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DOCTORAL THESIS REVIEW

Title: Scheduling with Alternative Process Plans

Author: Roman Čapek

Supervisor: prof. Dr. Ing. Zdeněk Hanzálek

Supervisor specialists: Ing. Přemysl Šůcha, PhD.

Referee: Ing. Jiří Kubalík, Ph.D.

This thesis deals with scheduling problems with alternative process plans, i.e. scheduling problems where some activities can be performed in several different ways while only one of them has to be used in the final process plan. Then, the goal of the scheduling is to solve two tasks simultaneously – (1) choose a subset of all activities that forms the process plan and (2) schedule the selected activities to a given set of resources optimally with respect to the given criterion. Up to now, there are no existing methods that solve the scheduling problem with alternatives in its full complexity. In my opinion, the subject of the thesis is very topical.

This work contributes to the field of scheduling with a general formulation of a new scheduling problem, the Resource Constrained Project Scheduling Problem with Alternative Process Plans (RCPSP-APP). The proposed model uses a formalism of the Nested Temporal Networks with Alternatives (NTNA) to represent a problem structure of the RCPSP-APP. NTNA allows to efficiently define all types of constraints present in the RCPSP-APP such as the shared resources with an arbitrary discrete capacity, selection constraints defined via the alternative process plans, generalized temporal constraints among activities and sequence dependent setup times. Further, three specific RCPSP-APP problems have been selected for proof-of-concept case studies. For each of them, a mathematical model based on the proposed representation of the general RCPSP-APP was formulated, and two types of solution approaches were implemented – exact solutions and heuristic algorithms. The heuristic ones were developed as alternatives for solving large instances of the studied problems. Finally, the solution approaches were experimentally evaluated through extensive experiments and compared with other existing approaches from literature. It shows the proposed heuristic algorithms are fully competitive with and sometimes even better than the state-of-the-art methods even on particular variants of RCPSP-APP for which the methods are specialized. This is an important achievement of this work, since the RCPSP-APP has many possible applications in complex real production processes.

I have the following questions and specific comments on this work:

- Is it possible to apply the proposed formalism and heuristic methods to problems with multiple optimization criteria?
- Algorithm IRSA, p. 28: How sensitive is the algorithm to the values of the constants c_1 and c_2? Have you used any systematic parameter tuning method to find them?
- p. 29: „A general observation for heuristic algorithms is that more incorrect decisions are made at the beginning ... ". Could you please explain this statement? What do you mean by *more incorrect decisions*?
- Section 3.3.4: What is the size of the problems used in the experiments?
- Structure of the text: Why are Sections 3.3.6, 3.3.7 and 3.3.8 included under the Section 3.3? These should rather constitute a separate section as their content is general and independent of Section 3. For example, the proposed metric for problem instance characterization is also referenced in Section 5.3.
- Table 3.8: I do not understand the table and its interpretation. I could not find anywhere in the text what values are presented in the table. I think it is the mean value of the corresponding

property calculated over instances on which the respective algorithm achieved the better result than the other one. Is this right? If so, then do you consider all instances where one of the algorithms produces better solution than the other or just the instances where the difference in the quality of two solutions is significant?

- Analysis of the results in Table 3.8: What threshold for statistical significance did you use to derive the conclusions? I am not really convinced of the presented importance of the analysed instance properties.
- Algorithm 4, STOAL: The local search procedure uses an acceptance rule "if(objective value improved)". Usually, local search algorithms use a soft version of the acceptance rule such as "if(objective value did not worsen)" in order to have a chance to traverse plateaus in the search space. Did you experiment with this acceptance rule?
- STOAL algorithm: Regarding the results presented in Table 4.2, is it possible to adapt the STOL algorithm so that it follows the same strategy as the one used in the algorithm by Focacci et al. (2000), i.e. generate a feasible solution optimal w.r.t. the makespan and then locally optimize the solution w.r.t. the minimal total setup time?
- Sections 4.4.1 and 4.4.2: I am missing a configuration of the STOAL algorithm that was used in the experiments presented in these sections.
- Section 5.2.1.3: The tournament selection with $n/4$ candidates induces rather high selection pressure. This might lead to a premature convergence. Did you experiment with tournament sizes other than $n/4$?
- DDE, crossover: A description of the crossover operator in DDE is unclear. In Algorithm 6, the crossover operates on the *mutant_individual* and *reference_individual* resulting in *trial_individual*. However, according to the description in Section 5.2.1.7 the crossover combines the original individual with the reference one. Could you please clarify this?
- Since two evolutionary-based algorithms are proposed for the third studied problem, the state-of-the-art section should cover more works on utilization of evolutionary algorithms for the RCPSP.

In summary, I find this thesis a nice piece of research work. It contains original and valuable results that will surely contribute to the expansion of knowledge in the field of scheduling. The candidate proved to have an ability to perform research and to achieve scientific results. The work is well written with a minimum number of errors and typos. It contains a thorough literature review and gives proper credit to previous studies.

The candidate's publication record is above-average containing 1 paper in journal with impact factor, 1 paper in impacted journal in the major revision phase, 9 international conference papers and 6 other publications.

All objectives of the thesis as stated in the text are fully achieved. In my opinion this work fully complies with the requirements imposed upon PhD thesis. In accordance with §47; letter (4) of the Law Nr. 111/98, I do recommend the thesis for presentation and defence with the aim of receiving the Degree of Ph.D.

Prague, May 13, 2016

Ing. Jiří Kubalík, Ph.D.