AIPS'02 Tutorial proposal: Constraint-Based Scheduling in an A.I. Planning and Scheduling Perspective

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1 Objective

The objective of the tutorial is to give an overview of the most widely used or emerging techniques in Constraint-Based Scheduling. The tutorial is particularly addressed to A.I. Planning or Scheduling researchers who are interested in a flexible framework to integrate A.I. Planning and Scheduling.

2 Abstract

Constraint Programming is a problem-solving paradigm that establishes a clear distinction between two pivotal aspects of a problem: (1) a precise definition of the constraints that define the problem to be solved and (2) the algorithms and heuristics enabling the selection of decisions to solve the problem.

It is because of these capabilities that Constraint Programming is increasingly being employed as a tool to solve scheduling problems. Hence the development of Constraint-Based Scheduling as a field of study.

This tutorial provides an overview of the most widely used or emerging Constraint-Based Scheduling techniques. It particularly emphasizes the features of Constraint-Based Scheduling that makes it a good framework for integrating A.I. Planning and Scheduling.

The first part of the tutorial provides an overview of Constraint Programming as well as a model for representing scheduling problems in the Constraint Programming framework. Some classical examples of scheduling problems are given. The end of this introductory part investigates the relations between Scheduling and A.I. Planning.

Following the clear distinction between (1) constraint propagation and (2) search space exploration provided by the Constraint Programming paradigm, those two aspects are treated in the second and third parts of the tutorial.

The second part is focused on the propagation of resource constraints, which usually are responsible for the "hardness" of a scheduling problem. The notion of a global constraint is introduced as a constraint that enforces a set of local properties on the partial schedule. The different techniques to propagate global resource constraints are then classified, described and compared.

The third part of the tutorial presents some classical search techniques in Constraint-Based Scheduling. It describes the most classical branching schemes and control of the search as well as some widely used techniques to deal with large and/or hard problems.

In order to show how to put things together, the resolution of two scheduling problems is described in the last part. These examples illustrate the use and the practical efficiency and flexibility of the Constraint-Based Scheduling approach.

3 Outline

1. Basic principles

1.1. Constraint Programming
- Definition of a Constraint Satisfaction Problem (CSP) [20]
- Constraint propagation [23, 4]
- Search techniques
  - Search heuristics
  - Search tree exploration: DFS, LDS, ...[15]
- Optimizing objective functions

1.2. Scheduling model [2, 16]
- Typology of activities: non-preemptive, preemptive
- Temporal constraints
- Typology of resources, alternative resources
- Extensions: transition times/costs, resource efficiency, state resources
- Objective functions

1.3. Examples of scheduling problems
- jobshop [17]
- RCPSP with min/max time lags [24]

1.4. Scheduling and A.I. Planning
- Relations with Partial Order Planning [28, 25]
- Close/not-close status of a resource [19, 14]

2. Propagation of Resource Constraints

2.1. Global constraints
- From local properties to global constraints
- Local properties and truth criteria in Partial Order Planning [8, 33]
- A framework to classify global constraints propagation algorithms

2.2. Algorithms based on activity time-windows [26, 9]
- Timetabling constraint [10]
- Disjunctive constraint [18]
- Edge-finding constraint [5]
- Not-first, not-last [31]
- Energetic reasoning [11, 12]

2.3. Algorithms based on relative position of activities
- Precedence energy constraint [30]
- Balance constraint [7, 21]

2.4. Comparison and complementarity of propagation algorithms [1, 2]

3. Search Techniques

3.1. Branching schemes
- Branching schemes as a non-deterministic way of enforcing local properties
- Classical branching schemes:
  - Resource allocation
  - Setting times
  - Rank first/not-first (last/not-last)
  - Pair ordering [22, 6]

3.2. Search heuristics
- Slack-based heuristics [29]
- Texture-based heuristics [3]

3.3. Beyond the basic search scheme

- Shaving [32]
- Probing
- Dichotomizing
- Large neighborhood search [13]

4. Putting things together on two examples

4.1. Jobshop [27]

4.2. RCPSP with min/max time lags [24]

5. Conclusion

4 About the speakers

Dr. Philippe Laborie graduated from École Nationale Supérieure des Télécommunications (Paris) in 1992, and did a PhD in Artificial Intelligence at LAAS/CNRS (Toulouse) on the integration of A.I. Planning and Scheduling in 1995. He is one of the developers of the IxTeT Planning system. He then worked for two years as post-doctoral fellow at Electricité de France (Paris) and INRIA/IRISA (Rennes) on the Supervision and Diagnosis of complex systems (telecommunication and power distribution networks). His main scientific interests include planning, scheduling, supervision and diagnosis of complex systems and more generally, any decision problems dealing with time. Since 1998, he is working as a Principal Scientist at ILOG R&D.

Dr. Wim Nuijten is Director of Optimization Technology at ILOG S.A. His main interests lie in using constraint programming, local search, mathematical programming, and their combination to solve scheduling problems. He received his MSc (cum laude) in 1990 and his PhD in 1994 from the Department of Mathematics and Computing Science of Eindhoven University. From 1992-1994 he was a consultant at RIKS in Maastricht. Begin 1995 he joined ILOG as a software developer, where later that year he became the Project Manager of ILOG Scheduler. In the years that followed Dr. Nuijten was a driving force behind making ILOG Scheduler the industrial success it is today. He was closely involved in the introduction and successful application of constraint-based scheduling in several major companies, amongst which SAP and Oracle. Since mid 1999 he is in his current position and leads a team of about 15 researchers that develop an array of constraint programming products.

5 Background required by audience

Some knowledge about Constraint Programming and Scheduling is an advantage but is not required as the first part of the tutorial will recap the main notions. Some basic knowledge about Partial Order Planning may also be useful.

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