. Figure 5 shows a model of appeal intensity control for joint attention and mutual gaze based on an utterance attitude model [12]. The largeness and frequency of movement are

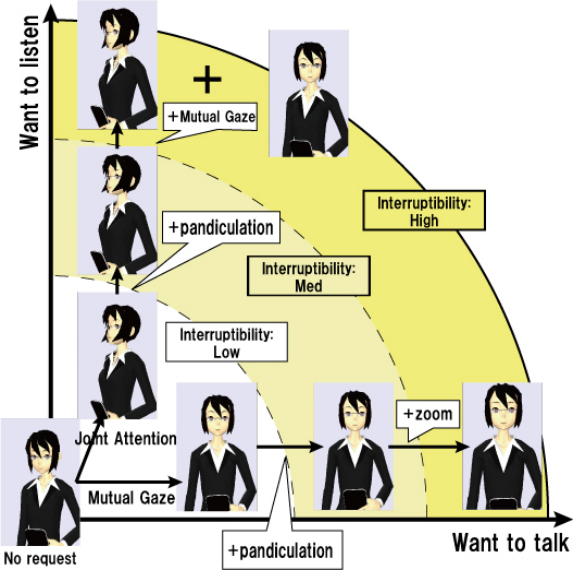

Fig. 5. Appeal intensity control for joint attention and mutual gaze

controlled on the basis of the user's interruptibility in three levels so as not to disturb the user's work. When the user's interruptibility is low, the agent appeals the request by using small movements and a low frequency. On the other hand, when the interruptibility is high, the agent frequently appeals the request by using large movements.

4 Experiment

The principal aim of this experiment is to confirm whether our interruptibility estimation method is useful for controlling presentation timing and whether the usage of a sub-monitor affects the impression of the secretary agent.

4.1 Procedure

In this experiment, the agent interrupts a subject performing given tasks in four experimental conditions. On being interrupted, the subject evaluates the interruptibility at the time. The evaluation is scaled from 1: "Absolutely uninterruptible" to 5: "No problem." Moreover, the subject evaluates his/her impression of the agent from three viewpoints by using a five-point scale: accuracy of interruption timing, tolerance of poorly timed interruptions, and motivation to use the agent. The subjects were eight university students who participated in this experiment in an environment shown in Figure 4. The subjects were assigned two tasks, a paper test and a puzzle. In addition, they were informed that the agent estimates the interruptibility and interrupts at highly interruptible times.

Two factors are crucial in this experiment. One is the control of presentation timing; the agent either interrupts the subject at random or estimates the interruptibility and interrupts at a highly interruptible time. The other is the position of the secretary agent; at the corner of the main monitor or sub-monitor. We set four experimental conditions as follows:

- A) Random timing and displaying in main monitor.
- B) Random timing and displaying in sub-monitor.
- C) Estimated timing and displaying in main monitor.
- D) Estimated timing and displaying in sub-monitor.

4.2 Results and Discussion

Figure 6 shows the evaluated interruptibility scores in random and estimation conditions. The average interruptibility of random interruptions was 2.5, whereas the average interruptibility of estimated interruptions was 3.6. Almost all random interruptions were during low interruptibility. On the other hand, the estimated interruptions were at high interruptibility. The interruptions at estimated timings were significantly higher than those at random. Thus, the results indicate the usefulness of the control of presentation timing based on the proposed method.

Figure 7 shows an interaction diagram of the four experimental conditions. The results of two-way factorial ANOVA without replication indicate that the level of interruptibility significantly affects the impression of the agent for all evaluations. Thus, it is considered that the interruption timing is very important for the impression of the agent because the agent has a well-defined purpose of controlling presentation timing.

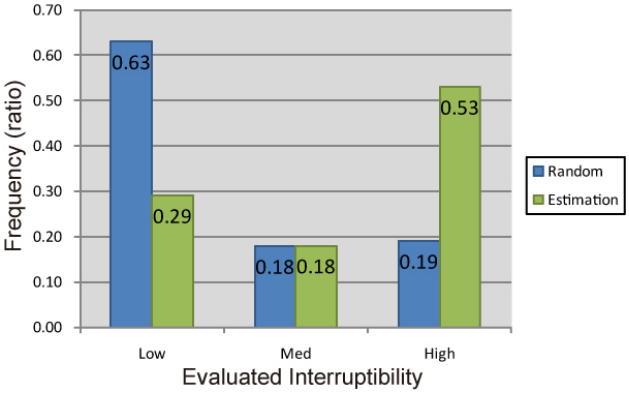

Fig. 6. Evaluated interruptibility: random vs. estimation

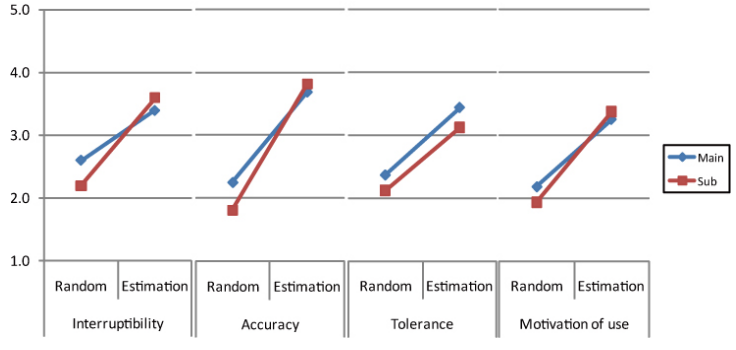

Fig. 7. Interaction diagram of evaluated scores

There was no significant difference regarding the display position of the agent. However, the subjects rated the agent displayed in the main monitor higher than that in the sub-monitor when evaluating the tolerance of a poorly timed interruption. At this point, we additionally interviewed the subjects regarding the reasoning behind this high rating. Some subjects assigned low scores for the tolerance because they expected improved agent performance with the use of particular devices and spaces such as a sub-monitor, and were disappointed because they did not observe any particular advantage of the device. In this experimental condition, we had turned off the request-appeal function because we attempted to evaluate the availability of the proposed estimation method. Therefore, the agent never moved during the experiment, even if it had a dedicated device and space. The user evaluates the agent according to not only its performance but also the cost or impression of the devices that comprise it.

5 Conclusions

In this paper, we proposed a secretary agent to mediate interactions between a user and other users or systems in order to start accepting interactions based on the

interruptibility estimation method. We experimentally confirmed that our proposed estimation method is useful for controlling the agent's presentation timing. In the future, we shall experimentally evaluate the ambient appeal method by using gazing actions to interrupt without causing stress.

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