# Epistemically Active Adaptive User Interfaces

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**ABSTRACT**
An accurate model of the user is one of the most important factors impacting the success of adaptive user interfaces. However, the input information from the user may not be sufficient for construction of accurate user models. We propose epistemically active adaptive user interfaces that initiate subtle interactions with the user in order to collect new information about the user's state based on his responses (as in mixed initiative systems) or reactions to the probe. These epistemic actions can increase accuracy and decrease the computational cost of user modeling while requiring only low cost responses from the user.

**ACM Classification:** H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

**General terms:** Design, Human Factors

**Keywords:** adaptive user interfaces, user modeling, epistemic action, embodied cognition

## INTRODUCTION

Adaptive user interfaces try to improve user experience by tailoring the interface or contents to the user's background, expertise, needs and abilities. These systems collect information about the user to build a user model to determine the required adaptations [7,9].

Data collection may involve explicit self-reports and non-explicit inputs. Explicit self-reports are the data that user intentionally enters, such as age, disabilities or personal preferences. Non-explicit inputs are the ones that can be collected without asking from the user such as natural interactions, and psychological signals [7]. The analysis and discovery of patterns in the collected data helps the system to make assumptions about the user and shape the user model. However, due to inaccuracy and unreliability of user models [5], often there are often situations that the collected information is not sufficient for the adaptive interface to make correct decisions or shape accurate user models (e.g. in the first stages of empirically deriving a model). Many of these situations can be identified by the algorithm underlying the adaptation mechanism. For example, conflicting decision rules in rule-based systems, and low confidence classifications in Bayesian learning systems indicate the possibility of making a wrong adaptation decision.

Accuracy of adaptive systems might be the most important factor in determining the likelihood of the adoption of them. Accuracy of an adaptive interface can be defined as the percentage of time that the correct interface is provided to the user [4] or the temporal and spatial settings of the interface that are suitable for the user's characteristics (e.g. correct interface components are made visible, or the correct timing of interface events is chosen). In this paper we propose that effective adaptation decisions can be implemented in a process that begins with hypothesizing based on the user model, followed by verification and clarification through epistemic actions in the form of subtle interactions and implicit negotiations with the user.


*UIST'09*, October 4–7, 2009, Victoria, BC, Canada.

## EMBODIED COGNITION AND EPISTEMIC ACTIONS

The enactive cognition approach focuses on the primary role of interaction in the cognitive processes of intelligent systems. The world of an agent is brought forth by the structural coupling of the agent and its environment [10]. Kirsh & Maglio studied the performance improvements that can be achieved by the physical "epistemic" actions [8] that human agents use to uncover information that would be hard to compute mentally. This perspective leads to considering interaction with the environment as an active component of cognition, thus avoiding redundantly modeling and creating representations of the environment [1, 2].

Epistemic actions are implemented to improve the performance of pragmatic actions that actually implement a decision or plan, as when Tetris players rotate the tiles to simplify matching, or people sort the nuts and bolts before beginning an assembly task to accelerate the assembly process. Through performing epistemic actions, intelligent agents make small changes in their world that facilitate processes that will be required to accomplish bigger or more important changes that directly support achieving the goal. Therefore, enactive adaptive interfaces can be designed to initiate interactions with their world, the user, to collect information from the user's conscious or unconscious responses to subtle changes in the interface's appearance, behavior or content, that can clarify the situations involving error-prone adaptation decisions. Explicit dialogues with user have been used in mixed-initiative systems; however, many possibilities for collecting information through subtle interactions have not yet been explored.

An example of such interactions is the step-by-step decreasing of the screen brightness for power saving purposes. The reason for using a gradual process is to allow user to cancel the wrong adaptation decision before turning off the screen which might be embarrassing if user is focused. By this approach the cost of accurate user modeling is avoided.

Similar strategies can be used in delivering adaptive content. For example, in adaptive search, the results of adaptation can be mixed with non-adaptive results and the user feedback can determine if the adaptive results are more desirable and the adaptation can be safely used for the next set of results. Based on a prototype of an adaptive interruption manager other possible strategies for performing epistemic actions in adaptive user interfaces are described.

## EPISTEMIC ACTIONS IN AN INTERRUPTION MANAGER

Interruption managers are designed to find the right time for interrupting the user and delivering messages and notifications [3]. In order to manage interruptions in a web-based collaborative system, we designed a prototype of an adaptive interruption manager to minimize the required sensory information and to detect interruptibility state based on interaction patterns; i.e. it adapts the notifications to the interruptibility. Reinforcement learning is used as the basic algorithm for mapping interaction patterns to interruptibility states; however, the user model, derived based on the interaction patterns, was insufficient for performing the right adaptation. One of the ambiguous user states is when the user is not interacting with the system. The adaptive interface clarifies this situation by moving the cursor to the center of the component in focus (figure 1) to decide based on the user's reaction. A fast reaction in moving the cursor means that he is focused on the workspace, but ignoring the cursor means that he is not paying attention to the screen.

Even considering special situations like the above, the adaptation errors were still common; therefore, we decided to use a general strategy to avoid costly interruptions. When an opportunity for delivery is detected, a permission dialog asks the user if he wants to see the message. Although this is a basic strategy in mixed initiative interfaces [6], it can also be considered as an epistemic action which can reduce the cost of a pragmatic action; if an action is possibly costly, it makes sense to spend users' resources to avoid possible higher costs. In this case, a short interruption is used to avoid a possible attention demanding task. Similar strategies and interaction techniques for low-cost negotiations (figure 2) can help design more satisfying adaptive user interfaces.

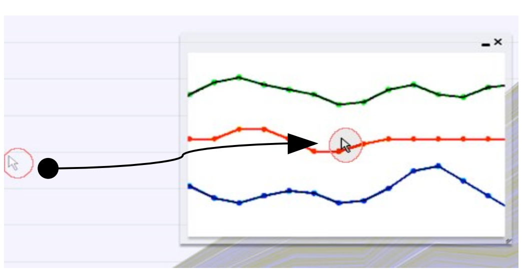

**Figure 1.** Epistemic action for dealing with "No interaction" state

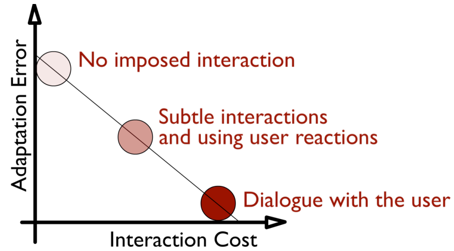


**Figure 2.** Subtle interactions may effectively decrease adaptation errors

## CONCLUSION

Epistemically active adaptive user interfaces can initiate subtle interactions with the user to resolve uncertainties about their hypotheses. They can use the user's conscious cooperation and feedback as in mixed initiative interfaces, but also they can take advantage of users' unconscious feedback and reactions through no-cost or low-cost implicit negotiations. These subtle interactions may increase the accuracy of the adaptations, while imposing very little additional burden on the user.

## ACKNOWLEDGMENTS

This work was supported by the Natural Sciences and Engineering Research Council of Canada.

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