A Model-Based Analysis of Errors in Display-Based HCI

*Muneo Kitajima†and Peter G. Polson**

†National Institute of Bioscience and Human-Technology
1-1 Higashi Tsukuba Ibaraki 305, JAPAN

*Institute of Cognitive Science
University of Colorado, Boulder, CO 80309-0344

phone: +81 298 54 6731
e-mail: kitajima@nibh.go.jp

ABSTRACT

This paper describes a model-based analysis of errors in expert use of graphical user interfaces. Two mechanisms, speed-accuracy tradeoffs and attention failures, were simulated by a model consisting of processes for display elaboration, selection of objects to be operated on, and selection of a next action. Both selection processes are performed in a context defined by the elaboration process, simulated by a sampling mechanism which uses knowledge in long-term memory for display comprehension. The model provides a well motivated account of errors made by expert users. Finally, the use of the model in interface evaluation is discussed.

KEYWORDS: errors, action cycle model, graphical user interface, display-based human-computer interaction

INTRODUCTION

The literature on errors has concluded that there are two qualitatively different types of errors[3, 5]. The first is errors of commission, or mistakes. Such errors are committed by users who are carrying out a novel tasks and fail to immediately discover the correct action sequence. The other is slips, where users have the correct intention but fail to successfully execute the correct action sequence. In this paper, two mechanisms of slips, speed-accuracy tradeoffs and attention failures, were simulated showing that they could account for the rate of slips made by expert users. Finally, the use of the model in interface evaluation is discussed.

Speed-Accuracy Tradeoff

A puzzling and frequently-ignored fact in HCI literature is that experts have surprisingly high error rates, in the range of 10 or 15%. Card, Moran, and Newell [1] proposed that experts accept high error rates in order to increase their productivity, because for them error recovery can be done easily and rapidly. They trade speed for accuracy, causing slips.

Submitted to CHI'94 Conference on Human Factors in Computing Systems (Boston, April 1994)

Attention Failures

Sellen [6] reviews classes of models that provide principled, qualitative accounts for errors. She argues that all of these models have a hierarchical representation of action sequences that include representations of top-level task goals and lower-level goals that actually control execution of elementary actions.

Reason [5] and many others argue that control of attention is a critical determinant for generating correct performance from such a hierarchical representation. Failure to adequately attend to the ongoing process and coordinate the interaction between the various schema causes a wrong low-level schema to become activated, generating related but incorrect actions for the current task. In HCI tasks, the users could be focusing on the task of composing new text or drawing a figure, and so on. This would lead to insufficient attention being allocated to subtasks involved in operating the interface.

THE ACTION CYCLE MODEL

This section describes a simulation model of display-based, human-computer interaction developed by us [2]. The mechanisms that produce errors are basic elements of the architecture and are not additional processes that have been added for the purpose of accounting for errors in expert performance.

Goal Formation and Display Representations

The model is given a representation of the user's goals and the display that resulted from the execution of the last action selected by the simulation. The display representation only includes information about identity of each object on the display and its visual status, *e.g.* highlighted. *No* information about the function of the object, what actions can be taken on the object, or its meaning and relationships to other objects in the display is included in this initial display representation. All such information is generated by the elaboration process from information stored in long-term memory.

Elaboration

The elaboration process is simulated by a random sampling process. The sampling process is governed by the strengths of the links between representations of objects on the display, the user's goals, and information stored in long-term memory. The parameters of the model determine the

strengths of the various links and the probabilities that each related item in long-term memory will be sampled. The strengths of the links to items associated with the goals are multiplied by *the attention parameter* which causes the elaboration process to increase the probabilities that these items will be incorporated into the elaborated display representation. A second parameter, *the elaboration parameter*, controls the number of times each item in the display and goal representations is used as retrieval cues. Values of 15 to 20 or greater cause the simulation to include all relevant information in long-term memory in the elaborated display representation. The model uses the elaborated display representation in its simulation of the processes that generate the next action.

Generating the Next Action

Object Selection. Of the 15 to 30 objects on the screen, the model limits its attention to 3 or 4 candidate objects when generating the next action. The object selection process is controlled by the elaborated display representation and is dominated by the strengths of links between the representation of the users goal's and the rest of the knowledge. These strengths are strongly influenced by the attention parameter.

Action Selection. The model considers all possible actions on each object. The model incorporates 18 possible actions, such as moving the mouse cursor to an item on the menu-bar in order to display a pull-down menu. The representation of each action is defined by combining a physical action like move the mouse cursor, single click, double click, and drag with representations of the purposes of the action and the properties of the object to be acted upon. The conditions are matched against the elaborated display representations. Observe that if information about a necessary condition is missing from an elaborated display representation, the model cannot perform that action on the "incorrectly" described object.

MODEL-BASED ANALYSIS OF ERRORS

Small values of the attention parameter cause the model to make errors because it does not focus on information related to user's goals during the elaboration process, and it fails to include the correct object in the set of candidate objects during the object selection process. Thus the model can simulate failures of attention.

Low values of the elaboration parameter cause the model to fail to incorporate all the conditions for the correct action in the elaborated display representation. This is the major source of errors. Parameter values in the range of 4 to 12 cause the model to simulate error rates in the range of 10% to 20%. We argue that the elaboration parameter describes a speed-accuracy tradeoff process where low values of the parameter reduce the amount of time taken by the elaboration process. Our model claims that many experts' errors are slips caused by failure to generate complete representations of objects on the screen.

MODEL-BASED EVALUATION OF INTERFACE DESIGNS FOR REDUCING ERRORS

The strength of our model is that it generates correct actions as well as occasional errors without assuming a special set of mechanisms to produce erroneous actions. The candidate objects and the next action selected by a simulation are the model's best selections given the context represented by the elaborated display representation.

The model enables a designer to anticipate the kinds of interactions that will lead to slips of the kind described in this paper. Requiring actions on objects that are not directly related to users' goals would force the model to generate a very complete display representation in order to select both the correct object and the correct action.

The Cognitive Walkthrough [4] methodology can be modified to enable a designer to detect such interactions. The current version evaluates the relationship among a display state, each step in an action sequence, and a new user's probable goals. Substituting the correct goals known to an expert user would enable the designer to evaluate the knowledge required to link a current goal to the correct action given a current display state that would appear in the interaction. Long inference chains can lead to errors because the elaboration process is more likely to leave out critical links in long chains. An action directly linked to a current goal and the current display will not be subject to perturbations in the elaboration process.

REFERENCES

[1] Card, S. K., Moran, T. P., & Newell, A. *The Psychology of Human-Computer Interaction.* NJ: Lawrence Erlbaum Associates. (1983).

[2] Kitajima, M. and Polson, P.G. A computational model of skilled use of a graphical user interface. *Proceedings of CHI'92 Conference on Human Factors in Computing Systems*. NY: ACM, pp. 241-249. (1992).

[3] Norman, D. A. Categorization of action slips. *Psychological Review*, **88**, 1-15. (1981).

[4] Polson, P.G., Lewis, C., Rieman, J., and Wharton, C. (1992). Cognitive Walkthroughs: A Method for Theory-Based Evaluation of User Interfaces. *International Journal of Man-Machine Studies,* **36**, 741-773.

[5] Reason, J. *Human Error.* New York, NY: Cambridge University Press. (1990).

[6] Sellen, A. *Mechanism of human error and human error detection.* Unpublished doctoral dissertation (1990).