Conditional Actions, Context Dependent Actions and Information Gathering

Position Paper

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At Honeywell Technology Center, we are applying planning technology to help humans use complex automated systems. Some example systems are suites of NASA satellite image-processing programs for EOSDIS, schedulers for batch manufacturing processes and automated support for medical treatment protocols. The problem is one of providing what Pattie Maes [8] calls "indirect interaction:" allowing users to perform intuitively meaningful, high-level actions with simple commands. Unlike Etzioni [4], we are not concerned with demonstrating fully autonomous "softbots;" our goal is to provide semi-autonomous systems that work in cooperation with their human users.

Planning provides an appealing way to realize the goal of managing collaboration with automated systems. Planning algorithms, unlike many less-structured decision support methods, provide guarantees of soundness and completeness (when affordable!). When actions on the world are mediated through automated systems, it is easier to hold to the assumptions underlying conventional planners. Indeed, in our scheduling assistant project, all actions affect a schedule and are mediated through a scheduling program. Actions have already had to be formalized in order to write the underlying system, so the knowledge acquisition problem is simplified.

We have still found ourselves chafing against some of the restrictions imposed by the action models of conventional planners. We are particularly interested in issues of knowledge-producing actions and in conditional execution. Our early research efforts have concentrated on carefully analyzing the model of conditional actions first introduced by Warren [15] and later refined by Peot and Smith [13].[1] We have developed a planner based on this model and have carried out preliminary experiments generating image processing plans [5].

While conditional actions expand the repertoire of classical planners, there are still substantial limitations. This model assumes that the outcome of conditional actions will be known immediately. This is a good assumption for observation actions and for more gross actions like "drive the truck across the frozen lake, either reaching the other side or crashing through the ice to your death." The assumption does not fit cases where it is difficult or costly to determine whether or not an action has succeeded. For example, in order to evaluate the results of some image processing actions, it may be necessary to have the user (an Earth scientist) personally inspect the results. Finally, it is not possible to construct fail-safe plans — plans which can be executed without knowing whether a proposition is true or not. One form of McDermott's bomb problem [9] calls for a fail-safe plan. If there are two packages, one of which contains a bomb and it is not possible to observe the contents without triggering the bomb, then the correct plan is to submerge both packages. On a more mundane level, if one can carry out a sequence of steps that will achieve the image-processing goals of an Earth scientist, perhaps by applying redundant filters to an image, that may be preferable to constructing a conditional plan in which the user is required to inspect and evaluate intermediate results.

Pryor, in her work on the Cassandra planner [14], has used actions with context-dependent effects to model actions under uncertainty. These context-dependent actions are those of Pednault's ADL [12]. To model uncertainty, one permits secondary preconditions of actions to be unknown. Pryor also adds decision actions, which model choice points in the plan explicitly.

In previous work we have criticized the use of context-dependent actions to model uncertainty as being semantically ill-founded [7]. We have shown that to use context-dependent actions under uncertainty requires representation of the distinction between conditions in the world and the agent's knowledge about the world.

Accordingly, we are currently investigating ways of working with models of agent knowledge, with an eye towards providing a clear semantics and a sound planner. We believe that this modeling will provide a clearer understanding of the use of run-time variables as suggested by Etzioni, et. al. [3] It is our hope to provide a framework simpler than that of Moore [10] or Morgenstern [11], in order to permit us to work with relatively efficient planners.

In related work, we have investigated annotating conditional plans with probabilities [6] (our work in this area is similar to that of Draper, et. al. [2]). While we feel that this is a promising direction, none of our task

[1] These conditional actions are *not* the same as ADL's [12] *context dependent* actions.

domains currently displays a need for such uncertainty management, or holds out the promise of supporting the relevant knowledge acquisition.

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