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Smart and Trouble-Free System (STS) for Selection of a Cutting Tool to be Used in Online Scheduling of FMS

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ABSTRACT: A smart and trouble-free system for selection of a cutting tool to be used in online scheduling of FMS is developed. To develop a prototype system for the problem of selection of a cutting tool to be used is thoroughly analyzed and indentified the important system parameters. An attempt has been made in this paper is to illustrate the smart and trouble-free system for selection of a cutting tool to be used in online scheduling of Flexible Manufacturing systems (FMS). The system parameters are tool magazine capacity, identical cutting tool, useful tool life and processing time of the operation. These parameters are categorized based on numerical values with definite range and corresponding ranks are assigned. Accordingly presented a smart and trouble-free system for selection of a cutting tool to be used in online scheduling of FMS

KEYWORDS: Cutting tool, FMS, Online scheduling

I. INTRODUCTION

Flexible manufacturing systems (FMS) are automated, integrated systems of equipment and information flow, arranged for the economic production of small batches of complex components. These systems are essentially composed of workstations and material transfer systems in which the control of operations is performed by a central computer [1]. A central computer is equipped with comprehensive software modules for scheduling, tool allocation, traffic, production processing, and possibly system simulation. The control unit takes as input information on the state of all resources and continuously monitors the activities of the equipment and provides supervisory and engineering reports. Under computer control, parts are prioritized to use the resources. It is concerned with the detailed decision making required for on-line scheduling of FMS. The on-line scheduling, suitably changes the production program to take all unexpected events into account, as soon as they are known. Operational problems would be easier to solve if manufacturing activities occur as planned. However, due to the dynamic nature of the shop floor, the operational problems are always unstructured and complex. The decisions of these problems are based on large amount of information and are always made under pressure of time. Most manufacturing systems, use simple heuristic rules to solve their control problems in shop floor by off-line scheduling method. However, FMS is more complex, implies the use of more and more advanced methods for management and control of the FMS [2,3]. In FMS, various parts are to be performed simultaneously and an efficient decision support system is needed to organize the processing of various parts efficiently. Because of the inherent flexibilities in an FMS, operational problem is a complex process. Flexibility was made possible largely due to the use of machining centers, which are capable of performing all the operations of all the jobs, and this in turn enables system to have alternative routing. The introduction of alternative routing made it possible to better balance of machine work-load and to achieve higher system robustness in case of machine failure. These were instrumental in achieving higher system productivity.

Online scheduling policy for FMS is more appropriate with operational decision based on the real state of the system [4]. The increased flexibility, complexity and automation clearly offer operational efficiency and productivity in FMS. But these make online scheduling extremely difficult. Managers at a shop floor have made their decisions mainly from their experiences and intuition, which are human abilities. Offline scheduling program and priority control policy cannot operate FMS efficiently. It would be more appropriate to have online scheduling system, where the control decisions are made according to the actual state of FMS. The inefficiency of offline control methods have stressed the need for online scheduling. The complexity and the dynamic nature of the real time operational problems for an FMS are not solved by any mathematical model. However, without a systematic representation of the elements, attributes and relationships, the system cannot be integrated or manipulated to support the decision requirements for unstructured problems [5]. Artificial intelligence (AI) methods are indicated as useful approaches to systematically represent

knowledge of planning and control in the control system [6]. Intelligent hybrid systems are the approaches developed for better performance by integrating two or more AI methods. In order to help the shop floor personnel in achieving their productivity goals, the intelligent hybrid system, which allow the user to request a variety of operational decisions on the real time basis, are highly required. Intelligent hybrid system approach can easily manage online scheduling of FMS and

II. LITERATURE REVIEW

The concept Because of the nature of the FMS structure, more complex communication and control systems required than those needed for traditional manufacturing methods [3,5,7], Analytical approaches to FMS control are very limited. Buzacott and Yao (1980) emphasized that an FMS is extremely complex, thus it is not likely that a single model can be used to fully describe its behavior and certainly there could be no analytical model of this nature that can hope to solve. Thus analytical models are addressed to small subsets of issues. Due to limitations of analytical models and use of the artificial intelligence techniques to control the systems have been proposed. Nof et al. (1970) and Fisher and Nof (1984) explored some of the typical problems in manufacturing systems planning and control, particularly those pertinent to the automatic operation by developing expert system[5,8]. Lianqing et al. (2009) proposed a radial basis function neural network (RBF-NN) model to schedule jobs in a general FMS[9]. Mehmet et al. (2006) proposed a framework that utilizes parallel neural networks to make decisions on the availability of resources, due date assignments for incoming orders, and dispatching rules for scheduling[10]. Paolo et al. (2003) proposed a scheduling approach that employs inductive learning and back propagation neural networks[11]. Noor et al. (2009) proposed a hybrid methodology, where traditional training algorithm in feed forward Back Error Propagation (BEP) ANN is replaced with Genetic Algorithm (GA) to optimize weights and biases for the ANN and a comprehensive search algorithm to find the optimum number of neurons in the hidden layer(s)[12]. The methodology has been applied to an example of a scheduling policy system for flexible manufacturing systems and the results for traditional and hybrid ANN has been compared. Luis and Serna (1989) presented an intelligent scheduling system for FMS under development that makes use of the integration of neural networks and expert systems[13]. Rabelo et al. (1993) developed a scheme for the scheduling of FMSs. This scheme is based on a hybrid architecture which utilizes neural networks, parallel Monte Carlo simulation, genetic algorithms, and induction mechanisms[14]. Rabelo and Alptekin (1989,1990) developed an adaptive expert scheduler that learns by itself and adapts to the dynamic FMS environment[15,16].

Literature review reveals that, researchers contributed a lot on FMS scheduling, developed good concepts, considered interesting objectives and constraints of FMS scheduling and used various AI approaches, developed hybrid systems by integrating two or more AI approaches by using intricate procedures for easy use of the user. However, most of the researchers are focused on few important scheduling decisions of FMS, but the operational control of the FMS consists of ten scheduling decisions. Selection of a cutting tool is one of the ten scheduling decisions. Therefore, there is a need for development of unique intelligent hybrid system for Smart and trouble-free selection of a cutting tool to be used in online scheduling of FMS.

III. METHODOLOGY

Development of intelligent system for selection of a cutting tool to be used

Problem identification

The first stage in the development of intelligent system is to analyze the problem thoroughly and identify the important system parameters involved. The FMS considered in work is a hypothetical system as defined bellow:

Problem definition:

The FMS considered in this work is defined bellow:

- Number of machining centres = M, (M= 2,3,4,..., M)
- Number of AGVs = N, (N = 1,2,..., N)
- Loading/unloading stations = 02
- Number of part types are known
- Number of pallet types are known
- Type of tool magazine and its capacity is also known (permanent or changeable)
- Processing time of operations known
- There is only one operation at a time on a machine



- Raw materials, tools, jigs, fixtures etc. are available as per the requirement
- Due dates of the parts are known
- Job values of the parts are known
- Batch size of the parts are known
- Distance of AGV from each work centre is known
- Any AGV can serve any work centre
- Distance between the work centres is known
- Type of cutting tools available and tool life of each cutting tool is known
- System condition is real time
- Machine condition is real time
- Pallet condition is real time
- Operator conditions are known
- The input/exit buffer queue lengths at work centre are known
- In case of system breakdown, alternate provisions are available
- The user will decide schedule frequency as per online requirements.

To develop a prototype of intelligent system for one of the control decision of online scheduling of FMS, the problem of selection of a cutting tool to be used is thoroughly analyzed and identified the important system parameters. The system parameters are tool magazine capacity, identical cutting tool, useful tool life and processing time of the operation.

Development of knowledge based system

Knowledge is a source of intelligence and both knowledge representation and knowledge management are crucial for intelligent systems. Well employed knowledge helps systems become aware of situations, recognize states and eventually respond to changes. An intelligent system shall incorporate knowledge that helps the system reason about important external and internal factors, and eventually learn from experience and infer missing knowledge (vassey, 2011). In this work a knowledge system is developed in excel spreadsheet of NeuroSolutions. It consists of two parts: conceptualization of the problem and development of initial training data required to train the artificial neural network.

Conceptualization of the problem

The development of intelligent system for selection of a cutting tool to be used in online scheduling of FMS is based on the hierarchical approach. At first level the input values ranges were given to system parameters, based on the given input value ranges of the individual parameters, correspondingly output rank ranges were given. Then the main parameters are categorized as sub parameters. The second level identifies the important criterion for the decisions namely, select high priority tool magazine, select the tools having in more number, select the tool having more tool life and select the tool with low processing time of operation. The third level identifies the best way to reach the decision based on the second and first levels. The system parameters, input value ranges, output rank ranges and selection criterion is given in table-1.

Table-1: The system parameters, input value ranges, output rank ranges and selection criterion for selection of a cutting tool to be used

S.No.	Parameter	Input value range	Output rank range	Selection criterion
1	Tool magazine capacity	0-80	0→8	High priority tool magazine
2	Identical cutting tool	0-16	0→8	Tools in more numbers
3	Useful tool life	0-160	0→8	Tool having more tool life
4	Processing time (min) of the operation	0-160	8→0	Tool with low processing time of operation



where

T_i TMC: Tool magazine capacity of tool i (i = 1,2,...,4)

T_i CTN: Identical cutting tool quantity of too i (i = 1,2,...,4)

T_i UTL: Useful tool life of tool i (i = 1,2,...,4)

T_i PTO: processing time of operation by tool i (i = 1,2,...,4)

Then the main parameters are categorized as sub parameters. The system parameters, categorized sub-parameters of the problem selection of a cutting tool to be used are given table-2.

Table -2: The system parameters. categorized sub-parameters of the problem selection of a cutting tool to be used.

S.No.	System parameter	Sub-parameter
1	Tool magazine capacity	T1-TMC
		T2-TMC
		T3-TMC
		T4-TMC
2	Identical cutting tool	T1-CTN
		T2-CTN
		T3-CTN
		T4-CTN
3	Useful tool life	T1-UTL
		T2-UTL
		T3-UTL
		T4-UTL
4	Processing time of the operation	T1-PTO
		T2-PTO
		T3-PTO
		T4-PTO

Then, a format for input table is developed in a excel spreadsheet to cope up with the NeuroSolutions excel add-in tools requirements, as NeuroSolutions tools are used to develop ANN module of this problem. Format of input table for ANN module for selection of a cutting tool to be used is shown in table-3.

Table-3: Format of input table for ANN module for selection of the cutting tool to be used

Input parameter	Enter input value	Selection criterion
T1-TMC (0-80)		Tool in high priority magazine
T1-CTN (0-16)		Tool in more number
T1-UTL (0-160)		Tool with high life
T1-PTO (0-160)		Tool required low processing time
T2-TMC (0-80)		Tool in high priority magazine
T2-CTN (0-16)		Tool in more number
T2-UTL (0-160)		Tool with high life
T2-PTO (0-160)		Tool required low processing time
T3-TMC (0-80)		Tool in high priority magazine
T3-CTN (0-16)		Tool in more number
T3-UTL (0-160)		Tool with high life
T3-PTO (0-160)		Tool required low processing time
T4-TMC (0-80)		Tool in high priority magazine
T4-CTN (0-16)		Tool in more number



Input parameter	Enter input value	Selection criterion
T4-UTL (0-160)		Tool with high life
T4-PTO (0-160)		Tool required low processing time

4.7.2.1 Development of initial training data required to train the ANN module

Development of any supervised neural networks, it is necessary to train the artificial neural network by known input values and output values. This data is called seen data. A procedure for the development of the seen data in excels spreadsheet for training the ANN is developed by observing of the table 4.7.1. The procedure for development of initial training data required to train the ANN module for selection of a cutting tool to be used in scheduling of FMS is given bellow:

1. Tool magazine capacity:

Total numbers in the range of input values = 80 (i.e. 0 → 80)

Total numbers in the rank range of output parameter = 8 (i.e. 0 → 8)

Selection criterion = Select high priority tool magazine

The selection criterion indicates that, selection preference starts from 80 to 0. Therefore, assign rank 8 for 80 and rank 0 for 0.

RULE for generation of the training data

If

X = Value in the earlier row of the column

Y = Value in the current row of the column

THEN $Y = X \pm 8 \div 80$ (+ for ascending values and – for descending values)

In this case the value in the first row of output column of tool magazine capacity is 8 for given input value 80 and is descending towards 0 for given input value of 0. Therefore,

$$X = 8$$

$$Y = 8 - 8/80 = 8 - 0.1 = 7.9$$

The value in the second row of output column is 7.9 for given input value 79. By selecting these two output rank values, drag the data up to 0. The excel inbuilt functions will generate the output rank values for all the input values from 80 to 0 in the range of 8 to 0.

2. Identical cutting tool:

Total numbers in the range of input values = 16 (i.e. 0 → 16)

Total numbers in the rank range of output parameter = 8 (i.e. 0 → 8)

Selection criterion = select the tools having in more number

The selection criterion indicates that, selection preference starts from 16 to 0 Therefore, assign rank 8 for 16 and rank 0 for 0.

RULE for generation of the training data

If

X = value in the earlier row of the column

Y = value in the current row of the column

Then $Y = X \pm 8 \div 16$ (+ for ascending values and – for descending values)

In this case the value in the first row of output column of identical cutting tool is 8 for given input value 16 and is descending towards 0 for given input value of 0. Therefore,

$$Y = 8 - 8/16 = 8 - 0.5 = 7.5$$

The value in the second row of output column is 7.5 for given input value 15. By selecting these two output rank values, drag the data up to 0. The excel inbuilt functions will generate the output rank values for all the input values from 16 to 0 in the range of 8 to 0.

3. Useful tool life:

Total numbers in the range of input values = 160 (i.e. 0 → 160)

Total numbers in the rank range of output parameter = 8 (i.e. 0 → 8)

Selection criterion = Select the tool having more tool

The selection criterion indicates that, selection preference starts from 160 to 0. Therefore, assign rank 8 for 160 and rank 0 for 0.

RULE for generation of the training data

If

X = value in the earlier row of the column

Y = value in the current row of the column

Then $Y = X \pm 8 \div 160$ (+ for ascending values and – for descending values)



In this case the value in the first row of output column of useful tool life is 8 for given input value 160 and is descending towards 0 for given input value of 0. Therefore,

$$X = 8$$

$$Y = 8 - 8/160 = 8 - 0.05 = 7.95$$

The value in the second row of output column is 7.95 for given input value 159. By selecting these two output rank values, drag the data up to 0. The excel inbuilt functions will generate the output rank values for all the input values from 160 to 0 in the range of 8 to 0.

4. Processing time of the operation:

Total numbers in the range of input values = 160 (i.e. 0 → 160)

Total numbers in the rank range of output parameter = 8 (i.e. 0 → 8)

Selection criterion = Select the tool with low processing time of operation

The selection criterion indicates that, selection preference starts from 0 to 1 Therefore, assign rank 8 for 0 and rank 0 for 160.

RULE for generation of the training data

If

X = value in the earlier row of the column

Y = value in the current row of the column

Then $Y = X \pm X \div 160$ (+ for ascending values and – for descending values)

In this case the value in the first row of output column of processing time of the operation is 8 for given input value 0 and is descending towards 0 for given input value of 160. Therefore,

$$X = 8 - 8/160 = 8 - 0.05 = 7.95$$

The value in the second row of output column is 7.95 for given input value 1. By selecting these two output rank values, drag the data up to 0. The excel inbuilt functions will generate the output rank values for all the input values from 0 to 160 in the range of 8 to 0.

By adopting the above procedure, the required training data is developed in excel spreadsheet. The visible portion of excel spreadsheet containing the initial training data required for training of ANN module is shown in the table -4.

Table-4: The visible portion of excel spreadsheet containing the initial training data required for training of ANN module for selection of a cutting tool to be used

80	8	16	8	160	8	0	8
79	7.9	15	7.5	159	7.95	1	7.95
78	7.8	14	7	158	7.9	2	7.9
77	7.7	13	6.5	157	7.85	3	7.85
76	7.6	12	6	156	7.8	4	7.8
75	7.5	11	5.5	155	7.75	5	7.75
74	7.4	10	5	154	7.7	6	7.7
73	7.3	9	4.5	153	7.65	7	7.65
72	7.2	8	4	152	7.6	8	7.6
71	7.1	7	3.5	151	7.55	9	7.55
70	7	6	3	150	7.5	10	7.5
69	6.9	5	2.5	149	7.45	11	7.45
68	6.8	4	2	148	7.4	12	7.4
67	6.7	3	1.5	147	7.35	13	7.35
66	6.6	2	1	146	7.3	14	7.3
65	6.5	1	0.5	145	7.25	15	7.25
64	6.4	0	0	144	7.2	16	7.2



Development of ANN module

The system parameters of the problem of selection of a cutting tool to be used are: tool magazine capacity, identical cutting tool, useful tool life and processing time of the operation. For each parameter a separate ANN module is developed. To develop ANN module, NeuroSolutions excel add-in tools are used. A Multi Layer perceptron (MLP) neural network is chosen to develop the network. For development of any supervised artificial neural networks, it is necessary to train the artificial neural network by known input values and output values. This data is called seen data. The seen data for training the network is developed by knowledge based system using excel spreadsheet. The NeuroSolutions excel add-in tools give the ability to train an artificial neural network, and test the artificial neural network's performance directly from within excel spreadsheet.

To train an artificial neural network in NeuroSolutions excel spreadsheet, it is needed to know which columns to use as inputs and which columns to use as the desired outputs. To accomplish this, select the columns required to use as inputs and then select "Tag Data | Column as Input" from the "NeuroSolutions" menu. Similarly, to tag the desired output columns, select the corresponding columns then select "Tag Data | Column as Desired" from the "NeuroSolutions" menu.

The rows of data must also be tagged before a training process can be run. To tag rows of data training, select the appropriate rows, and then select the tagging operation from the "NeuroSolutions" menu. A pre-saved one hidden layer multilayer perceptron (MLP) will be opened within NeuroSolutions and used for modeling this data. When a training process is run, files are automatically created (using the tagged cross-sections) and loaded into the active NeuroSolutions network. Training process displays a dialog box with user definable options corresponding to the type of training process being run. This step will train the artificial neural network one time.

After training, NeuroSolutions will generate a report named "Train1 Report". This report summarizes the training results. The plot shows the learning curves. The table gives the epoch at which the training mean-squared errors (MSEs) are minimum. From examining the learning curves, it can be concluded that, the trained MLP have done a good job in learning the given training data. To verify this conclusion, we need to run a test-run of the trained artificial neural network model.

IV. EXPERIMENTAL RESULTS

Test run of the intelligent system for selection of a cutting tool to be used

To select the cutting tool to be used in online scheduling of FMS, the procedure is given bellow:

Step-1: Enter the input data of parameters in the input table generated in excel spreadsheet. This action will copy the input values as data of production in the input row of the concern ANN module of intelligent system. The input values of system parameters and selection criterion for selection of a cutting tool to be used is shown in table-5.

Table-5: The input values of system parameters and selection criterion for selection of a cutting tool to be used

Input parameter	Enter input value	Selection criterion
T1-TMC (0-80)	30	Tool in high priority magazine
T1-CTN (0-16)	14	Tool in more number
T1-UTL (0-160)	90	Tool with high life
T1-PTO (0-160)	60	Tool required low processing time
T2-TMC (0-80)	12	Tool in high priority magazine
T2-CTN (0-16)	3	Tool in more number
T2-UTL (0-160)	50	Tool with high life
T2-PTO (0-160)	54	Tool required low processing time
T3-TMC (0-80)	20	Tool in high priority magazine
T3-CTN (0-16)	9	Tool in more number
T3-UTL (0-160)	95	Tool with high life

Input parameter	Enter input value	Selection criterion
T3-PTO (0-160)	90	Tool required low processing time
T4-TMC (0-80)	25	Tool in high priority magazine
T4-CTN (0-16)	4	Tool in more number
T4-UTL (0-160)	120	Tool with high life
T4-PTO (0-160)	125	Tool required low processing time

Step-2: Run the intelligent system (Tag rows of input as production and apply production data system for each parameter). This action will generate the output rank values for each part in ANN module. These output rank values will appear in the output rank value table in excel spreadsheet and the maximum output rank value out of four rank values of each cutting tool will appear in another table of excel spreadsheet. The output rank values of system parameters and selection criterion for selection of a cutting tool to be used is shown in table-6 and the maximum output rank value out of four rank values of each cutting tool are shown in table-7.

Table-6: The output rank values of system parameters and selection criterion for selection of a cutting tool to be used

Input parameter	Input value	Maximum output rank value	Selection criterion
T1-TMC (0-80)	30	3.10898	Tool in high priority magazine
T1-CTN (0-16)	14	6.884548	Tool in more number
T1-UTL (0-160)	90	4.334007	Tool with high life
T1-PTO (0-160)	60	4.98701	Tool required low processing time
T2-TMC (0-80)	12	1.092072	Tool in high priority magazine
T2-CTN (0-16)	3	1.56509	Tool in more number
T2-UTL(0-160)	50	2.303506	Tool with high life
T2-PTO (0-160)	54	5.288896	Tool required low processing time
T3-TMC (0-80)	20	2.245617	Tool in high priority magazine
T3-CTN (0-16)	9	4.902358	Tool in more number
T3-UTL (0-160)	95	4.143367	Tool with high life
T3-PTO (0-160)	90	3.513575	Tool required low processing time
T4-TMC (0-80)	25	2.600994	Tool in high priority magazine
T4-CTN (0-16)	4	2.009527	Tool in more number
T4-UTL (0-160)	120	5.995287	Tool with high life
T4-PTO (0-160)	125	1.684643	Tool required low processing time

Table-7: The maximum output rank value out of four rank values of each cutting tool

Cutting tool i	Max output rank value of cutting tool i	Enter selection criterion of maximum output rank value of cutting tool i
Cutting tool 1	6.884548	Tool in more number
Cutting tool 2	5.288896	Tool required low processing time
Cutting tool 3	4.902358	Tool in more number
Cutting tool 4	5.995287	Tool with high life



Step-3: Copy this output table and paste special with values as decision table. Sort the decision table with column of maximum output ranks from maximum to minimum. This action will give the selection sequence as appeared in table-8.

Table-8: Decision table for selection of a cutting tool to be used

Cutting tool i	Maximum output rank value	Selection criterion
Cutting tool 1	6.884548	Tool in more number
Cutting tool 4	5.995287	Tool with high life
Cutting tool 2	5.288896	Tool required low processing time
Cutting tool 3	4.902358	Tool in more number

In the above decision table, first column gives the selection sequence and third column gives the selection criterion.
Decision:

The selection sequence and selection criterion for selection of a cutting tool to be used is:

Cutting tool i	Cutting tool 1	Cutting tool 4	Cutting tool 2	Cutting tool 3
Selection criterion	Tool in more number	Tool with high life	Tool required low processing time	Tool in more number

V. CONCLUSION

An intelligent system for selection of a cutting tool to be used in online scheduling of FMS is developed and presented. Selection of right cutting tool increases the resource utilization by increased tool magazine utilization, increased machine utilization and reduced manufacturing lead time. It also avoids the breakdown of the system due to tool failure. An attempt is made to demonstrate the usefulness of a developed prototype of intelligent system to the selection of a cutting tool to be used in online scheduling of FMS.

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