Cooperation between Human and Machine for Shop Rescheduling

Guillaume Pinot Nasser Mebarki

IRCCyN — UMR CNRS 6597
Nantes, France
guillaume.pinot@irccyn.ec-nantes.fr
nasser.mebarki@univ-nantes.fr

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Table of Contents

Introduction

This work follows Julien Cegarra's PhD thesis [Cegarra, 2004][1] who was interested in a psychological point of view for cooperation. Here we present a computer science point of view for this problem. [Cegarra, 2004] highlighted some points:

- Humans are good at relaxing constraints.
- Handmade schedules have good performances in general.
- When the human has to reschedule a computed schedule, the understanding of the algorithm does not seem very helpful.
- Inter-individual differences between human schedulers are important.

[1] The management of complexity in planning: the case of scheduling situations

Goal

The goal of this work is to provide:

- methods,
- and tools

to facilitate the cooperation between human and machine for shop rescheduling.

Definitions

Definition: predictive phase of scheduling

The predictive phase of scheduling is the phase done before executing the schedule.

Definition: reactive phase of scheduling

The reactive phase of scheduling is the phase done during the execution of the schedule.

Uncertainty

Definition: Uncertainty

Uncertainties describe the possible modifications of the data between the predictive phase and the reactive phase. (From [Esswein, 2003])

Examples:

- Delay of an operation;
- Insertion of a job;
- Distance between the reality and the model (for example, the transport time between two machines is not considered in the model);
- Machine breakdown;
- Etc.

Flexibility, Definition

Definition: Flexibility

Flexibility measures the degrees of freedom present during the reactive phase of the schedule. (From [Esswein, 2003])

Different kinds of flexibility (From [Groupe flexibilité du GOThA, 2002]):

- Flexibility on time (modifications only on operations' time (right shifting));
- Flexibility on sequences (modification of the sequence of operations on a resource);
- Flexibility on resources (moving an operation from a resource to another);
- Flexibility on execution modes (for example the modification of a routing).

How to Measure Flexibility?

How to measure flexibility?

- Flexibility measurement depends on the kind of flexibility used.
- Flexibility measurement depends on the method used to generate the flexibility.
- A solution can be to compare the performance of a non-flexible schedule and the performance of a flexible schedule. This way, we need to measure the robustness.

Static Scheduling

Definition: Static Scheduling

Static scheduling can be defined as a scheduling method based completely on the predictive phase.

The reactive phase is very minimalist: the calculated schedule is followed strictly. Flexibility on time can be used to achieve a feasible schedule: the operations are right-shifted.

Dynamic Scheduling

Definition: Dynamic Scheduling

Dynamic scheduling is based only on the reactive part

Frequently, dynamic scheduling uses priority rules. (For example the "Shortest Processing Time" rule.)

Predictive-Reactive Scheduling

Definition: Predictive-Reactive Scheduling

Predictive-Reactive Scheduling is a method that exploits the predictive and the reactive phase (in a non-trivial way).

In practice, there is:

- A predictive phase: one or more schedules are constructed.
- A reactive phase: the schedules made during the predictive phase are used and adapted in real time.

Cooperation between Human and Machine

Human and machine complement each other: they have a different vision of the shop. Uncertainties can be different for the human and for the machine.
Many studies exhibit that combining human and machine gives better results than using only the human or the machine (cited by [Cegarra, 2004]).
The difficulty is to find an effective method that uses both the possibilities of the human and the machine.

Paradigm

The idea is to generate a schedule that is flexible on sequences during the predictive phase.
To express the flexibility on sequences, the method uses "groups of permutable operations."
Group scheduling is developed in
[Thomas, 1980, Billaut, 1993, Artigues, 1997, Esswein, 2003].

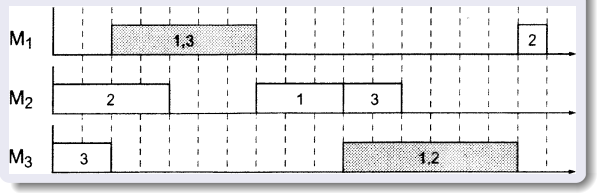
Example: a Job Shop Problem

i is the job, j is the operation (operations are sequenced), $M_{i,j}$ is the machine needed for the operation j of the job i, and $p_{i,j}$ is the time needed for the operation j of the job i.

Problem

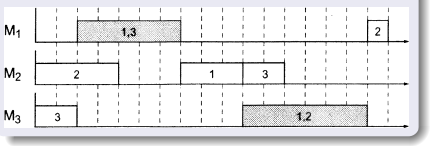
i	j	$M_{i,j}$	$p_{i,j}$
1	1	1	3
1	2	2	3
1	3	3	3
2	1	2	4
2	2	3	3
2	3	1	1
3	1	3	2
3	2	1	2
3	3	2	2

A Solution

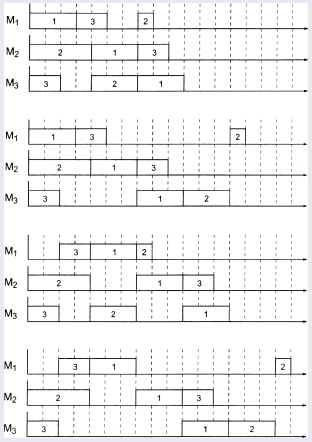


Execution of the Example

The group schedule



The Different Schedules



Why is Group Scheduling Interesting?

Why is group scheduling interesting?

- Predictive-reactive method;
- Flexibility on sequences;
- Evaluation of the worst schedule in polynomial time;
- Possibility to evaluate handmade modifications (for example insertion of an operation) in polynomial time;
- Uncertainties do not need to be modelled;
- Well-studied method.

What is Machine Learning?

Machine learning topics:

- classification;
- regression.

Different types of algorithms:

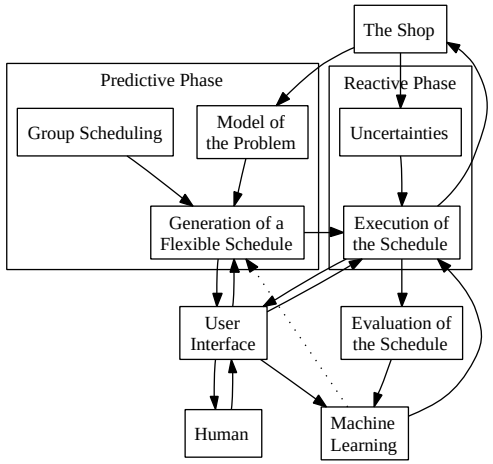
- supervised learning;
- unsupervised learning;
- semi-supervised learning;
- reinforcement learning.

Why and Where is Machine Learning Interesting?

Why and where is machine learning interesting?

- A set of well-studied and effective tools;
- Usable to evaluate a measure of the robustness of a schedule;
- Usable to help cooperation between human and machine;
- Usable to auto-adapt the algorithm to the instance of the problem.

Architecture



Conclusion

We have seen the context of cooperation between human and machine for rescheduling.
We have proposed an architecture for a future method of resolution of this problem using:

- Group scheduling.
- Machine learning.

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