IMPLEMENTATION OF FUZZY LOGIC IN SCHEDULING A FLEXIBLE MANUFACTURING SYSTEM

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ABSTRACT

A flexible manufacturing system (FMS) has the advantage that it can easily adapt to equipment malfunctions and changes in the quantity or type of the product being processed. Proper scheduling is critical for production planning in order to meet customer demand. The case study organisation has been facing challenges in meeting due dates while concurrently minimising lead time and maximising machine utilisation. This paper presents the deployment of fuzzy logic in scheduling a flexible manufacturing system. The proposed approach identifies scheduling parameters for routing parts through system and membership functions and fuzzy rules are constructed to develop the best schedule using a toolbox on a MATLAB fuzzy logic platform. After comparison of several priority rules for job sequencing, the results demonstrated the applicability of fuzzy logic as a decision tool in the scheduling of flexible manufacturing systems.

Keywords: Scheduling, Fuzzy logic, Flexible manufacturing system

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1 INTRODUCTION

Advances in technology have aided manufacturers cut down on the time and effort taken to process a batch of products and maintain a competitive edge in their industries through ensuring customer satisfaction [1]. However, when manufacturers attempt to be flexible enough and make products as per customer orders, they face numerous scheduling challenges such as failure to proactively anticipating shop floor variability, which would induce a domino effect across many operations and resources, causing significant production delays. Such volatile operational environments prompt for the need for innovative approaches, especially for a flexible manufacturing system (FMS). An FMS is designed to adapt to fluctuations or variations in product, production volumes, new product designs with the aid of computers and machines that can automate key manufacturing processes, including loading and unloading, machining and assembly, and data processing [2]. The case study organisation has been facing challenges in meeting due dates while concurrently minimising lead time and maximising machine utilisation. This paper presents the deployment of fuzzy logic in scheduling a flexible manufacturing system. The proposed approach identifies scheduling parameters for routing parts through system and membership functions and fuzzy rules are constructed to develop the best schedule using a toolbox on a MATLAB fuzzy logic platform. Fuzzy logic has the advantage that it is flexible, conceptually easy to comprehend, tolerant of imprecise data and can be deployed tomodel non-linear functions of arbitrary complexity.

2 RELATED LITERATURE

An FMS is a group of automated processing workstations that are interlinked by a material conveyance system and a centralised computer system that would synchronise and coordinate the manufacturing activities [3]. An FMS is characterised by several possibilities of routing paths and a combination of workstations served by a material handling system that deliveres parts as well as an automatic inspection.

Fuzzy logic has demostrated some interesting potential in solving scheduling problems in flexible manufacturing systems [4-6]. Bisht et al. [7] described basics of fuzzy sets, fuzzy rule base system, fuzzy memberships and defuzzification. The study embraced some standard fuzzy logic applications, diverse traits of fuzzy manufacturing systems as well as limitations of fuzzy modeling in flexible manufacturing systems.

With a scheduling algorithm based on distributed fuzzy control system design, Swe et al. [8] developed a flexible manufacturing process for autonomous control system for modern industries. A fuzzy logic controller design was utilised for scheduling algorithm based on distributed environment, resulting in more benefits in resource management, scheduling policies, on-time processing of work and speedy delivery.

Majdzik [9] designed of a framework for the implementation of fault-tolerant control of hybrid assembly systems that linked fully automated technical systems to human operators. The main challenge in such hybrid assembly systems was interconnected to delays that emanated from objective factors such as fatigue and experience that would influence human operators' work. The designed approach was able to guarantee real-time compensation of delays that were treated as faults, while the fully automated fragment of the system was accountable for this compensation. The use of a wireless IoTplatform that enabled a reference model of human performance to be defined using fuzzy logic was proposed for predictive delays-tolerant planning.

On the other hand, using fuzzy logic and fuzzy sets, Kazerooni et al. [10] developed two decision rules for real-time dispatching of parts and tested the model in a simulated FMS. Routing flexibility was considered as a vital aspect of FMSs, and by using fuzzy sets to incorporate system status in decision making, a routing selection approach was proposed. It was also observed that a traditional dispatching rule would uncritically pursue a single objective, yet in practice, it might be crucial to concurrently consider more than one objective. Thus, in this case, real time machine loading was also taken into consideration to develop two dispatching rules using fuzzy logic.

Several researchers have addressed the diverse facets and technologies that are related to smart manufacturing systems; however, less attention has been given to establishment of new smart manufacturing systems that necessitates pre-implementation planning and assessment. By identifying apparent evaluation factors for measuring the effectiveness of a particular smart manufacturing system configuration before implementation, Grace et al. [11] formulated an evaluation framework using lead time, quality, and cost as inputs to control the output of the configuration model. Several configurations were studied based on the trained fuzzy logic model using MATLAB's Fuzzy Logic Designer tool, and the compositions were manipulated according to how the factors influenced the manufacturing cost justification in compound setups. In order to weigh the level of satisfaction derived from the evaluation framework, the results obtained from the experimental study were validated by real field engineers from the relevant manufacturing industry.

3 PROCESS DESCRIPTION

The issue of improper scheduling has been problematic for the machineshop and there was no proper allocation of jobs at the right machines at the right time. The job may be available at a machine that is busy a part while another machine was idling due to poor scheduling. As shown in Figure 1, the FMS under study is characterised by 2 similar Horizontal CNC milling machines, 2 vertical CNC milling machines, 2 drill presses and a load/unload station served by material handling system. The system can process four dissimilar part types, A, B, C and D and it takes an average of 4 minutes for loading and unloading a part.

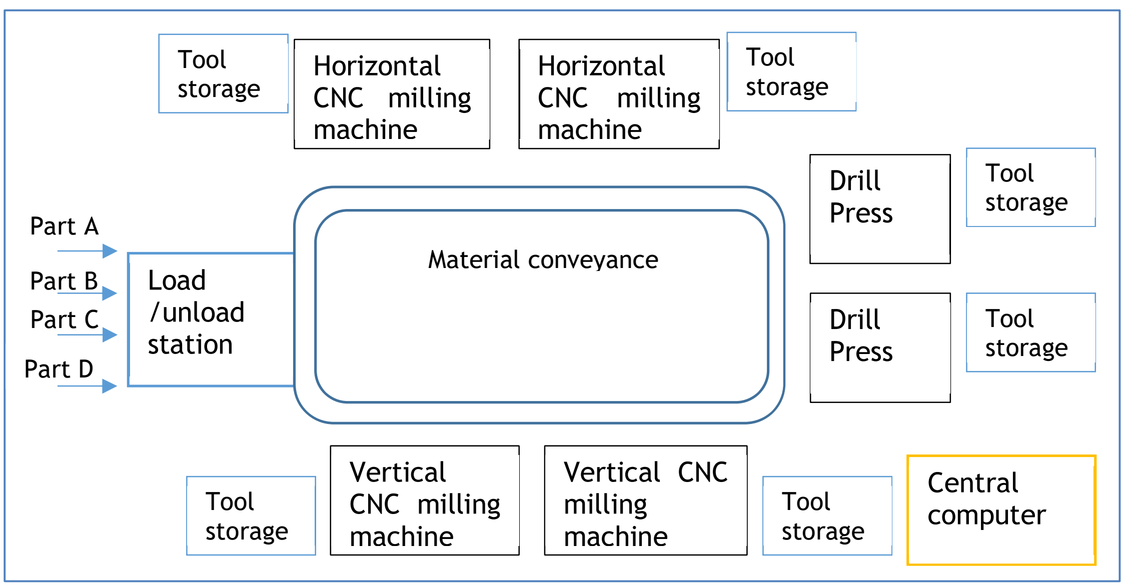

Figure 1: Schematic for FMS layout

The scheduling problem is to make a decision regarding the sequence of the jobs and alternate routes that could be chosen for individual part types. It was assumed that no machine could fabricate more than one component at an instance, every workstation has one input buffer and each machine was flexible to perform several operations. Additionally, any part type can follow numerous alternate routings and once commenced, operations cannot divided or interrupted. Set up times were considered to be independent of the job sequence and would be added to the processing times.

4 RESEARCH METHODS

Fuzzy Logic was applied in this research work to generate a fuzzy scheduling model for solving operation allocation and operation scheduling problems in FMS that can cope with several objectives of FMS scheduling. The fuzzy scheduler considered sequencing of job and routing as the two specific rules for the scheduling problem. The inputs were processing time and due dates and these were used to derive an optimal sequencing of jobs using fuzzy controllers and derive one consequent. The route for each part type loading on a machine was determined by the fuzzy system , such that if the load station or CNC machine was free, the job with the highest priority would be selected for processing. The routing problem was considered as a decisional point for selecting one route amongst several possible routes.

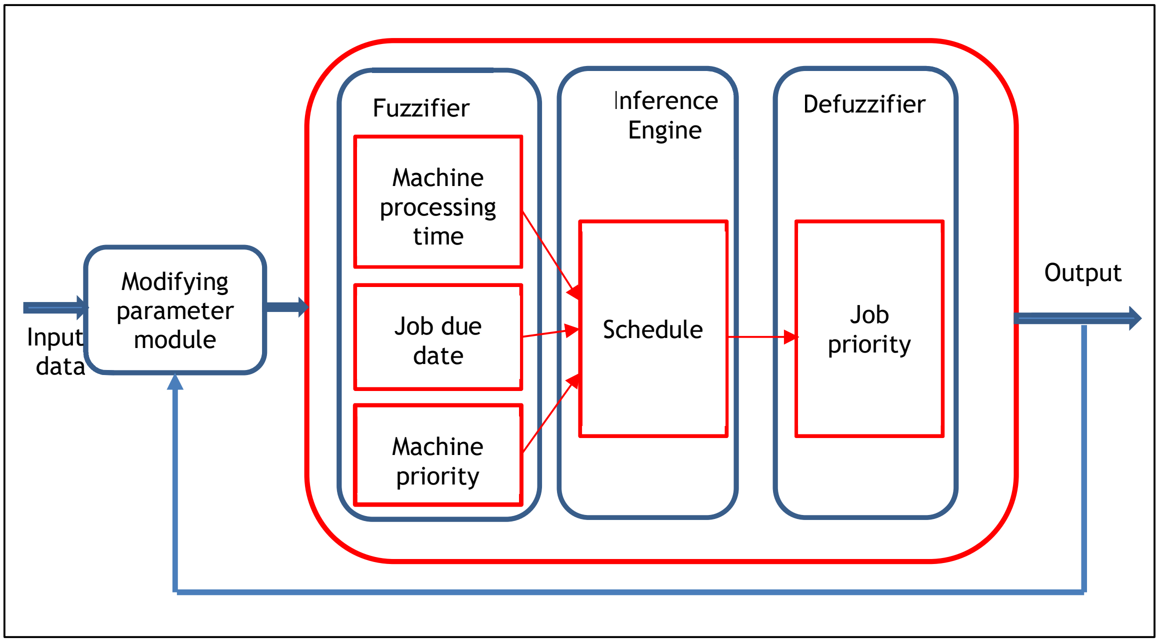

Figure 2: Steps for deployment of fuzzy logic

The first stage is fuzzification of inputs to establish the extent to which the inputs are appropriate to the applicable fuzzy sets through membership functions. The input was a crisp arithmetical value that was constrained to the universal discourse of the input variable while the output was a fuzzy degree of membership, spanning from 0 and 1.

Once the inputs have been fuzzified, the second step is applying the fuzzy operator since the extent to which each component of the antecedent has been fulfilled for each rule. The fuzzy operator was deployed to attain a numerical value that represented the yield of the antecedent for a specified rule if the antecedent of the specified rule had more than one component.

The third step was to apply the implication method whereby every rule was given a weight, that is a number between 0 and 1 before applying the method. Based on the antecedent, the implication method was defined as the shaping of the consequent fuzzy set. A single number given by the antecedent is the input for the implication process while the output is a fuzzy set. Implication occurs for each rule. The min (minimum) function which truncates the output fuzzy set is a built-in method that was used as the implication method.

The fourth step was to aggregate all outputs whereby the outputs of each rule were unified by joining the parallel threads. Aggregation would occur once for each output variable whereby all the fuzzy sets that represented the output of each rule were combined into a single fuzzy set. A list of truncated output functions returned by the implication process for each rule was input to the aggregation process while the output of the aggregation process is a single fuzzy set for each output variable.

The fifth and final step for fuzzy logic process was defuzzification process whereby the aggregate output fuzzy set was input and the output is a single crisp number. The centroid calculation was deployed as the defuzzification method.

5 RESULTS AND DISCUSSION

The study proposed to categorise dissimilar scheduling parameters and in this case, the job procesing time and routing and construct the membership functions and fuzzy rules. Using MATLAB fuzzy logic toolbox, the membership functions and fuzzy rules were used to develop a fuzzy interference system to select the best route. Figure 3 shows a sample fuzzy input variables for membership functions. Triangular membership function was assigned to all the variables, split into three zones viz small, medium and high. Job priority, varying from 0 to 1 was coded as the output of the processing time and due date variables. The priority variable was divided into nine portions and was also assigned with triangular membership functions as shown in Table 1.

Table 1: Categories for the priority variable

Maximum (MX)	Positive Average (PA)	Low (LO)
Positive High (PH)	Average (AV)	Negative Low (NL)
High (HI)	Negative Average (NA)	Minimum (MN)

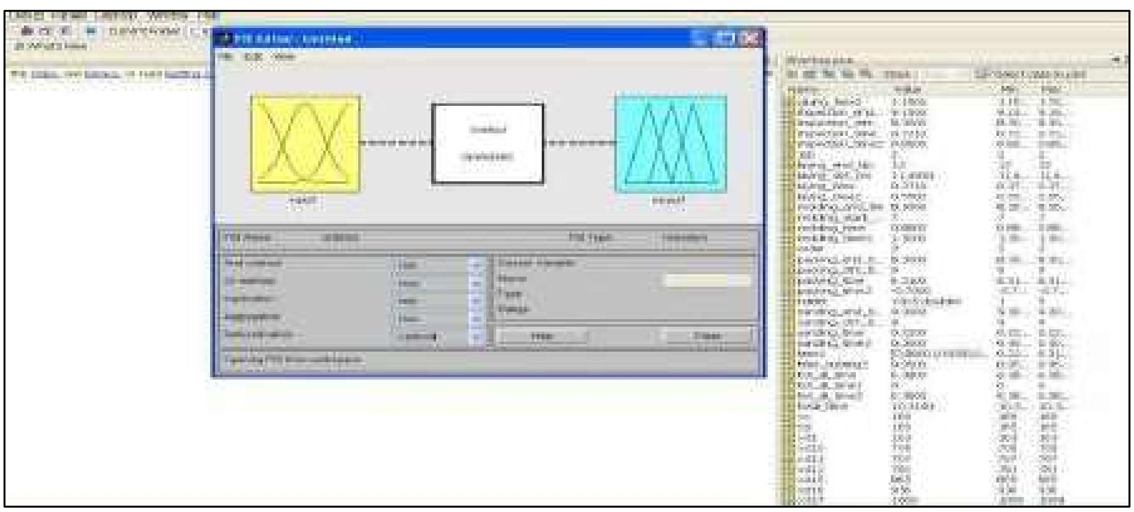

Figure 3: Sample fuzzy input variables for membership functions

Similar to job sequencing, concerning route selection, from the processing time variables, one had to establish the optimal state of variable route priority from a possible ordered 27 pairs. If l, m, n denote the number of categories defined for time of arrival, size of burst, priority respectively then the fuzzy rule base will have (lmn××) rules. Therefore, for the inference rules for route selection from using two inputs and one output, the decision is for instance, shown below:

1. If (Processing Time is High) then (Route Priority is Minimum)
2. If (Processing Time is High) then (Route Priority is Negative Low)

…
26. If (Processing Time is Small) then (Route Priority is Positive High)
27. If (Processing Time is Small) then (Route Priority is Maximum)

Table 2 shows a sample experminental results for routing from using fuzzy model with 1 denoting the horizontal CNC milling machine, 2 denoting the vertical CNC milling machine, and 3 denoting the drill press.

Table 2: Sample experimental results for routing from using fuzzy model

		Machine centre allocated to process part			Total processing time (Hours)
Part type or job	A	1	3	2	8.5
	D	2	1	3	9.2
	C	3	1	2	8.7
	D	1	2	3	8.5
	C	1	3	2	9.1
	B	3	1	2	8.2
	C	2	1	3	9.6
	D	1	3	2	8.8
	A	2	3	1	9.3
	B	3	1	2	9.4
	A	1	2	3	8.9

The results demonstrate that, for instance, that if job B with the smallest total processing time is scheduled first, considering due date constraints, it should first be processed on the drill press, followed by the horizontal CNC milling machine,and lastly on the vertical CNC milling machine.

6 CONCLUSION

The study provided insight into investigating the applicability of fuzzy logic as an aid to decision making for organisations has been facing challenges in meeting due dates while concurrently minimising lead time and maximising machine utilisation in their flexible manufacturing systems. The proposed approach identified scheduling parameters for routing parts through system and membership functions and fuzzy rules are constructed to develop the best schedule using a toolbox on a MATLAB fuzzy logic platform. After comparison of several priority rules for job sequencing, the results demonstrated the applicability of fuzzy logic as a decision tool in the scheduling of flexible manufacturing systems. Further investigations would embrace the robustness of the scheduling approaches in accommodating trends in Industry 4.0 and artificial intellegence.

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