Energy-efficient scheduling of automated container terminals using piecewise affine approximations

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Operational energy efficiency of container terminals needs to be improved, which typically involves optimizing the completion time and energy consumption simultaneously [1]. For this bi-objective optimization problem, the balance between the completion time and the energy consumption has been investigated [2, 3], while the energy consumption has been greatly reduced when the minimal completion time is obtained [1]. In [1], the completion time and the energy consumption are transformed through a hierarchical control architecture where the energy consumption is reduced implicitly. This transformation, however, cannot minimize the exact energy consumption directly, leading to a unknown gap from the minimal value. Therefore, it is still unclear that, when minimizing the completion time, how the energy consumption can be minimized straightforward.

To answer this research question, we propose a new approaching for the bi-objective optimization problem for which the energy consumption is minimized explicitly when a minimal makespan is considered. Regarding operation times as decision variables, the velocity of a particular piece of equipment is approximated using a piecewise affine representation. Using this approximation, the energy consumption can be explicitly expressed in the objective function mathematically together with the makespan. To model the case of multiple pieces of equipment in a stage, a hybrid flow shop representation is proposed. A bi-objective optimization problem is formulated where the energy consumption with a weighting factor is considered with the makespan together. Simulations will be conducted for comparing the performance of the proposed method with the result of a container terminal benchmark system proposed in [1]. Different levels of robustness involving sequencing, assignment, and processing times will be discussed as well.

References

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