Secretary Agent for Mediating Interaction Initiation

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Abstract: In recent years, the possibility that users might be interrupted by information systems has been increasing with the growing popularity of the Internet and the ubiquity of computing environments. However, the timing of interruptions is not controlled in most systems. In this study, we propose a secretary agent to mediate interaction initiation between users or human-computer. The agent appeals the request of interruption to user from other by controlling the character's gaze at the timing of less cognitive load based on the interruptibility estimation. We confirmed the usefulness of the mediation by the agent.

1 Introduction

In recent years, the possibility that users might be interrupted by information systems has been increasing with the growing popularity of the Internet and the ubiquity of computing environments. However, the timing of interruptions is not controlled in most systems. Previous studies have suggested that the suspension and resumption of the problem state and memory processes relating to a previous task occur as a result of interruption when task is switched in multitasking, thus the switch causes a time lag[1, 2] (Figure 1). In particular, it has been pointed out that the time lag or "Resumption Lag" can be potentially increased because of interruption timing, length of task execution time, the type of task being performed, and the relationship among difference tasks[3, 4]. Therefore, it has been pointed out that frequent interruptions do not reflect user status, can fragment the user 's working time and can decrease intellectual productivity[5, 6].

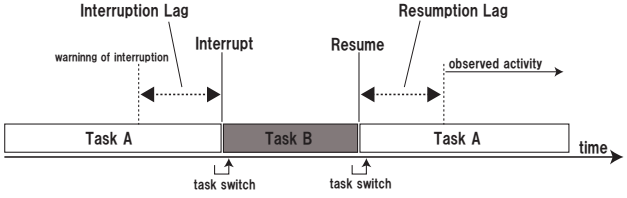

Figure 1: Cognitive load caused by an interruption during multitasking.

One potential method for estimating a user 's online status is by monitoring PC operations or by using sensors[7, 8, 9, 10, 11]. 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. On the other hand, previous studies suggested that interruptions at a recognized breakpoint are preferable to interruptions during an ongoing task because the Resumption Lag caused by an interruption at a breakpoint is significantly short[12, 13, 14, 15]. Therefore, real-time breakpoint estimation by an information system can be considered a method for controlling the timing of interruption. Iqbal and Bailey proposed breakpoint detection based on structural analysis of tasks[18], and there are suggestion that the timing of application switching during PC work is as an alternative breakpoint[16, 17]. However, in real world, variations of applications, tasks, and personal environments occur frequently. Therefore, it is difficult to apply the task-structure-based method and recognize the details of PC operations in each specific application.

In our previous studies, we considered focused application switching (AS) as an alternative of breakpoint during 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 during PC work[19]. However, as the estimation essentially has an error, there is a risk of unintentional disturbance. Interruptions by pop-up windows or sounds based on the error may seriously disturb the user 's work. Therefore, we need to consider a presentation method that is robust against estimation errors.

In this paper, we propose a secretary agent to mediate interactions between users or human-computer, in order to start interactions smoothly with others. The agent gently appeals interaction request from other by using gaze actions at estimated interruptible timing and leads the user to confirm the request on his/her own. We experimentally confirmed that the secretary agent is useful for smooth interaction initiation and our method reduced a cognitive load by the interruption.

2 Mediation of Interaction Initiation

We proposed an interaction initiation method with acceptable timing by using an agent to mediate the interaction based on the user-interruptibility estima-

tion. 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 at estimated high interruptible timing.

3. **Notice:** If B notices the appeal, B will access his/her agent for confirming the request on his/her own. If B decides to start a dialog with A, B sends a message to A. On the other hand, B is allowed to not respond to the request until a breakpoint, 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.

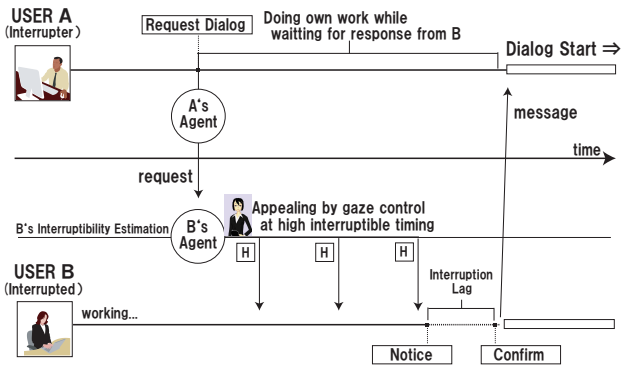

Figure 2: Exmaple of agent's mediation.

This agent uses the user interruptibility estimation method during PC work. This method provides a controlling interruption timing that is useful to start interactions without causing problems of disturbance from others. However, as the estimation essentially has an error, there is a risk of unintentional disturbance. Interruptions by pop-up windows or sounds based on the error may seriously disturb the user 's work. Therefore, we need to consider a presentation method that is robust against estimation errors. In this study, we combined the interruptibility estimation with the ambient presentation of the interruption which enables the busy user to not respond until a breakpoint. Moreover, the ambient method can set a brief time lag between the notice (warning of interruption) and the confirm (interruption) about several seconds. Previous studies suggested that the time lag or "Interruption Lag" can decrease a cognitive load by the interruption [20]. Therefore, the agent 's mediation realizes the acceptable interaction initiation without high cognitive load by interruptions.

3 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 motion using a web camera and then estimates user interruptibility in three levels. The request appeal component expresses the existence of an interaction request from others by the joint attention and mutual gaze motions at the timing when the agent estimates interruptibility as high.

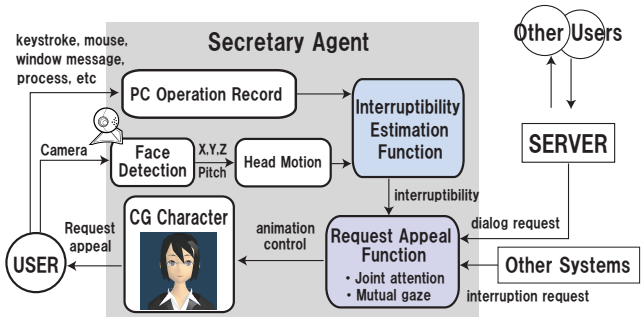

Figure 3: Architecture of secretary agent.

3.1 Interruptibility estimation function

The agent estimates the user interruptibility during PC work using the interruptibility estimation function. This function monitors user' s PC operation records, keystroke, mouse operation, process id, number of window and so on every 500ms. In previous study, we experimentally collected and analyzed several thousands hours records, and selected 23 indices that affect to the interruptibility during work. Moreover, we proposed the user interruptibility estimation method based on PC operation records [19]. We confirmed that the accuracy of our proposed method was about 60% in both of laboratory and office environments.

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. We analyzed a correlation between the head motion during work and the interruptibility, added some indices about head motions to our estimation method. Then, we confirmed the accuracy of the estimation increased to 75%. To recognize the user 's head motion, the agent captures the user 's image using the web camera, and then detects the user 's head motion Kinect or faceAPI (Figure 4). Currently, using a head motion is provided as an option because preliminary calibration is needed for the recognition.

Figure 4: Example of user interruptibility estimation with head motion.

3.2 Request appeal function

The agent presents a specific interaction request by using both joint attention and mutual gaze at the timing when the estimation function estimates high interruptibility as following.

- **Joint Attention:** If the user is continually using same application (NAS), the agent occasionally observes the user 's active window, which might be the user 's current work space. The agent appeals that there is something to inform to the user by displaying the interestedness to the user work.
- **Mutual Gaze:** On the user 's application switching (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 user, " to influence the user to talk.

Moreover, when the interruptibility is high, the agent frequently appeals the request by using appeals. Figure shows examples of both gaze controls, joint attention and mutual gaze.

4 Evaluation

4.1 Procedure

We conducted the experiment for evaluating the secretary agent. In this experiment, the agent interrupts a subject performing given tasks in four experimental conditions. On being interrupted, the subject evaluates a subjective interruptibility at the time. The evaluation is scaled from "Uninterruptible (low interruptibility)" to "Interruptible (high interruptibility)."

Two factors are crucial in this experiment. One is the control of presentation timing; the agent either interrupts the subject at random or interrupts at

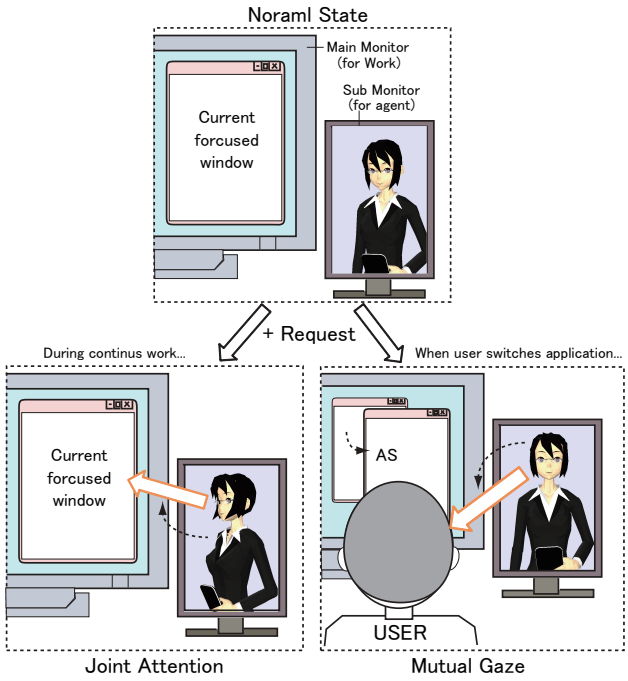

Figure 5: Appeal request using joint attention and mutual gaze.

estimated highly interruptible timing. The other is the presentation (interruption) method by the agent; interruption by dialog window which was suddenly displaied like a most common system or ambient appealing by gaze actions. We set four experimental conditions as follows:

- **A:** Random timing and Dialog interruption (like a most common system)
- **B:** Estimated timing and Dialog interruption
- **C:** Random timing and Appeal interruption
- **D:** Estimated timing and Appeal interruption (mediation method)

The subjects were ten university students. They were assigned two tasks, crossword and Sudoku. In addition, they were informed that the agent estimates the interruptibility and interrupts at highly interruptible times. During this experiment, the secretary agent was displaied on a sub monitor which set side by main monitor like Figure 5. Moreover, the agent estimated subject's interruptibility without head motions in this experiment.

4.2 Result

Figure 6 shows a frequency of the subjective interruptibility at interrupted timing on each conditions. In condition B and D, the agent estimated high interruptible timing. Therefore, the frequency of high interruptibility on both conditions can be regarded

as an accuracy of estimation. In condition A (random/dialog), over 60% of interruptions were conducted at low interruptible timing. On the other hand, in condition B (estimation/dialog), over 60% interruptions were at high interruptible timing. Therefore, the accuracy of the estimation method was about 60%, and this result was same as the previous study. The appealing interruption improved the interruptibility scores in both conditions C and D. In particular, the accuracy of high interruptibility in condition D was 85% even when the estimation algorithm is same as condition B. Moreover, the rate of serious error which the method evaluates low interruptibility as high one was only 4%.

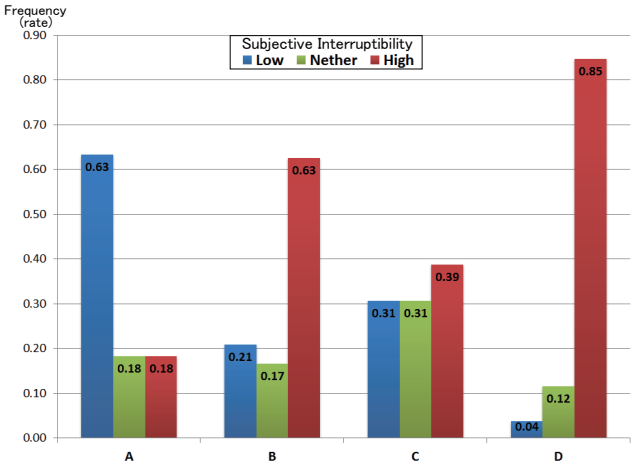

Figure 6: Frequency of the evaluated subjective interruptibility at interrupted timing on each conditions.

In previous studies suggested that Resumption Lag (RL) is one of indices for evaluating the cognitive load by an interruption during multitask. We calculated and compared RL of each interruptions in four conditions for evaluating the cognitive load. Referring to the previous study, we defined RL as the period of time required to return to the previous task (window) is until the first observed activity subsequent to an interruption. Here the activity involved keystrokes, mouse clicks, and wheel usage not specifically affected by the kind of task being performed.

Figure 7 shows a result of RL on each conditions. We analyzed RLs by one-way analysis of variances, then revealed that the condition significantly reflects RL by an interruption ($F(3, 170) = 4.31, p < 0.01$). After the multiple comparison by Bonferroni method, we confirmed that there are significant differences between A and C, and A and D ($p < 0.05$).

4.3 Discussion

From the result, the accuracy of interruptibility estimation was almost same as previous experiments. However, in condition D (estimation and appeal), the subjective accuracy of estimation was over 80%, so

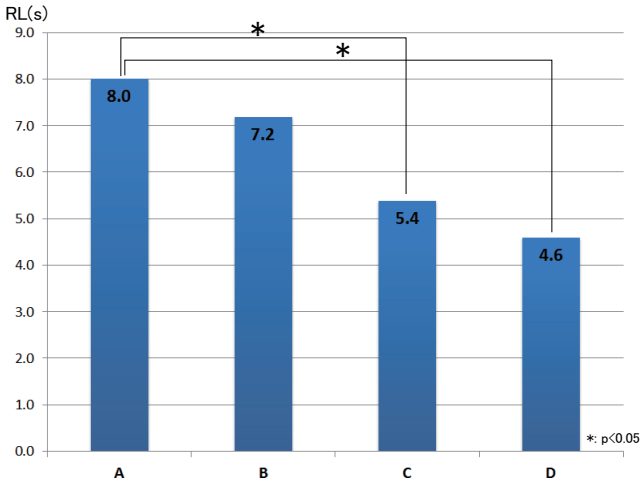

Figure 7: Comparing a resumption lag on each conditions.

proposed appeal interruption method improved the accuracy about 25%. Moreover, the rate of serious error was reduced to 4% from 21% (condition B). Therefore, this result suggested that the combination of estimation and appeal is a presentation method which is robust against estimation errors. In condition A (like a most common system), interruptions caused about 8 seconds time lag every time. Our mediation method significantly decreased the time lag to 4.6 seconds. From the view point of cognitive load, the mediation decreased the cost of interruption comparing to previous method. Furthermore, this result suggests that 100% of accuracy is not necessarily required for the user status esitmation if we consider people's cognitive characteristic.

5 Conclusion

In this paper, we proposed a secretary agent to mediate interactions between a user and other users or systems in order to start interactions at acceptable timing. We experimentally confirmed that the interaction mediation is useful for smooth interaction initiation and our method reduced a cognitive load by the interruption.

Acknowledgement

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