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Reduction of Permutation Flowshop Problems to Single Machine Problems using Machine Dominance Relations

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Abstract

The Permutation Flowshop Scheduling Problem with Makespan objective (PFSP-M) is known to be NP-hard for more than two machines, and literally hundreds of works in the last decades have proposed exact and approximate algorithms to solve it. These works –of computational/experimental nature– show that the PFSP-M is also *empirically* hard, in the sense that optimal or quasi-optimal sequences statistically represent a very small fraction of the space of feasible solutions, and that there are big differences among the corresponding makespan values. In the vast majority of these works, it has been assumed that a) processing times are not job- and/or machine-correlated, and b) all machines are initially available. However, some works have found that the problem turns to be almost trivial (i.e. almost every sequence yields an optimal or quasi-optimal solution) if one of these assumptions is dropped. To the best of our knowledge, no theoretical or experimental explanation has been proposed by this rather peculiar fact.

Our hypothesis is that, under certain conditions of machine availability, or correlated processing times, the performance of a given sequence in a flowshop is largely determined by only one stage, thus effectively transforming the flowshop layout into a single machine. Since the single machine scheduling problem with makespan objective is a trivial problem where all feasible sequences are optimal, it would follow that, under these conditions, the equivalent PFSP-M is almost trivial. To address this working hypothesis from a general perspective, we investigate some conditions that allow reducing a permutation flowshop scheduling problem to a single machine scheduling problem, focusing on the two most common objectives in the literature, namely makespan and flowtime. Our work is a combination of theoretical and computational analysis, therefore several properties are derived to prove the conditions for an exact (theoretical) equivalence, together with an extensive computational evaluation to establish an empirical equivalence.

Keywords: Scheduling, Flowshop, processing times, PFSP, makespan, flowtime, Single Machine, dominating machine

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