ENTIRE EDIH Training Course on AI Based Scheduling

Helmut Simonis
School of Computer Science and Information Technology
University College Cork
Cork, Ireland
email:helmut.simonis@insight-centre.org

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Abstract

This document describes the detailed structure of a training course on AI based scheduling for the ENTIRE EDIH project. The training course provides an overview of current Constraint-based techniques to model and solve scheduling problems arising in project scheduling and manufacturing industries. It provides some hands-on experience with available open-source tools, and also describes key features of commercial solutions.

1 Introduction

This document provides an outline of a two-day training program on AI based scheduling using constraint programming techniques. The document details the topics covered from the viewpoint of the course developer, it is not intended to be read by the potential audience. A separate description of the course focussing on business needs and benefits will be developed in parallel.

2 Intended Audience

The course is intended for decision makers and persons facing scheduling problems in their professional work. IT personnel or consultants charged with choice of tools, development of models, or integration into the existing infrastructure will also be interested.

3 Learning Outcomes

After attending the course, the students should be able to

- Position Constraint Based Scheduling in the general AI field
- Understand the need and potential for automated scheduling
- Understand the basic ideas behind Constraint-Based Scheduling

  - Declarative modeling
  - Abstraction of complex solving methods
  - Explainable reasoning
- Identify and apply the basic constraint types occurring in scheduling
- Understand the strength and weaknesses of available tools
- Be aware of basic visualization methods for scheduling

4 Timetable

Table 1 shows the format of the course delivered in a two-day event, with ten hours total teaching time. The course consists of seven modules, which will be described in more detail in Section 5. Alternatively, the course could be presented as ten one hour sessions (plus exercises) for self-study.

Table 1: Proposed Two Day Course Structure

Time	Day 1	Day 2
09:00-10:30	Introduction & Motivation	Costs & Objective Functions
10:30-11:00	Coffee	Coffee
11:00-12:30	Scheduling Concepts	Advanced Concepts
12:30-14:00	Lunch	Lunch
14:00-15:30	Machine Constraints	Case Studies
15:30-16:00	Coffee	Coffee & Close
16:00-17:00	Experiments	-

5 Modules

This section gives a brief bullet-point list of the key elements of each of the modules of the course. The course will be delivered as a mix of overview slides, some example problems and solutions using different solvers, and a hands-on session to explore programs and demonstrators.

The overall approach is morphology based, i.e. based on the structure of problems found in industry. This differs from a complexity/structural analysis often used in OR, or a technology based presentation used in Computer Science.

5.1 Introduction & Motivation

- AI - More than Chat-GPT
  - Deductive vs stochastic approaches
- What is scheduling?
- What is Constraint-Based Scheduling?

- Solution approaches
- Some industrial examples
  - From CP and CPAIOR papers
  - Where to find more industry specific examples
- Benefits of automated scheduling
- Presentation based on Morphology
  - Not complexity based
  - Not structure based
  - Not technology based
- Why not just use a package?
- What is not covered?
  - Stochastic variants
  - Process and semi-process based manufacturing
  - Assembly line balancing
  - Internal operations of a constraint solver
- A short history of Constraint-Based Scheduling

5.2 Scheduling Concepts

- Core concepts: Products, orders, jobs, tasks
- Temporal relations
  - End-to-start precedence
  - Precedence graph (linear, tree)
  - Max waiting time
  - Allen relations
  - Intra-job vs inter-job
  - Pipelining
- Release date and due date (hard, soft)
- Processes, bill of material (BoM)
- Problem classification
  - RCPSP
  - Job-Shop, flow-shop, open-shop
  - α, β, γ Notation
- Visualization methods
  - Gantt chart (job/machine view)
  - Precedence graphs
  - Process diagrams
  - Resource profiles

5.3 Machine Constraints

- Disjunctive resources
- Cumulative resources
- Machine choice
- Machine preferences
- Work in progress
- Planned shutdown
- Calendars
  - Factory-wide calendar
  - Machine specific calendars
  - Changing work pattern
  - Varying machine speed
- How do tasks work over breaks

5.4 Experiments

- Hands-on experience with some open-source tools
  - MiniZinc
  - CP-SAT
  - CPMPy
- Based on provided examples
- Impact of different solvers
- Visualization of results

5.5 Costs and Objective Functions

- Different types of objectives
- Cost vs. profit based objectives
- Make-span
- Flow-time
- Lateness
- Earliness
- Just-in-time
- Multi-Objective scheduling
- Interactive scheduling

5.6 Advanced Concepts

- Sequence dependent setup
- Transport time between resources
- Human resource constraints
  - Cumulative limits
  - Assigned operators
  - (Nested) Skill levels
  - Operator speed
  - Overtime
- Energy-cost aware scheduling
- Preemption
- Producer/Consumer constraints
- Alternative process paths
- Outsourcing decisions
- Explainability
  - Explain infeasibility
  - Explain lateness
  - Identify bottleneck resources
  - Ability to promise

5.7 Case Studies

- Present some industrial success stories
- Show how they fit into the framework provided
- Blades and vanes production for gas turbines (Siemens Energy)
- Oven scheduling: Short-term and long-term objectives (Atlas-Copco)
- Factory design analysis (Johnson & Johnson)
- A guide to the literature
- Teaser: Test before invest Scheduling

6 Conclusion