A Real-Time Rescheduling System for Production Processes

If you manage a production enterprise, you might have had the following experience: you made a production schedule before a production process took place. Then the production process ran following the schedule. However, at a time your production process could no longer follow the planed schedule. The reasons for that might be the following:

- Unexpected changes of the production environment (e.g. machine breakdowns; need to repeat a job operation because of its quality problem)
- Changes of production requirements during the production process (e.g. arrival of an urgent job; cancelation of a customer order)

The consequence is that the production process without a valid schedule can no longer guarantee the planned production objectives, i.e.

- The production duration
- The due dates of customer orders

In that case, to create a new schedule for the production process according to the current production system state is necessary.

Rescheduling

Rescheduling is a facility to create a new schedule after a change took place during the production process and invalidated the currently used schedule. In practice there are two alternative rescheduling approaches. The first is to use the scheduling approach, which generated the initial schedule before the production process took place. The advantage of this approach is its near-optimal solution. However, its disadvantage is a very long runtime (usually from a few hours to a few days). The long runtime makes it unsuitable for most cases of rescheduling during a production process. The reason for that is its runtime may be still longer than the total production duration. The second rescheduling approach is to use simple priority dispatching rules like FIFO (First In First Out), SPT (Shortest Processing Time at first), or EDD (Earliest Due Date at first). Its advantage is a shot runtime but its disadvantage is no guarantee of the schedule's quality. Today, how to efficiently reschedule a production process and at the same time to guarantee a plausible solution quality is a new challenge for production enterprises.

Research Goal

An innovative rescheduling approach, which can generate a schedule with plausible quality as well as in a short time, is investigated. Fig. 1 shows a scenario in which the proposed rescheduling approach generates a new schedule in real-time (< 1 sec.) after a change in the production system took place (in the example, a machine breakdown).

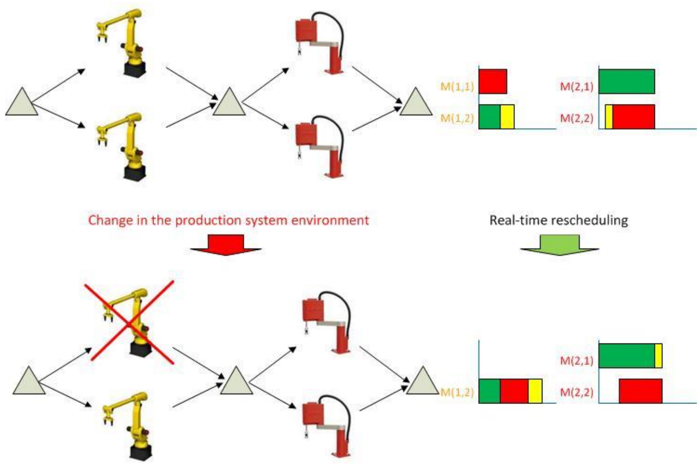
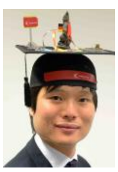


Figure 1: Rescheduling after a change of the production system environment

The proposed research concentrates on the Flexible-Job-shop scheduling problem and its three variants namely the Job-Shop, Flow-Shop, and Flexible-Flow-Shop, which are widely used for modeling industrial production processes. In addition, the research considers the optimality criteria



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regarding the production duration as well as the due dates of customer orders.

Fig. 2 demonstrates an example of the Flexible-Job-Shop scheduling problem in manufacturing. Each customer order, also called a job, must be processed by a sequence of workstations. Different jobs can have different workstation sequences. In the example the red job has the workstation sequence 1→ 2 → 3 and the green job 3 → 2 → 1. In one workstation there can be more than one parallel machine. Each of them can complete the operation of a job. For a job the processing times of the parallel machines at a workstation can be different. The goal of the proposed rescheduling approach is to find a schedule for the production process and to optimize an optimality criterion like the production duration or Lateness of customer orders.

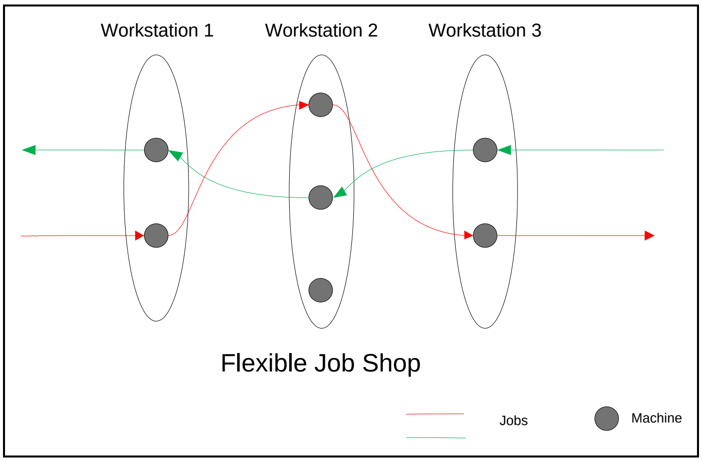

Figure 2: An example of the Flexible-Job-Shop in manufacturing

Machine Learning and Knowledge-based Systems

The proposed research uses the technologies of machine learning and knowledge-based systems to achieve a plausible quality of schedules. As shown in Fig. 3, the approach learns from the previous scheduling problems and their schedules in the off-line phase and acquires knowledge about the relationship between states of a production system (defined by various attributes like job remaining processing time, machine workload, due dates) and decisions (assignment of jobs to machines).

In the on-line phase (i.e. it is during the production process and resche-duling is necessary), the approach repeatedly makes a decision to assign a job-operation to a machine as next, regarding the current state of the production system. It is to note that the approach can not only make decisions for the known states given by the previous scheduling prob-lems but also for the previously unknown states by means of its acquired knowledge, in other words of its own intel-ligence. Furthermore, using the knowledge previously ac-quired in the off-line phase saves computational time in the on-line phase and makes a real-time efficiency of the approach possible.

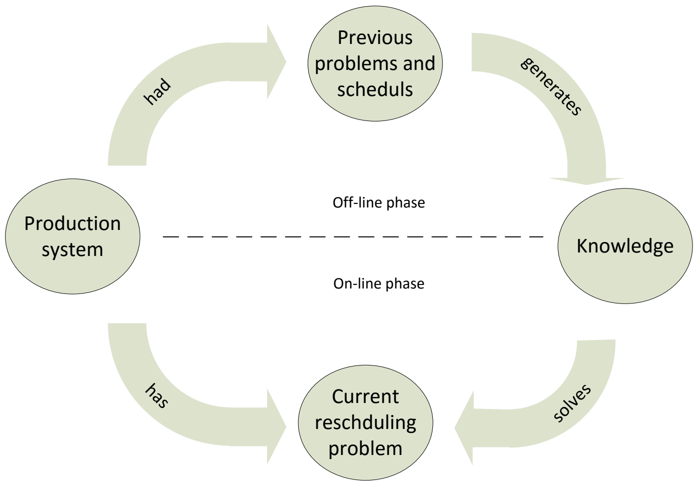

Figure 3: Off-line learning and on-line rescheduling using the acquired knowledge

Expected Result

The expected result of the research should show that the proposed approach is superior to other known rescheduling approaches for the considered Flexible-Job-Shop scheduling problem and its variants Flexible. On the other hand the result should also show that the efficiency of the proposed approach can fulfill the requirement of real-time rescheduling in manufacturing.

Further, the research can not only contribute to the production enterprises but also to the logistic enterprises with the requirement of real-time rescheduling, e.g. at ports or at the post distribution.

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