A Process Model for Errors

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INTRODUCTION

In companion papers, Kitajima and Polson (1992a, b) present a computational model of skilled use of applications with graphical user interfaces like the Apple Macintosh. The model provides a well-motivated explanation of the fact that skilled users make surprising numbers of errors in carrying out routine tasks. In this paper, we describe the processes that generate such errors and characterize the error patterns predicted in different situations. We relate the processes in our model to Norman's (1981) analysis of human errors.

Our model is based on Kintsch's construction-integration theory of text comprehension (Kintsch, 1988). Mannes and Kintsch (1991) extended this model to the domain of action planning in human-computer interaction. Doane, Kintsch, and Polson (1990), and Wharton and Lewis (1990) have developed related models.

SKILLED READING AS A MODEL OF EXPERT PERFORMANCE

This set of models assumes that the expert user computes their next correct action based on their current goals and expectations, information contained on the display, and facts about objects represented on the display retrieved from long-term memory. Skilled performance is analogous to reading. A reader's task is to generate the contextually appropriate interpretation given many possible interpretations of a text. A skilled computer user's task is to select the contextually appropriate action out of many possible actions available at any given time.

This comprehension-based model is in contrast to standard models of skilled performance that assume that expert behavior is mediated by a detailed representation of the correct sequence of actions necessary to perform routine tasks (Anderson 1987; Bovair, Kieras, and Polson, 1990; Newell, 1990). Theories like ACT* (Anderson, 1983, 1987) and SOAR (Newell, 1990) provide well-motivated accounts of novice errors. They assume that early in learning, behavior is generated by problem solving mechanisms and that correct sequences of action are stored in memory as production rules. Skilled performance is based on a complete set of correct rules that are reliably retrieved from memory. In order to account for errors on the part of experts, such theories have to be augmented by mechanisms that would cause occasional failures to fire the correct rule, and mechanisms that would generate actions when a rule failed to fire, i.e., a repair theory (Brown and VanLehn, 1980).

SUMMARY OF THE MODEL

Correct Actions

The Kitajima and Polson (1992a) model performs a task by generating a sequence of low level actions like pointer movements, button clicks, and drag operations using a two-phase, action selection process. During the construction phase, a network representation of the current context is constructed including the user's current goal and expectation, a description of the current display, information retrieved from long-term memory, and representations of the possible actions. During the integration phase, an activation process selects the contextually appropriate action.

Kitajima and Polson (1992b) describe an extension of this model in which the next correct action is selected in a process that involves three construction-integration cycles. The first cycle selects the current expectation given the user's goal and the current state of the display. The second cycle, an attention process, determines which of the many objects displayed on the screen are correct candidates for being operated on by user actions given the current goal, expectation, and display. The third cycle selects an action given the current goal, expectation, attended to objects, and the contents of the display. Kitajima and Polson (1992a) report an extensive series of simulation experiments on the action selection processes; they gave the model correct sequences of expectations and candidate objects.

Errors

There are numerous failure modes in the construction-integration model. This paper focuses on the model's characterization of errors made by expert users performing routine tasks. We will assume that such users have correct goals, expectations, representations of the possible actions, and knowledge stored in long term memory.

The model predicts that such users can make errors due to a stochastic memory retrieval process incorporated into the construction phase. During action selection, the model uses the goal, expectation, and contents of the display to sample associatively related knowledge from long term memory. Large values of the sampling parameter make it almost certain that all relevant knowledge will be included in the network. Small values of the sampling parameter can cause the model to fail to include critical information in the network. This memory retrieval process is part of Kintsch's (1988) original model of text comprehension.

Sampling failures cause the model to build an incorrect representation during the construction phase. A skilled user fails to retrieve relevant information from long-term memory. As a result, critical information is missing from the network. The correct action may not be executable because its prerequisites are missing from the network, or the wrong action receives the highest activation because of the incomplete representation. We have assumed that the size the sampling parameter is determined by a speed-accuracy trade off process.

There are other error modes. The model may build a correct representation but the parameters describing the activation process are wrong, leading to an incorrect action receiving the highest activation. Another possibility is that the user has incorrect or incomplete knowledge and/or representations of actions stored in long term memory.

NORMAN'S TAXONOMY OF ERRORS

We have simulated the equivalent of Norman's (1981) notion of slips. In our current models, the simulation is provided with the correct sequence of goals and expectations required to perform a task. The representation of the current situation is constructed from information in the goal, expectation, and the display. It is then augmented by information retrieved from long-term memory by the probabilistic process. The information retrieved from long term memory is critical to the interpretation of the information contained on the screen.

If critical information is not sampled during retrieval, the simulation can make an error. However, the likelihood of an error is dependent upon the details of the current situation. If the correct action can be selected based on knowledge of the goal, expectation and information in the display, missing information from long-term memory will have no effect. If, however, the correct action is dependent upon the information retrieved from long-term memory, sampling failures will lead to errors. In our talk, illustrations of these various situations will be discussed in detail.

The basic distinction in Norman's (1981) taxonomy of errors is between mistakes and slips. In our model, mistakes would be due to the selection of an incorrect goal and/or expectation. The same retrieval failures can cause the model to select the wrong expectation or attend to objects that are not relevant to completion of the current task.

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