Simulation and optimization for predictive-reactive job shop scheduling of reconfigurable manufacturing system

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ABSTRACT – Reconfigurable has been a demand for a manufacturing system, including job shop production, to support the hard to predict the global business market. Predictive-Reactive Job Shop Scheduling approach for the reconfigurable manufacturing system has been proved to be helpful. However, the job shop scheduling problems are NP-hard (non-deterministic polynomial-time – hard). Therefore, efficient heuristics must be applied for their solution. Simulation can be used to construct the mapping between situation description and appropriate parameters of the heuristic. For this instance, combining the advantages of simulation with the optimisation algorithm will be a promising solution. By combining both simulation and optimization, the production time can be decreased effectively.

1. INTRODUCTION

The contemporary market continues to push all kinds of business and especially manufacturers towards flexibility. Manufacturing systems must absorb fluctuations in demand, quickly adopt new products and changes in orders [1].

Effectively application of scheduling can bring to raises in efficiency and capacity utilization, together with the reduction of completion time and increased profit for the company [2]. Reconfigurable manufacturing systems have been quite popular in research works lately, and most of the algorithms, dispatching rules and strategies have been developed long ago. The development of algorithms, dispatching rules and strategies in reconfigurable manufacturing systems were aimed to boost and improve the efficiency and optimized the systems based on different layout and arrangements of manufacturing systems [3,4].

Until today, however, there is no framework or specific strategy developed to obtain accurate and fast control of these systems. Traditional methods imply high approximation of real systems and are complicated in formulation; also, most of available algorithms do not provide the result in a reasonable time due to complexity of and large number of variables and constraints [5]. Hence, the combination of simulation and optimization-based algorithm are required to be implemented in job shop scheduling to adapt to the real-world situation of flexible and reconfigurable production systems [6]. Simulation-based scheduling and controlling bring a lot of advantages and simplifications. It enables easy testing and analysis of new layouts and schedules, provides a possibility for direct control of production, and proves to become a great basis for optimization and scheduling process.

Thus, this work focuses on developing the simulation model for reconfigurable manufacturing cell, that will be able to bear flexibility in layout of the system, and product mix with flexible routing and processing sequence. On a basis of this model, schedule optimization framework will be also provided.

2. METHODOLOGY

The first objective will be achieved through the methodology of construction of feasible schedule approach and formulation of an algorithm for predictive job shop manufacturing. The second objective will be achieved through the development of simulation model using simulation software which is Tecnomatix Plant Simulation 12, then with the methodology of the generation of schedule by using a combination of rule-based simulation and optimization and the analysis of the results of the simulation model created. For the third objective, the algorithm created will be validated through lab-based and industrial case study, and improvement will be done based on the results obtained. The results will be analyzed and discussed, and the conclusion will be drawn together with recommendations.

3. RESULT AND DISCUSSION

The outcome of this project is a validated combined algorithm and is achieved through lab-based and industrial case studies. The outcome proved that the combination of simulation and the optimization-based algorithm is effective in predictive-reactive job shop scheduling of reconfigurable manufacturing systems. The main benefit of this algorithm will be in the aspect of reduction of production or cycle times and increase productivity.

The multi-process performance is compared. The GAwizard provides possibility to run optimization in multiple streams to shorten the optimization time. There is an increase of performance when running optimization in single and multiple streams, as shown in Figure 1. Time consumed in the case of four streams is 2.5 lower then in single stream, whcih indicated an exponential increase of performance .

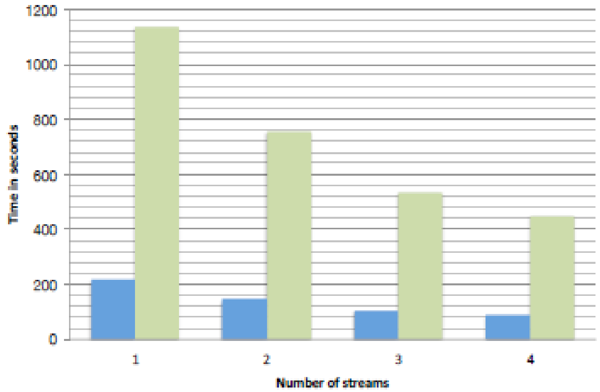

Figure 1 Multi-process performance

A series of optimization runs were made to assess the impact of different settings on schedule. As a result, there are several combinations show very similar performance. As it was expected, there are also some release and control option that show their release control limit system to strong system and leads to a week schedule. All other combinations of these settings led to blocked system.

A set of optimization runs was made with number of generations fixed to 20, and varying generation size in order to find if 30-40 range for generation size is optimal in regard to performance. The result in Figure 2 showed that the pattern of the improvement speed is decreasing with increase of generation size. The speed is calculated as improvement in fitness divided by time consumed, while for optimization runs with limited time or number of generations, smaller generation sizes show much better performance, longer runs show opposite.

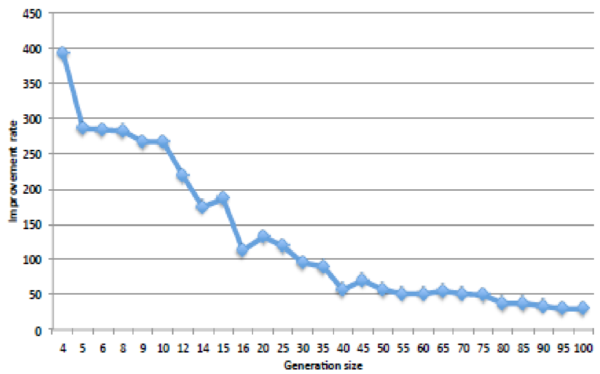

Figure 2 Improvement rate in 20 generations

Two Gantt chart were compared, with the criteria of one is not optimized schedule, and other one is the optimized schedule for the reference order, with pickup options enabled and first optional release control. These charts are generated by Gantt Wizard available in Tecnomatix Plant Simulation. This wizard does not provide possibilities to easy change settings like labels of blocks, grouping or even stations list. Although it is not very informative, it does show the optimization level of schedule. For objective functions that do not provide known or easy to calculate lower (upper) bound, like, for instance, makespan, it may show that even if schedule is not the most optimal it does not have much potential for improvement, which is comparing both charts to see that there are several stations do not have the gaps, which means that utilization is very high and they are not idling. Although utilization can be found in statistics of each station, having visual representation of schedule makes quick assessment easier.

4. CONCLUSION

In short, this research project is to prove that the combination of simulation and the optimization-based algorithm may potentially and successfully reduce the production throughput time of the complex reconfigurable manufacturing systems in predictive-reactive job shop scheduling. The formulation of artificial intelligence in simulation technology may also be implemented in other manufacturing systems with a different layout. The layout of a system may be easily modified in the simulation model, hence will increase the capability of the formulated algorithm in scheduling.

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