Genetic Algorithm and Fuzzy Logic Based Decision Making Technique for Shop Floor Control in Operations Management

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Abstract: ***Shop Floor Management is the major challenging problem for any manufacturing industry. The objectives of any shop floor are minimizing the wastages, reducing the idle time, maximizing the productivity and reducing the defectives. Our paper has tried to evolve a Decision Support System (DSS) that utilizes Fuzzy Logic Decision Making approach to identify the repetitive consumption of spare parts, poor performing machines etc. All these data are entered in the master database which could be manipulated and customized reports could be generated with the help of DSS. The reports will be of immense help in taking corporate decision making with respect to the shop floor management. Besides, the results of Fuzzy Logic have also been validated using Genetic Algorithm(GA). The maximum possible productivity and least idle time have been found by using GA by selecting a random population by tournament selection and various operations like Crossover, Mutation etc. have been performed on the mating pool retaining the best chromosomes and eliminating the chromosomes which cannot survive among the mating pool. These iterations are carried out until the productivity value converges.***

Key Words: ***Decision Support System, Fuzzy Logic Decision Making, Shop Floor Management, Genetic Algorithm, Productivity.***

I. INTRODUCTION

An organization earns its reputation by various factors like quality of the products being produced, economic considerations and services offered. There are various other factors which also influences the reputation of the organization among the masses. There are numerous obstacles faced for satisfying the customer requirements. In this paper, we have identified two of those ambiguities. The overall decisions in a shop floor are taken by the manager. This paper gives the various aspects which can be considered while making suitable decisions. The field where the manager must concentrate are the quality of the spare parts supplied, the skill of various operators, the skill of the maintenance technician and the performance of the machine. In this paper we have identified two involving checking the performance of the machine and identifying the skill of the operator. The performance of both the machine and operator is directly reflected on the productivity. These results were examined using Fuzzy logic system and Decision Support System. This paper has also tried to maximize the productivity using Genetic Algorithm.

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Literature review

Journal [18] has given the information about various machines so that the operation research manager can take the remedial actions. Journal [5]tried for Optimal inventory cost by using forecasting methods as the inventory requirements are fluctuating. This journal has also used Genetic algorithm to prove the above statement. In, Ivan the journal has implemented a new strategy for solving multi-dimensional complex problems using Modular Decomposition. Journal [2] developed an algorithm for Dynamic Vehicle Routing Problem which simultaneously deals with the order cancellations and new customer orders thereby optimizing Dynamic Courier Routing operations. Journal [17] has applied TOPSIS and Correlation for finding out the best performing operator considering factors like ergonomics, organizational structure, motivation and group cohesiveness. This journal has also given various suggestions that could be implemented to increase the productivity. Journal [15] developed a framework for maximum Warehousing of Spare parts. Journal[1] has made an overview of the use of Fuzzy tools to solve manufacturing problems for the past 2 decades. Then the journal deals with the problem of Mix Prioritization based on linear programming for the purpose of increased advantages. Journal[22] has given a new approach to Fuzzy Trees and a new method for evaluation and testing using Fuzzy Trees. Journal [23] developed an algorithm for Multi Criteria Decision making using both linguistic rating as well as numeric rating by applying average rating methods. This algorithm was also proved to be efficient on comparing with a similar method. Journal [24] has evaluated the performance of Machinery using Probability based Decision Tree technique and Fuzzy Logic approach considering four factors namely maintenance cost, Power cost, Defectives and Production.

Journal [3] has made a comparison between four methods namely Fuzzy model of Group Decision, Fuzzy Synthetic evaluation, Yager's Weighted goals method and Fuzzy Analytic Hierarchy process. Finally, the main advantage of using each method was stated. Journal [20] has used Similarity Analysis(SA) and Decision Analysis(DA) for an Irrigation process and proved that both these methods arrived at the same result. Journal [11] has adopted Genetic Algorithm to find the best combination of selective assembly in order to minimize the variations in the low precision components. Journal [8] applied Genetic Algorithm to minimize the various costs and proved that Genetic Algorithm provides a better solution than other approximation methods and these solutions were found to be closer to the boundaries which were considered for solving the problem.Journal [19] has used Genetic Algorithm for Maximal Covering Location Problem and discovered the best method for serving maximum clients using optimum resources. Journal [9] has created a new Hybrid Algorithm combining Genetic Algorithm and Particle Swarm Optimization Algorithm and defined it as Genetic Flock Algorithm.

II. PROBLEM DESCRIPTION

The various activities carried out by any organization is done to increase their profit. One of the major problems that they face is shop floor management. Shop floor management constitutes a major proportion in the profit obtained by any industry. Shop floor management is in turn dependent on various factors like working condition of the machine, wastages and number of breakdowns. Customers are satisfied not only with durable, eco-friendly and user-friendly products but also look forward to cost effective products. If there is a heavy demand for the products, then obviously the cost of the product rises and in case of reduced demand, there might be a situation where the product must be given some discount. The main factor which determines the profit are set up cost, storage cost and ordering cost. Profit indirectly determines the cost of the product. The more effectively the resources are utilized, the more will be the profit which is the main goal of all organizations. The problem we are going to deal with in this model is finding the faulty machines in the shop floor. Most of the industries use in-line production line. In such a case, the products are transferred to the next station after being processed in that station. If any one machine in the in-line production line is defective or faulty, then the entire production line is affected by the machine even if all other machines are working at maximum productivity. Thus, identifying the faulty machine is a must in shop floor. This case applies for all production lines. Another query we have is that whether the machine is faulty or the technician is less skilled. Even if the machine's condition is good, if the technician's handling and skill is not up to the mark, then obviously the productivity of that machine decreases. Thus, it is also necessary to find out if the operator is skilled.

III. FEATURES OF THE PROPOSED MODEL

A. Decision support System Environment

The ability to select an output from a set of alternatives using the given information and future prediction defines the skill of the worker. This skill is used to satisfy the existing needs, promote various actions to reach our goal and minimizing the various types of wastages. This decision of the manager also determines the survival of the organization. The decision-making process becomes simple if the calculations are tabulated for a long period of time. There are distinct differences between probability and uncertainty [21]. First, in probability we know all the possible outcomes and these outcomes are specified in the random space. But practically, we would not be knowing what the result might be. The Second drawback is that probability deals with the entire population and not a specified individual. When an individual is considered in an entire population, then he may have some additional qualifications when compared to the rest of the population. But as per probability, his chances of getting succeeded is same as that of the rest of the population who do not possess that special ability. Finally, the probability values are entirely vanished when the results of the process are arrived. (For example) On tossing a coin, the probability of getting a head is 0.5. But after the coin has been tossed, we know the exact probability. So, the probability value of 0.5 does not apply here. Thus [21] has concluded that fuzzy logic is a much better technique for solving problems with unknown solutions rather than probability. In precise, Fuzzy logic is an analysis method purposefully developed to incorporate uncertainty into a fuzzy model (Zadeh, 1997). The representation of a physical variable as a continuous curve is called as membership function.

B. Fuzzy logic based decision support system

A key feature on which an organization must focus on is decision making. We must select the best possible output from the list of given inputs. The best output implies maximum efficiency with reduced flaws. The problem with decision making is the uncertainty of the event, undecidability and ambiguity by various means. The classical methods are not effective in case of determining the uncertainty. The lack of information on one hand and the increasing complexity on the other hand gave a need for developing a new decision-making system. This gave rise to a new field called expert systems. In this journal, we have used a type of Expert system called Fuzzy Logic Decision making. Fuzzy set theory is an effective tool to handle the uncertainty arising due to vagueness. Uncertainty arises due to partial information about the problem or incorrect interpretation of the data or collection of conflicting information from various sources [16].

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Practically all problems which are faced are stochastic in nature. The general human thought is that the efficient way of solving any problem is by using human resources rather than machines. Separate coding needs to be written for solving problems using machines and the coding are complex in some cases. Thus, there is always a need to solve fuzzy problems using machines. These can be generally defined as making decision in a fuzzy environment[22]. The poorly performing machines in a shop floor was identified in a journal [17]. This journal also helps us to identify the defects in the quality of the spare parts supplied or poorly skilled technicians. The concept of Fuzzy logic decision making was introduced by Professor Zade in 1965. Fuzzy logic technique comes in handy when the data collected is inadequate. The data collected from various sources are called Singletons in fuzzy set. In this method, the numerical values have no significance. The input variables need to be converted into fuzzy variables called Membership grades or Truth functions. The process of converting singletons into membership grades is called as Fuzzification. The reverse process is called as Defuzzification. If there are only two possible outcomes for a problem, either yes or no or in binary equivalent 1 or 0, then they are referred as Crisp Set. On the other hand, most of the outputs we get as membership function lies between 0 and 1. This is termed as Fuzzy. The various criteria can be labeled as per our requirement. The membership grade is found out by the following methodology: Select the priority for the given data. That is whether the higher value or lower value should be given more priority.

1. Depending on the priority, the highest or lowest value is assumed to have a membership grade of 1.

2. Depending on this value of membership grade, the membership grade for all other values are found out using constant slope method.
3. Similar procedure is followed for the rest of our labeled criteria.
4. The membership grade values are tabulated.
5. The lowest membership grade value is selected for each input from the list of tabulated criteria.
6. Similar procedure is followed for all the given inputs.
7. Finally, the highest value of membership grade is taken from the result for best result and lowest value for the worst result.
8. The input having the highest value is the best selection and the input having the lowest value is the worst case.

Thus, fuzzy logic helps us to choose the best out of the given fuzzy set thereby reducing human stress and complexity.

C. Genetic Algorithm

Genetic Algorithm is a type of computer based problem solving techniques called evolutionary systems which sues computational models that follow the principles of evolution and heredity in design and implementation. It involves a few steps and it has got a wide range of applications. There are mainly two types of traditional methods namely Hooke Jeeve's Method and Gradient Based method. Hooke Jeeve's method uses the previous two points for finding the other points whereas Gradient method uses the search direction derivative to find out the neighboring points [6]. The main advantage of using Genetic Algorithm over the traditional methods are listed below Genetic algorithm computes on the encoded values whereas the traditional methods deal with the original values.Traditional methods operate on a single sample from the population whereas Genetic Algorithm works on the entire group which is selected from population.Genetic Algorithm deals with Fitness function rather than the derivatives. These are the reasons why Genetic Algorithm is preferred over traditional methods. Genetic Algorithm uses Crossover Point method which is like search direction method with only one variation; It does not limit its search direction to a particular direction [14]. The primary step involved in Genetic Algorithm is Encoding which is the process of converting the original data into a desired format. The most commonly used format is Binary Encoding. The three major steps involved in Genetic Algorithm are Selection or Reproduction Crossover

ANALYSIS OF THE SYSTEM

On analysis we have found various factors which determines the performance of the machine. The main factors we have considered are idle time of the machine, Number of defectives produced, Cost incurred and total number of parts manufactured. The data shown below were collected from a shop floor in an industry in Madurai.

Table 1

	Idle Time (In hours)	Number of Defectives	Cost incurred due to breakdown(Rs)	Total Number of Components manufactured
Machine 1	15	21	2500	300
Machine 2	5	47	5000	460
Machine 3	27	10	2300	270
Machine 4	8	51	1000	510
Machine 5	20	12	4250	270
Machine 6	23	19	5200	410

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Table 2

	Idle Time (In hours)	Number of Defectives	Cost incurred due to breakdown(Rs)	Total Number of Components manufactured
Machine 1	12	30	1700	340
Machine 2	10	25	4200	490
Machine 3	22	7	2700	250
Machine 4	15	19	2500	420
Machine 5	26	15	3500	300
Machine 6	19	29	4000	400

Table 3

	Idle Time (In hours)	Number of Defectives	Cost incurred due to breakdown(Rs)	Total Number of Components manufactured
Machine 1	20	17	2700	310
Machine 2	3	40	3300	400
Machine 3	17	23	1700	290
Machine 4	14	32	1900	590
Machine 5	30	11	4000	290
Machine 6	32	45	3700	550

Table 4

	Idle Time (In hours)	Number of Defectives	Cost incurred due to breakdown (Rs)	Total Number of Components manufactured
Machine 1	27	20	1900	300
Machine 2	7	31	5100	510
Machine 3	10	25	3500	210
Machine 4	19	22	3200	330
Machine 5	11	15	3100	350
Machine 6	25	37	5500	370

Table 5

	Number of Defectives	Number of Machines damaged	Idle Time (In Minutes)
Operator 1	17	2	30
Operator 2	42	-	25
Operator 3	21	1	20
Operator 4	28	-	45
Operator 5	34	-	40

Table 6

	Number of Defectives	Number of Machines damaged	Idle Time (In Minutes)
Operator 1	32	1	25
Operator 2	45	1	15
Operator 3	63	2	20
Operator 4	15	1	30
Operator 5	52	-	25

Table 7

	Number of Defectives	Number of Machines damaged	Idle Time (In Minutes)
Operator 1	12	1	10
Operator 2	20	-	25
Operator 3	37	-	15
Operator 4	25	2	30
Operator 5	40	1	35

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Table 8

	Number of Defectives	Number of Machines damaged	Idle Time (In Minutes)
Operator 1	18	1	15
Operator 2	16	3	30
Operator 3	33	-	20
Operator 4	30	1	20
Operator 5	23	-	40

Table 1 shows the information about various machines in random shifts during the first week
Table 2 shows the information about various machines in random shifts during the second week
Table 3 shows the information about various machines in random shifts during the third week
Table 4 shows the information about various machines in random shifts during the fourth week
Table 5 gives the details about various operators during the first week
Table 6 gives information about various operator analyzed for second week
Table 7 gives the data of various operators measured for third week
Table 8 gives the analyzed readings of various operators for the fourth week

IV. OBJECTIVE FUNCTION

The objective function for productivity considering the Idle Time, number of Defectives and Cost incurred due to Breakdown is found to be

$$P = [(9.007 \times D) + (0.00389 \times C) - (0.3499 \times I) + 554.919] \propto + (1-\propto)F$$

Where p – Productivity
D – Number of Defectives
C – Cost incurred due to Breakdown (In Rupees)
I – Idle Time (In Hours)
$\propto$ – Smoothing Coefficient
F – Forecasted Productivity

C.Encoding

D.The main advantage of Genetic algorithm as discussed above is that it works on encoded values. The process of converting the original data into a desired format is called as Encoding. In this, we use Binary Encoding system.

Depending on the boundaries of the variables, the number of encoding terms is selected. The boundaries are found to be

10 < Idle Time < 100 and thus 2^6

20 < Number of Defectives < 150 and thus 2^7

1 < Cost incurred due to Breakdown (in thousands)< 200 and thus 2^7

1000 < Productivity < 1950

B. Fitness of Chromosome

The values of fitness function were calculated for each machine using the data collected previously and thus the fitness was calculated as

C. Selection

Roulette Wheel Selection process is used in this case. The initial step is to find out the Probability and Probability Percentage of each machine simultaneously. Then the Probability percentage is divided by the Average probability percentage to get the Expected Count. The value of Expected Count was rounded off to get the Actual Count value. The machine with the least Actual Count value is eliminated and the machine with maximum Actual Count value is duplicated in the deleted position [16].

D. Crossover

The next operation to be performed after selection is Crossover. There are multiple types of crossover like Single point crossover, Multiple point crossover, Uniform crossover and Three parent crossover. For this case, Single point Crossover is used. The crossover point is specified and the values after the crossover point are interchanged. Crossover can also lead to retardation if not used properly.

E. Mutation

The final operation to be performed on the offspring obtained from crossover is Mutation. Mutation is done and the fitness function value of the offspring formed is calculated. If the value is close to the boundary specified, then the process is terminated. Else the iteration is continued till the value converges. It was found that the Overall Productivity increased and the Idle Time has been reduced to minimum.

VI. PERFORMANCE OF THE SYSTEM

Table 9 Overall details about the machines for entire month

	Idle time (In hours)	Number of Defectives produced	Cost incurred due to breakdown(Rs.)	Total number of components manufactured

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Machine 1	74	88	8800	1250
Machine 2	25	143	17600	1860
Machine 3	76	65	10200	1020
Machine 4	56	124	8600	1850
Machine 5	87	53	14850	1210
Machine 6	99	130	18400	1730

Table 10 Overall information of each operator analyzed for the entire month

	Machine 1	Machine 2	Machine 3	Machine4	Machine 5	Machine 6
Idle Time	0.52	1	0.5	0.69	0.4	0.28
No. of Defectives	0.64	0.08	0.88	0.27	1	0.22
Cost	0.97	0.12	0.83	1	0.38	0.4
No. of components	0.38	1	0.14	0.98	0.33	0.86

Table 11 Membership function values of various machines

	Number of Defectives	Number of Machines damaged	Idle Time (In Minutes)
Operator 1	79	5	80
Operator 2	123	4	95
Operator 3	154	3	75
Operator 4	98	4	125
Operator 5	149	1	140

Table 12 Truth function values of various operators

	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5
Number of Defectives	1	0.56	0.25	0.81	0.3
Number of Machines damaged	0.6	0.7	0.8	0.7	1
Idle time	0.95	0.8	1	0.5	0.35

Table 13 Machine Discipline

	Machine Discipline
Machine 1	0.38
Machine 2	0.08
Machine 3	0.14
Machine 4	0.38
Machine 5	0.27
Machine 6	0.22

Table 14 Operator Discipline

	Operator Discipline
Operator 1	0.6
Operator 2	0.56
Operator 3	0.25
Operator 4	0.5
Operator 5	0.3

A. Genetic Algorithm

Table 15

Machine No	Initial Population	X	Fitness Function F(X)	Probability	Probability Percentage	Expected Count	Actual Count	Mating Pool
1	1001010	74	1355	0.152	15.2	0.9118	1	1001010
2	0011001	25	1902	0.2133	21.33	1.2795	1	0011001
3	1001100	76	1153	0.1293	12.93	0.8756	1	1001100
4	0111000	56	1685	0.1899	18.99	1.133	1	0111000
5	1010111	87	1059	0.1188	11.88	0.713	0	0011001
6	1100011	99	1762	0.1976	19.76	1.185	1	1100011

Table 16

Machine No	Mating Pool	Crossover Point	Offspring	Mutation	Offspring	X	F(X)
1	1001010	2	1011001	1010011	0001010	10	1911
2	0011001	2	0001010	0000000	0001010	10	1678

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3	100 110 0	1	111 100 0	100 000 0	011 100 0	56	172 9
4	011 100 0	1	000 110 0	000 000 0	000 110 0	12	149 9
5	001 100 1	2	000 001 1	000 100 1	000 101 0	10	176 9
6	110 001 1	2	111 100 1	101 000 0	010 100 1	41	129 5

INFERENCES

1. From Table 1 Machine 3 was idle for most of the time but still it manufactured more number of components. Machine 4 produced more number of defectives. The maintenance cost of Machine 6 was high.
2. From Table 2 Machine 5 was idle. Machine 1 produced more number of defectives. The maintenance cost of Machine 6 continued to be higher while Machine 2 was slightly higher than Machine 6. Machine 4 continued its pace in manufacturing more components.
3. From Table 3 Machine 6 was idle for most of the time and even more, it produced more number of defectives. The maintenance cost of Machine 5 was high. It seemed like Machine 4 had the fastest manufacturing when compared to all other machines for
4. the past three weeks.
5. From Table 4 Machine 1 was idle for most of the time. Machine 6 kept on producing more number of defectives and the maintenance cost of Machine 6 was still high. Machine 2 manufactured more number of products.
6. From Table 5, it is obvious that Operator 2 produced most number of defectives while Operator 1 damaged most number of machines and Operator 4 was the laziest of them all.
7. From Table 6, it is found that operator 3 produced very high number of defectives and damaged more machines when compared to others. Operator 4 continued to be the idle.
8. From Table 7, it is observed that Operator 5 had a bad time during the third producing the highest number of defectives and being the idlest one among the operators while Operator 4 damaged many machines.
9. From Table 8, Operator 3 has produced more number of defectives while Operator 5 continued to be idle. Operator 2 damaged more number of machines in the fourth week.
10. Finally, from Table 13, we find that even though Machine 2 manufactures more number of components, it lags very much in all other fields. Thus Machine 2 is the worst machine in this shop floor and requires immediate necessary action.
11. From Table 13, we conclude that Machine 1 and Machine 4 are the best machines in this shop floor.
12. From Table 14, the operator discipline has been found out using Fuzzy logic technique.
13. From Table 14, the best operator is found to be Operator 1 despite his poor handling of machines.
14. From Table 14, the poor operator was identified to be Operator 3 followed by Operator 5, the laziest operator among the given sample.
15. It has been found from Genetic Algorithm that the Overall Productivity of the machines has been increased from 8918 to 9881 from Table 16.
16. The Idle Time of three machines has been reduced to 10 hours from Table 16.

VIII. CONCLUSION

Thus, this model uses fuzzy logic technique to identify the faulty machine in the shop floor and Decision support system has been used to take the necessary actions to reduce these negatives. Although these negatives cannot be totally avoided, it can be limited to a minimum. This paper has given its new way to minimize them. The skill of the technicians was also checked to be sure that the problem is with the machine and not the technician handling it. The following conclusions were made from these observations:

1. The worst machine in the shop floor has been identified using fuzzy multi criterion decision making.
2. The skill of the technicians was checked.
3. Necessary actions were taken to improve the performance of the worst machine.
4. Workshops were conducted to improve the skill of technicians.

Quality has been a key factor in the development of an organization. The technicians and machines needs to be in a perfect way to meet and satisfy these quality demands by the customers. American Society for Quality(ASQ) sorted the quality features as perceived by the customer rankings as

- Performance
- Features
- Service
- Warranty
- Price

Thus, this paper gives an overview and idea about identifying the machines and operators who are paced less or failing to satisfy the customer expectations and few ideas about how to overcome these issues. A key point to be noted is that customers are independent of the industries; It is the industries which are dependent on the customers. So, improve the quality even further to make them delighted which directly enhances the growth of the organization.

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