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Integrating Models of Human-Computer Visual Interaction

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Abstract
Predicting visual search behavior in human-computer interaction is a challenging problem. It is important for predictive modeling of human-computer interaction to integrate the visual search strategies identified in individual models in order to predict users' visual interaction with a variety of complex, real-world layouts. Individual research efforts have done well in developing models that predict users' visual search behavior for a single well-defined task. Considering the large variety of visual layouts users can encounter, many visual search strategies can come into play during visual search. This dissertation investigates principles for integrating strategies of visual search. These principles will be used to integrate four models of visual search from HCI literature.

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Introduction
Computational cognitive models — computer programs that simulate some aspects of human cognition and action — have been used to better understand how and why design decisions affect human-computer visual interaction. For example, the effects of icon complexity [1], hierarchical organization [2], and the relevance of link labels [3] have been investigated with cognitive modeling to better understand how these factors affect visual search. However, most existing cognitive models of visual search account for just one visual search strategy (the plans people use to visually search based on properties of the objects searched and the actual or expected layout being searched) at a time.

Cognitive modeling shows promise for allowing designers to test their interfaces early in the design cycle, delaying the need for expensive user testing. In order for cognitive modeling to reach its potential in HCI, the models must make predictions in a variety of tasks with a variety of layouts. Integrating existing models is a means of accomplishing this goal that capitalizes on models produced in past research.

This dissertation is a significant step in the direction of integrating cognitive models of human-computer visual interaction. This research will: (a) build theory and extend methodologies of model integration, (b) produce an integrated model of visual search that is more robust than the individual models, and (c) build theory of visual search for HCI.

Model Integration

Integrated models may be either multitask or single-task models. Multitask models involve two or more goals. For example, a model of driving and a model of cell-phone use can be integrated to predict the effect of cell phone use of driving [4]. Single-task models involve two or more strategies for accomplishing the *same* goal. For example, a model of the effect of word meaning on visual search and a model of the effect of a menu hierarchy on visual search can be integrated to predict the effect of the meaning of hierarchical group labels on visual search.

This dissertation proposes principles for integrating models of visual search that will extend and expand the principles proposed by Kieras et al. [5]. Kieras et al. investigate methods of multitask model integration (which they call managerial styles) that differ in the amount of temporal overlap in execution of the integrated models. The temporal overlap can be either conservative (i.e. serial) or liberal (i.e. parallel). Either one, however, assumes that the processes will be competitive. That is, there are two independent tasks that compete for the same resources and do not participate in a common task. With the integration of models for tasks like visual search, the integrated processes may cooperate on a single task.

Another aspect of model integration method, that of *cooperation level*, will be investigated in this dissertation. The models to be integrated can either work in cooperation or competition towards a common goal. *Cooperative* models work together to decide where to move the eyes next. *Competitive* models work independently to decide where to move the eyes next.

Using both temporal overlap and degree of cooperation produces four possible methods of integrating models of visual search shown in Table 1: conservative-cooperative, conservative-competitive, liberal-cooperative, and liberal-competitive. These four methods of integration will be used in this dissertation to integrate existing cognitive models of human-computer visual interaction. Figure 1 illustrates two of these integration methods.

Proposed Work

The dissertation consists of two major goals: the development of integrated cognitive models and the evaluation of the models with experiments.

Integrating Models

Four different models of human-computer visual interaction will be integrated: the icon search model [1], the hierarchical search model [2], the

Table 1. Proposed methods of model integration.

		Strategy Cooperation	
		Competitive	Cooperative
Temporal Overlap	Conservative	The strategies take turns deciding where to move the eyes next	The strategies alternatively assess where to move the eyes, but finally agree where to move the eyes next
	Liberal	The strategies race to decide where to move the eyes next	The strategies simultaneously assess where to move the eyes, but finally agree where to move the eyes

interdependence of link assessment model [3], and the local density model [6]. The icon search model explains the visual search of icons of varying complexity. The hierarchical search model explains the effect a menu hierarchy has on visual search. The interdependence of link assessment model explains the effect of word meaning on the visual search of menus. The local density model explains the effect of groups of menus that vary in density.

Two other issues will need to be addressed before all four models can be integrated. First, the visual search strategies of the icon search model and the interdependence of link assessment model will be instantiated in the EPIC cognitive architecture (a framework for building psychologically plausible models). These two models are currently built using another cognitive architecture, ACT-R (discussed in [1]). I believe this is the first research that will address integrating models from different cognitive architectures. Second, a means of predicting semantic similarity between words will be added to EPIC to support the interdependence of link assessment model. A semantic system that automatically predicts word similarity will be used (for example, [7]).

Two of the models [2, 6] have been integrated. The integrated model predicts the observed data from both of the original tasks quite well. While the original models predict the observed search times better than the integrated model, the integrated model predicts some eye movement data better than the original models. This initial exploration of model integration demonstrates the potential benefits for HCI: a model derived from integrating two models can predict user behavior for multiple tasks.

Evaluating the Integrated Models

The methods of model integration and the resulting integrated models will be evaluated with data collected from experiments. The stimuli and task of the experiments will be motivated by predictions made by the integrated models. If the different integration methods make contradictory predictions, this information will be used to inform the methodology of these experiments.

Search time, accuracy, and eye movements metrics will be used to compare the observed data from the human participants and predictions from the models. A detailed analysis of the eye movement data, as has been done in my previous work [6], will be extremely useful in this comparison. Based on these results, it is expected that some of the integrated models will predict the observed data better than the rest of the models. The models that predict the human data the best will be carried

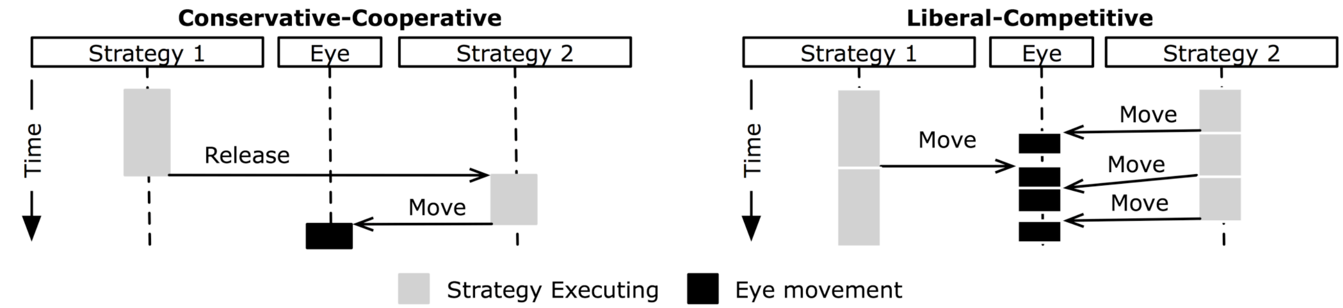

Figure 1. Timelines for execution of conservative-cooperative strategies (left) and liberal-competitive strategies (right). The arrows labeled "Release" indicate that one strategy is waiting on the completion of another. The arrows labeled "Move" indicate that an eye movement is waiting on completion of a strategy. Note that the strategies execute in series in the conservative method and in parallel in the liberal method. Also note that the eyes move after both strategies execute in the cooperative method and after either strategy executes in the competitive.

forward and used to predict human behavior in new HCI tasks.

Conclusion

Cognitive modeling is useful to the study of HCI. It aids us in considering design issues, predicting their effects, and explaining why these effects occur. This research will investigate methods of integrating cognitive models, and produce an integrated model that is more robust than any of the integrated models alone.

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References

[1] Fleetwood, M.D. and Byrne, M.D. Modeling the Visual Search of Displays: A Revised ACT-R/PM Model of Icon Search Based on Eye Tracking Data. *Human-Computer Interaction* (in press).

[2] Hornof, A.J. Cognitive Strategies for the Visual Search of Hierarchical Computer Displays. *Human-Computer Interaction 19*, 3 (2004), 183-223.

[3] Brumby, D.P. and Howes, A. Good Enough but I'll Just Check: Web-page Search as Attentional Refocusing. In *Proc. ICCM 2004*, Lawrence Erlbaum Associates (2004), 46-51.

[4] Salvucci, D. and Macuga, K.L. Predicting the effects of cellular-phone dialing on driver performance. *Cognitive Systems Research 3* (2002), 95-102.

[5] Kieras, D.E., et al., Modern Computational Perspectives on Executive Mental Processes and Cognitive Control: Where to from Here? in *Control of Cognitive Processes: Attention and Performance XVIII*, S. Monsell and J. Driver, Editors, MIT Press (2000), 681-712.

[6] Halverson, T. and Hornof, A.J. Explaining Eye Movements in the Visual Search of Varying Density Layouts. In *Proc. ICCM 2004*, Lawrence Erlbaum Associates (2004),124-129.

[7] GLSA @ PARC. [2006 January 11th] http://glsa.parc.com/index.wml.