Job scheduling: Optimizing energy Consumption and total tardiness

**Motivation & Objectives**
The project aims at reducing the energy consumption in a dynamic job shop by optimizing operational procedures with the objective of optimizing idling time of machines regarding total (electrical) energy consumption in a non-bottleneck situation.

The goal shall be to rearrange jobs, which are normally characterized by their release date, due date, processing time and sequence in the case of a multiple machine job shop, in such a way, that either the machine might be switched off while waiting for new jobs - since a long enough waiting time is planned - or the jobs are being processed without idling time in between. Thereby a further objective shall be minimized as well: total tardiness.

It is believed, that by introducing new operational methods, the electrical energy consumption of a job shop can be decreased in a significant way.

**Objective functions**
The following objective functions were used for the single- and two machine job shop:

- total completion time of all jobs
- tardiness for all jobs
- idling energy using a shut-down time, whereas the machine switches off in the case of waiting time being large enough

Those objectives have also been combined (such as idling energy and total tardiness) whereas additional multi-objective methods have been used, such as:

- Weighted sum method (WSM)
- a proposed version of the e-constraint method

**Dispatching rules**
Dispatching rules can be described as heuristic procedures which choose among available jobs those given a certain priority, whereas every rule normally optimizes one performance objective. Such rules have the advantage of not using too much computational time and thereby offer a relatively good schedule but without guaranteeing optimality.

For the single machine environment, the SPT (shortest processing time first), LPT (longest processing time first), and a proposed version of the LTP rule optimizing idling energy have been studied. For the two machine job shop, the LTP and proposed modified LTP rule were studied.

By running 50 random jobs on a single machine with 200 iterations with given random processing times, whereas the date distribution has been changed, some improvements regarding energy consumption were achieved, namely for the single machine case:

Energy consumption can be decreased between 0.4% and 16.6% depending on the job distribution while not increasing total tardiness.

For the two machine job shop, 50 random jobs on every machine with 100 iterations were simulated. The results which were achieved:

Energy consumption can be decreased between 0.3% and 10.2% depending on the job distribution and sequence while not increasing total tardiness for the given machine parameters.

**Comparison of MIP objective functions and dispatching rules**
For the single machine job shop, four different scenario were run with 7 random jobs and ten iterations. For the two machine job shop, four different scenario were run with 5 random jobs on every machine and ten iterations. Additionally, a case study was done for single- and two machine job shop in order to show the effects of optimizing a certain objective function.

For every scenario, the schedule provided by the dispatching rule and the schedule resulting from optimizing the objective function was used, whereas the comparison was done for total energy consumption and total tardiness, calculating a so called solution gap between optimal value provided by the linear programming solution and the heuristic, non-optimal dispatching rule results. It was found, that:

The proposed modified dispatching rule decreased the solution gap regarding idling energy by around 4 - 10 % regarding some optimal objective values compared to the classic dispatching rules for the single machine job shop

The possible gain dropped to 0.3 – 6 % in the case of a two machine job shop.

**Conclusion**
Several different dispatching rules have been implemented successfully within MATLAB for a single- and two-machine job shop environment, whereas a modified due date based dispatching rule has been proposed.

Several different objective functions together with its constraints in linear programming have been successfully implemented within MATLAB, simulating a single- and two machine job shop.

Optimal objective values and dispatching rule and the proposed schedule performance variables have been compared by calculating a solution gap.

It was stated, that the proposed dispatching rule performed better (especially for the single machine scenario) than the classic dispatching rules regarding idling energy (while not worsening the total tardiness criteria).

It was found that the CPU time increases exponentially regarding number of jobs (see figure below) for some objective functions and hence limited the simulation of considering larger problems.

**Mixed integer linear programming**
Linear programming is a method which defines a model by constraints, using continuous or integer variables in a linear form, whereas these constraints are subject to a optimization algorithm optimizing an objective function with the given constraints. Possible algorithms are for example the simplex algorithm or the branch and bound algorithm, implemented in software packages such as CPLEX by IBM, which has been used within this project. Several objective functions with adequate constraints were used and the information of the software can be seen below:

**Acknowledgements**
Prof. Paul Xirochakis
PhD Yong-Chan Choi
PhD Oliver Avram

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