E-Mail Delivery Mediation System Based on User Interruptibility

Yasumasa Kobayashi[1(✉)], Takahiro Tanaka[2], Kazuaki Aoki[1], and Kinya Fujita[1]

[1] Graduate School, Tokyo University of Agriculture and Technology, 2-24-16 Nakacho, Koganei, Tokyo 184-8588, Japan
50014646116@st.tuat.ac.jp, kfujita@cc.tuat.ac.jp
[2] Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

Abstract. To eliminate the distraction caused by inappropriately timed e-mail delivery notification, we constructed a prototype e-mail delivery mediation system. The system was designed to mediate incoming e-mails based on user interruptibility, which is estimated from PC operational activities of the user. The system delivers e-mails at higher interruptibility times, especially at application switching moments, which are considered a substitute for task breakpoints in work which uses PC. A trial experiment with eight participants in an ordinary working environment was conducted. The experiment results suggested that e-mails were delivered at higher estimated interruptibility times and decreased feelings of hindrance regarding incoming e-mails. However, there were e-mail deliveries at low interruptibility moments even though participants were using the system. Therefore, further study must be conducted to improve the system and to conduct analysis on work efficiency.

Keywords: E-mail · Interruptibility · Interruption · Work efficiency

1 Introduction

Computer-mediated human-to-human communication in workplaces has become popular due to growth of computer technologies and the Internet. Such communication may facilitate smooth interaction between workers. However, there is a concern that computer system notifications not reflecting user states may decrease intellectual productivity [1]. For example, e-mail systems are considered a source of interruption even though they are well used in many workplaces [2]. In particular, increase of worker frustration is considered a major problem caused by frequent interruptions. Therefore, systems that adequately control user interruption are desired.

To address this issue, several studies have been conducted. Sharing awareness information among workers has been proposed to facilitate smooth communication. For example, myUnity shares awareness information, including recommended communication tools, selected by the interruptee [3]. This allows the sender to decide the appropriate time to interrupt a partner. A more automated system, MyVine, also bears mention [4]. MyVine automatically estimates and recommends communication tools

M. Kurosu (Ed.): Human-Computer Interaction, Part I, HCII 2015, LNCS 9169, pp. 370–380, 2015.
DOI: 10.1007/978-3-319-20901-2_34

based on location, PC operation status, and conversational status. These systems are proposed to facilitate smooth communication between employees, although workers still need to judge the timing and appropriateness of an interruption. Therefore, an automatic interruption mediation system is required.

In order to achieve automatic mediation via computer, the user's state must be estimated and reflected in the interruption timing. One of the indices of user state is called "User Interruptibility." It is the subjective extent to which a user can accept an interruption. Several methods are proposed to estimate user interruptibility. For example, keystroke-based estimation during PC operation [5] and sensor-based estimation [6] have been proposed. On the other hand, studies on multitasking suggest that interruption has a cognitive impact on an interruptee that it is reduced when the interruptee is interrupted at task breakpoints [7]. Therefore, user interruptibility estimation methods based on PC operational activities and application-switching, which is considered a task breakpoints in PC works, has been proposed [8–10]. Because that method uses no sensors, it has an advantage in terms of implementation effort in a real working environment. Therefore, this study is designed to mediate e-mail delivery based on the estimated user interruptibility based on PC operational activities and application-switching.

It is known that the interruption cost of e-mail is high. However, the automatic mediation of e-mail delivery with more acceptable timing has not yet been achieved. Therefore, we have developed a prototype incoming e-mail delivery mediation system (EDMS) based on the estimated user interruptibility to achieve more appropriate timing for e-mail delivery.

2 E-Mail Delivery Mediation System

2.1 System Requirements

In order to achieve appropriate mediation by the system, system requirements should be considered from receivers' and senders' points of view, in order to facilitate smooth communications between workers.

From a receiver's viewpoint, e-mail interruptions during busy working conditions (i.e. while the user's interruptibility is low) should be avoided so as not to disrupt the user. For example, interruptions should be delayed until a user reaches task breakpoints while the user is working on highly intellectual tasks. Additionally, the system should be used as extension of current e-mail systems in order to lower integration cost and to assure access to stored old e-mails.

From a sender's viewpoint, e-mails should not be delayed for an excessive time in order to smoothly communicate with their partner. Otherwise, overall performance of workers might decrease even though the receiver is not interrupted.

Therefore, the following requirements should be included in order to achieve an appropriate e-mail mediation system:

1. Defer e-mail when a user's interruptibility is low. This can be achieved by blocking e-mails while user interruptibility is low and allow e-mails to be delivered only when user interruptibility is high.
2. Low implementation cost of the system. This can be achieved by constructing the system as a program which is external to the mail server and e-mail clients.
3. Keep access to stored old e-mails. This can be achieved by constructing the system as a program compatible with current e-mail clients.
4. Prevent e-mails from being blocked for an excessive time. This can be achieved by increasing the chance of e-mail delivery depending on e-mail deferral time.

2.2 System Configuration

The configuration of the prototype system is shown in Fig. 1. The EDMS was implemented as a software application that functions between the mail client and the mail server, which supports POP over SSL. Therefore, EDMS is compatible with any existing e-mail client; this enables users to access old e-mails.

Essentially, the system relays commands from the client and responses from the server. Because e-mail delivery notification by mail clients depends on a received server response, the EDMS controls the notification timing by modifying the timing and content of the server response.

When the EDMS receives a response from the server notifying it of the existence of a new e-mail, the EDMS executes a notification determination algorithm (explained in Sect. 2.4) to determine the appropriateness of delivery timing based on estimated interruptibility.

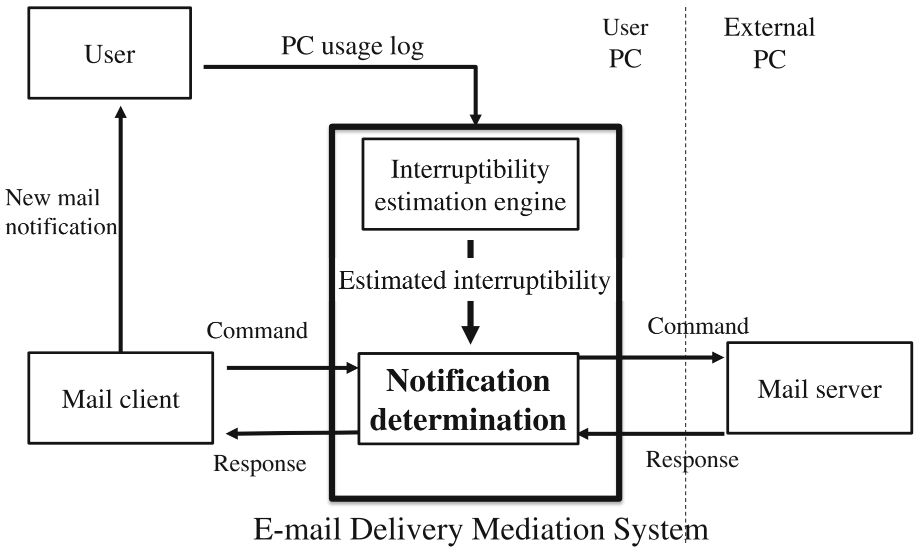

Fig. 1. System configuration

2.3 User Interruptibility Estimation Method

The EDMS estimates user interruptibility at three levels, i.e., “3: High,” “2: Medium,” and “1: Low”. Estimation is based on the PC’s operation activity levels at two different times: application switching (AS) moments and not application switching (NAS) periods. In both cases, the PC usage information, such as keystroke, mouse click, mouse wheel, active window name, process ID, window message, and the number of simultaneously open application windows, is used to estimate the interruptibility of a user. At AS moments, 19 indices are related to the degree of breakpoint, such as work discontinuity, application coupling, and indices that are related to the amount of PC operation activity, as shown in Table 1 [2]. For example, if the number of open windows decreases, the situation is considered to be the end of a task, which is estimated to show high interruptibility.

Table 1. Indices of interruptibility at AS moments

id	Group 1: Work Discontinuity
A	Increase of opened window.
B	Decrease of opened window.
C	Increase of opened window compared to ave. of last 2 min.
D	Decrease of opened window compared to ave. of last 2 min.
E	Window message (quit).
id	**Group 2: Application Coupling**
F	Window message (clipboard).
G	Parent-window to child-window transition.
H	Child-window to parent-window transition.
I	Reuse of the same application within 2 min.
J	Transition to the shell (Explorer).
K	Transition from the shell (Explorer).
L	Re-transition to the shell within 2 min.
M	Re-transition from the shell within 2 min.
N	Continuous use of one application over 2 min.
id	**Group 3: Physical Activity**
O	Continuous use of one application within 15 sec.
P	Typing activity within 20 sec before AS.
Q	Mouse activity within 20 sec before AS.
R	More than 10% operating time in last 2 min.
S	Use of both keyboard and mouse in last 2 min.

During NAS period, only the indices related to the amount of PC usage can be obtained, such as the keystroke usage, PC activity detection rate, a combination of keyboard and mouse usage, and transitions from the shell, as shown in Table 2 [3]. For example, if a user is working hard, then a higher amount of keyboard and mouse activity will be detected. This means the user's interruptibility will be estimated as low.

Table 2. Indices of interruptibility during NAS period

id	Effect of four indices on NAS interruptibility
T	Typing activity within 20 sec before
U	More than 30% operating time in last 2 min.
V	Use of both keyboard and mouse in last 2 min.
W	Re-transition from the shell within 5 min.

In addition, the estimated errors for exchanging high-interruptibility and low-interruptibility during AS and NAS were 22 % and 29 %, respectively, in an uncontrolled working environment. Because of the low chances of serious errors, such as incorrectly estimating low interruptibility as high, this method is considered capable of significantly reducing inappropriate interruptions during a low interruptibility state.

The advantage of the adopted estimation method is that it uses no sensors and can estimate interruptibility in real-time. Therefore, it is easily integrated into an actual working environment.

2.4 EDMS Algorithm and E-Mail Delivery Rules

The EDMS executes the following algorithm when it receives a response from the server notifying it of the existence of a new e-mail. Basically, the EDMS relays the server response to the client, with or without modification based on the user's estimated interruptibility.

1. EDMS holds the response from the server and waits for an increase in the estimated user interruptibility until the end of the automatic mail-checking period of the client (determination process). This waiting period allows the EDMS to send a response to the client at a suitable moment.
2. The EDMS transfers the actual server response to the client when the estimated interruptibility matches the delivery rules. If there is no match until the end of the new mail-checking period, the EDMS sends a modified response as if there were no incoming e-mail. Figure 2 (a) shows an example of mediated e-mail delivery, in which e-mail is blocked from the beginning of automatic e-mail checking until the user's estimated interruptibility reaches a high level. Figure 2 (b) shows an example

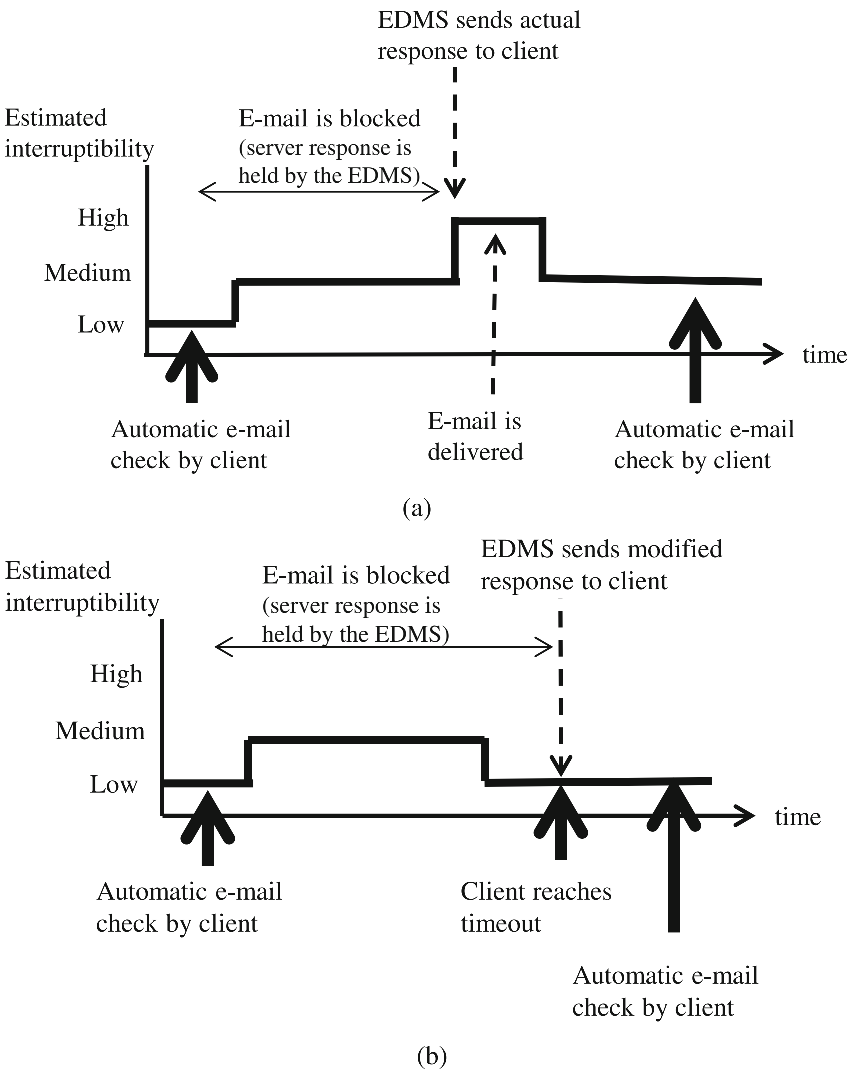

Fig. 2. Example of e-mail mediation: (a) when e-mail is delivered (b) when e-mail is blocked

in which an e-mail is blocked until the client reaches timeout because the user's estimated interruptibility did not reach a high level (notice that the determination process will occur at the beginning of the next automatic e-mail check by the client).

3. The EDMS checks for the existence of suspended e-mails and suspension time. If suspended e-mails exist, the rule is relaxed at 30-minute intervals so e-mails are not blocked for an excessive period, so as to facilitate smooth communication with the sender. If there are no suspended e-mails, the rules are initialized to be ready for new e-mail mediation.

The delivery rules governed by the e-mail suspension time t (in min) are shown in Table 3. The rules were designed to prioritize delivery during AS periods, which are considered to be task breakpoints, because they are more reliable for interruptibility estimation. After the detection of AS moments, the EDMS compares the estimated interruptibility of immediately before the AS and at the AS moment with the corresponding values. During the NAS period, the determination is based on the 1-min average interruptibility because the NAS state continues and averaging provides more reliable scores. Initially, we set the rules and they were adjusted by three pilot users in a seven-week trial. An adjustment session was performed every Friday to reflect feedback received from Monday to Thursday.

Table 3. Rules for e-mail delivery (*indicates “irrelevant”)

	t<30	t<60	t<90	t<120	120<t
AS	*−3	*−3	*−3	*−3	*−3
(Before – At AS)	2–2	2–2	2–2	2–2	2–2
			1–2	1–2	1–2
NAS (1 min average)	3	2.5≤	2.5≤	2.1≤	1≤

3 Trial Experiments

3.1 Experimental Conditions

Trial experiments were performed to evaluate the effect of EDMS on subject feelings of hindrance. Six faculty members and two university students participated in the experiments in an ordinary working environment. The experiments were performed under two conditions: “No EDMS” and “With EDMS” for five days each. We collected estimated interruptibility at each e-mail notification interval. Additionally, we requested that the participants rate their feelings of hindrance on a scale ranging from 1 (none) to 7 (strong) at the end of office hours every day. We have also collected the estimated interruptibility of each participant in order to observe the system’s operation.

3.2 Results

The estimated interruptibility at the moment of e-mail delivery is shown in Fig. 3. Data gathered while the participant was away from their keyboard was excluded. The average scores for without and with EDMS conditions were 2.24 and 2.50, respectively (t-test, $p < 0.05$). From the graph, it can be considered that the system successfully decreased inappropriate interruptions to a certain extent. Therefore, the system has operated successfully up to a certain level.

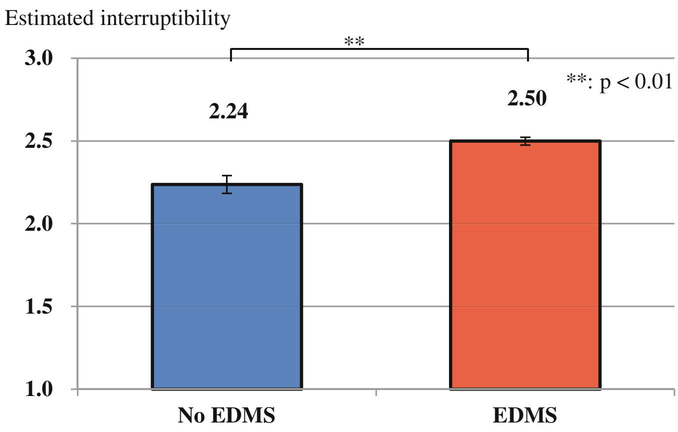

Fig. 3. The estimated interruptibility at the moment of e-mail delivery

We expected that mediation of incoming e-mails would decrease users' frustration. Therefore, we collected subjective feeling of hindrance, which were scored on a scale from 1 to 7 (1: no feeling of hindrance; 7: strong feeling of hindrance). As the result of mediation of incoming e-mails, feelings of hindrance decreased from 2.6 to 1.8 (t-test, $p < 0.05$), as shown in Fig. 4.

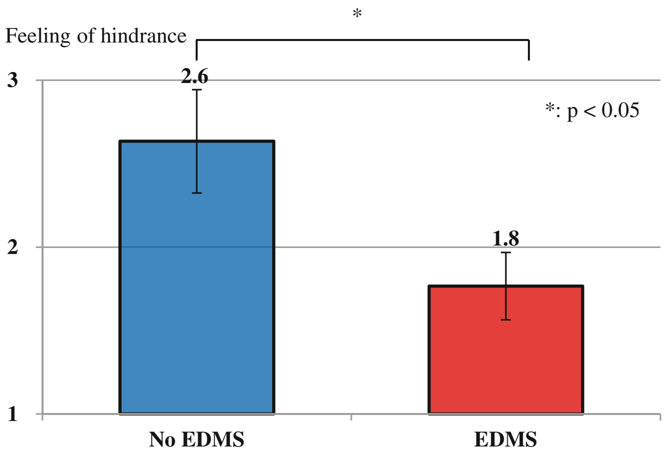

Fig. 4. Feeling of hindrance correlated to incoming e-mails

From these results, the EDMS may allow e-mail notifications to occur at more appropriate times and decrease user frustration.

4 Discussion

4.1 Prototype EDMS

As discussed in Sect. 3.2, the EDMS reduced e-mail interruptions while the user's estimated interruptibility was low. However, we had several requests from the participants regarding improvements to the system. One user's feedback mentions that "some e-mail seems to have arrived while interruptibility is low even though we are using the EDMS." In order to check this phenomenon, we have analyzed the amount of e-mail arrival during low-interruptibility periods. As a result, 34 e-mails out of 347 overall e-mails were found to have been delivered when estimated interruptibility was low. The results suggest that e-mails were not immediately delivered after determination, which means the existence of a lag between the determination process and actual notification. We are improving the algorithm of the prototype EDMS to reduce the response lag.

4.2 Evaluation Experiments

One concern regarding the conducted experiments is that we gave information about e-mail mediation condition to the participants. Therefore, cognitive bias in subjective hindrance scores is conceivable. To avoid this bias and obtain more reliable results, we need to conduct an experimental evaluation using a modified system, which randomly switches e-mail mediation mode.

Another requirement for the experiment is the evaluation of the appropriateness of interruption timing. One potential method is to look at the user's degree of engagement in a task at the e-mail delivery. However, because quantitative measurement of a user's engagement in a real working scenario is a challenge, we have to employ a substitutive index that reflects a user's engagement. The amount of PC operational activity at time of interruption is a potential measure.

On the other hand, in the field of cognitive science, it is known that interruption at an appropriate time reduces the cognitive cost of the interruption. Furthermore, resumption lag is considered as an index of cognitive cost. Therefore, resumption lag, which is the time taken to resume the original task from the end of the interruption, is one of the more promising measures for evaluating the appropriateness of an interruption. The problem is that resumption lag in a real working scenario is ambiguous because a user's task is not constrained and has wide variety. Therefore, we may approximate resumption lag by, for example, measuring "time until the first PC operation detection after switching back to the software that was being used before the e-mail interruption."

Furthermore, we can expect that receiving email at appropriate timing gives shorter response time. Because the user would switch to the email task after they have finished a subtask, a shorter response time would suggest that the user was at the breakpoint of a subtask. Therefore, response time, which is the time from notification until the user voluntarily switches to the mail client, may be addressed as another measure for evaluating the appropriateness of an interruption.

The final target of this study is to increase the work efficiency of users by avoiding inappropriate e-mail interruptions. However, overall work efficiency has not yet been evaluated. Furthermore, the examined environment and duration in this study is rather limited. Long-term experimental evaluation of work efficiency in a wider variety of working environments is needed.

Another concern of employing EMDS is that e-mail suspension may increase message-transmission delay in a working team. The overall team performance is based not only on e-mail receivers but also on senders. Therefore, analysis of the effect on e-mail senders and the entire team is also desired.

4.3 Limitations and Future Works

The current EDMS prototype does not reflect the importance or priority of e-mail on the delivery determination. Because the e-mail receiver may want to receive particular e-mails, such as e-mails warning of emergencies or e-mails from his/her superior, reflection of content and sender of e-mail in the delivery determination algorithm will also be addressed in future work.

5 Conclusions

We developed a prototype EDMS that allows the automatic mediation of e-mail delivery based on estimated interruptibility in order to provide e-mail notifications at appropriate times. Currently, the prototype EDMS is still improving the system response. The next step is an experimental evaluation in an actual working environment using the improved system.

Acknowledgements. This work was partly supported by KAKENHI from JSPS, funds for Smart Space Technology toward a Sustainable Society from MEXT, and funds for Ultra-realistic Communication Systems from NICT.

References

1. Barley, S.R., Meyerson, D.E., Grodal, S.: E-mail as a source and symbol of stress. Organ. Sci. **22**(4), 887–906 (2011)
2. Jackson, T., Dawson, R., Wilson, D.: The cost of email interruption. J. Syst. Inf. Technol. **5**(1), 81–92 (2001)
3. Wiese, J., Biehl, J.T., Turner, T., van Melle, W., Girgensohn, A.: Beyond yesterday's tomorrow: towards the design of awareness technologies for the contemporary worker. In: Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services, pp. 455–464. ACM (2011)
4. Fogarty, J., Lai, J., Christensen, J.: Presence versus availability: the design and evaluation of a context-aware communication client. Int. J. Hum. Comput. Stud. **61**(3), 299–317 (2004)

5. Minakuchi, M., Takeuchi, T., Kuramoto, I., Shibuya, Y., Tsujino, Y.: An automatic estimation method for busyness at deskwork. Trans. Hum. Interface Soc. **6**(1), 69–74 (2004). (in Japanese)
6. Fogarty, J., Hudson, S.E., Atkeson, C.G., Avrahami, D., Forlizzi, J., Kiesler, S., Yang, J.: Predicting human interruptibility with sensors. ACM Trans. Comput.-Hum. Interact. (TOCHI) **12**(1), 119–146 (2005)
7. Iqbal, S.T., Bailey, B.P.: Investigating the effectiveness of mental workload as a predictor of opportune moments for interruption. In: CHI 2005 Extended Abstracts on Human Factors in Computing Systems, pp. 1489–1492. ACM (2005)
8. Tanaka, T., Fujita, K.: Study of user interruptibility estimation based on focused application switching. In: Proceedings of the ACM 2011 Conference on Computer Supported Cooperative Work, pp. 721–724. ACM (2011)
9. Hashimoto, S., Tanaka, T., Fujita, K.: Improvement of interruptibility estimation during PC work by reflecting conversation status. IEICE Trans. Inf. Syst. **97**(12), 3171–3180 (2014)
10. Tanaka, T., Abe, R., Aoki, K., Fujita, K.: Interruptibility estimation based on head motion and PC operation. Int. J. Hum.-Comput. Interact. **31**(3), 167–179 (2015, to appear)