Information Processing and Management 000 (2016) 1–15

Contents lists available at ScienceDirect

Information Processing and Management

journal homepage: www.elsevier.com/locate/ipm

Strokes of insight: User intent detection and kinematic compression of mouse cursor trails

Daniel Martín-Albo[a], Luis A. Leiva[b,1,*], Jeff Huang[c], Réjean Plamondon[d]

[a] Universitat Politècnica de València, 46022 Valencia, Spain
[b] Sciling, 46022 Valencia, Spain
[c] Brown University, Providence, RI 02912, United States
[d] École Polytechnique de Montréal, QC 06079, Canada

ARTICLE INFO

Article history:
Received 28 December 2015
Revised 6 April 2016
Accepted 13 April 2016
Available online xxx

Keywords:
Mouse cursor analysis
User intent
Segmentation
Compression
Synthesis
Kinematics
Sigma-Lognormal

ABSTRACT

Web users often have a specific goal in mind comprising various stages that are reflected, as executed, by their mouse cursor movements. Therefore, is it possible to detect automatically which parts of those movements bear any intent and discard the parts that have no intent? Can we estimate the intent degree of the non-discarded parts? To achieve this goal, we tap into the Kinematic Theory and its associated Sigma-Lognormal model ($\Sigma\Lambda$M). According to this theory, the production of a mouse cursor movement requires beforehand the instantiation of an action plan. The $\Sigma\Lambda$M models such an action plan as a sequence of strokes' velocity profiles, one stroke at a time, providing thus a reconstruction of the original mouse cursor movement. When a user intent is clear, the pointing movement is faster and the cursor movement is reconstructed almost perfectly, while the reverse is observed when the user intent is unclear.

We analyzed more than 10,000 browsing sessions comprising about 5 million of data points, and compared different segmentation techniques to detect discrete cursor chunks that were then reconstructed with the $\Sigma\Lambda$M. Our main contribution is thus a novel methodology to automatically tell chunks with and without intention apart. We also contribute with kinematic compression, a novel application to compress mouse cursor data while preserving most of the original information. Ultimately, this work enables a deeper understanding of mouse cursor movements production, providing an informed means to gain additional insight about users' browsing behavior.

1. Introduction

A website can easily find out where a user has been on their pages through server access logs, but this yields an incomplete picture of what their users were actually doing. In contrast, page-level interactions, derived from recorded client-side mouse cursor data, provide fine-grained information about users' browsing behavior. More concretely, to find out *what* content is consumed and *how* it was consumed at the page level, the website can record richer interactions such as cursor movements and hovering, scrolling activity, and text highlighting. These interactions can then be interpreted

* Corresponding author. Tel.: +34963878172.
E-mail addresses: damarsi1@upv.es (D. Martín-Albo), llt@acm.org (L.A. Leiva), ipm@jeffhuang.com (J. Huang), rejean.plamondon@polymtl.ca (R. Plamondon).
[1] Work partially conducted while affiliated with the Universitat Politècnica de València.

http://dx.doi.org/10.1016/j.ipm.2016.04.005
0306-4573/

into higher-level behaviors like reading and marking interesting text with the cursor, quickly skimming the entire page, or moving the cursor out of the way to the side (Leiva & Huang, 2015).

While browsing a website, users often have a specific goal in mind (e.g. purchasing an item), which arises from a decision process comprising various stages (Karimi, Papamichail, & Holland, 2015; MacKay & Watters, 2012; Sellen, Murphy, & Shaw, 2002). The execution of each stage is ultimately reflected by different mouse cursor movements, since they are initiated unconsciously at first and enter consciousness afterward (Haggard, 2011). In other words, "users first focus and then execute actions" (Leiva & Vivó, 2007). How to leverage this type of movements is still a subject of debate in the research community. For example, search engines can re-rank search results using what people click as implicit feedback (either personalizing results for individuals from their click history, or using aggregated data from past searches to improve the overall ranking), e-commerce sites can learn what parts of the page deter potential customers, and social networking sites can use aggregated usage metrics to improve the usability of their application. However, not all parts of a cursor movement have an explicit goal or intention, nor does every cursor coordinate have equal value to website developers or data scientists. Therefore, is it possible to automatically detect which parts of those movements have a high probability of bearing any intent[2] and discard the parts that have no intent? Furthermore, can we estimate the intent degree of the non-discarded parts?

The Kinematic Theory (Plamondon, 1995a) provides a well-established and solid framework for the study of the production of human movements. The Sigma-Lognormal Model ($\Sigma\Lambda$M) (Plamondon & Djioua, 2006) is the latest instantiation of this framework and has been used, among others, in graphonomics (Galbally, Plamondon, Fierrez, & Garcia, 2012; O'Reilly & Plamondon, 2009), handwriting (Djioua & Plamondon, 2009; Martín-Albo, Plamondon, & Vidal, 2014), gestures (Leiva, Martín-Albo, & Plamondon, 2015; Plamondon, O'Reilly, Galbally, Almaksour, & Anquetil, 2014), or reproducing wrist movement and eye saccades (Plamondon, 1995b). Furthermore, it has been shown that a computer mouse is reliable enough to be considered as a velocity acquisition device (O'Reilly & Plamondon, 2011). Yet to date, $\Sigma\Lambda$M has not been used to study mouse cursor movements on websites. There has never been any study into treating cursor trails as the result of complex human motor control behaviors. After all, given that a mouse cursor movement is a specific class of human pointing movement, it makes sense to use the $\Sigma\Lambda$M to study user intent on websites from mouse cursor trails. Our work is the first to model the movements themselves using the Kinematic Theory.

Moreover, transforming the cursor trail into a 6-parameter model reduces the dimensionality to something that is more easily interpretable. This simpler feature set can be applied e.g. to supervised learning algorithms that train classifiers of user intent or relevance based on cursor activity.

In this article, we contribute with a novel methodology to automatically tell mouse cursor trails with and without intention apart. We also contribute with kinematic compression, a novel technique to compress mouse cursor data while preserving most of the original information. Ultimately, this work enables a deeper understanding of mouse cursor movements production, providing an informed means to gain additional insight about users' browsing behavior.

2. Related work

In this section we first review previous work on mouse cursor tracking, in order to provide the necessary background for the reader. Then we discuss previous work on modeling human movements, which laid the foundations of the Kinematic Theory. In the next section we elaborate more on such theory and show its value to determine intent from mouse cursor trails.

2.1. Mouse cursor tracking

There has been an enormous body of research investigating user interactions from mouse cursor data. The first research projects modified the Web browser to collect cursor data, mainly to identify user interest in the page. In early work, Goecks and Shavlik (2000) modified a Web browser to record themselves browsing hundreds of Web pages. They found that a neural network could predict variables such as the amount of cursor activity, which they considered surrogate measurements of user interest. Claypool, Le, Wased, and Brown (2001) developed the "curious browser", a custom Web browser that recorded activity from 75 students browsing over 2500 pages. They found that cursor travel time was a positive indicator of a Web page's relevance, but could only differentiate highly irrelevant pages. They also found that the number of clicks on a page did not correlate with its relevance, despite the intuition that clicks represent links that users found appealing. Shapira, Taieb-Maimon, and Moskowitz (2006) developed a special Web browser and recorded cursor activity from a small number of company employees browsing the Web. They found that the ratio of cursor movements to reading time was a better indicator of page quality than cursor travel distance and overall length of time that users spent on a page.

There are several services, including commercial products (e.g., ClickTale, LuckyOrange, MouseFlow) that have offered cursor tracking analytics for website operators, typically presenting the data as heatmaps and replays. These services offer cursor interaction data to website developers to apply in usability analysis as they see fit. Leiva and Vivó released smt2ϵ (Leiva & Vivó, 2013), an open source cursor tracking toolkit that allows website owners to set up their own cursor-based analytics on their website. Their toolkit has been used by numerous website developers to track the cursor interactions from their own users.

[2] We refer to "intent" as "the user has a target position in mind".

Please cite this article as: D. Martín-Albo et al., Strokes of insight: User intent detection and kinematic compression of mouse cursor trails, Information Processing and Management (2016), http://dx.doi.org/10.1016/j.ipm.2016.04.005