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The Coupled Task Scheduling Problem: Models and Solution Methods

by

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Certificate of Authorship/Originality

I, Mostafa Khatami, certify that the work in this thesis has not been previously submitted for a degree nor has it been submitted as a part of the requirements for other degree except as fully acknowledged within the text.

I also certify that this thesis has been written by me. Any help that I have received in my research and in the preparation of the thesis itself has been fully acknowledged. In addition, I certify that all information sources and literature used are quoted in the thesis.

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ABSTRACT

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The coupled task scheduling problem (CTSP) is studied in this thesis. The problem consists of scheduling a set of jobs on one or a set of machines, where each job consists of at least two tasks. The main characteristic of the problem is a fixed time-lag between the process of each two consecutive tasks of the same job, where its duration is fixed, i.e., the succeeding task cannot be started earlier or later than the time-lag is passed. The fixed time-lags were introduced to model radar tracking systems, and later extended to formulate problems in chemistry manufacturing systems and robotic cells. The motivation for studying the CTSP in this thesis is to model certain problems in healthcare scheduling with the same characteristics. One example is the scheduling of patients in a chemotherapy clinic, where each patient must undergo a number of consecutive treatments with time-lags in between. Meeting the fixed delays between the treatments of a patient is an important factor in gaining the best outcomes for them. To study the CTSP, a literature review is first conducted, followed by studying the problem in different scheduling environments, including the single-machine, parallel-machine, open-shop and flow-shop settings, where we propose several new complexity results and solution algorithms for different variants of the problem.

Regarding the single-machine coupled task problem, a new mathematical formulation and two matheuristic algorithms are proposed for the classical problem, as well as a dynamic programming algorithm for a variant of the problem with time-dependent processing times.

With regard to the parallel-machine environment, we first explore the complexity of the problem and propose NP-hardness proofs for certain cases, followed by approximation bounds for the two-machine problem. The latter result is then extended to the open-shop scheduling environment.

The problem in the flow-shop environment is then extensively investigated under the permutation setting, and also under the case of ordered processing times. A set of publicly available hard data set and state-of-the-art algorithms are proposed for the ordered flow-shops. Then, flow-shop problem with coupled tasks is studied and polynomial-time algorithms are proposed for various settings of the problem, including the ordered processing times.

Dissertation directed by Dr Amir Salehipour
School of Mathematical and Physical Sciences

Dedication

I would have never accomplished this degree without your wholehearted love, *Mahboubeh*. To you, my beloved wife, and our little *Ali*.

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List of Publications

Journal Papers

J-1. Khatami, M., Salehipour, A., and Hwang, F. J. (2019). "Makespan minimization for the m-machine ordered flow shop scheduling problem". *Computers and Operations Research* 111, 400–414.

J-2. Khatami, M., Salehipour, A., and Cheng, T. C. E. (2020). "Coupled task scheduling with exact delays: Literature review and models". *European Journal of Operational Research* 282(1), 19 –39.

J-3. Khatami, M. and Salehipour, A. (2021a). "A binary search algorithm for the general coupled task scheduling problem". *4OR* 19(4), 593–611.

J-4. Khatami, M. and Salehipour, A. (2021b). "Coupled task scheduling with time-dependent processing times". *Journal of Scheduling* 24, 223–236.

Conference Papers

C-1. Khatami, M., Salehipour, A., and Hwang, F. J. (2018). "Single-machine coupled task scheduling with time-dependent processing times". *ASOR 2018.* Melbourne, Australia.

C-2. Khatami, M. and Salehipour, A. (2019). "A simple heuristic for the coupled task scheduling problem". *MODSIM 2019.* Canberra, Australia.

C-3. Khatami, M. and Salehipour, A. (2020). "A relax-and-solve algorithm for the ordered flow-shop scheduling problem". *IEEE IEEM 2020.* Singapore.

Preprints under review

P-1. Khatami, M. and Salehipour, A. (2021c). "The coupled task scheduling problem: An improved mathematical program and a new solution algorithm". *Submitted to International Transactions in Operational Research.*

P-2. Khatami, M., Salehipour, A., and Cheng, T. C. E. (2021b). "Flow-shop scheduling with exact delays to minimize makespan". *Submitted to Computers & Industrial Engineering.*

P-3. Khatami, M., Oron, D., and Salehipour, A. (2021a). "Scheduling coupled tasks on parallel identical machines". *Submitted to Annals of Operations Research.*

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