6. 6.

A Review of Doctoral Thesis
"Scheduling with Alternative Process Plans"
by *Roman Čapek*

The PhD thesis deals with the problem of scheduling manufacturing process with the focus on alternative processes and various optimization criteria. This is a practically very important problem and the author focuses on a less explored area. The major innovation is the formulation of various heuristic algorithms for solving the problems and their broad experimental evaluation.

There are basically four new contribution regarding the new techniques. The author suggests heuristic algorithm Iterative Resource Scheduling with Alternatives (IRSA) for scheduling problems with alternative processes, heuristic Setup Time Optimization Algorithm (STOAL) for minimizing setup times, and two population-based algorithms Discrete Differential Evolution (DDE) and Scatter Search (ScS) for minimizing combined setup times and activity costs. I appreciate that all algorithms are presented in the same style and that the author attempts to compare them with existing techniques using existing benchmarks even if they do not fit fully the intended problem to be solved. What I do not like about the presentation of algorithms is that they are described as they are without giving any motivation why the algorithm looks as it looks. There is a huge number of possible heuristic techniques and it would be useful to understand better why a given technique works well for a given problem. At least the motivation for proposing a particular heuristic should be given. The author attempts to study the properties of algorithms based on structural properties of the problems but the results are not very conclusive there and they are too shallow. Anyway, proposing some measurable properties that could be used to classify problems is another contribution of the thesis.

The writing style of thesis is good, the text is well organized and I did not find significant problems in English. I appreciate that the author keeps the same notation and the same style of writing in the whole thesis. This makes reading much easier. On the other hand, for all the mathematical models it would be good to recall the meaning of the variables as they were frequently introduced many pages earlier. I also miss specific description if and where the particular novel contribution was published. There is a list of author's publications in the thesis but they are not explicitly related to presented material.

Some particular comments and questions (in the order of appearance):

In Section 2 the formal mathematical model of the problem to be solved is presented. It should be clearly said that this is a linear programming model that requires linear constraints. Obviously, constraints could be specified in a more natural way if they can be non-linear. This also relates to my later comment about CP models.

Page 28: Priorities of actions for selection are formally defined ($apriori_i$) using a formula. This is a typical example of writing "this is what we did" without telling why. Why this specific formula is used for action selection? What is the motivation? Were other formulas assumed in the design of the algorithm?

Page 32, Figure 3.2 (step 9): Should not action 7 finish before action 8 starts? Or does the constraint say that 8 cannot start before the action 7 starts? From the reader perspective it is a bit confusing that a precedence relation defined in TNA means the temporal relation between the start times of activities rather than classical precedence between activities.

Page 34: There is a comparison of MILP and CP models presented. I suppose that the MILP solver uses the model defined in the mathematical formulation of the problem, but the CP model is never presented in the paper. The efficiency of CP is strongly dependent on the constraint model. Constraint-based scheduling is based heavily on resource global constraints with various filtering techniques. What constraint model is used in that study? And which search strategy (variable and value selection) was applied there? Note also that CP can be used to find some feasible solution and then to improve it while time allows. This is somehow close to presented heuristic algorithms so we can re-implement many heuristic algorithms in CP just by using the specific heuristics during CP search. Without giving complete details about the CP model and the search strategy, the results might be misleading.

Page 49: The paper describes a cumulative resource there and if I understand right, this is modelled using a set of unary resources (there are units of capacity that are assigned to activities separately). If this is correct, then the model is not very efficient as it introduces many symmetries – it is not important whether units 1,3,5 or units 1,4,5 are assigned to the same activity, the only thing that matters is that enough capacity units are assigned to the activity. This is something to be clarified.

Page 55: There is a claim that all activities from the ready set have to be scheduled. Technically, this is correct, but if we added some alternative activity to this set and we later find that it cannot be scheduled, we can still use the other alternatives. So it is not really dead-end and we could continue from this point.

Page 60: I would not use the term Limited Discrepancy Search. This is a specific algorithm and this algorithm is not used in the thesis. The text presents some form of discrepancy search, but it is not LDS.

In summary, the achieved results show that the student is capable of doing independent research and achieve novel results. The thesis is well organized with clear focus on solving realistic problems with alternative processes and with practically important objectives. The achieved results are broad but also a bit shallow. I suggest that the work is accepted as Doctoral Thesis.

Prof. RNDr. Roman Barták, Ph.D.
Charles University in Prague, Faculty of Mathematics and Physics

Prague, May 21, 2016