Planning is (after a period of disfavour) a large, popular and growing area of AI. What I have attempted to do is point out some of the choices that have to be made when one wants to reason about action, and to sketch some of the planning systems that have made those choices in different ways. Those sketches try to extract what seem to be the central ideas of a piece of work. That has meant a presentation sometimes rather different from the authors' own.

At the end are listed some good general introductions to planning. If you want to find out about the most recent work, I recommend (Georgeff & Lansky 86), (papers all of a high standard), (Brown 87) and IJCAI-87 (which had a gratifying number of planning papers in it.) The principal omissions are: the interaction of planning and knowledge (for which I have given some references); conditional planning; planning and language; distributed planning; plan recognition; execution monitoring.

1. Introduction

Any general term, such as "planning", is going to have soft edges and defy definition. Here are some generalities.

The central idea of planning is the stringing together of actions to transform the world from a given state to a desired state, without problems. So, by the time one comes to execute an action in the plan, one can be sure that that action will be possible.

It is worth contrasting that with something else that gets called "planning", as in "factory planning", but which might be called "scheduling". Scheduling takes a partially ordered set of actions as a given, and tries to give each action a precise time and a precise list of the objects and resources it is going to use. Clearly planning and scheduling fade into each other.

Planning can also be seen as a special case of "planning" as in "town planning" or "planning a kitchen", where what is happening is that some objects (cookers, sinks) are being laid out in some space (here, physical space), such that each object imposes constraints on other objects around it; and not just that; one object (a gas cooker, say) may not just constrain other objects (eg not to intrude into its space) but may actually demand the existence of other objects (as a gas cooker demands the existence of a gas supply pipe.) Planned action can be seen as the special case of planning of this general sort, where the objects arranged are actions, and the space they are arranged in is time. In fact, seeing this generalization does not make planning actions any easier. It does however show a difference between planning and pure constraint satisfaction problems. Actions can be like the gas cooker. Not only do they constrain other actions, but they actually demand the existence of other actions, usually to ensure the truth of their preconditions.
Within the parts of AI concerned with reasoning, problems usually have three aspects: representation, inference, and control. This is true within planning. The ideal presentation of planning would identify the axes of variation of representation, inference and control, and locate the various planners that people have devised in the space thereby defined. That cannot alas yet be done. The decisions about one aspect are too strongly linked to decisions about another. But since doing that would be very worthwhile, here are the axes as far as I can identify them. The main questions in each are:

**Representation**

How shall we divide the continuous stream of the changing world? The main choice seems to be between taking as basic one of these two things:

- Some selection of temporal entities (instants, or intervals) with some structure imposed on them. The focus is on when things happen, and the next problem is, how are facts about non-temporal parts of the world (chairs, blocks, colours) associated with such entities?

- Some selection of entities such as actions, states and events, with some structure imposed on them. The focus is on what changes in the world, and the next problem is, What are the possible temporal relations of such facts and changes?

**Inference**

Given some divisions of the continuous world, what is the temporal relation between them? (Eg "Is A before, during or after B?") If some facts are associated with some of those divisions, what facts must be associated with the others? (Eg "If the cup was on the saucer before the door opened, is it still there after the door opened?")

**Control**

In plan-making proper, what one has to control is search through the space of possible plans, which are going to be some sort of partial description of a possible future world. This has a sub-task: controlling the deduction about what facts are associated with particular divisions of the world, and what the relations between them are.

What approaches give one good control? Production systems? Strategies proposed to control deduction, as in mathematical reasoning? Constraint satisfaction? Self application of planning, leading to meta-planning?

2. The frame problem: what makes planning hard

2.1. The problem

Here is a review of the frame problem, followed by a discussion of some of the ways that it has been dealt with. Those ways show the difference between worrying about the correctness of one's representation and the efficiency of one's planning.

The most obvious way to divide the continuous world up is to divide it into states, or as they are often called in this context, "situations". History is sequence of states. Each state is associated with a set of facts. A change in