A Novel Heuristic Rule for Job Shop Scheduling

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ABSTRACT

Scheduling systems based on traditional heuristic rules, which deal with the complexities of manufacturing systems, have been used by researchers for the past six decades. These heuristics rules prioritise all jobs that are waiting to be processed on a resource. In this paper, a novel Index Based Heuristic (IBH) solution for the Job Shop Scheduling Problem (JSSP) is presented with the objective of minimising the overall Makespan ($C_{\text{max}}$). The JSSP is still a challenge to researchers and is far from being completely solved due to its combinatorial nature. JSSP suits the challenges of current manufacturing environments. The proposed IBH calculates the indices of candidate jobs and assigns the job with the lower index value to the available machine. To minimise the gap between jobs, a swap technique is introduced. The swap technique takes candidate jobs for a machine and swaps them without violating the precedence constraint. Several benchmark problems are solved from the literature to test the validity and effectiveness of the proposed heuristic. The results show that the proposed IBH based algorithm outperforms the traditional heuristics and is a valid methodology for JSSP optimization.

Keywords: Index Based Heuristic (IBH), Job Index Value (IVal), Job Shop Scheduling Problem, Makespan, Manufacturing Scheduling

1. INTRODUCTION

In current manufacturing environments, low unit cost and high quality products no longer solely define an efficient manufacturing system (Maqsood, Khan, & Wood, 2010, 2011; Wu, Storer, & Martin-Vega, 1998). To maintain market share, the manufacturing system must be fast to respond (Jain & Meeran, 1999). It has been estimated that more than 75% of manufacturing processes occur in small batches. Scheduling organises the simultaneous execution of such batch manufacturing on machines, which becomes a complex problem to solve (Hussain, 1998; Noor, 2007). In manufacturing

DOI: 10.4018/jcrmm.2013010103
systems, with characteristics such as fluctuating demand, jobs with various product types and priorities, unbalanced capacity, re-entry of jobs into machines, alternative machines with unequal capacity, and shifting bottlenecks make scheduling a very difficult task (Chen, 2009). These conflicting requirements demand efficient, effective and accurate scheduling which is complex in all but the simplest production environments. As a result there is a great need for effective scheduling algorithms and heuristics (Chen, 2009; Jain & Meeran, 1999). Hence, scheduling is ultimately responsible for efficient manufacturing systems, and its efficiency and failure will therefore highly condition a company’s relationship with its customers (Lopez & Roubellat, 2008).

Within companies a scheduling function has always been present, but currently it faces increasingly complex scenarios because of the large number of variety in jobs that must be executed simultaneously with shorter manufacturing times (Lopez & Roubellat, 2008). Manufacturing systems operate under constant pressure due to unpredictability in demand and the ever decreasing product life cycles. Low volume manufacturing sectors are mainly facing this challenge. The job shop manufacturing environment best suits the mentioned challenges and improvement in its scheduling provides some immediate benefits of reduced material handling cost, reduced setup times and lower Work-In-Process (WIP) (Mohamed & Khan, 2011; Tariq, 2008).

2. JOB SHOP SCHEDULING PROBLEM (JSSP)

An efficient scheduling system is an essential part of any manufacturing environment and depends on the scheduling scenario (Janiak & Janiak, 2011; Maqsood, et al., 2011; Noor & Khan, 2007). In the literature various researchers (Blazewicz, Ecker, & Trystram, 2005; Blazewicz, Ecker, Pesch, Schmidt, & Weglarz, 1996; Jain & Meeran, 1998; Morshed, 2006; Noor, 2007; Zhang & Wu, 2010) have discussed mathematical models with the objective function of minimising Makespan ($C_{\text{max}}$). This objective is considered in this paper because it normally performs well on average with respect to criteria such as due date compliance, total completion time, total tardiness, total flow time, and maximum lateness.

In manufacturing scheduling problems, the resource is either disjunctive, where activities must be allocated in such a way that they do not overlap in time, or cumulative, which may be identical or non-identical copies of disjunctive resource in parallel. In this paper, a Job Shop Scheduling Problem (JSSP) is one which consists of a set of different machines (resources) that perform operations on jobs. Each job has a specified processing order or plan through the machines with certain processing times. The job shop environment considered in this paper, does not allow pre-emption or interruption during a process. In JSSP terminology $N$ is the number of jobs and ‘$O_M$’ is the number of operations of each job, which have to be processed on a set of $M$ machines. In JSSP ‘$O_M$’ is equal to the number of $M$ ($O_M = M$) with predetermined order or constraint for a given span of time. At any time, only one operation is possible on a single machine. The scheduling problem, regardless of the resource being disjunctive or made up of multiple copies or cumulative, is NP-hard combinatorial problem (Maqsood et al., 2010; Zhan, Qiu, & Xue, 2009).

For the last 50 years, researchers have developed and applied various heuristics and techniques to reduce the gap between two operations on a job. The dispatching rules or heuristic rules are the most common heuristics used for solving process scheduling problems. Based on predefined criteria these heuristics select a job to be processed from a queue of jobs. Due to their ease of implementation and substantially reduced computational requirements these approximation-based heuristics are very popular techniques in scheduling (Morshed, 2006). Some well-known heuristic rules are discussed in Section 3. Their importance is derived from the fact that these techniques generate active
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