Decision Making Process of Genetic Algorithm Based Fuzzy Rules Optimization [Excavation Step in Construction Workface]

Phyo Ma Ma Kyaw, Khin Lay Myaing
University of Computer Studies, Yangon, Myanmar
phyomamakyaw18@gmail.com,myaingkhinlay@gmail.com

Abstract

Combination of Fuzzy logic and Genetic Algorithm is used for searching of optimal solutions. To obtain the globally optimal rules, the Fuzzy rule-bases are searched by means of Genetic Algorithm. In Fuzzy inference mechanism, GA is used to find the optimal rules. Defuzzified the rules from inference and then the optimal result is produced. This paper introduced the main concept of Fuzzy Logic, Genetic Algorithm and the use of GA and Fuzzy Logic. The input values entered by user are fuzzified with Triangular or Trapezoidal membership function. These memberships' values are used to find the active rules. These active rules are optimized by GA with various population sizes. Then the optimal rule is defuzzified with Weight Average Method and then the results are described as number of workers and working days. Genetic Algorithms mimic the process of natural selection, creating a number of potentially optimal solutions to some complex search problem. Computer simulations demonstrate that the fuzzy logic system with genetic algorithms processes good robustness.
Key words: Fuzzy Logic, Genetic Algorithms.

1. Introduction

In real world, people facing many problems in various fields such as weather, medicine, social-economic and engineering and so on. There are many problem during project of construction like not enough time, weakness of labour forces and unavailable of materials that are needed for project. Some problem are difficult for solve because of ambiguity.

Fuzzy Logic is a useful tool for modeling complex system and driving useful fuzzy relations or rules. In the field of artificial intelligence (machine intelligence), there are various ways to represent knowledge. Perhaps the most common way to represent human knowledge is to form it into natural language expressions of the type:

IF premise (antecedent) THEN conclusion (consequence) (A).

The form in expression (A) is commonly referred to as the IF_THEN rule-based form; this form generally is referred to as the deductive form [1].

Genetic Algorithms are evolutionary optimization approaches which are alternative to traditional optimization method. Genetic Algorithm is a family of computational models based on principle of evolution and natural selection. Theses algorithms convert the problem in a specific domain into a model by using a chromosome-like data structure and evolve the chromosomes using selection, recombination, and mutation operators. Genetic Algorithm employs chromosomes through three operations to generate new offspring for next iterations. There have been some researches in discussing the design of fuzzy logic with genetic algorithm [2].

Decision making plays an important roles in economic and business, management and sciences, engineering and manufacturing, social and political science, biology, military strategy, drug infusion, and automated sleep-state classification, from the speaker' own research background, and so on. Engineering is one of the fields in which the applicability of Fuzzy Logic and Genetic Algorithm.

2. Fuzzy Decision System

The control system is an arrangement of physical components designed to alter, to regulate or to command through a control action, another physical system so that it exhibits certain desired characteristics or behavior. Control systems are typically of two types: open loop control systems in which the control action is independent of the physical system output, and closed-loop control systems also known as feedback control systems in which the control action depends on the physical output [6].

2.1. Fuzzy Logic System

A fuzzy logic system was designed in four main input variables. They are State of Soil, Classes of labour, Excavated Volume, and Working Hours of Labours. The output fuzzy variables are Number of Workers and Working Days. General structure of Fuzzy logic system is illustrates as follow in figure (1).

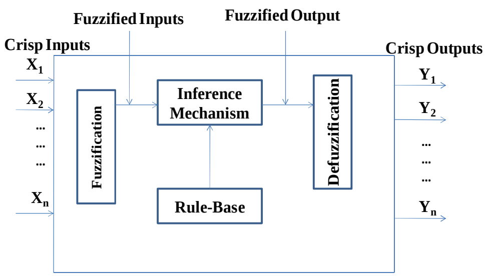

Figure 1 Block Diagram of Fuzzy Logic System

3. Membership Function of the System

The input and output membership functions are divided in three and four fuzzy sets. In this paper, State of Soil (SS), Classes of Labours (CL), Excavated Volume (EV), and Working Hours (WH) are used as the inputs.

Table 1 Linguistic Variable of Input Fuzzy Sets

State of Soil		Classes of Labours		Excavated Volume		Working Hours of Labours	
Origin	O	Third Class	T	Little	L	Half Time	HT
Medium	M	Second Class	S	Normal	N	Full Time	FT
Hard	H	First Class	F	Much	M	Over Time	OT
				Very Much	VM		

In SS, the linguistic values are O (Original), M (Medium), and H (Hard). This is shown in figure (2). At the second input CL, the variables are defined as T (Third), S (Second), and Third (Third), and shown in figure (3).

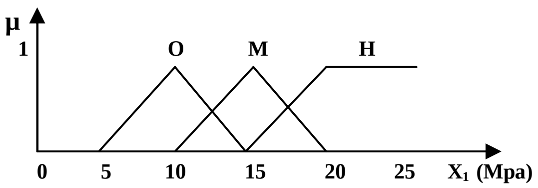

Figure 2 State of Soil

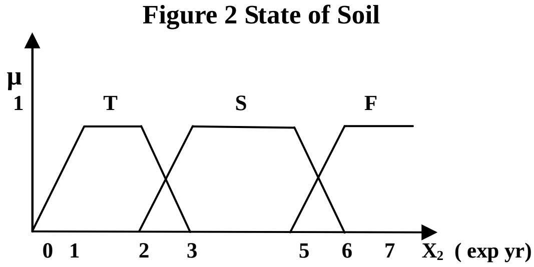

Figure 3 Classes of Labours

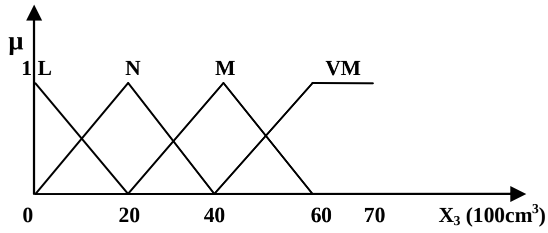

Figure 4 Excavated Volumes

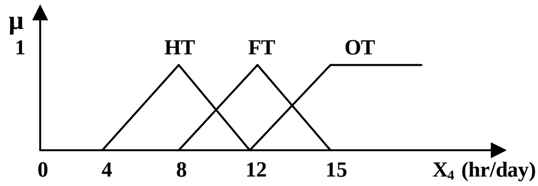

Figure 5 Working Hours of labours

Third input, EV, L (Low), N (Normal), M (Much), and VM (Very Much) are defined as linguistic variables and shown in figure (4). The last input is WH and its variables are HT (Half Time), FT (Full Time), and OT (Over Time), see at figure (5).

The outputs are the Number of Workers (NW), and the Working Days (WD).

Table 2 Linguistic Variables of Fuzzy Outputs

Number of Workers			Working Days		
Normal	NR	01	Normal	NO	01
Medium	ME	10	Medium	MD	10
Large	LA	11	Many	MA	11

The first output is the Number of Workers; its variables are NR (Normal), ME (Medium) and LA (Large), shown in figure (6).

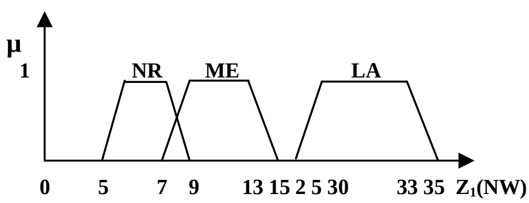

Figure 6 Numbers of Workers

The second output is Working Days and its variables are NO (Normal), MD (Medium), and MA (Many) and it is shown in figure (7).

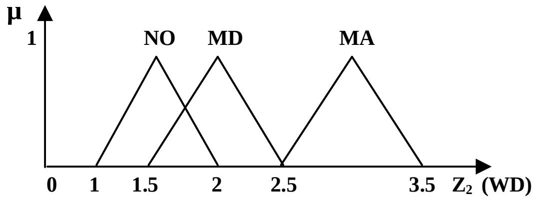

Figure 7 Working Days

The graphical representation of membership function of linguistic variable is presented in figure (8) and figure (9) in which y-axis is the degree of the membership of each of the fuzzy variable [2]. For the output fuzzy variable, the universes of discourse are the length of the R.P.M of wash-cycle. The membership functions and fuzzy rules are derived and turned by human experts in most of fuzzy control applications. Turning of FLC by human experts needs more computational time and experience and which may not be optimal [3].

Membership values are calculated as according to the method of Triangular and Trapezoidal fuzzy number. Which method is choice to calculate membership value is depended on the fuzzy number in the input fuzzy set.

Triangular fuzzy number A is defined by the membership function

$$A(x: a_1, a_2, a_3) = \begin{cases} \dfrac{x - a_1}{a_1 - a_2} & a_2 > x > a_1 \\ \dfrac{a_3 - x}{a_3 - a_2} & a_2 > x > a_3 \\ 0 & otherwise \end{cases} \quad (1)$$

Triangular fuzzy numbers are very often used in the applications (fuzzy controllers, managerial decision making, social science, etc.) They have a membership function consisting of two linear segments joined at the peak (a,1) which make graphical representations and operations with triangular fuzzy numbers very simple. Also it is important that they can be constructed easily on the basis of little information [4].

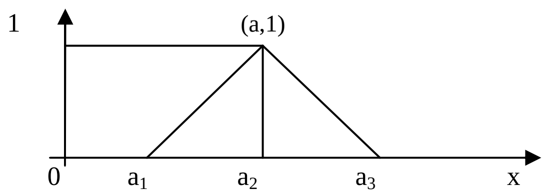

Figure 8 Triangular Membership Function

$$A(x: a_1, a_2, a_3) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} & a_2 \le x \le a_1 \\ 1 & a_2 \le x \le a_3 \\ \dfrac{a_3 - x}{a_3 - a_2} & a_3 \le x \le a_4 \end{cases} \quad (2)$$

A Trapezoidal fuzzy number A is defined by the membership function [3].

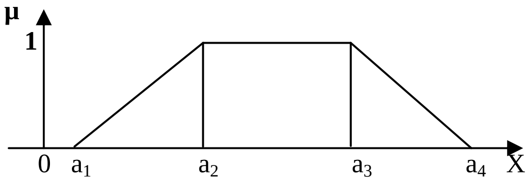

Figure 9 Trapezoidal Membership Function

Membership values are calculated according to the above two methods and restrict the rules from the rule-bases in the form of fuzzy IF-THEN rule. There are 108 rules in the rule-base and show the active rules as the fuzzification results. And then the active rules are change into the bit strings and optimized the rules using GA. Finally the optimal rules are defuzzified with Weight Average defuzzification method.

The equation for weight average method is

$$Z^* = \frac{\sum \mu c(\bar{z}) \cdot (\bar{z})}{\sum \mu c(\bar{z})} \quad (3)$$

where, Z^* = Defuzzified output
$\mu c(\bar{z})$ = Area of output fuzzy set
$(\bar{z})$ = Height of the fuzzy

Finally, the final result is produced with sentence.

4. Genetic Algorithm Overview

Genetic Algorithm (GA) is a search algorithm based on natural selection, a biological adaptive behavior that expouses the mechanism of “survival of the fitness”. It carried out stochastic evolutionary processes to achieve global optimization through the user of selection, crossover, and mutation operators. The search space of the problem at hand is represented as a collection of chromosomes. Each chromosome is a potential solution for the problem. GA associated each potential candidate solution in the population with a fitness measure to evaluate the quality of the solution. [5]

The fundamental idea behind genetic algorithm is the same idea behind Darwinian evolution, “survival of the fitness”. These concepts in the theory of evolution have been translated into algorithms to search for solutions to problems in a more “natural” ways. First, different possible solutions to a problem are created. These solutions are then tested for their performance (i.e., how good a solution they provided).Among all possible solutions, a fraction of the good solution is selected, and the other are eliminate (survival of the fitness).

Table 3 Parameters for GA

Parameters	Values
Population Size (1)	50
Population Size (2)	80
Population Size (3)	110
Crossover Rate	0.2
Mutation Rate	0.002
Generation Number	130

In this paper, fuzzy rules are coded with 12-bits string. There are **n-number** of active rules and **n*12-bits** string is represented one chromosome. Single point crossover is used and mutation operator is rarely used. The generation numbers of this system are 50, 80 and 110, respectively. The population size 130 is used in this system. These facts are shown in Table 3 Parameters for GA.

5. GA Based Fuzzy Rules Optimization

A fuzzy rule set from fuzzification is coded in binary value and optimized in the various population sizes. The fitness value can be calculated with the following equation:

$$fitness = \frac{Z_1(\max .w - \min .w)}{x_4} \quad (4)$$

where, Z_1 = output fuzzy set
max.w = maximum number of worker
min.w = minimum number of worker
X_4 = last input value from use

The value Z_1 (max.w – min.w) will change according to the output 1 in the rule-bases. The value x_4 is not change because it is the input from user and it is change when the user changes the input value.

Then the average value of fitness is calculated in

$$F_{av} = \frac{\sum_{i=1}^{n} Fitness\ (i)}{n} \quad (5)$$

where, Fav = Average fitness
n = No. of active rules
i = 1, 2, 3………

$$Y = \frac{C_3}{(C_1 + (C_2/2))/2} \quad (6)$$

C_1 and C_2 are decimal value of first 8-bits. C_3 is the last 4-bits of output decimal value. C_3 is the last 4-bits of output decimal value. After comparing the average fitness and system function, eliminate the smaller value of system and operate in the procedure of selection, crossover, and mutation. Finally, the optimal rules are produced from GA.

6. System Overview and Experimental Results

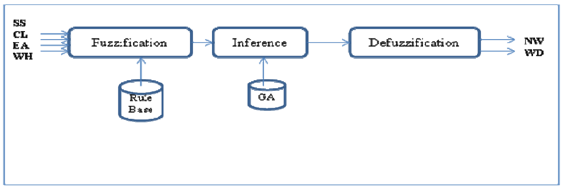

Figure 10 Block Diagram of the Overall System

In this paper, Multiple Input Multiple Output [MIMO] is introduced as in the case of Excavation Step in the construction workface. There are four input variables and two output variables. They are State of Soil, Classes of Labour, Excavated Volume and Working Hours. The outputs are Number of Workers, and the Working Days.

The overall system design with this input and output are shown in figure (10). Membership values are calculated by the Triangular or Trapezoidal method. According to the input values, the membership value and active rules are showed as follow:

State of Soil (21-Mpa) 1(H)s

Classes of Labours (exp year) 1(H)

Excavated Volume (32-cm^3) 0.4(N) 0.6(M)

Working Hours (6-hr/day) 0.5(HT) 0.5(FT)

According to the abovre input, the active rules are

IF X_1 = H, X_2 = S, X_3 = N AND X_4 = HT THEN μ_1 = ME AND μ_2 = MA
IF X_1 = H, X_2= S, X_3 = M AND X_4 = HT THEN μ_1 = ME AND μ_2 = MD
IF X_1 = H, X_2 = S, X_3 = N AND X_4 = FT THEN μ_1 = ME AND μ_2 = MD
IF X_1 = H, X_2 = S, X_3 = M AND X_4= FT THEN μ_1 = LA AND μ_2 = MD

The parameters H, S, M, N,HT, FT are Hard, Second class, Much, Normal, Half time and Full time. The rule is decode in 12-bits string and optimize as the fuzzification stage. Then the second stage is coded the active **n-rules** with the length of **n*12-bits** in one string and using population sizes of 50. These strings are optimized with GA and the optimal string are defuzzified. Next stage operates with the above procedure using various population size.

The chromosome structure for four active rules of population size 50 is **[11011011011100110000000001011111111100101100 01100];** using this strings and other random strings are optimized with GA. After optimization, the most optimal rule is defuzzified with Weight Average defuzzification method and produce the output result in sentences.

The final result can be shown in :

Stage 1. (Fuzzification) : This system require **17.5 workers and 3.00 days.**

Stage 2. (Using size 50) : This system require **18.58 workers and 1.95 days.**

Stage 3. (Using size 80) : This system require **16.27 workers and 2.08 days.**

Stage 4. **(Using size 110)** : This system require **17.12 workers and 1.98 days.**

Stage 5. (Using optimal) : This system require **29.00 workers and 2.70 days.**

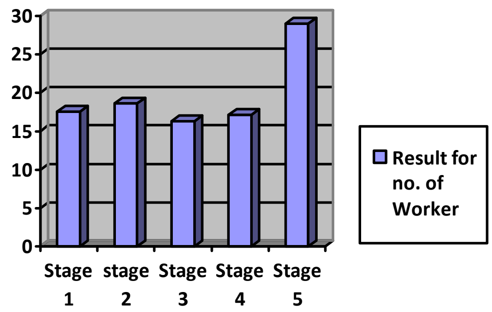

Figure 11 Result for number of workers

The range of workers and working hours for this system is based on the amount of input variables, so the range of No. for Workers is from 0 to 30 and the range for Working Days is from 0 to 3 and half days. Finally, the two results from five stages are compare by the graph figures (11) and (12).

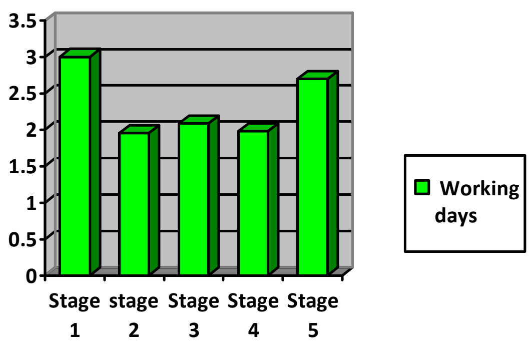

Figure 12 Result for working days

7. Conclusion

This paper introduced the optimization of fuzzy rules by GA in simple procedure. We can compare the final result of optimal rules with GA and without GA. Advantage of this system is that the results with GA are more optimal than the results without GA. To optimize the fuzzy rule sets will be the further study of this. Also in GA, other crossover method such as multipoint crossover can be used to achieve more optimal results. The membership function for each input and output fuzzy sets are represented in three levels except from input number (3). Other level of fuzzy sets can be used to improve the result than this system. Although the strings are not equal, the fitness values may equal because of the binary value that defined the fuzzy sets .Redefined the fuzzy sets and its values to be improved the system may receive the more optimal values.

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