Reinforcement Learning for Dual-Resource Constrained Scheduling ⋆

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Abstract: This paper proposes using reinforcement learning to solve scheduling problems where two types of resources of limited availability must be allocated. The goal is to minimize the makespan of a dual-resource constrained flexible job shop scheduling problem. Efficient practical implementation is very valuable to industry, yet it is often only solved combining heuristics and expert knowledge. A framework for training a reinforcement learning agent to schedule diverse dual-resource constrained job shops is presented. Comparison with other state-of-the-art approaches is done on both simpler and more complex instances that the ones used for training. Results show the agent produces competitive solutions for small instances that can outperform the implemented heuristic if given enough time. Other extensions are needed before real-world deployment, such as deadlines and constraining resources to work shifts.

Keywords: Production planning and control, Job and activity scheduling, Intelligent manufacturing systems

1. INTRODUCTION

Scheduling is an integral part of manufacturing and service industries. Efficiently assigning work to the available resources can have a big impact on overall efficiency. One of the most common approaches to modelling manufacturing units is the *job shop* (JS) formulation, as can be seen in Pinedo (2009).

The JS is concerned with efficiently assigning the workload, the *jobs*, to the available resources, commonly *machines*. For over forty years the JS has been a widely researched topic. It has many extensions and a wide range of solution approaches dedicated to each, as detailed in Morshed et al. (2017). If multiple equivalent resources exist it is called a *flexible* JP problem.

In many practical applications it is of interest to also allocate other auxiliary resources when these are limited and shared by all jobs. The *dual-resource constrained* (DRC) problem is used to model capacity constraints by two types of shared resources. Typically, these two constraints represent labour and machines. Labour commonly refers to worker availability for job processing or machine handling, as can be seen in Cunha et al. (2019). However, the constraining auxiliary resource could also a transporter between machines, as seen in Nouri et al. (2016). Moreover, a second material resource might also be needed simultaneously with machines. As detailed in Huiyuan et al. (2009), in a mass injection molding case study, neither machines nor moulds can be scheduled independently of each other. The same can be said on photolithography processes for semiconductor production, where machines and reticles are need simultaneous as presented in Ham (2018). A schematic of the DRC methodology considered for this paper can be seen on figure 1.

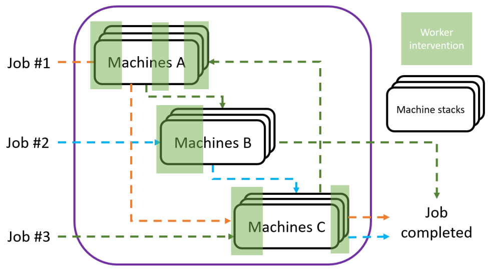

Fig. 1. A DRC flexible job shop combining machines (white rectangles) and workers (green rectangles).

Job shop literature considering the DRC is limited, as can be seen in Dhiflaoui et al. (2018). Only a handful of publications model workers who only need to be present for smaller periods of machine run time, such as: Shen et al. (2018); Cunha et al. (2019). On these most recent publications, worker intervention is modelled with the desired level of freedom of multiple varying interventions per operation. The formulation considered for the work

⋆ This work was supported by FCT, through IDMEC, under LAETA, project UIDP/50022/2020