Visualizing User Interface Events
Event Stream Summarization through Signs

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Abstract: Effective visual representation is related to how people interpret signs created to carry specific information. In the last years many user interface evaluation tools are considering detailed usage data to represent users' actions. The volume of data gathered is leading developers to represent usage in a summarized way through graphical representations. If visual components used to represent complex data are not effective, then graphics used to summarize data may turn the interpretation of complex terms even harder. This work presents a study about graphical representations for user interface (UI) events and contributes with the validation of usage graph visualization and an open set of signs to support the summarization of client-side logs. The study involved 28 Information Technology specialists, potential users of UI evaluation tools. From the results one expects that evaluation tool developers, evaluators, and Web usage miners can reuse the validated usage graph representation and proposed set of signs to represent usage data in a summarized way.

1 INTRODUCTION

The evaluation of user interface (UI) is a key task when developing information systems and is part of a number of Software Engineering development processes. UI evaluation represents a way of verifying whether the whole system is communicating effectively and efficiently with users. In the Web, the heterogeneity of UIs and the wide range of UI elements that designers can use when composing UIs reinforce the role of UI evaluation.

Website evaluation can be made remotely or non-remotely. Non-remote evaluation requires participants to move to some controlled environment (e.g., usability laboratory) while remote evaluation allows participant and evaluator to be separated in space and time, without requiring them to move to a controlled environment (Ivory and Hearst, 2001). Thus, remote evaluation allows users to participate in an evaluation from anywhere, a key characteristic when evaluators want to consider accessibility or mobile devices.

Events can be defined as effects resulting from user's or system's action. They may occur at client-side or at server-side and often the collection of these events is called, respectively, client-side logs and server-side logs (Santana and Baranauskas, 2010a).

In the last decade, website evaluation tools using server-side data (i.e., based on Web server logs) became popular. They are used to analyze a number of metrics such as page-views, visited Web pages, referrers, landing pages, etc. Examples of tools that use server-side data are: Web Utilization Miner (Spiliopoulou and Faulstich, 1999), WebSift (Web Site Information Filter) (Cooley et al., 2000), WebQuilt (Hong et al., 2001), LumberJack (Chi et al., 2002), WebCANVAS (Cadez et al., 2003), and DCW (*Descubridor de Conhecimento en la Web*) (Domenech and Lorenzo, 2007).

On the other hand, data capture at client-side allows evaluators to discover more precisely how a UI is used, since one page-view may be represented by a stream of hundred of events representing the user's behavior. This characteristic makes client-side data a more adequate source to represent details of the interaction of users with UIs. However, using this data source also brings challenges concerning logging, transferring, summarizing, and presenting logged event streams. Examples of tools that use client-side data are: WebRemUSINE (Web Remote

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User Interface Evaluator) (Paganelli and Paternò, 2002), WAUTER (Web Automatic Usability Testing Environment) (Balbo et al., 2005), MouseTrack (Arroyo et al., 2006), MultiModalWebRemUSINE (Paternò et al., 2006), UsaProxy (Atterer and Schmidt, 2007), WebInSitu (Bigham et al., 2007), Google Analytics (Google, 2009), WELFIT (Web Event Logger and Flow Identification Tool) (Santana and Baranauskas, 2010), WebHint (Vargas et al., 2010), and WUP (Web Usability Probe) (Carta et al., 2011).

Considering the presented evaluation tools, it is possible to verify that there is a trend in the last decade towards the use of client-side logs as data source. In addition, the summarization of the captured data appears as vital task in order to get the behavior data contained in hundreds of log lines.

The literature counts on works that deal with the issue of representing behavioral data. The visual representation commonly considered in these works is via graphs, which allows the visualization of patterns (through edges' attributes) and actions performed by users (through nodes' attributes) (Santana and Baranauskas, 2010b; Spiliopoulou and Faulstich, 1999). In addition, Mutzel and Eades (2002) reinforce that graphs are the most common form of visualization provided by software.

In the context of evaluation tools, evaluators should easily grasp users' behavior when analyzing tools' reports. Usage graph is a type of report containing a directed cyclic graph in which nodes represent events occurred in a Web page and edges represent the sequence in which events had occurred (Santana and Baranauskas, 2010a). A usage graph representation was proposed in Santana and Baranauskas (2010b) after a comparison considering different representations of behavior through graphs. In the mentioned study authors presented that the maximum number of nodes is given by the product of the total Web page elements and the number of events tracked, not depending on the number of tracked sessions. The presented solution is a graph containing only textual data, which makes it difficult for an evaluator to analyze a usage graph representing thousands of events. In addition, such usage graphs require evaluators to know all events represented in the nodes, which usually is not the case as we will detail in Section 4.

Considering the previous mentioned works and trends as main motivators, our research aims at presenting such usage graphs in an efficient manner, converting as many textual information as possible into signs. Thus, the main goal of this work is to represent events through the use of icons. According to Peirce (1974), icons are the only way of directly communicating an idea.

The Peirce's Semiotics counts on deep studies regarding signs. Moreover, Peirce presents rich taxonomies and different and efficient ways of classifying signs in a precise way. The thorough study of signs made by Peirce corroborates the use of his works as the main theoretical reference.

In this context, this work's contributes with the validation of a usage graph representation and the proposal of a set of signs to represent UI events. The set is open and is available for the HCI (Human-Computer Interaction) community at http://argos.nied.unicamp.br:8888/welfit/images/. The set was designed, evaluated, and validated. These phases will be detailed in the following sections. Regarding the evaluation of the designed signs, works of Rubin (1994) and Wainer (2007) guided methodologically the experiment design, forms composition, bias avoidance, and conduction of evaluations.

This work is organized as follows: the next section summarizes the theoretical basis and the rational of the proposed signs; section 3 details the evaluation methodology; section 4 presents the results, and section 5 concludes and shows further directions.

2 BACKGROUND

It is not difficult to find open icon libraries for developing websites or GUI (Graphical User Interface), but there is no such availability of open library to represent UI events, indicating the need of such set of icons. A popular example of icon library is the Open Icon Library (2010). It is a consolidated source of icons for people to customize UI. It offers a free resource for developers looking for icons to use in their free/open projects and has more than 10,000 icons; none of them refers to UI events.

This work is theoretically grounded on Peirce's Semiotics. Semiotics can be defined as the discipline that studies signs and systems of signs. A sign (or *representamen*) is something that, under certain aspect, represents something to somebody, i.e., creates – in the mind of a person – an equivalent or a more developed sign (*interpretant*). Sign represents an object, not obligatorily in all of its aspects, giving an idea of the represented object (Peirce, 1974).

Peirce presents properties and details signs based on *trichotomies*. This work follows the most important *trichotomy* in which a sign can be classified as an icon, an index, or a symbol. The icon (Figure 1, A) is a sign that refers to the object as a result of *representamen's* characteristics. From its observation it is possible to discover characteristics of the object being represented. For example, a house drawing presenting its main characteristics (i.e., walls, door, and roof) in simple lines refers to the proper house object. The index (Figure 1, B) is a sign that refers to the object that it denotes as if the *representamen* was directly affected by the Object. An index has the cause-effect relationship between object and *representamen* and can also be seen as an organic pair between the *representamen* and the object. For example, when seeing smoke coming from a chimney the smoke is the effect that makes you think about what caused it. The symbol (Figure 1, C) is a sign that refers to the object it denotes by virtue of an established convention, law, or rule. For example, a road sign presenting the letter 'P' may indicate, by an established convention, a parking lot (Peirce, 1974; Rocha and Baranauskas, 2003).

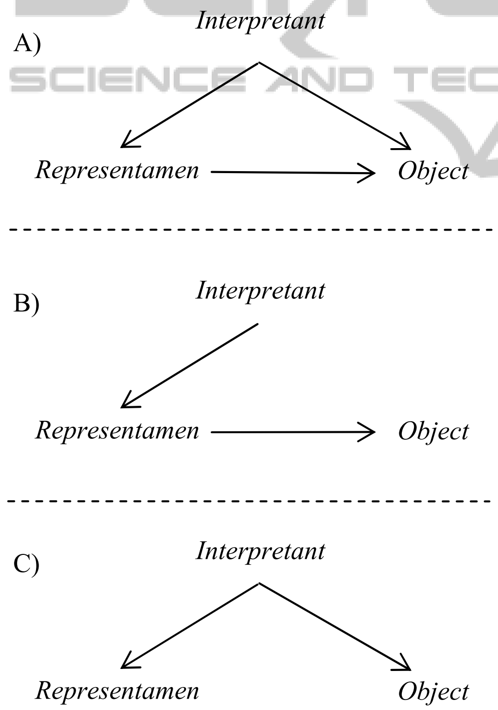


Figure 1: Relationship of terms of the *trichotomy* that defines: icon (A), index (B), and symbol (C).

Considering the chosen data source, the signs proposed to represent UI events are based on standard events (Table 1).

Bearing in mind that the only way of directly communicating an idea is through an icon (Peirce, 1974) and that reports displayed to evaluators should present the big picture of users' behavior (Santana and Baranauskas, 2010), then the rationale of the design of the signs to represent UI events focused first in creating effective icons. Then, in case of signs failing to be represented as icons, the fall backs were index, and, lastly, symbol.

Table 1: Standard UI events considered in the study (W3Schools, 2011).

Event	**Triggered when...**
Abort	the loading of a document or an image is cancelled
Blur	an element loses focus
Change	the content of a field changes
Click	the mouse clicks an object
Dblclick	the mouse double-clicks an object
Dragdrop	an element is dragged and dropped in a new position
Error	an error occurs when loading a document or an image
Focus	an element gets focus
Keydown	a keyboard key is pressed
Keypress	a keyboard key is pressed or held down
Keyup	a keyboard key is released
Load	a Web page or image is finished loading
Mousedown	a mouse button is pressed
Mousemove	the mouse is moved
Mouseout	the mouse is moved off an element
Mouseover	the mouse is moved over an element
Mouseup	a mouse button is released
Move	a window is moved
Resize	a window or frame is resized
Reset	all the content filled in a form is deleted
Select	a text is selected
Submit	a form is submitted
Unload	the user exits the Web page

It is worth mentioning that events related to concrete actions of users that are at users' and evaluators' sight were easier to represent as icons (e.g., click). However, signs representing events triggered by the browser (e.g., load) or as direct consequence of events triggered by users (e.g., change) were harder to represent as icons, falling back to symbolic or indexical representations. The relationship among these UI events and the classes of sign considered resulted in a mapping that supports the creation of new signs and it will be presented in the results section.

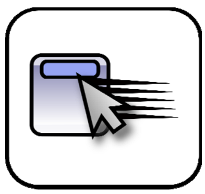


Figure 2: The Sign representing the *mouseover* event.

The creation of the signs involved a base element to represent a window-like abstract UI element, as presented in Figure 2.

UI events are commonly related to movements just performed. Thus, in order to represent them graphically, photographic streaking effect presented by McCloud (1994) was added in order to represent movements, actions performed, and state change (Figure 2).

In order to build other signs, the base UI element was combined with elements inspired in well known UI components (e.g., pointer and hand) and personal computer hardware (e.g., mouse and keyboard keys). However, some events are not triggered directly by users, for instance, load and abort. This reinforces the need of evaluating signs in order to represent this kind of events to evaluators.

3 EXPERIMENT DESIGN

The first set of signs was analyzed in an evaluation counting on 15 participants of a graduate discipline on Special Topics on HCI. The second set of redesigned signs counted on 13 participants of a graduate discipline on Design Patterns. Both of the classes were formed by software engineers that are potential users of such signs representing UI events.

There is no intersection or contact among these participants in order to avoid bias related to previous experience considering the interpretation of the evaluated signs, reports, and evaluation forms.

The second evaluation was done 9 months later, based on results of the first evaluation; this means that the signs were redesigned based on results of the first evaluation and then checked in the second evaluation. These two groups of participants were chosen because their profiles are part of the target population considered (i.e., potential users of UI evaluation tools). They are researchers, students, and professionals that would use an evaluation tool to analyze users' behavior.

The evaluations had three printed forms (A, B, and C) and a questionnaire to verify the representations used in the usage graph report. With these forms we also gathered data concerning gender, age, and profession of the participants. The instruments are detailed as follows.

Form A investigates the activity of interpretation of signs without context; this means that the signs were not presented in a meaningful order. The form has a 4 x 6 table containing the 23 proposed signs in random order, since some of them have a direct relationship (e.g., *keydown-keypress*) and placing them together or in alphabetical order might influence results. Along with each sign there was a bracket gap to be filled with an index representing the filling order and a gap to be filled with the meaning that the sign has for the user (e.g., the gaps pair [_] _____ could be filled as [1] click). Regarding instructions, the form A asked participants to write down the meaning of each image.

Form B focuses on presenting to participants a usage graph report representing a real usage of a Web page being evaluated by WELFIT (Santana and Baranauskas, 2010), one of the studied tools that considers detailed data. In the form B the participants were asked to write down the meaning of the usage graph report representing the usage (Figure 3). In other words, they were asked to identify the meaning of signs in a situated context.

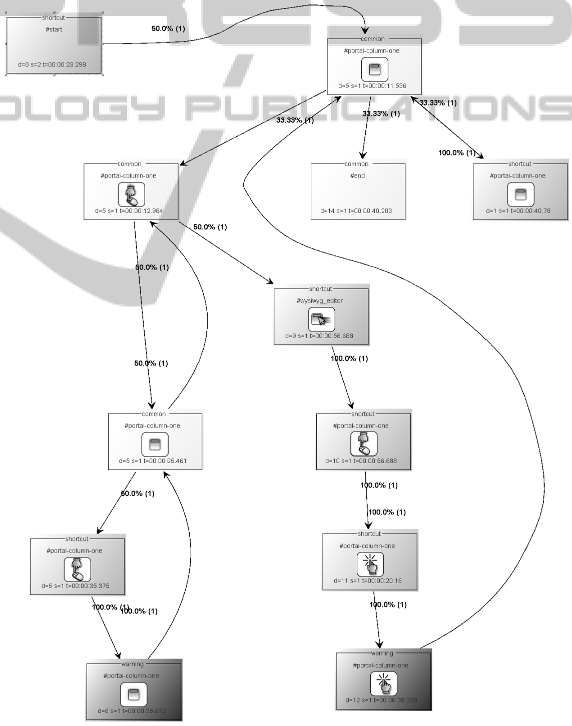


Figure 3: Overview of the usage graph that was part of the form B, representing the evaluated signs in a situated context.

The usage graph report uses the proposed signs in logical and meaningful sequence (e.g., *blur-focus*, *keydown-keypress-keyup*, *mousemove-click*). The usage graph was designed to help the identification of the detailed interaction of users with UI elements. Regarding instructions, the form B asked participants to describe what might have happened during the usage represented in the usage graph. It is worth mentioning that Figure 3 was resized in order to present the whole usage graph, just as would occur when using an evaluation tool if zoomed out; in this case the textual information are almost unreadable, but the signs can be identified. This example presents another context that motivates this study.

Form C was given to participants only after finishing forms A and B. The form C was used as a matching exercise between the signs and their intended meanings, using the indexes that participants had filled in the form A. This was done in order to verify the accuracy of the signs in a context of an Information System in which they will count on a legend to get signs actual meanings.

The final questionnaire was presented in order to try to identify weak points in the representation contained in the form B concerning information added to nodes.

The procedure of each of the two evaluations was the following: 1) At the first moment, half of the students (plus/minus one) received first the form A and then (10 minutes later) the form B. This group of students is referred from now on as **group AB**; 2) The other half received first the form B then the form A, referred from now on as **group BA**. This was done in order to verify the influence when participants were trying to identify signs' meaning without context (before the usage graph report containing the signs in a meaningful order) and vice versa; 3) Lastly, once both groups had filled up the forms that were given, then all participants received the form C and the questionnaire.

4 RESULTS AND DISCUSSION

The accuracy was measured considering the term filled by participants in the form A and if they matched the designer's pragmatics. If the term filled by respondents refers, in an unambiguous way, to the action/event being represented, then the sign was considered successful in communicating its meaning to the participant. For instance, one participant filled the term 'click' for the *mouseup* sign; then it was counted as not successful because there is another event named 'click'. Other participant filled the term with 'release mouse'; this was counted as successful.

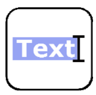
Table 2 presents the summary of evaluations and accuracy of signs. Considering participants' answers, the mean of answers that met the meaning of the event being represented, for each participant, were: in the 1st evaluation, 61.74% (standard deviation (s) of 19.11%); and in the 2nd evaluation 65.22% (s=15.68%). The low mean and high standard deviation of right answers per participant might be related to the following points: the strict and unambiguous analysis performed regarding the terms filled by participants, since some participants left blanks or filled the same term for more than one event; and, the difficulty of participants in defining events triggered by the browser.

Taking into account signs' accuracy, we obtained the following means: in the 1st evaluation, 62.61% (s=27.02%); and in the 2nd evaluation, 64.88% (s=25.28%). These results represented a small improvement considering redesigned signs.

Table 2: Summary of evaluations' results.

Attribute	1st evaluation	2nd evaluation
Participants	15 participants (12 males, 3 females)	13 participants (7 males, 6 females)
Mean age	28.35 years (s = 6.1 years)	28.09 years (s = 4.41 years)
Right definition for sign per participant (Total)	61.74% (s = 19.11%)	65.22% (s = 15.68%)
Mean accuracy of signs	62.61% (s = 27.02%)	64.88% (s = 25.28%)
Mean of correct matches between sign and event meaning (Total)	78.26% (s = 15.68%)	77.26% (s = 15.18%)
Mean of correct interpretations of the usage graph	40%	61.54%

Table 3: Examples of redesign results.

Event	1st evaluation		2nd evaluation	
	Sign	Accur.	Sign	Accur.
Click		33.33%		61.54%
Dblclick		33.33%		46.15%
Select		40.00%		69.23%

The best results (accuracy > mean accuracy + s) were related to the signs representing the events: in the 1st evaluation, *abort, mousemove, mousedown*, and *submit*; and in the 2nd evaluation, *abort, error, mousedown*, and *submit*.

The worst results (accuracy < mean accuracy - s) were related to signs representing the events: in the 1st evaluation, *change, click, dblclick, error, focus*, and *unload;* and in the 2nd evaluation, *change, mouseover, mouseout*, and *unload.*

In the last case, *unload* and *change* events were also present, revealing the most difficult events to be represented, this difficulty on designing them will be discussed in the next section.

Regarding lack of responses, the first evaluation had 4 empty fields (in the 15 forms A), two of them referring to the *change* and *unload* events. In the second evaluation, the 13 forms A had 8 empty fields, two of them referring to *dblclick* event.

Regarding the order in which gaps were filled in form A, it is possible to check what signs had quicker interpretation from the users. The signs defined first by the users were related to the following events: in the 1st evaluation, *abort, resize, dragdrop,* and *mousemove*; and in the 2nd evaluation, *abort, unload, dragdrop,* and *reset*.

The last ones defined, indicating that their meanings were harder to grasp, were: in the 1st evaluation, *mouseover*, *move, focus*, and *mouseup*; and in the 2nd evaluation, *dblclick, focus, mouseover*, and *mouseup*.

Referring to the validation of the usage graph as summarized representation of event stream data (i.e., form B) an improvement was also obtained. In the 1st evaluation the usage graph was correctly interpreted by 6 out of 15 participants (3 from group AB and 3 from group BA). The main problem in the descriptions filled by participants was related to the *click* event, since 6 out of 9 participants that interpreted the usage graph differently from what was expected informed that the *click* event was something referred to an 'mark as favorite' action. This reinforces our rationale in combining the two types of evaluation presented in this work, i.e., the signs seen in isolation and within the usage graph. In the 2nd evaluation the usage graph was correctly interpreted by 8 out of 13 participants (4 from group AB and 4 from BA group). The main issue here was related to the fact that each usage graph node was thought as referring to a Web page, which usually occur in evaluation tools considering page-view as the navigational unit. Table 3 presents samples of redesigned signs that helped in improving these results.

Considering form C, which was used to mach the event meanings with signs of the sheet A, as a matching terms exercise, the successful matching had a mean of 78.26% (s=15.68%) per respondent; and in the second evaluation the result was 77.26% (s=19.40%). This reveals that if the system using these signs was using a legend, no significant improvement should be expected. According to this point and to the amount of information present in a usage graph, it seems more adequate to consider tool tips than legend for the elements present in the usage graph. This suggestion was also made by some participants through the questionnaires.

The results obtained from the 1st and 2nd evaluations lead to some hypothesis considering the improvement of the signs in isolation and the usage graph. The hypothesis for the improvement in the accuracy of signs is that the redesign eliminated some of the elements that were leading to the misunderstanding on mapping signs to proper events, e.g., the click sign that was revoking the star element used in many websites for rating/ranking and the select sign that, after redesign, is representing more clearly the ongoing action. In addition, the hypothesis for the noteworthy improvement of the correct interpretation of usage graphs is that the redesigned signs improved the understanding of the whole graph and, consequently, the usage context. This point was reinforced by the fact that evaluators were not aware of all standard events of Web UIs, thus the interpretation of signs in a usage graph helps in decoding the signs considering the meaning of the whole context.

It was possible to check the differences regarding the evaluation of usage graphs and the interpretation for each single sign's meaning. Hence, the accuracy of signs is a key factor on understanding the entire usage graph. This outcome points out that, as presented before, interpreting the whole usage graph is easier than understanding the signs without context. However, it was also verified that improving single elements that compose the whole usage graph impacts significantly in grasping the meaning of the usage graph. In sum, the mean accuracy of signs improvement from 62.61% to 64.88% impacted on the improvement of the correct interpretation of the usage graph from 40.00% to 61.54%.

The difficulty of designing accurate signs was more present when referring to events that are distant from evaluators' perspective, i.e., is not part of the daily work of evaluators that do not work daily with Web pages event handlers. Consequently, it was harder to obtain a *representamen* to stand for such actions that, in turn, creates the desired *interpretant* in the mind of the participants. This was observed in different cases (e.g., *unload* and *change* events). In addition, after analyzing why some signs obtained better accuracy than others based on evaluations and on the Semiotics, we found a correlation considering the *trichotomy* and the categories of UI events. From that correlation, we present a mapping among the classes of signs and the three categories found (Table 4).

The three categories are related to events that are directly triggered by users, triggered as a result of events triggered by users, and events triggered by the browser as its natural functioning (i.e., without any direct connection with users events). The mapping can be used as a guide to design and organize new signs for representing client-side single events, composed events, and abstract events, since there are tools that consider this kind of client-side event abstractions, for example, Google Analytics (2009) and WUP (Carta et al., 2010).

Table 4: Mapping relating events according to their sources and the candidate class of Sign to represent it.

Candidate Class of Sign	Event category	UI events
Icon	Direct users actions	*click, dblclick, keydown, keypress, keyup, mousedown, mousemove, mouseout, mouseover, and mouseup*
Index	Effect of users' actions or abstract events	*change, dragdrop, move, resize, reset, select, and submit*
Symbol	Browser functioning	*abort, blur, error, focus, load, and unload*

5 CONCLUSIONS

Several user interface evaluation tools are collecting detailed usage data to represent users' actions. The volume of information demands a summarized way of presenting data through graphical representations. This paper presented a study on how to graphically represent detailed users' actions occurred at client-side, grounded on the Peirce's Semiotics. The proposed set of signs is a first approach to deal with the problem of the inexistence of an open library to represent UI events. The set of signs, now available to the Human-Computer Interface community at http://argos.nied.unicamp.br:8888/welfit/images/, was analyzed in order to adequately represent end users' behaviors to evaluators, achieving an accuracy that is close to the matching terms accuracy. In addition, the proposed signs were applied in a validation of usage graphs as a way of summarizing event stream data for evaluators.

A mapping of signs was presented, combining events, events categories, and candidate classes of signs to represent them. The mapping illustrates the complexity one has to deal with when designing icons in the context of usage visualization, especially when designing signs representing events that are not direct effects of users' actions. Thus, the mapping proposed may help designers who want to create signs for new UI events, guiding them in terms of what kind of sign to use and where to focus the pragmatics concerning the event to be represented.

The set of developed signs can be reused by other evaluation tools in order to represent users' behavior. Tools are gathering and presenting detailed usage data year after year, thus the HCI community is welcome to improve it.

Future works involve distributing the online versions of the forms and questionnaires used in this work to the community in order to allow the improvement of the proposed signs in large scale and to include new signs for events that are appearing along with emerging technologies (e.g., touch displays).

Finally, the complexity of UI is growing but events compose a defined set. Thus, in the very low level, UI events change a lot less than UIs, since they are coupled with technologies not with the use designers and developers make of it. New events are slowly appearing as those triggered by accelerometers. Even though, these new events can all be translated into signs and reported through usage graphs for analysis. Hence, a study regarding events of modern UIs and mobile applications are also considered for future work.

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