Artificial Intelligence

Planning Agent

Outline

- Search vs Planning
- STRIPS Operators
- Partial-order Planning
- Scheduling Actions
- What can go wrong?

Search vs Planning

- Planning is the process of finding a sequence of steps to solve a problem before actually executing any of the steps.

- Search and planning have many similarities.

- The major difference between search and planning is in the representation of states. States in search are blackboxes, their internal structure is not used by search algorithms.

	Search	Planning
States	data structures	logical sentences
Actions	code	preconditions/outcomes
Goal	code	logical sentence (conjunction)
Plan	sequence from S_0	constraints on actions

Classic Planning

- States have structured representation (collection of properties) that can be used by planning algorithms.
- Planning system do the following:
    - open up action and goal representation to allow selection
    - divide-and-conquer by sub-goaling
    - relax requirement for sequential construction of solutions
- Assumptions:
    - Environment is deterministic
    - Environment is observable
    - Environment is static

STRIPS operators

- STRIPS planning language (Fikes and Nilsson, 1971)

- Tidily arranged actions descriptions, restricted language
  Action: Buy(x)
  Precondition: At(p), Sells(p, x)
  Effect: Have(x) [, ¬Have(‘Money’)

- The language abstracts away many important details.

- Restricted language allows efficient algorithm

  - Precondition is conjunction of positive literals

  - Effect is conjunction of literals

- A complete set of STRIPS operators can be translated into a set of successor-state axioms

Totally/Partially Ordered Plans

- A totally ordered plan is a linear sequence of actions.

- Often it doesn't matter in which order some of the actions are executed.

- For problems with independent subgoals, it is often easier to find a partially ordered plan: a plan which is a set of actions and a set of constraints before(a_i, a_j).

- Partially ordered plans are created by a search through a space of plans (rather than the state space).

Partially Ordered Plans

- Partially ordered plan consists collection of steps with
  - Start step — has the initial state description as its effect;
  - Finish step — has the goal description as its precondition;
  - causal links — from outcome of one step to precondition of another step;
  - temporal ordering —between pairs of steps.
- Open condition is a precondition of a step not yet causally linked.
- A plan is complete if and only if every precondition is achieved.
- A precondition is achieved if and only if it is the effect of an earlier step and no possibly intervening step undoes it.

Planning Process

- Operators on partial plans:
  - add a link from an existing action to an open condition
  - add a step to fulfill an open condition
    - order one step with respect to another to remove possible conflicts (demotion/promotion)
- Gradually move from incomplete/vague plans to complete, correct plans
- Backtrack if an open condition is unachievable or if a conflict is unresolvable

Time

- In classical planning, we assume that:
  - actions are instantaneous
  - action preconditions must hold before the action is executed and the effects of the action persist indefinitely

- Many planning problems are more complex:
  - actions take time to execute
  - preconditions may need to hold when the action begins, or throughout the execution of the action
  - effects may not be true immediately and theire effects may persist for only a limited time.

Resources

- Time is a particular instance of a resource.
- A resource is any quantity or (set of) object(s) whose value or availability determines whether an action can be executed.
- resources may be consumable or reusable.
- In some cases, actions may produce resources.
- When planning with resources, a solution is defined as a plan that achieves the goals while allocating resources to actions so that all resource constraints are satisfied.
- Many planners treat time as a special case.

Scheduling Actions

- One approach is to plan first and schedule later.
- Split the overall problem into:
  - a planning phase in which actions are selected and partially ordered to achieve the goal(s)
  - a scheduling phase in which temporal information is added to the plan to ensure it meets resource and deadline constraints
- Assumes that plans have minimal ordering constraints required for correctness.

Computing ES and LS for Actions

- ES — Earliest start time; LS — Latest start time
- ES(Start_action) = 0
- ES(B) = $MAX_{A<B}$(ES(A) + Duration(A))
- LS(Finish_action) = ES(Finish_action)
- LS(A) = $MIN_{A<B}$(LS(B) - Duration(A))
- Complexity of computing ES and LS is O(Nb) where N is the number of actions and b is the maximum branching factor into or out of an action.
- Critical path is the sequence of the actions whose ES and LS are the same.

Integrating Planning and Scheduling

- The approach of planning first and scheduling the actions next is simple, but not complete.

- Intuitively obvious that it may be necessary to take resources into account when choosing which actions to perform

- For completeness, we can integrate planning and scheduling—consider the time and resource implications of choosing a particular action when generating a plan.

Things go wrong

- Incomplete information
  - unknown precondition
  - disjunctive effects
- Incorrect information
  - current state incorrect
  - missing/incorrect effects in operators
- Qualification problem
  - can never finish listing all the required preconditions and possible conditional outcomes of actions

Solutions

- Conformant or sensorless planning
  - devise a plan that works regardless of state or outcome
- Conditional planning
  - plan to obtain information — observation actions
  - sub-plan for each contingency — expensive because it plans for many unlikely cases
- Monitoring and replanning
  - assume normal states, outcomes
  - check progress during execution, replan if necessary
  - unanticipated outcomes may lead to failure

Summary

- Planning is important.
- Planning is difficult.
- Planning is complicated.