Navigational Complexity in Web Interactions

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ABSTRACT

As the web grows in size, interfaces & interactions across websites diverge - for differentiation and arguably for a better user experience. However, this size & diversity is also a cognitive load for the user who has to learn a new user interface for every new website she visits. Several studies have confirmed the importance of well designed websites. In this paper, we propose a method for quantitative evaluation of the navigational complexity of user interactions on the web. Our approach of quantifying interaction complexity exploits the modeling of the web as a graph and uses the information theoretic definition of complexity. It enables us to measure the navigational complexity of web interaction in *bits*. Our approach is structural in nature and can be applied to both traditional paradigm of web interaction (browsing) and to emerging paradigms of web interaction like web widgets.

Categories and Subject Descriptors

D.2.8 [**Metrics**]: Complexity Measures. H.1.2 [**User/Machine Systems**]: Human Factors, Human Information Processing. H.5.4 [**Hypertext / Hypermedia**]: Navigation, Theory, User Issues.

General Terms

Measurement, Human Factors, Algorithms.

Keywords

User interaction, complexity, widgets, graph theory, hypertext.

1. INTRODUCTION

'User interactions on the web' is not a homogeneous group – each website is designed differently & has a unique interaction experience. A quantitative evaluation of interaction complexity has potentially widespread applications for e.g. search engines can use interaction complexity as a parameter in ranking search results. We propose an approach to quantify the navigational complexity of web interactions. The rest of the paper is organized as follows. Section 2 briefly outlines the related work in quantitative measures for interaction complexity. Section 3 discusses our proposed approach. In Section 4, we give some examples of how our proposed approach can be applied. Section 5 discusses future work & concludes.

2. RELATED WORK

Efforts to quantify user interaction have a rich history. One of the early works which used a structural graph theoretic approach to quantify complexity was a Petri net based approach applied to an interactive (dialog-based) system [1]. A state (s_i) transition (t_j) matrix described all possible user actions to change from one dialog state to another. Thus, a user interaction was modeled as

$(s_1) \rightarrow [t_1] \rightarrow (s_2) \rightarrow [t_2] \ldots \rightarrow (s_n)$. Based on this framework & empirical data from user studies, the authors found that the measure which best captured interaction complexity was the cyclomatic number of the Petri net. For a graph G, of n vertices, e edges, & p connected components, the cyclomatic number is defined as $v(G) = e - n + p$. In a strongly connected graph, the cyclomatic number measures the maximum number of linearly independent circuits [3] – which can serve as the basis for generating the graph. Thus, as the number of potential flows in the interaction graph increases, the cyclomatic number grows correspondingly [2].

In recent work, the MAUSE project [7] is a collaborative effort to measure user experiences provided by graphical user interfaces, using multiple Usability Evaluation Methods (UEM). Comber [4] has focused on analyzing the complexity of layout design on GUI usability. Our work is different from these, in that we concentrate on measuring the navigational complexity due to the hypertext feature in web interactions. This work was, in fact, motivated by our prior work on Tasklets [6] that reduce web interaction complexity by packaging web interaction flows into widgets. We formulate a graph theoretic structural model to measure the reduction in complexity achieved by these widgets created automatically.

3. WEB INTERACTION COMPLEXITY

In this work, we focus exclusively on the interaction complexity due to the navigational complexity of a web interaction i.e. the cognitive load induced on a first time user on a website to achieve her goal. Our approach is structural in nature and independent of the interaction semantics & UI design which we are pursuing in future work. We start with the assumption that the start & end of the web interaction are known.
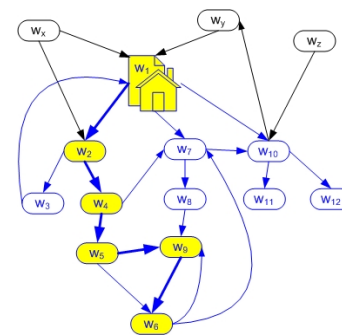

Figure 1 : An interaction flow through the web (highlighted).

To capture the complexity due to navigation, we model a web interaction as a flow (W) through a graph (set of web pages w_k) as highlighted in Figure 1. The interaction complexity of this flow should then capture the cognitive load due to navigation. If the user is on page w_i and should ideally go to w_{i+1} to achieve her goal, the cognitive load on the user is the *choice among the number of outgoing hyperlinks, r_i from w_i*. This notion is captured in eq. 1 below - the extra "1" in the eq. accounts for (a) the Back

button in the web browsers and / or (b) leaf web pages graph which have no outgoing link e.g. w_{11} & w_{12} in Figure 1.

$$p(w_{i+1}|w_i) = f(1 + r_i) \sim 1/(1 + r_i) \qquad (Eq. 1)$$

$$p(W) = p(w_1).p(w_2|w_1)\, p(w_3|w_2)\ldots\ldots p(w_k|w_{k-1}) \qquad (Eq.2)$$

$$p(w_1) = g(Page\ Rank(w_1)) \qquad (Eq. 3)$$

The exact form of function $f()$ will depend on whether & how we want to differentiate between outgoing links for e.g. it can incorporate UI design in future work. Under the simplifying assumption of treating all outgoing links homogeneously, eq. 1 reduces to $1/(1 + r_i)$.

Eq. 2 extends the model from a single web page to a flow over a web graph. We make the simplifying assumption that the probability of going from page w_i to w_{i+1} is independent of the path that led to w_i.

The value of p(W) has a range between $(0, p(w_1)]$. The upper bound of $p(w_1)$ is met when each node in the underlying web graph has just one outgoing link to the next node. The lower bound tends to zero as the cyclomatic number of the underlying web graph increases. The first term, $p(w_1)$ captures the probability of the user reaching the starting web page of the user interaction. This can either be '1' if the starting page of the web interaction is known or it can be defined using eq. 3 if the starting point of the interaction is reached via a search engine. The exact form of $g()$ is search engine dependent.

We now define an information theoretic measure of complexity. If we assume a random walker on the web, we can restate the navigational complexity in terms of the *'lack of information'* of a random walker to choose among the number of outgoing hyperlinks, r_i available on a web page, w_i. In information theory, entropy [5] measures the information content one is missing when one does not know the value of the random variable & is defined as $H(A) = -\sum_i p_i \log p_i$. Using this definition of entropy, with eq. 1,2 & 3,

$$H(w_i) = -\sum_{r_i} p(w_{i+1}|w_i)\log_2 p(w_{i+1}|w_i)$$

$$H(w_i) = -\frac{r_i}{1+r_i}\log_2\left(\frac{1}{1+r_i}\right)$$

$$H(W) = G + \sum_2^k H(w_i)$$

This entropy measures (in *bits*) the information content that a first time user is to be able to decide where to navigate on the web to achiever her goal. The form of G will depend on $g()$ in eq. 6. The above equations focus explicitly on defining a quantitative measure of user interaction complexity due to navigational complexity but other interactions such as form filling can also be included for e.g. if each potential user action on a particular web page w_i (e.g. a radio button) is taken to have an equal cognitive load a_i, then the interaction complexity can be modeled as,

$$p(w_{i+1}|w_i) = f(1 + r_i, a_i) \sim 1/(1 + r_i + a_i)$$

Thus, correspondingly:

$$H(w_i) = -\frac{r_i + a_i}{1+r_i+a_i}\log_2\left(\frac{1}{1+r_i+a_i}\right)$$

4. PRELIMINARY RESULTS

We applied our proposed complexity measure to a number of web interactions but we present only two here due to space limitations. In all cases, we assumed that the user knew the starting webpage of the web interaction needed to achieve her task/goal.

Getting local weather information from www.weather.com: starting page has 192 outgoing links, 3 radio buttons, 2 text boxes and 2 associated submit buttons. Accessing the weather information of a desired location requires 2 mouse clicks & filling out one form field. Thus, r_1=192 & a_1=7, p(W)=p($w_2|w_1$) = 1/(1+192+7)=0.005 & H(W)=199/200 $\log_2$(200)=7.61 ~ **8 bits.**

Getting personal horoscope from www.msn.com: starting page has 198 outgoing links, 4 textboxes & 4 associated submit buttons; second page has 169 outgoing links with 3 text boxes, 5 checkboxes, 3 buttons & 4 drop down lists with 2, 12, 31 & 110 drop down items respectively. Therefore, we have r_1=198 & a_1=8, r_2=169 & a_2=15; p(W)=p($w_2|w_1$). p($w_3|w_2$)=(1/(1+198+8)). (1/(1+169+15))=0.000026 & H(W)=206/207 $\log_2$(207)+174/175 $\log_2$(175)=15.07 ~ **16 bit**s.

Since widgets provide 1-button access to personalized information such as local weather or horoscope, H**(**W**)** also measures the reduction in interaction complexity achieved by a widget. This is mainly due to reduced number of user-actions required to achieve user's goal. A widget reduces the navigational uncertainty by capturing one of the many flows that are possible across a graph. Thus, the proposed measure, quantifies the reduction in navigational complexity achieved by a widget. The above example shows that a widget for getting horoscope has more value than the one getting weather information – purely from complexity reduction perspective.

5. CONCLUSIONS & FUTURE WORK

We have proposed a method to measure the navigational complexity of a web interaction. We have also shown how the proposed complexity measure may be applied to measure the reduction in interaction complexity due to a web widget. Our future work will (a) validate the proposed measure with user studies & (b) extend the proposed measure to account for UI design & non-navigational interactions like form filling etc.

6. REFERENCES

[1] Rauterberg, M. How to Measure Cognitive Complexity in Human-Computer Interaction, Cybernetics and systems research V2 (1996)

[2] McCabe, T.J. A Complexity Measure. in IEEE Transactions on Software Engineering. Issue: 4 (1976), pp. 308- 320

[3] C. Berge, Graphs and Hypergraphs. Amsterdam, The Netherlands: North-Holland, 1973.

[4] Comber T. and Maltby J.R. Layout Complexity: Does It Measure Usability? IFIP TC13 Intl Conference on HCI (1997). pp: 623 - 626

[5] C.E. Shannon, A Mathematical Theory of Communication, Bell System Technical Journal, vol. 27, July, October, 1948.

[6] Manjunath, G. et al. Creating Personal Mobile Widgets without Programming in Developers Track at 18th international conference on World wide web (2009)

[7] MAUSE project, http://cost294.org