Schoelles, M. J., Gray, W. D., Veksler, V. D., Gamard, S., & Grintsvayg, A. (2006, July). *Cognitive modeling of web search.* Paper presented at the 13th Annual ACT-R Workshop, Carnegie Mellon University, Pittsburgh, PA.

Cognitive Modeling of Web Search

Michael Schoelles, Wayne D. Gray, Vladislav Veksler,
Stephane Gamard, and Alex Grintsvayg

CogWorks Laboratory
Cognitive Science Department
Rensselaer Polytechnic Institute

A significant challenge for computational cognitive modeling is to develop high-fidelity models of web surfing. To successfully model the entire task both software and cognitive engineering problems must be solved. At ACT-R-2005, we addressed some of the software engineering challenges posed by the task of attaching an ACT-R model to a web browser (Gamard, Schoelles, Kofila, Veksler, & Gray, 2005). In this talk we focus on the cognitive engineering challenges posed by the need to navigate and search a near infinite number of heterogeneously designed web pages in pursuit of a weakly specified target.

PRIOR WORK

Our work builds on the pioneering efforts of others. The first effort to bring semantics into the search of an unbounded data source was SNIF-ACT (Peter Pirolli & Fu, 2003). The SNIF-ACT model replaced ACT-R's expected utility function with one that was derived from the Rational Activation Theory (Anderson & Schooler, 1991) of declarative memory. Choice of actions was based on the activation spread to memory chunks based on similarity to the user's goal. Similarity was based on metrics derived from the Pointwise Mutual Information (P. Pirolli, 2005) measure of semantic distance (MSD).

An important class of models of web surfing are those based in the Construction-Integration Architecture (Kintsch, 1998). CoLiDeS (Kitajima, Blackmon, & Polson, 2000) claims that the perceived relevance of the Web page text or image to the goal determines what the users act on. Like SNIF-ACT, the similarity of the text to the goal is based on a MSD. In contrast to SNIF-ACT, CoLiDeS uses Latent Semantic Analysis (Dumais, 2003) as its MSD.

CoLiDeS+ (Juvina, Oostendorp, Karbor, & Pauw, 2005) extends CoLiDeS with the concept of *path adequacy,* which is a history of the similarities computed. This approach performs similar to humans in that it ends up at the same page; however, the model takes more steps. Juvina attributes the differences in decision making to the weakness of LSA. In particular, the "general reading " corpus was used. Juvina proposes that a more specialized semantic space would have given better results.

The SNIF-ACT and CoLiDeS work suffers from two issues. First, neither class of models performs a realistic search of a web page. Although SNIF-ACT is based on ACT-R, it did not use ACT-R's perceptual-motor capabilities. As far as we know, CoLiDeS has no perceptual-motor capability. Although the lack of perceptual-motor capabilities are a realistic simplification for an initial effort, it means that neither SNIF-ACT nor CoLiDeS can account for search time or search order as a function of the visual layout of a page. In other tasks, perceptual-motor costs defined by time have been shown to act as *soft constraints* which determines people's tendency to plan versus act (Fu & Gray, 2006). Small increments in perceptual-motor costs may lead to large tradeoffs between interaction-intensive and memory-intensive strategies (Gray, Sims, Fu, & Schoelles, 2006). If the visual layout of a page affects search order, it is also affecting search time. Hence, high-cognitive-fidelity models of web search will have to take account of the endogenous influence of visual features on search order.

Second, both SNIF-ACT and CoLiDeS used different MSDs to compute relatedness. It has been shown that all MSDs are not functionally equivalent (Kaur & Hornof, 2005). It is not clear to what extent which MSDs mimic human relatedness judgments (V. D. Veksler & Gray, 2006) for what web-based tasks.

CURRENT EFFORT

Realistic models of web search require a realistic accounting of the time required to search each new web page. Search time and the success of finding the most related target depends on how many prior items are visited and the semantic relatedness of those items to the searched for information. The order in which a new page is searched may be partially depended on exogenous features such as a tendency to search a new page from top-down and left-right. However, it also depends on endogenous influences of the visual design of a display. Hence, our research has turned to incorporating visual saliency metrics (Itti & Koch, 2001; Rosenholtz, 2001) into our models. Likewise, we have been impressed by the diversity of results returned by diverse measures of semantic distance (Kaur & Hornof, 2005). The problems of directly comparing results of various measures of semantic distance are very complex and require the development of new methodologies to compare various MSDs under various conditions (V. D. Veksler & Gray, 2006).

We are building ACT-R 6 models that incorporate both MSDs and visual saliency metrics. In contrast to SNIF-ACT and CoLiDeS+, we employ ACT-R's perceptual and motor processes to perceive and act on web pages. We feel it is essential to model the whole task, since human search is influenced by visual features of the task environment. The model has the capability to represent in the ACT-R's visual memory a web page and to access or calculate in real-time any one of 20 MSDs to assess the semantic relatedness of found text to a navigation goal.

Our model is a work-in-progress and during the talk we will present some of the problems we have encountered in web surfing that are easy for humans, but difficult for ACT-R. Some of these problems are software engineering issues, others relate to the theory and functioning of various modules, while others may inform central assumptions of the ACT-R architecture. In any case, we believe the challenged posed by the web is one that the modeling community must face. The ability to search a near-infinite source for information and to interact with heterogeneously designed web pages presents a significant challenge to the state-of-the-art in computational cognitive modeling.

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