Planning and Scheduling Under Uncertainty
Outline of the Survey Paper

September 19, 2003

1 Introduction: aims and scope

Basically we find both systems and algorithms in the literature dedicated to planning and scheduling problems under uncertainty. However there are not yet benchmarks proposed to date for comparing these different systems or techniques as far as we know. Furthermore, there is a large terminology used for describing them. This paper proposes a literature framework that permits us to classify techniques or systems independently of any representation model or reasoning techniques. In this section I propose to also give:

- the definitions of classical scheduling and planning with their respective limitations
- the common features of planning and scheduling

1.1 What this paper is not about

It is not an exhaustive survey. It is not a definition of a new model for P&S under uncertainty. It does not account for goal and/or sensor uncertainty.

The aim is actually to define a "grid" for characterizing and classifying existing techniques, which does not depend on representation models nor on reasoning techniques.

It lists exemplary references, covering most of the known techniques, w.r.t. that grid.

It deals both with plan generation and execution.

1.2 Plan generation and execution in classical planning and scheduling

Basic definitions with references to existing surveys, and most famous systems (STRIPS, Graphplan, IxTeT, ILOG Scheduler, etc).

1.3 Dealing with uncertainties

Types of uncertainties one may be faced with: the different sources of uncertainty in planning and scheduling.

Shortcomings of the classical approach.

Ways to model uncertainty, when possible.

2 The grid: an overall view (literature framework)

This section presents the literature framework we propose and is divided in five subsections. The first subsection gives some definitions. The second subsection is dedicated to reactive techniques. The third subsection concentrates on proactive techniques. The fourth subsection focuses on progressive techniques. The last subsection proposes some ideas for combining these three different families of techniques.

2.1 Basic and tentative definitions

This subsection gives a series of definitions in order that there is no confusion in the reading of the rest of the paper. I propose to define the following terms: off-line/on-line reasoning, dynamic process, real-time process, stability, robustness, flexibility, contingency, synchronous/asynchronous events, monotonicity/non-monotonicity, and predictive, indicative and effective plan/schedule.

2.2 Reactive approaches

Definition, generic features, intuitive example.

2.3 Proactive approaches

Idem.

2.4 Progressive approaches

Idem.

2.5 A summary

List the strengths and weaknesses of each type of approach. We can summarize some issues that have still to be coped with:

- reactive issues:
  - Time pressure: ratio between activity duration and time-to-resolve
  - Resolving strategies: constructive versus iterative repair
  - Optimization criteria: original versus perturbation (exploiting positive changes)
  - Brittleness
  - Comparison with other approaches:
    - Do we really need to reason about uncertainty at all?
    - Can we do without reactivity?
- proactive issues:
  - The aim is twofold:
    - guarantee off line the plan execution feasibility
    - limit the need to reason on line
  - Completeness?
    - Mid term: may be complete (task duration intervals: controllability checking)
    - Long term: incomplete (allocate slack, maximize likelihood of some level of performance)
- progressive issues:
  - anticipation guarantees responsiveness
  - planning is reactivated because of incoming data arriving dynamically (not known before execution): effective times, new actions, new goals, etc
  - the time horizon is a crucial parameter: the larger, the more predictive, the smaller, the more "reactive"
  - progressive techniques often used in combination with reactive techniques

3 A quick survey of reactive techniques

List of references to be defined: 3.1, 3.2, etc

- Sadeh et al. 1993:
  - a complete schedule is built before execution
  - machines can break down during execution
  - rule-based recovery: if some machine breaks down then a simple rule (e.g. Right Shift Rule) is used to repair the schedule

4 A quick survey of proactive techniques

Idem

- Davenport et al. 2001:
  - add slack to activities on breakable resources and schedule then classically
- Smith and Weld 1998:
  - conformant planning: no observation...
  - open loop: the plan guarantees to reach the goal whatever the actual situation will be
- Drummond et al. 1994:
  - Real world telescope observation scheduling problem
  - Durations of observations are uncertain
  - Solution: provide a contingent schedule, i.e takes into account likely failures and provides a new schedule to switch to

5 A quick survey of progressive techniques

Idem

- Vidal et al. 1996:
  - uncertainty on activity durations
  - short-term allocation of rovers to tasks: made when new effective times come from execution
  - interleave execution and scheduling over a rolling-time horizon

6 Combining approaches?

6.1 Progressive and reactive: some examples

Idem

- Chien et al. 2000: CASPER system
  - new goals + unexpected events during execution, uncertainty on activity durations, resource breakdowns, and resource oversubscription
  - complete and/or modify the current plan: plan merging + plan iterative repair if needed
  - continuous planning

6.2 Proactive and reactive: some examples

Idem

- Wu et al. 1999:
  - identify a critical subset of decisions that, to a large extent, dictate global schedule performance
  - make these decisions off line
  - make the rest of the decisions on line

6.3 Towards a global approach?

Introduce and summarize the idea of our model, with basic definitions.

7 Conclusion

A reference framework for:

- assessing existing techniques
- choosing an approach to tackle a given problem
- building more ambitious systems capable of combining some or all approaches

Mixed issues:

- still not many contributions, but becoming more attractive...
- mixed techniques respond to various needs:
  - limit the memory blow-up induced by proactive techniques: do not take everything into account
  - account for unavoidable failures and handle them better: proactive/progressive techniques restrict the need to react, hence more effort can be devoted to unforeseen events