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Event Patterns as Indicators of Usability Problems

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Abstract. Event logs collected automatically contain a wealth of information about the usability of an application's user interface. Manual analysis of the event logs to identify usability problems is, however, a time consuming process. There are certain generic event patterns that can be associated with usability problems and can act as indicators of usability problems. These patterns can be automatically detected in event logs. We survey the event pattern indicators that have been identified and reported earlier in the literature. We identify new event patterns that get generated when users face usability problems during web browsing. We report on an experimental study that establishes the connection between these patterns and usability problems. The ultimate goal of this research is to develop techniques that can discover these patterns in event logs and reduce the time and cost of usability evaluation of the user interface.

1. Introduction

Event logs contain a wealth of usability related information about an application's user interface. Manual analysis of the event logs is, however, a time consuming process. Automatic analysis techniques have been developed to extract usability related information from events [9]. One such technique identifies certain generic event patterns in event logs that are known to be associated with usability problems. This paper proposes new event patterns that can act as indicators of usability problems and reports on an experimental study that establishes the connection between these patterns and usability problems.

As an example of an event pattern that is an indicator of usability problem is the "action repetition pattern" reported by Siochi in [16]. This event pattern gets generated when a user tries to achieve a goal by repeatedly performing an action at the user interface and repeatedly failing to achieve it. For example, a user trying to click on a graphic that he mistakenly perceives as a link. Another example would be user trying to type and execute a command in a command line interface repeatedly and each time getting an error message. Detecting such repetition patterns in event logs and analyzing their cause can lead to discovery of usability problems with the interface.

Analysis of event logs is usually a time consuming task. Analysts often have to go through the event logs in conjunction with a video recording of the user interaction to determine the problems the test participants face. The advantage of using event patterns as indicators of usability problems is that they can be identified automatically [2, 16]. After having located the event patterns the analysts can focus on the event log segments where these patterns occur to identify usability problems. This can lead to savings in time and cost of the usability evaluation of an interface.

We surveyed literature for generic event patterns that are known indicators of usability problems. Commonly occurring such event patterns are Siochi's 'Maximal Repetition Pattern' [16] and Balbo's 'Action Cancellation' [2]. Other patterns that can be detected with the help of an interface's task model are 'Direction Shift' and 'Irrelevant Actions' [2].

Ting has identified browsing patterns that can also act as indicators of usability problems. These are the 'Footstep' and 'Fingers' pattern [18].

We propose new event patterns that we believe result when users face difficulties during browsing. One such difficulty users face is when users have to ‘search’ during browsing, for example, for a piece of information or for a choice from a list of options. We believe excessive ‘search’ by a user during browsing is due to an interaction problem. The event patterns we propose result from users searching one way or the other during browsing. The first event pattern relates to user’s mouse movement during browsing. While visually searching on a page e.g. examining a vertical or horizontal list of items, users often use mouse pointer as a cue to point to the items. This generates a sequence of mouse move events in a narrow vertical or horizontal area in which the items are arranged. The second event pattern relates to scrolling. A sequence of quick up and down scrolling events could indicate the user is skimming or scanning the contents of a page. Steady scroll down events in a page could indicate user possibly reading its contents. The third event pattern relates to page accesses. When a user accesses pages in quick succession without dwelling on a page for too long, a page access event pattern gets generated that could indicate the user searching across pages. We conducted experiments and made participants execute browsing tasks that had known usability problems and/or required user to search. Results confirm that the above event patterns get generated in these situations and thus the patterns can act as indicators of usability problems.

A future goal of this research is to develop techniques to detect these patterns in client-sided event logs. Client-side event logs can be collected remotely and on a large-scale, without the users having to work in an expensive laboratory set up [15].

This paper describes the nature of the event logs in Section 2. Event patterns reported in literature, as known indicators of usability problems, are presented in Section 3. Section 4 presents new event patterns. Experimental study conducted to establish the relation between the proposed event patterns and usability problems is described in Section 5. The conclusion is presented in Section 6.

2. Event Logs

Event logging is a data capturing technique used in usability evaluation techniques [15]. Event logs record the user-interface events that get generated as a result of the user actions, their time and order of occurrence and the interface objects manipulated in each action. Event logs thus provide a more or less complete record of the actions that user performs during interaction with the interface. Event logs can be recorded automatically and processed to obtain

EVENT NAME		TIME	
PAGE LOADED	http://10.10.11.149:8080/WL/	10:52:02:100	READ START
MOUSE MOVE	(246,0)(291,32)	10:52:04:462	
MOUSE MOVE	(291,32)(291,32)	10:52:05:43	
MOUSE MOVE	(292,32)(762,273)	10:52:10:641	
MOUSE MOVE	(761,273)(104,402)	10:52:13:214	
MOUSE MOVE	(105,402)(829,318)	10:52:14:46	
CLICK	916 389 TD undefined 0	10:52:15:768	
MOUSE MOVE	(830,318)(1017,275)	10:52:16:830	
SCROLL DOWN	260 MouseWheel	10:52:17:631	READ END: 1
		10:52:19:413	READ START:
MOUSE MOVE	(1016,275)(970,272)	10:52:19:413	
SCROLL UP	260 MouseWheel	10:52:19:924	READ END: 1
		10:52:21:506	READ START:
MOUSE MOVE	(542,325)(761,207)	10:52:23:459	
SCROLL DOWN	260 MouseWheel	10:52:24:631	READ END: 4
		10:52:26:273	READ START:
MOUSE MOVE	(761,207)(761,207)	10:52:26:283	
SCROLL UP	260 MouseWheel	10:52:26:854	READ END: 1
		10:52:28:707	READ START:
MOUSE MOVE	(501,329)(843,119)	10:52:30:720	
MOUSE MOVE	(842,119)(54,1)	10:52:32:482	
SCROLL DOWN	0	10:52:32:732	READ END: 5
PAGE EXITED	15	10:52:33:922	

Fig. 1. An example web event log. The number after ‘READ END’ is the time in seconds the contents of the page were viewed prior to scrolling.

usability information such as, the task completion times, task errors, etc. In fact, most of the measurable usability indicators of a user-interface can be computed from the information in the event logs alone [11]. This paper mainly deals with web event logs recorded in a web browser.

The web event logging techniques can be classified into various categories on the basis of the point where the event data is accessed for logging [15]. Web event logging can take place on the client-side e.g. as in [6, 14], in the proxy e.g. as in [10] or on the server side e.g. as in [5]. In this paper it is assumed that the event logs are client-sided, collected by embedding scripting code into the pages of a website for logging events. Fig. 1 presents an example of a web event log recorded in users' browsers, with event names given in the first column.

3. Event Patterns

According to Norman's model of interaction [4], to achieve a task's goal, a user formulates a plan and executes it at the user interfaces as a sequence of actions. After executing an action or a set of actions the user observes the state of the interface and evaluates the result of the actions with respect to the task goal and determines what further actions s/he needs to take. Interaction problems are faced by some users, due to the difficulty in formulating an action sequence i.e. deciding what to do next (articulation translation) or in understanding the system response i.e. changes in the interface state caused by the executed actions (observation translation). These difficulties manifest in user behavior as, for example, a user pausing during interaction and pondering what to do next, or searching by trying out various actions one by one and backtracking to a previous state after an incorrect action, visually searching the interface, expressing frustration, etc. As a result typical event sequences or *patterns* get generated in the user interface that can be associated with interaction or usability problems.

Detecting event patterns in event logs that are known to be associated with usability problems saves evaluation time and cost. Evaluators, instead of analyzing the complete event log, focus on the segments where the event patterns occur. In this section we present event patterns that have been reported in literature as indicators of interaction problems. We do not discuss patterns that are specific to a website or a particular type of interface but discuss patterns that are generic in nature and can be found in event logs of any user interface. Most of these patterns have been successfully used in the evaluation of user interfaces.

3.1 Siochi's maximal repeating patterns

Siochi et al. relate a pattern of repeated sequences of user actions to certain usability problems [16]. A user performing a set of actions repeatedly could be an indicator of a user trying to achieve a goal and repeatedly failing to achieve it due to possible problems in the user-interface. Repeated patterns could also be generated due to a user performing a task repeatedly, which could be normal error free interaction. The 'action repetition pattern' indicator has been used successfully in the evaluation of the command-line interface of an image processing system [16].

3.2 Balbo's patterns

Balbo has identified event patterns that are used in the usability evaluation system, WAUTER [1, 2, 3], to detect usability problems in a user-interface. WAUTER is a task model based usability evaluation system. It compares users' actions with the task model to detect any discrepancy between the two. Balbo has identified the following patterns that indicate usability problems.

- *Direction Shift*. Direction shift is detected from a task model when a user stops progressing along a branch of a task tree. This usually happens when the user encounters difficulties along that path that prevent him from taking further actions. For example, a user may stop searching for an item in a given list and instead go in for keyword search.
- *Action Cancellation*. Action cancellation occurs when a user backtracks immediately after taking an action. For example, a user pressing back button immediately after navigating to a page indicates that user did not intend to visit the page and could be an indication of a navigation problem.
- *Irrelevant Actions*. Performing irrelevant actions during a task is also indicative of usability problems.
- *Action Re-occurrence*. Repeatedly performing an elementary action, such as

mouse clicks and key-presses, may indicate a lack of feedback from the interface that misleads the user into thinking that the system has not recognized his/her action.

3.3 Ting's patterns

Ting has identified unexpected browsing behavior patterns [18]. These patterns are used in a manner similar to WAUTER [3]. The routes taken by users in a website are compared with a set of expected and common routes. The routes that deviate from the common routes are defined as unexpected browsing patterns and are believed to indicate usability problems. Ting reports on following common patterns that indicate certain user behavior and a possible usability problem with the website. These patterns have been discovered through visualizing users' browsing behavior as a *footstep* graph, which is a plot of page visited versus time spent on the page.

- *Upstairs Pattern*. This pattern's footstep graph has the shape of a staircase and can in some ecommerce sites mean that the user is browsing the website smoothly. However, it could be the case that the user is not following the route that the designer of the website intended.
- *Fingers Pattern*. This pattern's footstep graph is finger shaped and indicates a possible problem with the website design. This pattern arises when a user navigates to other pages in a website from a certain page but returns to the page after short intervals of time. The pattern can also arise when a user is just exploring the website and the designer may be intending this sort of behavior from the visitors of the website. Time spent on a page is important here. Longer duration of visits to other pages before returning could be normal browsing behavior.

EVENT NAME		TIME (msec)	READ TIME (s)
SCROLL DOWN	0 89 1004 59	MWheel	097179
READ END: 6			
MOUSE MOVE	(190,210)(197,212)		098280
MOUSE MOVE	(197,212)(205,206)		099542
MOUSE MOVE	(205,206)(215,212)		100864
MOUSE MOVE	(215,212)(221,212)		101305
MOUSE MOVE	(221,212)(226,205)		101976
MOUSE MOVE	(226,205)(230,225)		102657
MOUSE MOVE	(230,225)(156,350)		105190
MOUSE MOVE	(156,350)(153,333)		105651
MOUSE MOVE	(153,333)(157,310)		106502
MOUSE MOVE	(157,310)(153,290)		107243
MOUSE MOVE	(153,290)(155,270)		107724
MOUSE MOVE			(155,270)(153,255)
108333			
SCROLL DOWN	0 255 1004 596	MWheel	108535
READ END: 11			
MOUSE MOVE	(158,258)(145,401)		109627
MOUSE MOVE	(146,401)(150,469)		111610
SCROLL UP	0 0 1004 596	MWheel	112461
READ END: 5			
MOUSE MOVE	(151,469)(483,226)		114694
MOUSE MOVE	(483,228)(474,302)		116096
MOUSE MOVE	(474,303)(474,366)		118069
MOUSE MOVE	(474,369)(473,433)		120112
MOUSE MOVE	(473,433)(473,466)		121434
SCROLL DOWN	0 89 1004 596	Mwheel	121063
READ END: 8			

Fig. 2. An event log segment showing the 'Vertical Mouse Movement' pattern.

3.4 Other patterns

Oertel et al. have performed the analysis of users eye gaze behaviour recorded with the tool RealEYE-iAnalyzer and have identified recurring sequences of gaze-mouse behaviour [12]. The analysis of these eye gaze behaviour patterns has led to the conclusions, for example:

- The right area of the interface is not attractive for gazing even if presents useful information.
- During non-problematic task performance the number of fixations of the gaze and the dwell time of the gaze (> 250ms) is higher, compared to task performance where problems occur.

Swallow in [17] has proposed and tested efficacy of some usability problem indicators. These include indicators that count certain events, such as: number of times on-line help and undo action is invoked; number of times error and warning messages are triggered; number of times an action without effect is carried out. Other problem indicators proposed include: the same drop down and combo box is closed more than once; the same menu item/button selected more than four times; the same object is moved more than two times, etc.

- The mouse is a widely used device in web browsing. Users not only use the mouse pointer to manipulate interface elements but also use it to point to items displayed on the screen. When a user is unable to proceed with execution of a task s/he visually searches for the next option to try and often uses mouse pointer as a cue to point to various items on the screen. This behaviour gets reflected in the motion of the mouse pointer. Since the items/options are often arranged vertically or horizontally in a webpage, the user moves the mouse pointer in a narrow vertical or horizontal band, hovering the pointer over each option temporarily. We call this 'Vertical/Horizontal Mouse Movement' event pattern. The log shown in Fig. 2 exhibits this pattern. The shaded log segment, visualized as a plot in Fig. 3, clearly shows the horizontal and vertical movement of the mouse pointer. A browsing session log containing many such patterns could indicate a user facing interaction problems and spending time searching.

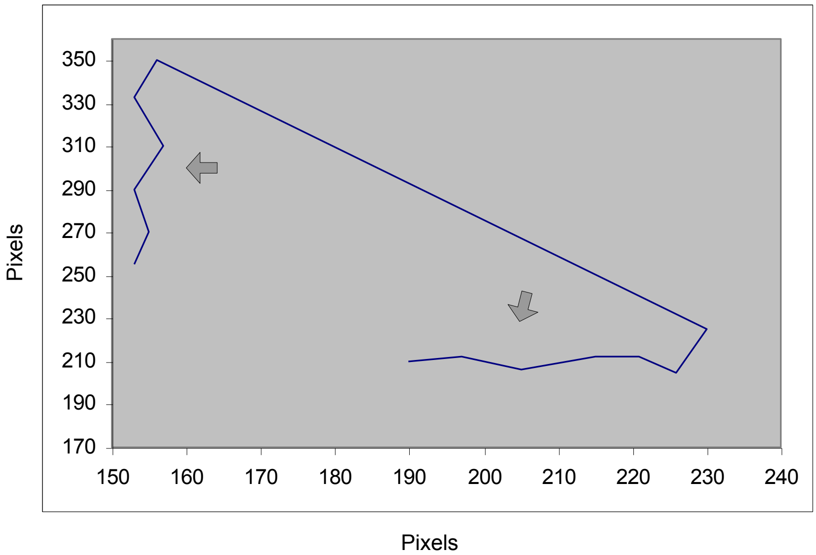

Fig. 3. Plot showing the 'Vertical/Horizontal Mouse Movement' patterns.

4. Proposed New Patterns

Through our own experience of web browsing and observing other users browsing we have come up with new event patterns that we believe result when a user faces interaction problems during browsing.

- Scrolling is another common activity that users perform during browsing. The advent of the wheel mouse has made scrolling more accessible to the user. We believe scrolling patterns reflect a user's reading and searching behaviour. A steady downward scrolling with pauses of almost constant intervals between scrolls indicates the user is engaged in reading the page. We call this 'Steady Scroll Down' pattern. The event log shown in Fig. 4 exhibits this pattern. However when a user is searching for information and skimming a page, s/he makes quick up and down scrolling actions with pauses of very short intervals between the scrolls. We call this 'Quick Up/Down Scroll' pattern. We visualize scrolling behaviour as the plot of the *percentages* of 'the page length viewed' and 'the total page view time'. Fig. 5 shows the typical such plots for steady and quick up/down scrolling patterns. In the plot for steady scrolling (not real), the user first starts by viewing 40% of the total page length s/he viewed (i.e. the browser window height), spends 40% of the total view time viewing this portion and then scrolled 10% and spend 10% time viewing before scrolling by another 10% and so on. We also use scroll/time (s/t) ratio to characterize scrolling patterns, where 'scroll' is the length of the page scrolled in pixels and 'time' the time page is viewed before the next scroll. We expect the average s/t ratio to be higher in pages with 'Quick Up/Down Scroll' patterns.
- A common page access pattern that emerges when users search for information across pages or when a user is lost in a website and tries to backtrack and go back to the pages s/he is familiar with is a pattern of a user accessing pages in quick succession without dwelling on a page for too long. We call this pattern 'Page Hopping'. In the short interval a user spends on the page, the user skims/scans the information on the page without reading it in detail and may scroll up and down quickly. We call the pattern of going from page to page with quick scrolling 'Page Hopping with Scroll'.

EVENT NAME			TIME (msec)	READ TIME (s)
PAGE LOADED	news.bbc.co.uk/m_e/658.stm		1727100	
MOUSE MOVE	(566,318)(892,180)		1728881	
SCROLL DOWN	0 182 1004 613	MWheel	1734288	READ END: 7
MOUSE MOVE	(892,177)(896,177)		1735836	
SCROLL DOWN	0 364 1004 613	MWheel	1772217	READ END: 38
SCROLL DOWN	0 546 1004 613	MWheel	1825601	READ END: 53
SCROLL DOWN	0 637 1004 613	MWheel	1864061	READ END: 38
SCROLL DOWN	0 819 1004 613	MWheel	1871109	READ END: 7
SCROLL DOWN	0 910 1004 613	MWheel	1900005	READ END: 29
SCROLL DOWN	0 1092 1004 613	MWheel	1914304	READ END: 14
MOUSE MOVE	(898,176)(898,176)		1921430	
SCROLL DOWN	0 1365 1004 613	MWheel	1939433	READ END: 25
SCROLL DOWN	0 1456 1004 613	MWheel	1989439	READ END: 50
SCROLL DOWN	0 1638 1004 61	MWheel	2012706	READ END: 23
SCROLL DOWN	0 1820 1004 613	MWheel	2054896	READ END: 42
SCROLL DOWN	0 1911 1004 613	MWheel	2071382	READ END: 16
MOUSE MOVE	(899,176)(899,176)		2083804	
SCROLL DOWN	0 2093 1004 613	MWheel	2084351	READ END: 13
SCROLL DOWN	0 2162 1004 613	MWheel	2109978	READ END: 25
MOUSE MOVE	(899,170)(181,0)		2130026	
PAGE EXITED	404		2131338	READ END: 21

Fig. 4. An event log showing 'Steady Scroll Down' pattern indicating that the user is reading the contents of the page. The second number after 'SCROLL DOWN' is amount scrolled in pixels while as the number after READ END is time spend on the page before the next scroll.

- Another common page access pattern occurs when a user keeps returning to a familiar page e.g. the home page, after accessing an unfamiliar page. The user never goes more than a page or two away from the familiar page, possibly for the fear of getting 'lost'. This access pattern is called 'Hub and Spoke' navigation pattern [19]. This pattern could also result from a website design, in which designer intentionally wants the users to follow this pattern or could result from a new user trying to explore the website.

We believe that the above event patterns could indicate users not browsing smoothly and resorting to search of some kind. Search is unavoidable during browsing or execution of a task and these patterns could appear in the event log of a normal interaction session, however, a longer duration and frequent occurrence of the patterns in many user sessions should alert the evaluators to possible usability problems.

5.1.1 Method

The experiment used standard usability testing techniques. Users where made to access a banking website, a shopping website and a search engine and made to execute the tasks listed below. We assumed these web applications and the tasks to be quite representative of the websites on the web and the tasks users perform. The users were encouraged to 'think aloud' during interaction. Screen video of the interaction, sound and event log was recorded for each user. Post-usability test interviews were conducted and the users were asked to describe the problems they encountered during interaction. The tasks users executed were the following:

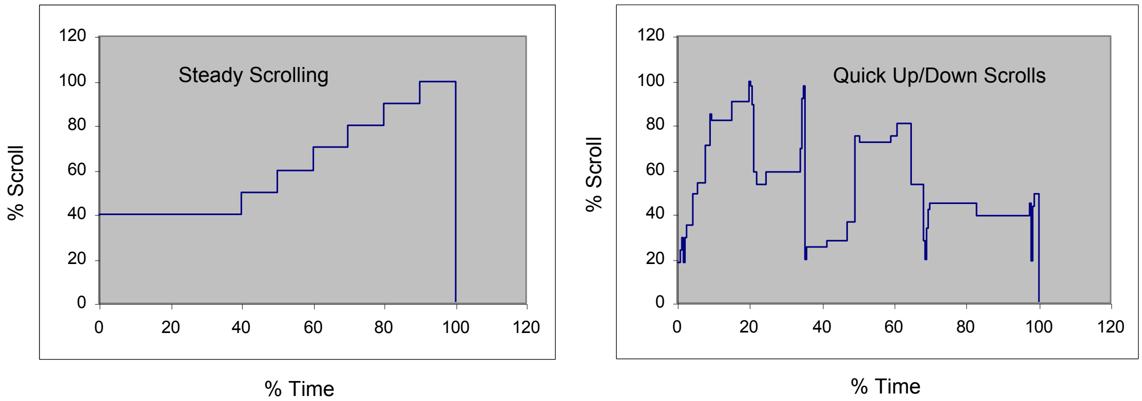

Fig. 5. Typical scroll-time plots for 'Steady Scroll Down' and 'Quick Up/Down Scroll' patterns.

5. Experimental Study

We conducted experiments to confirm that there is a connection between the above patterns and usability problems. We performed usability tests on a group of users or the test participants, making them access different web applications and execute a set of tasks that we had experienced usability problems with. Users' interaction was recorded with Morae, usability evaluation software. We observed that these patterns indeed get generated when users experience interaction problems with the user-interface.

5.1 Experiment 1

In this experiment the goal was to determine the truth of the hypothesis that *vertical/horizontal mouse movement* pattern gets generated when a user faces difficulty in deciding on the next action to take during a task execution, and/or searches visually lists of options presented on the screen, using mouse pointer as a cue to point to the options.

(i) Users were made to access a banking website and perform the task of finding exchange rate of a foreign currency. This task was well structured and had a clearly defined goal. From our experience with the website, we knew this task was rarely performed and not many users were familiar with it. We were also aware that first time users were facing difficulty with this task as it had been wrongly categorized in the menus and we expected many users to face difficulty with this task. (Task T1)

(ii) Users were made to access an online bookstore's website and choose an item to buy, such as, a book or a laptop. This task did not have a clearly defined goal since the users did not know what exactly was available in the online store.

The task goal evolved during the session into a more specific and clearly defined goal, for example, to 'buy a Toshiba'. This task required users to go through a list of items presented on a webpage. (Task T2)

(iii) Users were made to perform a keyword search through a search engine, and search for a particular document in the search results displayed. This was a task with a clearly defined goal and users had to go through a list of search results. (Task T3)

5.1.2 Results

The recordings of the test participants were analyzed using the Morae manager with focus on the mouse movements. The total time to complete task T1 was obtained and so was the time users spend moving the mouse pointer vertically or horizontally while going through the options on the screen. This information is presented in the Table 1.

Table 1. Results of experiment 1. Pattern time refers to the time users spend moving the mouse in horizontal or vertical bands.

Participant	Task	Task Experience	Task Time (sec.)	Pattern Time (sec.)	Pattern Time (%)	Problem Faced
1	T1	None	161.12	94.88	58.88%	Moderate
2	T1	Yes	47.76	7.37	15.43%	None
3	T1	None	102.62	40.42	39.38%	Moderate
4	T1	None	586.11	485.53	82.83%	Extreme
5	T1	None	160.70	70.76	44.03%	Moderate
6	T1	None	474.81	336.79	70.93%	Extreme
7	T1	None	46.58	119.12	39.10%	Moderate
8	T1	None	406.14	255.97	63.02%	Moderate
9	T1	None	206.81	140.27	67.82%	Moderate
10	T1	None	466.52	239.88	51.41%	Extreme

The users, who had no experience with task T1, faced moderate to extreme difficulty in executing the task. These users spent a high percentage of the task completion time (> 39%) visually searching and moving the mouse pointer vertically or horizontally. During post usability test interviews these users confirmed that during these intervals they had no idea how to proceed and were figuring out the next action to take.

During execution of the tasks T2 and T3 we hardly observed any vertical or horizontal mouse movement patterns and therefore the tasks do not appear in Table 1. We believe this was due to the fact that the options (i.e. hyperlinks to various products or search results) were spaced quite apart from each other on the screen and users seemed to have no difficulty in focusing their attention on them without using mouse pointer as a cue. We, however, noticed some users using the mouse pointer as a cue while reading text in the pages.

5.1.3 Limitations

It was difficult to choose test users with similar levels of familiarity with tasks T2 and T3. Some test participants were more familiar with online shopping of laptops than others and were able to perform task T2 with relative ease. Since no patterns were observed during the tasks this limitation did not affect the results.

5.2 Experiment 2

This experiment focused on event patterns generated from users' page accesses and scrolling behaviour within a page displayed in the browser. The aim of this experiment was to establish the truth of the hypothesis that: *steady scroll down* pattern indicates a user reading the contents of a page; *quick up/down scroll* pattern indicates user skimming or scanning the contents of a page while searching for a piece of information; and *page hopping* pattern indicates user searching for information in the website across pages.

5.2.1 Method

The test users where first made to access a news website of their choice and allowed to browse the site freely as they would do normally (Task T4). In this type of browsing the users have no particular goal in mind, their aim being to read anything they find interesting. As in experiment 1, the screen video of the interaction, sound and event log was recorded for each user. During the post usability-test interview the users were asked to recall the articles they felt interested in and read. The pages a user browsed were categorized according to the user claim as: pages about which user made no claim of interest or disinterest (N), pages user claimed to have felt interested in and read (R), and pages user claimed to have skimmed (S). From the observations and recordings made, we categorized user reading behaviour in a page as: having read the page (1), skimmed the page (2), scanned the page (3) and not having read the page (4).

Following the free browsing session, users were made to execute the following two tasks related to the browsing session:

i. Each user was asked to find a page from the pages just visited. The page was described to the user in such a way that it would not require the user to read the page in depth. For example, the user would be asked to ‘go to the page that has a certain graphic or a visible headline news’. The aim behind this task was to determine if the user would search for the pages by going from page to page until s/he would find it or give up, and thus generate a page hopping page access pattern. (Task T5)

ii. Each user was next asked to locate a specific piece of information from the pages they had visited during task T4. The piece of information was chosen to be such that it would require some reading (or skimming). For example, a particular fact embedded in the text of a page. The aim behind this task was to determine if the users would search by going from page to page and scroll up and down within the page to skim and search in the page to locate the piece of information. (Task T6)

5.2.2 Results

As before the recordings of the test participants were carefully analyzed using the Morae manager. The recordings of Task T4 were analyzed for scrolling patterns. We determined the amount of scroll and the time interval between scrolls from the event logs. This information is presented in the Table 2 for selected set of pages accessed. The recording and logs of Task T5 and T6 were analyzed for the page access patterns and the time a user spent on each page. This information is presented in the Table 3.

The scrolling patterns correlated well with the user reading behaviour in a page. We found that users, who were observed to have read a certain page, had scrolled *steadily* to the bottom of that page. Typical %scroll versus %time plot of such pages is shown in Fig. 6. Users, who skimmed and scanned the pages, had quickly scrolled up and/or down the page. The average S/T ratio, averaged over pages *read* by a participant, was lower than the average S/T ratio averaged over pages *skimmed* or *scanned*, for four out of five test participants (Table 2).

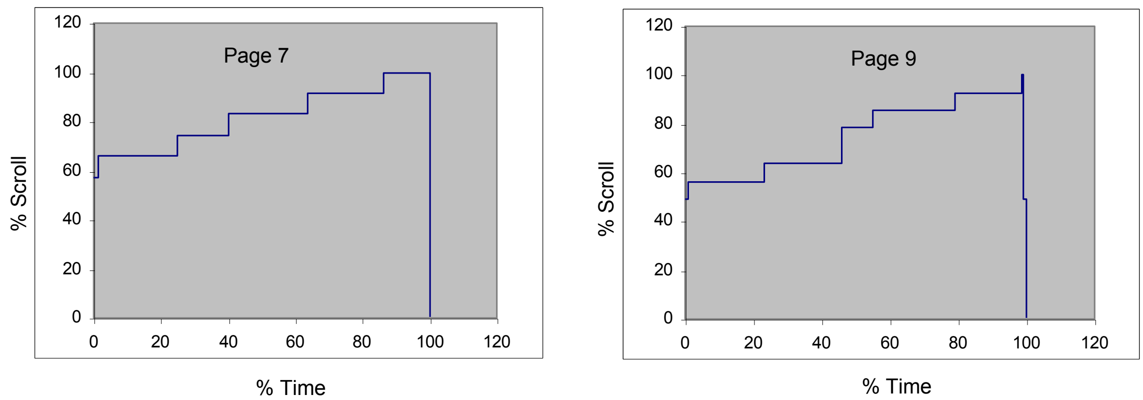

Fig. 6. Scroll-time plots for pages 7 and 9 read by user 1.

With regard to tasks T5 and T6 we observed that during execution of T5 users went quickly from page to page, in search of the page they were asked to find, and in the process generated a page hopping access pattern. During execution of task T6 users skimmed and scanned pages, scrolling up and down, searching for the piece of information they were asked to locate. We calculated the 'average time spent on a page' (ATP) during each task. For three out of five test participants, ATP during task T5 was less than ATP during task T6, indicating participants went quickly from page to page during T5. We also counted average number of scroll events per page (AS) during each task. Four out of five test participants performed less number of scrolls per page on average during task T5 as compared to task T6.

While calculating average S/T ratio for a page, we considered scroll ups as well as scroll downs. On closer examination we found that scroll ups always have a higher S/T ratio and users scroll up not to expose new text for reading but to recollect or refresh previously read information. Scroll/time ratios due to scroll ups are therefore extreme outliers that bias the average S/T ratio. We believe that averages are not enough. By using more sophisticated statistical measures we might get sharper values that would indicate more clearly whether a user read, skimmed or scanned a page.

Table 2. Selected set of pages accessed during task T4. Data for each page enclosed in square brackets includes page number, average s/t ratio, percent of the page viewed, user's claim of having read or skimmed a page and observation by evaluators.

User	(Page, Average S/T Ratio, %Viewed, User Claim, Observation)
1	[1,62.8,97.2,N,2][2,105.1,94.1,R,1][3,107.0,99.2,R,1][1,49.7,83.1,N,2] [4,43.5,87.7,R,1][5,80.1,78.6,N,2][6,3.9,64.5,R,1][5,191.9,66.9,N,3] [7,32.6,47.9,N,1][8,0.00,37.0,N,1][9,95.9,75.0,R,1][5,541.0,78.8,N,3]
	Avg. S/T Ratio for Pages Read = 64.7 Avg. S/T Ratio for Pages Skimmed or Scanned = 185.1
2	[7,255.0,84.9,N,3][9,58.9,94.1,R,2][3,69.4,84.2,N,2]
	Avg. S/T Ratio for Pages Read = N.A. Avg. S/T Ratio for Pages Skimmed or Scanned = 127.8
3	[3,111.0,23.9,N,2][7,120.3,24.34,N,2][16,66.1,85.3,R,1][17,60.8,83.1,R,1] [18,10.9,39.1,N,1][4,316.7,N,3][15,113.3,100.0,R,1][11,42.3,99.7,R,1]
	Avg. S/T Ratio for Pages Read = 58.7 Avg. S/T Ratio for Pages Skimmed or Scanned = 182.8
4	[3,89.4,51.3,R,1][8,28.2,16.4,R,1][2,83.9,62.8,N,1][11,129.8,18.5,N,1] [12,25.6,72.2,N,1][13,128.0,7.8,R,1][14,36.2,12.6,N,1][4,89.1,57.5,R,2] [5,47.5,33.1,R,2]
	Avg. S/T Ratio for Pages Read = 74.4 Avg. S/T Ratio for Pages Skimmed or Scanned = 68.3
5	[3,47.3,54.9,R,1][4,89.8,47.3,N,2][5,9.9,65.5,R,1][6,107.7,89.7,N,2] [7,29.4,100,R,1][8,50.6,23,N,2][7,605.9,88,N,2][10,102.4,100.0,N,2] [11,168.5,88.9,R,1][12,105.3,87,R,1][13,151.1,99,S,3][14,34.7,92.3,R,1]
	Avg. S/T Ratio for Pages Read = 65.9 Avg. S/T Ratio for Pages Skimmed or Scanned = 184.6

5.2.3 Limitations

It was quite impossible to ensure that all users had tasks T5 and T6 of similar level of difficulty; the reason being that it was difficult to design tasks T5 and T6 on the fly, immediately after a user had executed task T4. For example, user 2 was able to locate a page during task T5 after just two page accesses (i.e. after very little search) while as user 5 was able to do so after five page accesses. Similarly, user 3 found task T6 very difficult while as user 4 found it quite easy. This limitation can be overcome if the test participants are made to work with a website well known to the evaluators and made to locate more than one page and piece of information during tasks T5 and T6 respectively.

6. Discussion

The experimental results point to the fact that the new event patterns proposed by us are related to usability problems. Vertical/horizontal mouse movement is generated when a user is considering a list of options and is finding difficult to make a choice. Quick up/down scrolls could indicate that user is skimming or scanning the page to search for information on the page. Page hopping pattern of page accesses could indicate that user is having difficulty in locating a page in a website and is searching across the pages of a website.

Could normal user interaction generate one of these patterns? Or how likely is it that during normal interaction one of these patterns gets generated? The answer to this question needs an experimental study on a wider user population. For example, page hopping pattern could get generated when a user is just exploring a website. But in any case, presence of one or more of the above patterns in event logs should alert the evaluators to the possibility of a usability problem and make them take a closer look at what caused the pattern to generate. A closer look may reveal that the patterns resulted from normal interaction or a problem with the user interface. Other factors such as the duration and the frequency, with which they appear across many users logs, must also be taken into consideration.

There is a need to characterize the above event patterns more precisely. For example, precisely when is a page access pattern considered a page-hopping pattern? What should be the average time spent per page in a page-hopping pattern? This also requires an elaborate experimental study. Variables such as user reading speed and text font need to be taken into account [13]. This also applies to scrolling patterns. For what range of values of average S/T ratio can a scrolling pattern be considered as a steady scrolling pattern or quick up/down-scrolling pattern?

6.1 Future research

Considerable amount of research has been reported on extracting usability related information from the event data [9]. The detection of patterns in event logs is one such technique [16]. Detection techniques developed include use of regular expressions and grammars in describing the patterns and using matching algorithms to detect the patterns [7]. This research can be extended to the patterns described above and techniques could be developed to detect the above patterns.

Another area of research relevant here is web usage mining [8]. The above patterns can be mined from event log data collected on a large scale from the visitors to a website. The mining results can tell us, for example, how frequently a pattern is appearing in the event logs of different users.

7. Conclusion

Event logs can be collected very easily but their analysis is time consuming and expensive. There are certain event patterns that get generated when users face usability problems and therefore can act as indicators of usability problems. The contribution of this paper is the identification of new such patterns. These event patterns are: the 'vertical/horizontal mouse movement' pattern that gets generated when a user searches a list of items using mouse pointer as a

Table 3: 'Page Hopping' Pattern. ATP stands for 'average time spent on a page' and, AS stands for 'average number of scrolls per page'.

User	Task	Pages	ATP (s)	AS
1	T4	2,3,4,6,7,8,9	103	9
1	T5	1,2,3	8	3
1	T6	1,2,3	23	5
2	T4	N.A.	-	-
2	T5	5,6	23	3
2	T6	1,2,1,3,1,4	21	4
3	T4	16,17,18,15,11	152	11
3	T5	3,4,1,2	12	2
3	T6	3,4,7,8,7,4,1,2,1,4,7,6,7,9,7,5	35	7
4	T4	3,8,2,11,12,13,14	107	13
4	T5	2,3	24	3
4	T6	2,1,2	70	8
5	T4	3,5,7,11,12,14	305	15
5	T5	4,6,16,6,11	18	3
5	T6	4,5,4,6,7,6,10,12	13	3

cue; the 'steady scroll down' pattern that indicates a user reading contents of a page; the 'quick up/down scrolling' pattern that indicates user skimming or scanning contents of a page; the 'page hopping' page access pattern that is generated when a user searches for a particular page in a website; and the 'page hopping with scroll' pattern that is generated when a user searches for specific information in the pages of a website. The 'steady scroll down' pattern results from normal reading while as other patterns indicate user searching and finding it difficult to locate information or making a choice during browsing. Experimental study established the correlation between these patterns and users facing difficulties during browsing. We believe focusing on the segments of event logs where these patterns occur can save evaluation time.

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استخدام أنماط الأحداث مؤشر هام لحل مشاكل المستخدم

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ملخص البحث. أن جميع الأحداث تسجل بشكل أوتوماتيكي داخل سجل المستخدم يدعى لوغ. هذه الأحداث هي عبارة عن غزارة من المعلومات ترصد عند أستخدام أي برنامج على الكميوتر. ان تحليل هذه الكمية الضخمة من الأحداث داخل سجل المتسخدم يدويا لحل مشكلة ما يتطلب كمية كبيرة من الوقت. توجد بعض طرق أنماط الأحداث التي تستخدم من أجل تحديد الحدث المسبب للمشكلة بشكل أوتوماتيكي. هذا البحث يحتوي على طريقة جديدة من أنماط الأحداث التي تتطلب وقت أقل للبحث داخل السجل وتحديد المشكلة من الطرق المتبعة سابقا.