Automated Planning in the Real World (tm)

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Summary

- (More or Less Successfull) Applications of Planning:
  - Planning in Space.
  - "Intelligent Control".
  - Project/Operations Planning.
  - Project/Operations Scheduling.
- Why Is It So Hard, or Is It Really That Hard?
  - What to Automate?
  - Knowledge Engineering.
  - Domain Complexity & Scaling.
  - Plan Management.

Planning in Space

- The Remote Agent Experiment (RAX):
  - Experimental AI system – including a planner – commanded DS-1 probe for a few days in 1999.
- MAPGEN: Mars Rover Daily Planning.
  - Mixed-initiative planning/scheduling system used by ground staff to generate rover plans.
  - Over-subscribed problems, complex time/resource constraints, but "causally simple".
- Constraint-based planner/scheduler (HSTS/Europa) integrated with domain-specific solvers.
- Still requires (highly tuned) domain-specific search control.

Planning as Intelligent Control

- On-line problems: New goals arrive while plan executing.
- Schindler's Elevator Destination Control:
  - Passengers input destination before entering the elevator – system allocates elevators to waiting passengers to optimise, *e.g.*, mean wait or travel time.
  - Can be modelled as a (almost classical) planning problem, but domain-specific implementation required for efficiency.
- PARC's Flexible Printer Control:
  - High-speed printer constructed from multiple (standard) print units and flexible, redundant "paper path" elements – plan moves and operations for each sheet in turn, respecting sheets already in progress and output order.
  - Domain-specialised implementation of general (domain-independent) planning techniques sufficiently expressive and efficient.

Project/Operations Planning

- "Crisis Response" Scenarios:
  - Oil-spills, Forest fires, Militiary operations.
- Extensive Use of HTN Representation:
  - Hierarchical organisation & "standard operating procedures".
  - Minimise/eliminate search.
- Extensive Use of External/Legacy Software:
  - Databases (*e.g.*, GIS).
  - Specialised solvers, Forecasting, Plan analysis.
  - Temporal Reasoning & Scheduling.
- Demonstrators only.
- Mixed-initiative planning & "What If?"-analysis.
- Knowledge-intensive.

Project/Operations Scheduling

- Logistics (air transport) for US army.
- Large-scale construction projects (nuclear submarine).
- Constaint-based scheduling:
  - "Domain-specific" by nature (emphasis on modelling), but (re-)using general techniques.
  - Integration of domain-specific solvers for subproblems.
  - For large-scale problems, typically use local search – not optimal, but "good enough".

Level of Automation

- Plan sketching tool ("scratchpad").
- Plan validation tool / constraint checker.
- Scheduling.
- Limited planning (*e.g.*, goal selection in oversubscribed problems, alternatives in scheduling).
- Full automated planning.

Knowledge Engineering

- Planning is *model-based*.
- *Acquiring* and *maintaining* a *correct* model is often the hardest part!
- Can planners be extended/modified to cope with incorrect / incomplete models?

Domain Complexity & Scaling

- Does modelling "real-world domains" require
  - temporal reasoning? "expressive" temporal reasoning?
  - resources, "geographic reasoning", general numeric reasoning?
  - complex optimisation criteria, such as "soft goals"?
  - probabilities, incomplete information, or other kinds of uncertainty?
- Does solving "real-world problems" require solving very large problems very fast?

Plan Management

- Finding a plan is not the *only* problem:
  - Validation & explanation.
  - Execution & monitoring of execution.
  - Plan repair / replanning.
  - Storage, retrieval & adaptation.
- Finding a set of *diverse* plans, providing users with options.