8.0 Computer-Aided Planning

Introduction

A number of research efforts currently underway will markedly improve the state of the art and practice in computer-aided planning over the next several decades. Given the scale and significance of planning operations in the Air Force, even evolutionary-scale improvements can have enormous significance. We see four threads that will have important impact on planning.

8.1 Constraint-Based Techniques Will Vastly Speed Up Planning

Recent laboratory experiments have demonstrated significant speed improvements with a technique called constraint-based scheduling. This approach speeds the search for a schedule by incorporating into the search process knowledge about the constraints the schedule must meet (e.g., ordering of events, intervals between events). Recent lab experiments have created automated schedulers by combining a powerful general purpose scheduler with constraints from a specific task; the result is a single, new program capable of very high speed generation of schedules that meet the specified constraints.

We believe that work of this type will continue to provide advances, resulting in an additional two orders of magnitude improvement in the speed of schedule generation, permitting substantially more schedules to be considered during a planning operation, offering more and better options to command personnel.

8.2 Rationale Capture Will Enable Powerful Planning Systems

Detailed operational plans are often similar enough to one another to produce in planners a sense of déjà vu and frustration ("Didn't we just do something like this last month?"). Yet the plans are typically different enough to prevent straightforward reuse, resulting in a major (re)planning effort that repeats some substantial part of what may have been done recently.

One development that will help solve this problem is the capture of plan rationales, i.e., plans that indicate not only what to do, but what they were trying to achieve—their objectives—and why the actions given were selected as a way of achieving the goal (e.g., arguments for and against a particular action as a way of accomplishing an objective, underlying assumptions (such as troop strength) and estimates (e.g., likelihood of response)). Plans annotated in this fashion will have two important properties. First, they can be retrieved based on what they were trying to do, hence previous plans can easily be selected for review when a similar objective is encountered in the future. Second, where an off-the-shelf plan differs in its objectives from the current set of objectives, the off-the-shelf plan can easily be modified. Because actions are linked to objectives, such plans will have a kind of spreadsheet-like character to them: if objectives are deleted, the corresponding actions are easily identified, and if those actions now serve no other objectives, they can themselves be deleted. Because actions are annotated with explicit assumptions and arguments, where those assumptions or arguments differ, appropriate modifications to the plan are easily identified. An early version of this capability is the Air Campaign Planning Tool (ACPT) of the Air Force Pentagon Checkmate Office.

Such power will require development of sophisticated plan rationale description languages and advances in the technology developed to date to support only-line argumentation. While it

is relatively easy to imagine plans annotated with the sort of information described above, there is a formidable task involved in developing a language that a computer program can use to express, track, and reason about plans with nearly the same facility that is possible with spreadsheets containing numbers.

We suggest that within five years such systems will enable semi-automated planning and plan modification for applications such as transportation and force planning, using case-based reasoning, within the scope of one course of action. Within ten years we predict 90% automated plan selection and modification, over the scope of multiple courses of action.

8.3 Advances in Decision Theory Will Enable Adaptive Planning in Uncertain Environments

Advances in decision theory and reasoning about uncertainty will enable execution-time plan modification even in the highly uncertain environments characteristic of conflict. Numerous studies and extensive experience have shown that humans routinely err when faced with the need to reason with uncertain information. Advances in automated reasoning in this area have included developments such as belief nets, which provide an effective mechanism for expressing likelihood's and interdependencies of events. Some work has also been done on adaptive planning, i.e., the interlacing of planning and execution that is necessary when (as is typical in military environments) plans must be adapted to changing conditions.

Within ten years the combination of these two technologies will provide the routine ability to do adaptive planning in the face of uncertainty. In this world, plans will be formulated to take into account probabilities of various hypotheses, selecting the best option given the current best guesses, and will be appropriately modified in real time as additional information comes in or unanticipated events occur.

8.4 Multi-Agent Planning Will Permit Large-Scale Continuous Planning

A variety of increasingly powerful multi-agent planners will permit the integration of concurrent multiple viewpoints and, eventually, permit planning to be done continuously by multiple teams of people and software agents working together.

In the next five years we will see coordinated, multi-agent planning, by which we mean multiple programs and people working on a planning problem at the same time, "checking in" with each other as appropriate to coordinate their efforts. This will result in part from progress in computer-supported cooperative work (CSCW), but will build in important ways on AI work to automate planning (CSCW is aimed primarily at facilitating human work). One important payoff here will be the ability to automate planning that takes into account multiple perspectives (e.g., warfighter, supply, doctrine, etc.).

Five years beyond that we see the advent of *concurrent* multi-agent planning, by which we mean agents (both human and software) that are planning while in continuous contact with each other's efforts and results. The result will be a considerable speed-up in multiple perspective planning.

As these basic advances are made, impact of this technology area will depend significantly on advances in modeling and simulation: the effectiveness of any planner (whether human or automated) depends to considerable degree on the level of detail available for describing the resources being scheduled (e.g., capabilities of various transport vehicles, size, weight, range of warfighting equipment, etc.). As a consequence, we believe that coordinated parallel effort should be put into developing appropriately detailed and powerful models of Air Force equipment, so that these advanced planning techniques have the relevant raw material to work with.