Study of User Interruptibility Estimation Based on Focused Application Switching

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Abstract
In this study, we propose a user-interruptibility estimation method based on focused application switching (AS) during PC work. It was experimentally demonstrated that the interruptions of AS are more acceptable than those during continuous work. Therefore, we constructed an algorithm that estimates the interruptibility of AS at three levels based on 19 selected indexes. The feasibility of the interruptibility estimation of AS was demonstrated by an estimation experiment using another dataset of 11 users.

Keywords
interruptibility, breakpoint, application switching

ACM Classification Keywords
H5.2 [User Interface]: Theory and methods. H5.3 [Group and Organization Interfaces]: Computer-supported cooperative work.

General Terms
Theory

Introduction
In recent years, the possibility that users are interrupted by information systems has been increasing along with popularization of the Internet and the

ubiquitous computing environment. However, the timing of interruptions has not been controlled in most systems. Preceding studies [1] have shown that frequent interruptions that do not reflect the user status can fragment the user's working time and decrease intellectual productivity.

In this study, we consentrated on focused application switching (AS) that is change of using application, which is considered to be not only the breakpoint of PC work, but also of intellectual activity. We present the experimental data and propose an interruptibility-estimation rule for AS.

Idea

There are several studies that aim to estimate the user status using various techniques such as counting keystrokes or mouse clicks and using various sensors that are set in the living space or on the users [2-4]. These methods are expected to adequately estimate the user status by observable physical activity indexes. However, intellectual activity such as deep thinking has no observable output. On the other hand, some studies reported the relationship between interruptibility and the breakpoint of the work [5-7]. At the breakpoint, the user's interruptibility is expected to increase instantaneously, even if the task requires intellectual activity. Furthermore, it was suggested that the breakpoint level affects interruptibility [5]. A task-structure which categorized operations analysis is thus required to determine this level. The multi-tasking aspect of PC usage also makes it potentially difficult to apply the task-structure-based method. Therefore, distinguishing the interruptibility level of a breakpoint remains challenging [7].

We concentrated on focused application switching as a breakpoint in PC work, which is a transition of the active application window. AS is considered to be the user's intentional switching of his 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, which implies that AS is a potential source of information presentation with low risk of task disturbance.

Experiment I: Selection of Indexes

To examine the assumption, we experimentally collected PC operation records and subjective interrupt-evaluation logs and analyzed them. Figure 1 shows the logging tool we developed that records user operations at every 500 ms. The tool interrupts subjects at automatically selected AS, or every five min during continuous work (NAS), and requires the users to subjectively evaluate interruptibility, which means if and how they want to be interrupted. The scores were

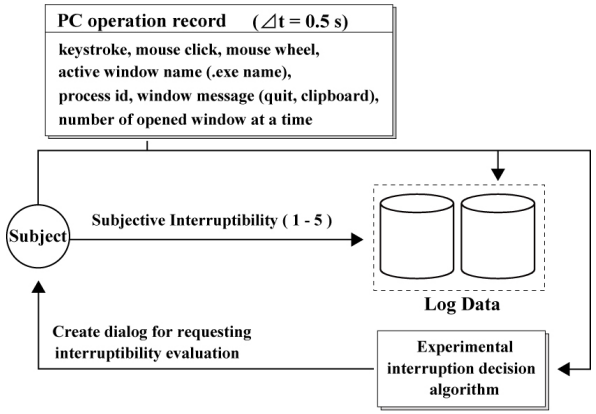

Figure 1. Experimental logging system.

Table 1. Subjective interruptibility scores at AS vs. NAS.

	Subjective Interruptibility					Freq.	Ave.
	1	2	3	4	5		
AS	97	144	206	263	131	841	3.2
NAS	58	85	63	62	33	301	2.8

scaled from "1: Absolutely uninterruptible" to "5: No problem." The evaluation logs, which consist of 40 sets of daily 1-h PC activity, were collected from 10 university students, who did their own tasks such as data arranging, programming, writing report and so on.

Result

Table 1 shows an interruptibility comparison between AS and NAS, including the frequencies and averages. The experimental results demonstrate that the interruptions of AS are significantly more acceptable for users than those during continuous work ($p < 0.01$, t-test). However, information systems must distinguish the more interruptible AS based on acquired information. Therefore, we analyzed the relationship between the interruptibility scores and indexes from the operation records.

Interruptibility-Estimation Rule

In general, the opening of an application window is considered to be the beginning of a new task, while its closure the end. This type of index is expected to reflect the discontinuity of work. The close coupling of tasks that are performed in two focused applications may make AS uninterruptible. The indexes that might reflect the application coupling such as "copy and paste" was also examined. Furthermore, physical activities, such as keystrokes and mouse operations, are expected to reflect interruptibility as reported in [2]. Therefore, we analyzed over 12 h of operation records using the above three viewpoints.

From this analysis, we selected 19 indexes with an example shown in Table 2. We investigated a co-occurrence relation among 19 indexes to define the estimation rule. It was anticipated that the effect of the indexes varies with situations such as the beginning, the end, and the continuity of the task. Therefore, we divided ASes and defined estimation rules according to the three situations based on the number of windows opened as increased, decreased, and no change after AS. We compressed the interruptibility into three levels: interruptible, neither, and not interruptible, from the practical viewpoint. Scores 4 and 5 were converted to High, score 3 was converted to Medium, and scores 1 and 2 were converted to Low interruptibility.

Experiment II: Evaluation

We evaluated the interruptibility-estimation rule of AS using recently collected 50-h log data from 11 university students, and the results using our method are shown in Table 3. The precision of high interruptibility was 54% and the probability that the estimated error is ≤ 1 was 88%.

Discussion

By the results of the evaluation, the precisions of high and low interruptibility were both 54%, and the average of the three levels was 44%. Although the proposed method did not provide accuracy, it demonstrated the feasibility for estimating highly interruptible, implying the chance to interrupt, AS at more than 50% precision. In addition, the precision improves almost to 90% if the user allows interruptions at a moderate interruptibility level. The high-risk

Table 2. Examples of indexes affecting interruptibility at AS.

id	Indexes
Group 1: Work discontinuity	
C	Increase of opened window compared to avg. of last 2 min.
D	Decrease of opened window compared to avg. of last 2 min.
E	Window message (quit).
Group 2: Application coupling	
F	Window message (clipboard).
G	Parent-window to child-window transition.
I	Reuse of the same application within 2 min.
Group 3: Physical activity	
N	Continuous use of one application over 2 min.
P	Typing activity within 20 s before AS.
R	More than 10% operating time in the last 2 min.

estimation rate, which is the misestimation of low interruptibility ASes to high ones, was 16 cases and 1.6% of the entire ASes. The proposed method appears to allow information systems to reduce the risk of serious work disturbance by interruption. The other features of this method, which could serve as practical advantages, are: 1) it works without any sensors and 2) the estimation rule requires no restriction in PC usage. We need to improve the rule to estimate the highly interruptible ASes with greater accuracy.

Conclusion

We experimentally confirmed that application switching is a relatively good opportunity to interrupt PC work. Furthermore, we proposed an interruptibility-estimation rule and demonstrated the feasibility of the estimation.

Table 3. Results of interruptibility estimation on evaluation.

		Evaluated			Precision	Recall	Error ≤ 1
		Low	Med	High			
Estimated	High	16	44	69	0.54	0.22	0.88
	Med	294	159	192	0.25	0.60	1.00
	Low	135	63	53	0.54	0.30	0.79

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