

**Review of the dissertation thesis of Ing. Libor Bukata entitled
„Parallel Algorithms for Optimization of Production Systems”**

The new methods of production systems optimization in parallel computing environment are proposed in the thesis. The main contributions made by the candidate and reported in the thesis can be summarized in the following points:

1. General approach to the energy optimization of robotic cells.
2. Solving the resource-constrained project scheduling problem (RCPSP) with the use of GPUs.

The reviewed thesis consists of 105 pages and three chapters, conclusions, bibliography and four appendices (A-D). There are 10 co-authored publications by the candidate listed in the thesis as well as 4 technical reports including one in which he is a single author.

Relevance to the current needs of the scientific community

Contributions made by the candidate are solid and closely related to the current research directions in the field of operational research and parallel algorithms, especially with the use of GPU. The main research results derived from the thesis have been published in two high-indexed journals (IEEE Transactions on Industrial Informatics and Journal of Parallel and Distributed Computing). The methodology used in the research issues is appropriate, discussions of the results and the background are logical. Computer experiments were well-designed and made in the right way.

Fulfilling the main objectives of the work

The thesis is well-organized and properly written (there are not any editorial errors), containing extensive literature review (Sections 1.1, 2.1 and 3.1). It demonstrates that the candidate has a good knowledge about current state-of-the-art in the field of parallel algorithms designing for industry engineering applications. Concluding, the doctoral thesis of Ing. Libor Bukata forms a solid piece of work and it fulfills the requirements of Ph.D. degree.

Methods used in the thesis

In my opinion the candidate has sufficient knowledge in the field of methods and tools of the research. The extensive literature review also demonstrates that the author has a deep and wide understanding of processors cache classifications and usage, including also hash based approaches. The author

exhibits sufficient knowledge of the research topic and familiarity with the discipline presenting detailed information about theory and practice, using analysis techniques together with synthesis and evaluation appropriately adjusted to the research topics.

Main results and contributions of the work area

Chapter 2 presents a holistic approach to the energy optimization of robotic cells that considers many optimization aspects. A universal mathematical model for describing robotic cells is proposed, from which a MILP formulation is derived that is directly resolvable by MILP solvers. Due to limitations of exact methods for larger sizes of problem instances, the parallel Hybrid Heuristic and Branch & Bound algorithm have been proposed.

Chapter 3 presents the algorithm for solving the resource-constrained project scheduling problem (RCPSP) using GPUs. The proposed parallel algorithm is based on Tabu Search method and it is implemented in CUDA environment. The research has empirical character and it is fully based on heuristic approach. The author focused on technical elements of the algorithm, such as initial solution determination and moves (neighborhood) generation. As the interesting element, the author proposes an algorithm for infeasible moves detection and removing.

Importance for the further development of science

The proposed approach was used to optimize the problem from practice, namely existing robotic cell from Skoda Auto, for which the measurements used were connected with energy savings levels. Robotic cells work optimization was obtained by changing the robot speeds and applying power saving modes.

Satisfying the conditions of a creative scientific work

In my opinion the candidate demonstrates the ability to conceptualize the research problem as well as to present research results in appropriate form which is commonly used in the literature. The contribution to the Field of Knowledge is done by the candidate's original investigation.

The author of the thesis proved to have the ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

Wojciech
Bożejko

Elektronicznie podpisany przez Wojciech
Bożejko
DN: c=PL, st=dolnośląskie, l=Wrocław,
o=Politechnika Wrocławska, sn=Bożejko,
givenName=Wojciech,
serialNumber=PESEL: 74051505098,
cn=Wojciech Bożejko,
postalAddress=Wyrbrzeże St.
Wyspiańskiego 27, 50-370 Wrocław
Data: 2018.07.19 12:14:19 +02'00'

Minor comments:

1. There is a lack of exact speedup (theoretical as well as empirical) and cost comparison for the algorithm proposed in Chapter 2. A short speedup approximation presented in Section 2.12.1 is not very accurate.

2. There is a speedup discussion in Chapter 3, however, this measure is not defined in the dissertation. It seems that the author considers parallel GPU against (multi-core) CPU versions of the algorithm. Perhaps it would be worth considering a comparison of the times of the parallel p -cores GPU version against 1-core GPU version, as a 'weak speedup' to show the algorithm scalability. In such a case the values of achieved speedups will be undoubtedly much greater than these obtained against CPU version.

3. It is not clear if there is a parallel run-time or walltime presented on the horizontal axe in Figure 2.13. If it is a walltime, there is no surprise that the parallel heuristic obtains better results in the same time as sequential one does. The question is about the results of both approaches (parallel and sequential) with the same computations cost, understood as the number of cores multiplied by computation time (walltime).

Furthermore – being inspired by Figure 2.13 – it would be very interesting to see algorithms efficiency in time as a function of the electric energy used in calculations (in J or Wh (Watt times hour)). It would be an 'absolute' comparison with – exactly – the same cost, understood here as an energy consumption (by the computer).

For instance, when the author writes that 'total throughput for Gurobi solver was increased from 8.4 to 393 nodes/s' it is not clear, if the computations cost is the same. It seems as if it was not. Therefore, if it was possible to obtain better results in the longer (total) time or cost, it wouldn't be surprising.

4. (page 58) When writing about a parallel TS algorithm the author refers to the work of James et al. from 2009, while the classification of parallel TS algorithms quite long ago (in 1999) was proposed by Voss.