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Textile Weaving Order Planning Decision Support Tool Based on Fuzzy Logic

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Abstract : *In the manufacturing environment, the process of order planning is on-going as a result of more orders coming in from customers. To process the orders, raw materials are needed, and these are limited and need to be utilised efficiently in a sustainable manner. A tool, based on fuzzy logic was developed to aid textile weaving production management in decision support. Matlab 7.8.347(r2009a) was used to develop the fuzzy logic module. The tool is capable of providing an optimum number of orders that can be processed in the weaving shed given the raw material in stock and the number of orders received from customers. A verification of the model showed that from the orders that were received and the available raw material in stock, 80% of the orders could be processed instead of only 50% that were currently being processed, indicating 30% possible improvement in production, and 1.2% improvement in daily profit.*

Keywords: *fuzzy logic, textile weaving, order planning, decision support, beam length*

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I. INTRODUCTION

The textile industry is one of the most complicated industries among manufacturing industries. The weaving process is the bottleneck of textile mills as it is the section where usable fabric is produced through interlacement of warp and weft yarns on a weaving machine traditionally referred to as a loom. Studies reveal that the weaving operation contributes by far the largest proportion to the cost of conversion of yarn into fabric, with the cost of actual weaving attributing approximately 60-65% of the total cost [1]. It therefore goes without say that it has to be effectively and efficiently managed so as to maximize production. When an order for a woven fabric is placed, management must allocate a loom to produce it. This involves the gathering of inventory data, current loom allocation and identifying which orders can be immediately produced. The decision of how much material can be allocated to each weaving machine which involves the determination of the warp beam length offers the biggest challenge. With yarn stock constraints, it is a norm to prepare weaver's beams with lesser length in a bid to keep all weaving machines loaded. This process is carried out by experienced personnel and it can be time consuming and tedious. This inevitably leads to poor order planning. For this motivation, a tool to aid decision making during the process of order planning was developed to aid the preparation for weaving to impart to the weaving mills sufficient flexibility to permit them to cope with a variable market demand. Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO. Compared to classical logical systems, FL has been proven to best represent human thinking [2]. Also, knowledge-based systems have been developed to make use of human knowledge to solve a wide range of problems that ordinarily require human intelligence [3]. Fuzzy inference is the process of formulating the mapping from a given input to an output using FL. This process offers a basis from which decisions can be made or patterns recognised. There are basically two types of Fuzzy Inference System (FIS), the Mamdani-type and Sugeno-type [4]. When building up FL models to capture expert knowledge, the Mamdani method has been widely accepted [2]. It provides for the conscience describing of the expertise in more intuitive, more human-like manner and because of the interpretable and intuitive nature of the rule base, Mamdani-type FIS is chiefly employed in particular for decision support application. Production planning and management involves can be defined as the function of management involved in planning, coordinating and controlling the resources required to produce specified products by specified methods, with optimal utilization of resources [5]. A production system comprises of those functions that convert a set of inputs into a set of desired outputs [6]. In any manufacturing set up, production forms the backbone from which other functions stem out. The production process is governed by the activities of process planning, loading and scheduling [7]. Resources are scarce and must be utilized in the best sustainable way to achieve optimum levels of productivity. Resource assignments affect the selection and ordering of activities and the problem is hard to solve by simple sequencing of planning and scheduling. For this motivation, the Artificial Intelligence (AI) community is defining new algorithms in a bid to find quality solutions to solve planning problems, with time and resource constraints [8]. The three main AI techniques are fuzzy logic, genetic algorithms and neural networks. Hybrid systems that make use of a combination of algorithms have also been synthesised to aid in manufacturing decision making. Decision support systems can be defined as interactive, computer-based systems that aid users in judgment and choice activities. These systems pay off in strategic or tactical decision making and have found much use in planning and management in various sectors of the industry. Decision making is to do with making a choice from given possibilities and in making the decision, human judgement may be subjective. People who have expertise in a field are perceived as individuals who are not subject to judgmental biases. However, studies have shown that even though experts are accurate they are also subject to making errors and inconsistencies [9, 10, 11]. To improve human decision making, a number of modelling tools in the various disciplines have been developed. These tools capture knowledge about a system through the use of algebraic, logical or statistical variables which can be expressed as equations or logical rules. As such, this offers motivation to explore available tools to suite user specific needs by aiding in decision making. Textile weaving order planning process in Zimbabwe still heavily relies on human expertise, the goal was to build a textile weaving order planning tool that is capable of mimicking how an expert would carry out planning and reasoning in a bid to make the most efficient use of material. Since the tool will neither be prone to subjectivity nor 'get tired', it will assist to eliminate errors that may arise as the human expert tires and makes subjective decisions during production planning.

II. METHODOLOGY

The fuzzy decision module was constructed using Matlab Version 7.8.347(R2009a) using order information, yarn inventory data and production data obtained from a textile weaving factory.

Fuzzy Inputs and Outputs

The inputs consist of the number of yarn counts that are available in stock and the weight of yarn that is in stock. The output consists of the number of orders that have to be processed and the beam length.

Membership Ranges and Functions

The membership functions used for both the inputs and outputs are the triangular membership functions (trimf). Their membership parameters (a b c) represent their respective linguistic variables. These were prepared as follows;

Number of yarn count membership range and function

Range: 0-9
Low: (0-2-9)
EnoughForActiveOrders: (2-4-9)
AllCountsInStock: (4-9-9)

Stock balance in yarn store membership range and function

Range: 0 – 180000
Low: (0 – 26788.28 – 53576.56)
BufferStock: (26788.28 – 53576.56 – 180000)
YarnStoreCapacity: (53576.56 – 180000 – 180000)

Number of orders to process membership range and function

Range: 0 – 10
Low: (0 – 2.5 – 5)
ActiveOrders: (2.5 – 5 – 10)
AllOrders: (5 – 10 – 10)

Beam Length to use membership range and function

Range: 0 – 5000
Minimum: (0 – 1250 – 2500)
Average: (1250 – 2500 – 5000)
Maximum: (2500 – 5000 – 5000)

Fuzzy Rules

The rules employed were all given a weight of 1 and the connection employed was the “and” connector. The rules are listed below;

1) If (YarnCounts is Low) and (YarnStock is Low) then (Orders is Low)(BeamLength is Low)(1)
2) If (YarnCounts is Low) and (YarnStock is BufferStock) then (Orders is Low)(BeamLength is Average)(1)
3) If (YarnCounts is Low) and (YarnStock is YarnStoreCapacity) then (Orders is Low)(BeamLength is Maximum)(1)
4) If (Yarn Counts is Enough For Active Orders) and (YarnStock is Low) then (Orders is Active Orders) (Beam Length is low)(1)
5) If (Yarn Counts is Enough For Active Orders) and (Yarn Stock is Buffer Stock) then (Orders is Active Orders) (Beam Length is Average)(1)
6) If (YarnCounts is EnoughForActiveOrders) and (YarnStock is YarnStoreCapacity) then (Orders is ActiveOrders)(BeamLength is Maximum)(1)
7) If (YarnCounts is EnoughForAllOrders) and (YarnStock is Low) then (Orders AllOrders)(BeamLength is Low)(1)
8) If (YarnCounts is EnoughForAllOrders) and (YarnStock is BufferStock) then (Orders is AllOrders)(BeamLength is Average)(1)
9) If (YarnCounts is EnoughForAllOrders) and (YarnStock is YarnStoreCapacity) then (Orders is AllOrders)(BeamLength is Maximum)(1)

Fuzzy Inference System

This is a method that inteprates the values in the input vector and, based on some set of rules, assigns values to the output vector. The inference system was defined as follows;

FIS Type:	Mandami
And Method:	Max
Implication:	Min
Aggregation:	Max
Deffuzification:	Centroid

The designed fuzzy system is a multi-input, multi-output system, which is a two-input, two-output, nine-rule order planning system. The overview of the fuzzy inference process is illustrated in the following Figure 1.

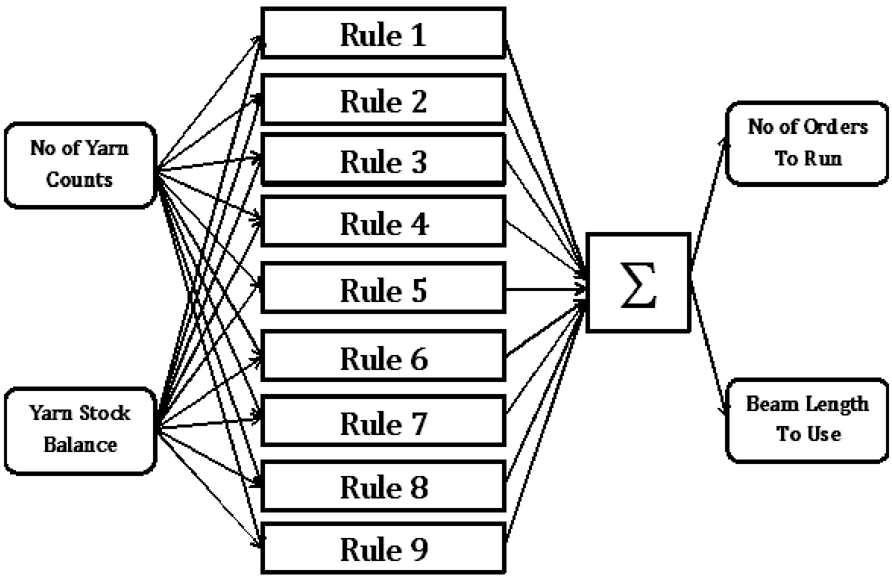

Figure 1: 2 Input, 2Output, 9 Rule Fuzzy System

III. RESULTS AND DISCUSSIONS

Preparation for weaving comprises steps undertaken prior to the actual weaving on the weaving machine which ensure that good quality fabric is produced [12]. In addition to correct yarn preparation to obtain satisfactory weaving performance, it is also essential to have efficient organisation of activities so as to make available warp beams at the right moment, thus avoiding any dead time with style or beam change.

Fuzzy Output Surface Viewer

The Surface Viewer generates and plots an output surface map for the system. It displays a three-dimensional curve to show the dependency of one of the outputs on any one or both of the inputs.

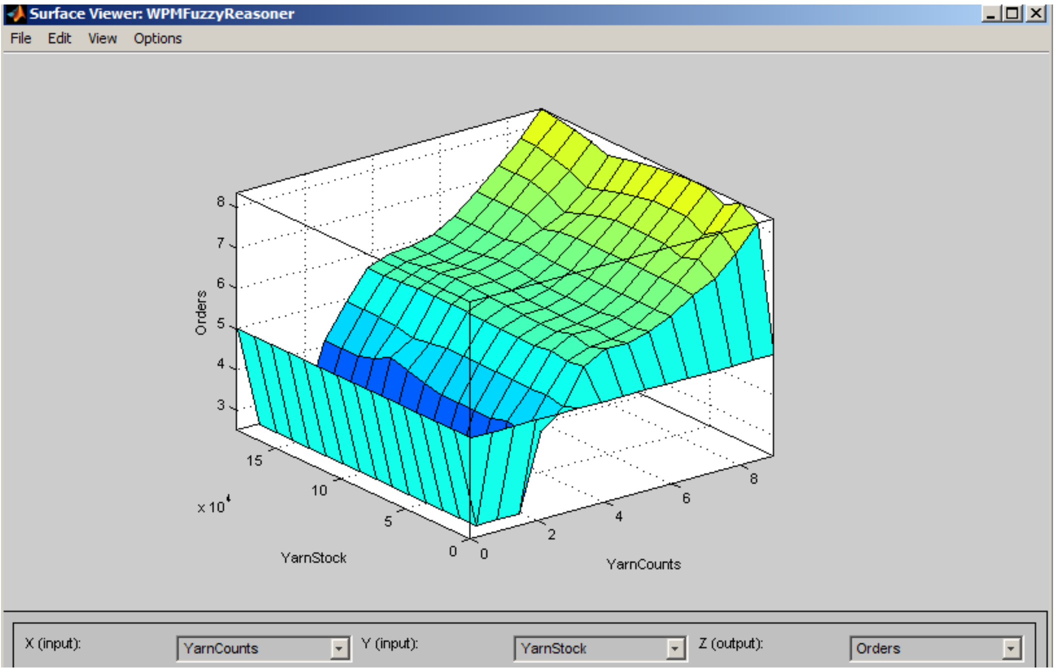

Figure 2: Surface Viewer for Output: Orders

The two inputs are number of yarn counts and balance in yarn stock and are shown on the x and y-axis respectively. On the z-axis is the output number of orders. The curve represents the mapping from YarnCounts and YarnStock to number of Orders. It can be observed that when yarn stock is low and number of yarn counts is low, the resultant number of orders is low. However, as the number of yarn counts and balance in yarn stock increase, so does the number of orders.

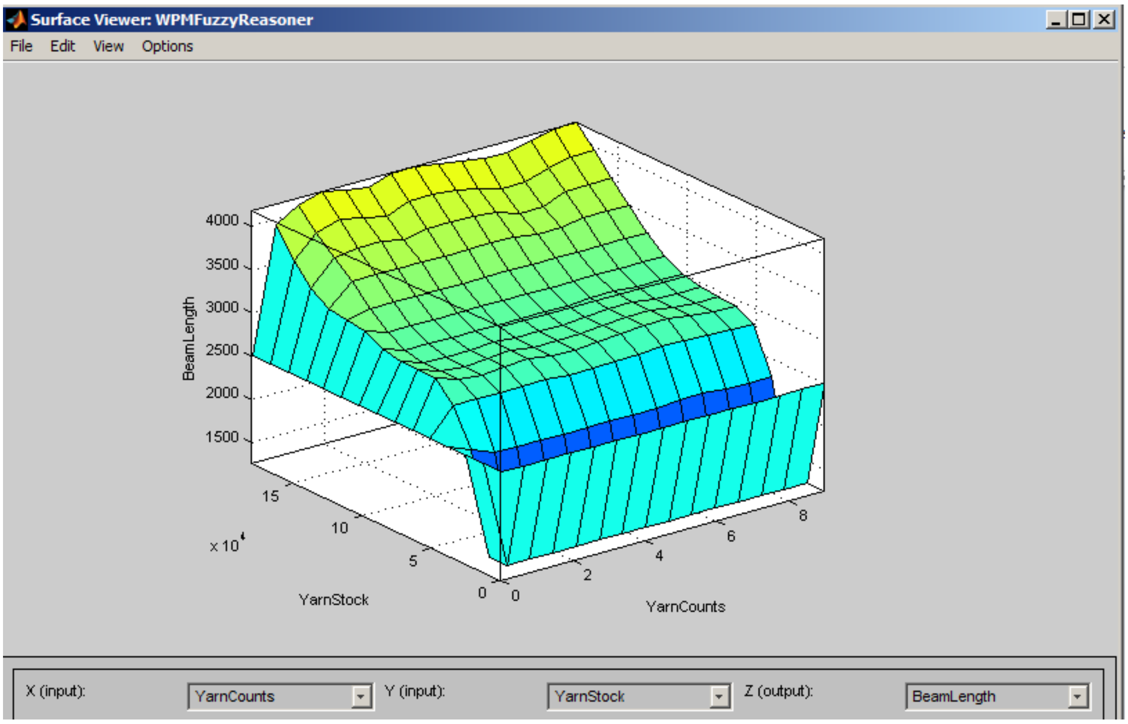

Figure 3: Surface Viewer for Output: Beam Length

The two inputs are number of yarn counts and balance in yarn stock and are shown on the x and y-axis respectively. On the z-axis is the output Beam Length. The curve represents the mapping from YarnCounts and YarnStock to Beam Length. It can be observed that the beam length increases as both yarn stock balances and number of yarn counts is increasing. Also, yarn stock can influence the increase of beam length even if yarn counts remains low.

Fuzzy Logic Decision

The two inputs into the system were the number of yarn counts in current stock (9) and the current yarn stock balance (31892kgs). The fuzzy logic then processed these values to give a result that recommended orders to run as 8, and a recommended beam length of 1890m. These results were read out from the rule viewer shown in Figure 4.

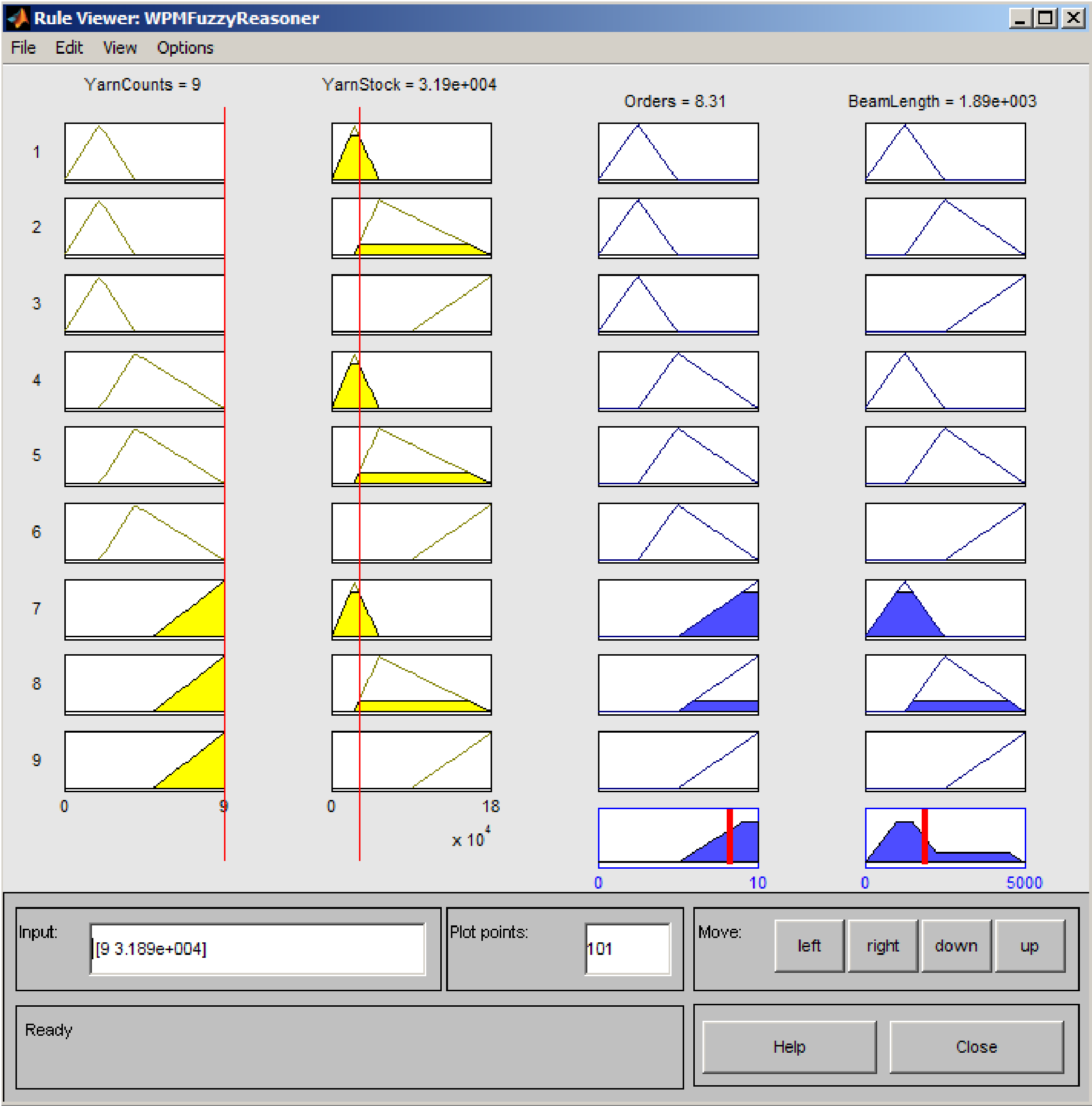

Figure 4: Rule Viewer

The results showed that instead of the 5 orders that were currently being processed in the mill, 8 orders could be processed. Total orders given to the mill were 10, this meant instead of having 5 inactive orders, there can be a reduction to 2 inactive orders. Therefore, 80% of the orders could be processed instead of only 50% that were currently being processed, indicating 30% improvement in order processing. Companies are in business to make profit. To compare the current state of 5 orders running and the 8 recommended orders, the following table was computed to project expected profit per day's production assuming machines ran at budgeted efficiency.

Table 1: Profit Comparison

	CURRENT 5 ORDERS			RECOMMENDED 8 ORDERS		
Loom I.D.	Order No	Product	Expected Profit/day ($)	Order No	Product	Expected Profit /day ($)
1	3	Fabric J	627.26	1	Fabric C	204.59
2	1	Fabric C	204.59	1	Fabric C	204.59
3	1	Fabric C	204.59	2	Fabric E	585.79
4	5	Fabric M	631.60	2	Fabric E	423.07
5	5	Fabric M	631.60	3	Fabric J	453.02
6	4	Fabric K	302.40	4	Fabric K	302.40
7	2	Fabric E	488.16	5	Fabric M	728.77
8	4	Fabric K	302.40	6	Fabric K	302.40
9	2	Fabric E	488.16	7	Fabric M	728.77
10	2	Fabric E	520.70	8	Fabric E	520.70
		Total Profit	**4,401.45**		Total Profit	**4,454.09**

Table 1 shows that if orders were allocated as recommended, assuming all machines ran at budgeted efficiency for comparison purposes, there will be an increase in profit from $4401.45 to $4454.09 which translates to approximately 1.2% profit increase. To add to the profit increase, more orders would be under processing at a time.

IV. CONCLUSION

Decision support involves identifying all the data required to make a decision, gathering it together organised as meaningful information. Human experts are still responsible for weaving order planning in Zimbabwe and may be subject to making errors as the expert becomes tired or makes subjective decisions. Fuzzy logic may be employed to capture the human skill and be used as a tool to aid in planning for production. This tool can be employed to provide an optimum number of orders that can be processed in the weaving shed given the raw material in stock and it is also capable of recommending how much raw material, in terms of beam length, can be prepared for the suggested orders to be processed. Therefore, the fuzzy model may be used as a tool to help the decision makers when planning for orders.

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