# Research Outline on Reconfigurable Manufacturing System Production Scheduling Employing Fuzzy Logic

Taravatsadat Nehzati, Napsiah Ismail, Faieza Abdul Aziz, and Seyed Ali Hosseini

***Abstract*—This paper presents a research project carry out at Faculty of Engineering, University Putra Malaysia in the area of fuzzy scheduling. The fuzzy based scheduling model, in this paper, will only deal with the job assignment problem in Reconfigurable Manufacturing System (RMS). The model will select the best alternative machine with multi-criteria scheduling through an approach based on a fuzzy logic. This paper aim to show the framework of research and methodology, which aspire to be constructing based on.**

***Index Terms*—Production scheduling, fuzzy logic, reconfiguration, modularity**

## I. Introduction

Manufacturing systems passed through different paradigms to respond to the increasing size and dynamics of the evolving market place, which is today based on heavy competitiveness. Shorter product life-cycles, unpredictable demand, and customized products have forced manufacturing system to operate more responsively to customer demand, and their ever changing requirements.

Evolution of manufacturing systems has taken several forms. Job shops use general purpose machines for low volume and high variety product orders. Dedicated Manufacturing System (DMS) is driven by economy of scale for high volume and low variety products. The needs for mass customization and greater responsiveness to changes in products lead to the concept of flexible manufacturing systems (FMSs) for mid-volume, mid variety production needs ([1], [2] and[3]) .

Today's global markets are characterized by shorter product life cycle and unanticipated change in the demand. The demand change in dynamic environments, where changes to production requirements are random [4], stretch the limits of conventional manufacturing systems. To alleviate this strain on conventional manufacturing, new and innovative ways of designing manufacturing landscape have been well researched and implemented ([5], [6]). Such efforts have culminated in the advent of reconfigurable manufacturing systems (RMSs) which was first introduced by Koren et al. [6].

The new RMS needs production scheduling system to cope with the new characteristics of the RMS which is subject to different configuration changes to cope with sudden demand changes in both the hardware and software levels. These configuration changes include changes of/within machine or tools; add/remove machines or tools, changes in resources and the location or layout of machines.

Methods for scheduling of production process have been previously developed based on the existing manufacturing system capabilities. However, in RMS the capabilities of machines and manufacturing system change with each reconfiguration and may result in changes in scheduling (timing sequencing, routing, and priority setting). For this reason there is a need for new methodologies for production scheduling and machine selection in RMS. According to [7] considering the Reconfigurable Manufacturing challenge lies in three indentified critical issues; optimal process selection, optimal process sequencing and optimal part load scheduling.

This optimal situation would not be attainable unless the manufacturing system functions in design, production planning, scheduling, and controlling sections work properly. Various kinds of scheduling problems might be generated based on the considered approaches for measuring the scheduling performance. Scheduling methods can be classed into different categories, such as combinatorial optimization, artificial intelligence, simulation-based scheduling with dispatching rules, heuristics-oriented, and multi criteria decision making. However, face with production scheduling problem in a reconfigurable environment is usually very complex, since the manufacturing arena is dynamic as result of reconfigurable components. Not only the RMS but other manufacturing systems which encounter with dynamicity, are in need of dynamic and unpredictable conditions' scheduling. Like other dynamic manufacturing environment which used artificial intelligent techniques, artificial intelligence and heuristic based approaches have been considered in RMS production planning and scheduling.

As one of AI techniques, Fuzzy Logic (FL) - which was commenced by Zadeh (1965) - has been applied to different industrial issues as well as manufacturing systems. Lately, there has been remarkable concentrating gave to modeling production scheduling problems within a fuzzy framework. The ascendancy of the fuzzy logic system approach is that it includes both numerical results (from a previous solution or simulation) and the scheduling expertise (from knowledge or remark), and ease of implementation. Although comparison between previous researches due to various scopes in objectives and their applications makes it complicated but when it comes to RMS production scheduling it doesn't exceed a few. Several fuzzy logic based scheduling systems have been developed, however none of them tackled scheduling in reconfigurable

Manuscript received May 16, 2012; revised June 18, 2012.

The authors are with the Department of Mechanical and Manufacturing Engineering, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia(e-mail: Taravat.s.nehzati@gmail.com, napsiah@eng.upm.edu.my, aieza@eng.upm.edu.my, ali.hoseini83@gmail.com).

DOI: 10.7763/IJIEE.2012.V2.214

manufacturing environment (see Table I).

TABLE I: SUMMARY OF RELATED RESEARCH WORKS

| Ref num | Year | Problem Properties | | | | Solution Technique | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RMS | Scheduling | Capacity/Demand variation Management | CAPP | Fuzzy | DSS | Math/static | Neural Network | GA |
| [8] | 2003 | ■ | | ■ | | | | ■ | | |
| [9] | 2004 | ■ | ■ | | | | | | | |
| [10] | 2005 | ■ | | | | | | ■ | | |
| [4] | 2006 | ■ | ■ | | | | | | | ■ |
| [11] | 2006 | ■ | | ■ | | | | | | |
| [12] | 2007 | ■ | | | ■ | | | ■ | | |
| [13] | 2008 | ■ | ■ | | | | | ■ | ■ | ■ |
| [14] | 2008 | ■ | | | ■ | | | | | ■ |
| [1] | 2009 | ■ | | | | ■ | | | | |
| [16] | 2009 | ■ | | | | | | | | |

A fuzzy logic system that integrates both dispatching rules and scheduling expertise has been proposed to guide a dynamic selection of dispatching rules in job shops with objective to minimize the total weighted. Reference [17] proposed a fuzzy scheduler that uses the prevailing conditions in the job shop to select dynamically the most appropriate dispatching rule from several candidate rules. The results indicate that the fuzzy scheduler is effective. Nevertheless developed frame work employing fuzzy logic just considered flexible manufacturing systems and job shop environments. This research attempts to improve this method to be applicable for reconfigurable manufacturing system.

In this research, Fuzzy Logic is employed to generate a Fuzzy Scheduling model in order to select the best job assignment for a given job.

## II. INDUSTRIAL IMPLICATION

Scheduling is the process of organizing, choosing and timing resource usage to carry out all the activities necessary to produce the desired outputs of activities and resources [3] . In an RMS, the objective of scheduling is to optimize the use of resources so that the overall production goals are met. A Fuzzy Based Scheduling Model for RMS which is developed here aims at making real-time control decisions that include dynamic scheduling and variable part routing used to solve scheduling problems in FMS environments. Otherwise the model will be verified by adopting a case from literature [16]. Reconfigurable Machine Tool (RMT) information will be use to cover the leakage of information in adopted case from literature.

## III. FUZZY LOGIC APPROUCH TO SCHEDULING PROBLEM

Fuzzy logic, although a mathematical technique, defines its behavioral framework through a compact linguistic rule base. It has the ability to concurrently consider multiple criteria and to model human experience in the form of simple rules. Furthermore, the advantage of the fuzzy logic system approach is that it incorporates both numerical and linguistic variables.

In this paper, we apply a fuzzy logic to the dynamic scheduling problems in an RMS environment. The fuzzy based scheduling, in this paper, is designed to solve the problem of selecting the best job assignment for a given job which is the sub-problem of scheduling in a reconfigurable manufacturing system (RMS). In particular, we will show how to obtain scheduling via a proposed fuzzy model as shown in Fig. 1.

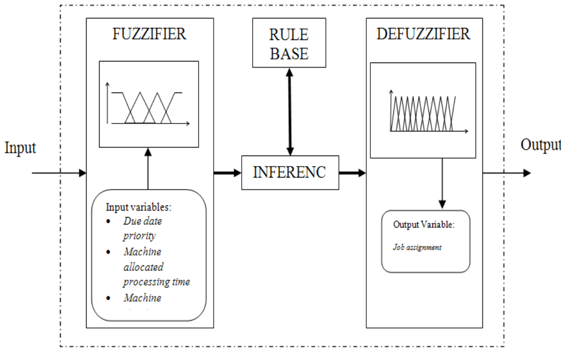


Fig. 1. Fuzzy model for job assignment

## IV. FUZZY MODEL STRUCTURE

### A. Manufacturing Content

The RMS considered here consists of;

A set M of different machines (RMT), M= {1,2,….N}

L part types (jobs) J = 1… L.

Consists of Q parts

Each job J has a sequence of N operations to be produced

Every job J has corresponding due dateD

Each operation i for a job J may be performed by any of the machines in subset E of Machine set M (based on the machine's module/ matching ability) in a given uninterrupted processing time P and the corresponding setup time S.

The model proposes to indicate Job priority on reconfiguration environment.

### B. Assumption

The following assumptions has considered as a base for model development:

- No allowance for breakdowns in machines or material handling.
- Machines are reconfigurable (RMT) and consist of several fixed bases. There is a wide variety of modules for each of axes to be added to the machine base to obtain the required machine capability.
- The machines are not identical
- Each machine is capable of performing different operations.
- Raw materials, such as machine structure, tools, and fixtures are always available
- Operations are not divided or interrupted when started.

### C. Fuzzy Input Variable

The manufacturing system is dealing with many subjective inputs and variables. This research applies Fuzzy

Logic to capture the nature of the inputs and variables more realistically and effectively.

- **Due date priority:** This variable assigns the deadline at which the processing of job $J$ is due to be complete.
- **Machine structure:** This input variable is used to establish the minimum machine module need to be use for each part type to be process.
- **Machine allocated processing time:** This variable is used in order to balance the machine loads.
- **Machine priority:** This variable forces the assignment of the next operation of a given job to start at the closest possible time to finishing of the previous operation of the same job

### D. Fuzzy Output Variable

- **Job priority:** Job priority $J_p$ determines the machine to perform the next operation for job $J$. This output variable which produced by the fuzzy system, depends on the four fuzzy time factors explained earlier.

The proposed model evaluates the contribution of four membership functions to the three performance measures namely makespan, average machine utilization and flow time.

### E. Fuzzy Inference System

When the inputs are entered into the system, they are first fuzzified according to the membership functions of input fuzzy variables. Then the proper fuzzy estimation decision is inferred based on a defined set of linguistic rules. Since there are four input variables the total number of possible ordered pairs of these states is calculating as follow:

$a_1 \times a_2 \times a_3 \times a_4 =$ *number of rules*

Where: $a_*$ is number of defined fuzzy set for variable

For each of these ordered pairs of states, an appropriate state of the variable job priority has to be determined. Usually rule definition is based on common sense, the engineer's knowledge and the operator's experience. However, it has been noticed in practice by researchers that for monotonic systems a symmetrical rule table is appropriate, although sometimes in may need slight adjustment based on the behavior of the specific system. Trial-and-error procedures and experience play an important role in defining the rules.

When four inputs are entered into the system as shown in Fig. 1, a crisp output will be obtained for job priority. This value is calculated using Mamdani's (1975) method as inference mechanism.

## V. Case Problem

Nowadays the implementation of RMS is in the beginning and therefore it is not possible to obtain real data of the operational costs required to configure the production system. To overcome this limitation this study attempts to adopt the job shop problem from Gamila and Motevalli [18] combining with reconfigurable machine tools (RMT) characteristics in Spicer [10].

In case study of Gamila and Motevalli [16] five (5) machines in the FMS which have a tool magazine with the capacity of 60 tool slots has been considered. The travelling time of parts and the time to put the pallet on or to take it off the material handling device are negligible. In their FMS model, five different part types have been defined each part type is consist of five (5) operations; due date and setup time for each part type has been defined. Figure 2 demonstrate a sample manufacturing layout.

As it stated in [2] product features is needed to generate machine configuration, so to put machine structure as an input variable, there would be a necessary need for part types feature to be define in advance. Regarding to this necessity, detailed information on reconfigurable machine tools exploited from Spicer [10].

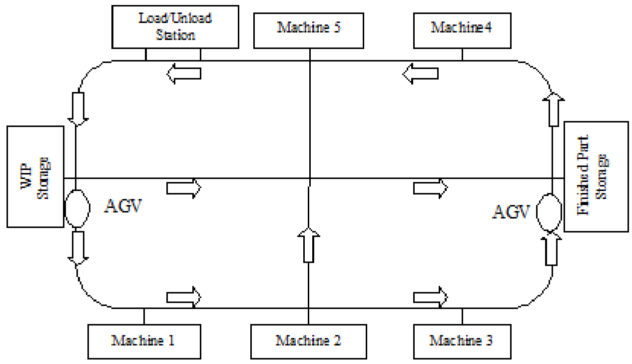


Fig. 2. Scheme of reconfigurable manufacturing system

Landers et al. [19] introduced the concept of reconfigurable machine tool (RMT) as a modular machine with a modular control system that gives manufacturers the ability to modify machine structure to suit specific manufacturing needs. They provide an example of modular (scalable) machine that can be reconfigures to decrease cycle time, therefore increasing the productivity of machine. Spicer et al. [10] introduced the concept of a machine tool designed specifically for scalability. It is called a multi-spindle scalable machine tool. This concept provides the option of adding and removing multiple spindles on an as-needed basis. The benefit of this concept is: reducing capital investment, reduced reconfiguration time, and reduced consumption of space.

## VI. Conclusion

In light of the discussion in previous sections, this research work outlines production scheduling solution methodology in RMS environment which fell in logical (soft) type of configuration. Employing fuzzy logic for RMS production scheduling, provides both qualitative and quantitative comparisons on the broader scope of the implemented techniques. As such, the effort of this work goes beyond proof of concept by: (i) analytically assessing the effectiveness of the fuzzy solution profiles in an application environment and (ii) evaluating the effects of fuzzy solution on adaptability as well as on the overall performance of reconfigurable manufacturing systems. A job shop case problem is applied for experimental validation of fuzzy model to assess the suitability of generated alternative manufacturing production scheduling.

It is acknowledged that reconfigurable manufacturing systems (RMSs) are a relatively new paradigm. Therefore, the importance of logical enablers of RMS concepts and techniques, such as reconfigurable production scheduling can never be underestimated. Hence, the main thrust in this work is using fuzzy based model and comparing its performance in handling reconfigurable production scheduling in manufacturing systems.

## REFERENCES


[1] E. Aleisa and L. Lin, "For effectiveness facilities planning: Layout optimization then simulation, or vice versa," in *Proc. 37th Winter Simulation Conference*, Orlando, FL, USA, 2005, pp. 1381-1385.

[2] H. A. ElMaraghy, "Flexible and reconfigurable manufacturing systems paradigms," *International Journal of Flexible Manufacturing Systems*, vol. 17, no. 4, pp. 261-276, 2005.

[3] P. Srinoi, E. Shayan, and F.Ghotb, "Scheduling of flexible manufacturing systems using fuzzy logic," Swinburne University.

[4] A. Li and N. Xie, "A robust scheduling for reconfigurable manufacturing system using petri nets and genetic algorithm," in *Proc. of the 6th World* Congress *on Intelligent Control and Automation*, 2006, pp.7302-7306.

[5] Y. Koren and A. G. Ulsoy, "Vision, principles and impact of reconfigurable manufacturing systems," *Powertrain International*, pp.14-21, 2002.

[6] Y. Koren, U. Heisel, F. Jovane, T. Moriwaki, G. Pritschow, and G. Ulsoy, "Reconfigurable manufacturing systems," *CIRP Annals* - Manufacturing *Technology*, vol. 48, no. 2, pp. 527-540, 1999.

[7] F. Musharavati, "Process planning optimization in reconfigurable manufacturing systems," Ph.D dissertation, Dep. Mech and Mnfc Eng., University Putra Malaysia., Selangor, Malaysia, 2008.

[8] F. M. Asl and A. G. Ulsoy, "Stochastic Optimal Capacity Management in Reconfigurable Manufacturing Systems," *CIRP Ann. Manuf. Technol,* vol. 52, pp. 371-374, 2003.

[9] M. Bruccoleri, Z. J. Pasek, and Y. Koren, "Operation management in reconfigurable manufacturing systems: Reconfiguration for error handling," *Int J Prod Econ,* vol. 100, pp. 87-100, 3, 2006.

[10] S. D. Y. Hoi and Y. Koren, "Scalable reconfigurable equipment design principles," *Int J Prod Res*, vol. 43, pp. 4839-4852, 2005.

[11] A. M. Deif and W. H. ElMaraghy, "A control approach to explore the dynamics of capacity scalability in reconfigurable manufacturing systems," *J. Manuf. Syst,* vol. 25, pp. 12-24, 2006.

[12] A. Azab and H. A. ElMaraghy, "Mathematical Modeling for Reconfigurable Process Planning," CIRP Ann. Manuf. Technol, vol. 56, pp. 467-472, 2007.

[13] R. Galan, J. Racero, I. Eguia, and J. M. Garcia, "A systematic approach for product families formation in Reconfigurable Manufacturing Systems," *Robot. Comput. Integrated Manuf,* vol. 23, pp. 489-502, 10, 2007.

[14] N. Ismail, F. Musharavati, A. S. M. Hamouda, and A. R. Ramli, "Manufacturing process planning optimization in reconfigurable multiple part flow lines," *Journal of Achievement in Materials and Manufacturing Engineering*, vol. 31, no. 2, pp. 671-677, 2008.

[15] R. Abdi, "Fuzzy multi-criteria decision model for evaluating reconfigurable machines," *Int J Prod Econ,* vol. 117, pp. 1-15, 1, 2009.

[16] J. Li, X. Dai, Z. Meng, J. Dou, and X. Guan, "Rapid design and reconfiguration of Petri net models for reconfigurable manufacturing cells with improved net rewriting systems and activity diagrams," *Comput. Ind. Eng*, vol. 57, pp. 1431-1451, December 2009.

[17] V. Subramaniam, T. Ramesh, G.K. Lee, Y.S. Wong, and G.S. Hong, "Job Shop Scheduling with Dynamic Fuzzy Selection of Dispatching Rules," *International Journal of Advanced Manufacturing Technology*, vol. 16, Springer-Verlag, pp.759-764, 2000.

[18] M. A. Gamila, and S. Motavalli, "A modeling technique for loading and scheduling problems in FMS," Robotics and Computer-Integrated Manufacturing, vol.19, pp. 45-54, 2003.

[19] R. G. Landers, B. Min and Y. Koren, "Reconfigurable Machine Tools," CIRP *Ann. Manuf. Technol,* vol. 50, pp. 269-274, 2001.