Uncertain Case-Based Reasoning

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Uncertainty in Case-Based Reasoning (CBR) can occur due to three main reasons. First, information may be simply missing. For example, the problem domain may be so complex that it can only be represented incompletely. Even in simpler domains it is not always appropriate to describe a complex situation in every detail, but to tend to use the functionality and the ease of acquisition of the information represented in the case as criterion to decide the representation of a case. Second, for different problems, different features of the world and the problem description will play different roles in achieving a solution. In other words, the importance of problem description will often not be the same. Third, perfect prediction is impossible. We believe that there is no way to remove or reduce this kind of uncertainty from the problem. The best we can do is to select a course of action according to our expectation and understanding about the current situation, then keep track of the state of the world, learn more about the situation if possible, and adjust the actions dynamically (see for example work in reactive planning).

We propose a new methodological approach to CBR that allows it to use decision theoretic approaches to deal with multiple types of uncertainty. The retrieval of old cases in CBR is viewed as a decision problem, where each case from the case base provides an alternative solution and a prediction for the possible outcomes for the current problem. When uncertainty is encountered during case-based problem solving, decision theory is applied to evaluate each potential case in terms of the attributes that are significant for the current problem, so that the most desirable old case can be selected. Such integration provides a perfect complement between CBR and decision analysis.

The retrieval of a case or a set of cases from the case base is treated as a three-phase process. During the deterministic phase the system identifies potential decision variables. During the predictive phase the system identifies the possible outcomes. During the ranking phase a decision theoretic approach is used to evaluate the best case(s) based on the subjective probabilities assigned to the decision variables and the utilities of the possible outcomes. If new information becomes available the system must determine whether its previous decisions are consistent with the new knowledge, and, if not, perform retrieval again.

To demonstrate the application of decision theory in CBR we implemented a case-based reasoning system that uses a decision theoretic approach to perform case retrieval in instances of uncertainty. Our system chooses a preliminary set of cases based on surface similarity, determines decision variables, constructs a decision model, assesses probabilities to decision variables and utilities to outcomes, analyzes the decision problem at hand, and finally retrieves the best case. In the process of retrieval, if any value of a decision variable becomes known, the system will re-evaluate its decision to insure the most appropriate case is selected, thus reacting to changing information about the world and the problem.

Both CBR and decision theory have substantial limitations - CBR cannot handle uncertainty and decision theory is not good at alternative generation and outcome prediction. Our work lends support to the belief that an effective consultation system that integrates techniques of CBR and decision theory can be built to assist CBR in handling uncertain situations. This integration contributes in three ways: first, it makes the uncertainty problem in CBR easier to cope with; second, it actively formulates, evaluates, and appraises a customized model of the decision at hand that reflects the decision maker's available alternatives, his/her best information, and his/her genuine preferences; third, it enhances the ability of a CBR system to solve problems in which explicit consideration of tradeoffs is essential.