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Using a cognitive model to generate web navigation support

Herre van Oostendorp[a,*], Ion Juvina[b]

[a]Center for Content and Knowledge Engineering, Institute of Information and Computing Sciences, Utrecht University, Padualaan 14, 3584 CH Utrecht, The Netherlands

[b]Department of Psychology, Carnegie Mellon University, USA

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Abstract

A computational cognitive model of web navigation is proposed. Based on theories and models of text comprehension and web navigation, the plausibility of the proposed model is discussed. The model was used to generate navigation support and this support was offered to users in real time during their navigation sessions, in two experiments. In the first experiment navigation support was offered in the auditory modality and it had a positive effect on user's task performance, especially for users with low spatial abilities. In the second experiment navigation support was offered in the visual modality and users positively evaluated it. Users navigated in a more structured way, judged the system as more usable, and perceived themselves as less disoriented. Support did also here lead to better task performance. Finally, some aspects concerning further enhancement of the validity of the proposed model and its practical relevance are discussed.

Keywords: Cognitive modelling; Individual differences; Web navigation; Navigation support; Information scent

1. Introduction

Several attempts to model cognitive processes involved in web navigation are based on the assessed semantic relevance of screen objects to users' goals ('information scent') (Kitajima et al., 2000; Pirolli and Fu, 2003). In a previous study we found out that not only semantic but also spatial processes are employed in web navigation tasks (Juvina and van Oostendorp, 2006). Based on this and also on other findings (Chen, 2000; Howes et al., 2002; Wen, 2003), we assume that assessing relevance of a particular screen object to the user's goal depends not only on user's knowledge about that particular screen object but also on the context of a navigation session, i.e. what has been done up to that moment, where the current position is represented in the information space, how close to the target the user perceives herself, etc. In this paper, we argue for considering 'path adequacy', that is the relevance of a navigation path to the user's goal, beside 'information scent', in modelling web navigation. A navigation path is a memory representation of the user's past selections. For instance, if the user has selected the links labelled 'car', 'loan', and 'payment', the path would be 'car loan payment'. Path adequacy is a measure of semantic similarity between a path and the user's goal. Including an incoming knowledge element in a path and recalculating path adequacy would be a way to determine whether the incoming knowledge element is consistent with the user's past selections and goal-relevant. We believe this would be a first step in modelling the role of contextual information in selecting specific navigation actions. Based on the model we propose, it is possible to generate goal-relevant navigation support.

The next section introduces the model of web navigation that we propose and its cognitive grounds. Then two studies are described which attempt to validate the model. In the end, results of these studies are commented and further developments of the model are suggested.

*Corresponding author. Tel.: +31 302 538711; fax: +31 302 513791.
E-mail addresses: herre@cs.uu.nl (H. van Oostendorp), ijuvina@andrew.cmu.edu (I. Juvina).

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2. A cognitive model of web navigation

There are various approaches in cognitive modelling of web navigation behaviour. Pirolli and Fu (2003) developed Scent-based Navigation and Information Foraging in the ACT architecture (SNIF-ACT), a computational cognitive model that simulates users performing web tasks. Their model predicts navigational choices, i.e., where to go next and when to stop (leave the website) based on the concept of information scent. Information scent is calculated as a mutual relevance between the user's goal and link texts based on word occurrences and co-occurrences in the Internet. Kitajima et al. (2000) introduced CoLiDeS—a *Co*mprehension-based *Li*nked model of *De*liberate *S*earch. CoLiDeS measures relatedness of a particular screen object to the user's goal (information scent) based on three factors: semantic similarity, frequency and literal matching. Semantic similarity is calculated based on co-occurrences between words and documents with the aid of an algorithm called latent semantic analysis (LSA). Miller and Remington (2004) model the common situation in which link labels are not fully descriptive for their targets or users are not knowledgeable enough to accurately assess the relevance of link descriptions to their goals. Their model, called method for evaluating site architectures (MESA), does not give an account for how link relevancies are assessed, but takes them as input. It rather focuses on effectiveness of various link selection strategies, given various link relevancies and site structures.

2.1. CoLiDeS+

We have made a few amendments to the CoLiDeS model (Kitajima et al., 2000). The altered model has been labelled CoLiDeS+, to indicate that it is a working version, shares the main assumptions with the original CoLiDeS, and is intended to eventually become an augmented model.

CoLiDeS compares a user's goal with link texts on web pages using LSA and selects the link that best matches the user's goal. The selected link is clicked on and the process of judging link relevance (information scent) and selecting a link is repeated until the user's goal is attained or the user gives up. CoLiDeS+ brings in the concept of 'path adequacy' as a complement to the concept of 'information scent'. Path adequacy is the semantic similarity between a navigation path and a user's goal. A navigation path is a succession of links that have been selected prior to a particular moment in a navigation session. Information scent pertains to the incoming information elements, whereas path adequacy indicates the goal-relevance of past selections. Based on both information scent and path adequacy, the user can decide whether a candidate information element is goal-relevant and consistent with past selections.

In a previous study (Juvina and van Oostendorp, 2006), we found two significant determiners of users' performance in web tasks: *spatial ability* (measured with a mental rotation task, Shepard and Metzler, 1971) and *domain expertise*. A linear multiple regression model with these two factors as independent variables explained 39% of the variance in *task performance*. Spatial ability was relatively more important (Beta = .50) than domain expertise (Beta = .39). Spatial ability was considered to indicate users ability to handle information spaces consisting of multiple web pages. Other factors such as *episodic memory* and *working memory capacity* were tested and found non-significant as predictors of task performance (not beyond spatial ability). *Working memory capacity* was a significant predictor of users *perceived disorientation*. In the same study, we also found that *path adequacy* (calculated at the end of the session) significantly correlated with *the rate of returning to previously viewed pages* ($r = -.48$), *spatial ability* ($r = .36$) and *task performance* ($r = .47$).

The correlations between spatial ability, path adequacy, and web task performance were considered evidence for the process of building a mental representation of the information space and operating on this representation during web navigation. By including the user's navigation path in the model by using path adequacy we aimed to making the model accountable (at least to some extent) for user's spatial cognition involved in web navigation. Therefore, in CoLiDeS+ selecting a link on a specific web page is a function of *goal* description, *link* description and *path* description.

CoLiDeS models mainly the ideal situation of forward linear navigation; backtracking steps are considered erratic actions. When no particular object on the current page sufficiently matches the user's goal, an impasse is said to have occurred. Solutions to impasses are only described and not computationally modelled by Kitajima et al. (2000). However, backtracking and impasses seem to be natural in web navigation and rather frequent (Cockburn and McKenzie, 2001; Wen, 2003). Therefore they need to be modelled within the same framework as forward linear navigation. Miller and Remington (2004) propose navigation strategies to deal with ambiguity of link labels or with users' errors in judging link relevance.

CoLiDeS+ tries to incorporate navigation strategies. First, it tries to prevent impasses by checking at each step for latent impasses based on path adequacy. A latent impasse occurs when path adequacy does not increase after selecting a link and it is a possible reason to switch the path. It is called latent because it only signals a possible path switch and it causes considering concurrent paths. If a concurrent path with a better adequacy is found, the current path is switched toward the concurrent one. If impasses still occur, CoLiDeS+ reacts with a strategy that we called 'next best' and it is to some extent similar with the opportunistic strategy of Miller and Remington (2004). 'Next best' means that not only the link with the highest similarity to user's goal is considered but also links with lower similarities provided that they contribute to an increase in path adequacy. And eventually the options of backtracking one or more pages or going to index pages are available.