

# The implementation of the Multi-population Genetic Algorithm using Fuzzy Logic Controller

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## Abstract

A Genetic algorithm is a searching algorithm that based on the law of the survival of the fittest. Multi-population Genetic Algorithms are a modified form of genetic algorithm. Therefore, experience with fuzzy logic and genetic algorithm has proven to be that a combination of them can efficiently make up for their own deficiency.

The Multi-population Genetic Algorithms independently evolve subpopulations. In this paper, we suggest a new coding method that independently evolves subpopulations using the fuzzy logic controller. The fuzzy logic controller has applied two fuzzy logic controllers that are implemented to adaptively adjust the crossover rate and mutation rate during the optimization process.

The migration scheme in the multi-population genetic algorithms using fuzzy logic controllers is tested for a function optimization problem, and compared with other group migration schemes, therefore the groups migration scheme is then performed. The results demonstrate that the migration scheme in the multi-population genetic algorithms using fuzzy logic controller has a much better performance.

## Keyword

Genetic Algorithm, Migration Scheme, Fuzzy Control

## Introduction

Genetic algorithm was proposed by John Holland. Genetic algorithms, as powerful and broadly applicable stochastic search and optimization techniques, are one of the most widely known evolutionary computation methods. In the last few years the genetic algorithm community has focused his mind on optimization problems in industrial engineering.

Around the late 1980s, fuzzy control emerged as one of the most active and fruitful areas for research in the application of fuzzy set theory. Fuzzy logic is much closer in spirit to human thinking and natural language than traditional logical systems. [1]

The experts' knowledge is stored in the knowledge base in the form of linguistic control rules. The fuzzification interface is used to transform crisp data into fuzzy data. The inference system, provides approximate reasoning stored in the knowledge base. The defuzzification interface translates fuzzy control action to non-fuzzy control action. [1]

When utilizing a fuzzy logic controller to adjust the strategy parameters of genetic algorithms,

such as diversity measures, fitness values, and current parameters, these are taken as inputs of the if-then rules. Outputs indicate values of strategy parameters or variation in these parameters, such as crossover ratio, mutation ratio, population size, and selective pressure.

Generally, the behavior of genetic algorithms depends on uncertain factors, and only incomplete knowledge and imprecise information are available for identification of the relationship between the strategy parameters and the behavior of genetic algorithms. Therefore, it is acceptable for fuzzy logic controllers to adjust these parameters dynamically. [1]

The migration scheme in the multi-population genetic algorithm using a fuzzy logic controller is tested for the function optimization problem, and the compared with the group migration scheme using the fuzzy logic controller.

## Multi-population Genetic Algorithms

The multi-population genetic algorithm demonstrates excellent performance on immaturity to early convergence.

Figure 1 illustrates the strategy of the multi-population genetic algorithms.

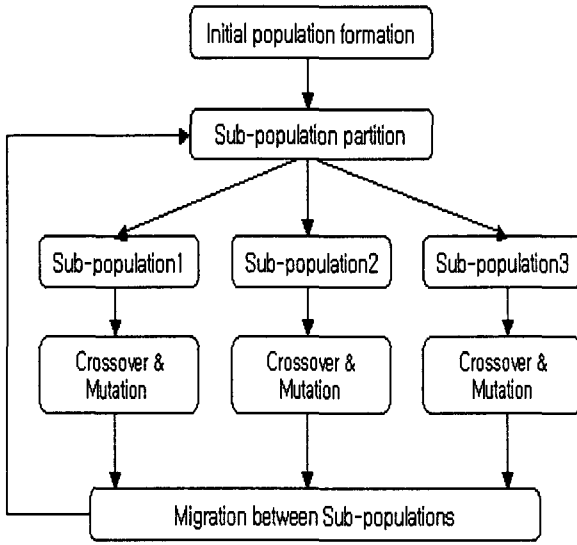


Figure 1 - The migration scheme in the multi-population genetic algorithms

The migration scheme subpopulations are applied between subpopulations in which each individual is competing and selecting. This model has an advantage to keep the diversity of populations from the moment can improve the whole convergence speed to improve average fitness.

Not that the subpopulation is excluded from the migration and cannot attend in the migration forever, but the subpopulation is selected by each, and the decided generation can then change. Passing the isolated generations after each evolution to the decided generation, can evaluate the average fitness of each subpopulation, and then be selected by the subpopulation to be the selection object. The migration has occurred between the sub-populations that are to be selected. Figure 2 illustrates the migration scheme between groups. [5]

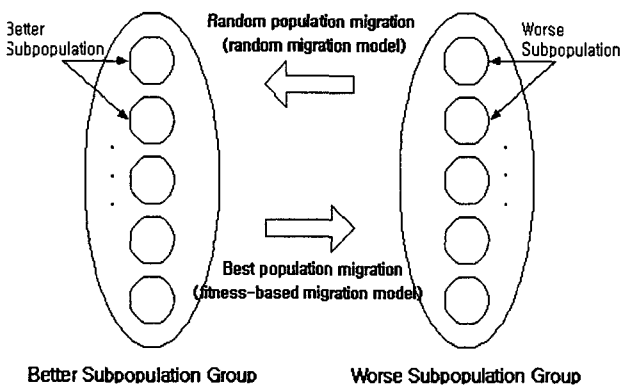


Figure 2 – Migration Scheme

## Fuzzy Control Algorithms

This section describes the detailed implementation of the proposed crossover and mutation fuzzy controller.

### (1) Inputs and Output

The inputs to the crossover and mutation fuzzy logic controller are the changes in fitness at 2 consecutive steps, i.e.  $\Delta f(t-1), \Delta f(t)$  (change of average fitness to t-1, t). And the outputs of which are the changes to crossover  $\Delta c(t)$  and the changes to mutation  $\Delta m(t)$ .

### (2) Membership Functions

$\Delta f(t-1), \Delta f(t)$  are respectively standardized into the range of  $[-1.0, 1.0]$  and  $\Delta c(t)$  is standardized into the range of  $[-0.1, 0.1]$  and  $\Delta m(t)$  is standardized into the range of  $[-0.01, 0.01]$  according to their corresponding maximum values.

Membership functions of fuzzy input and output linguistic variables are illustrated in Figure 3.

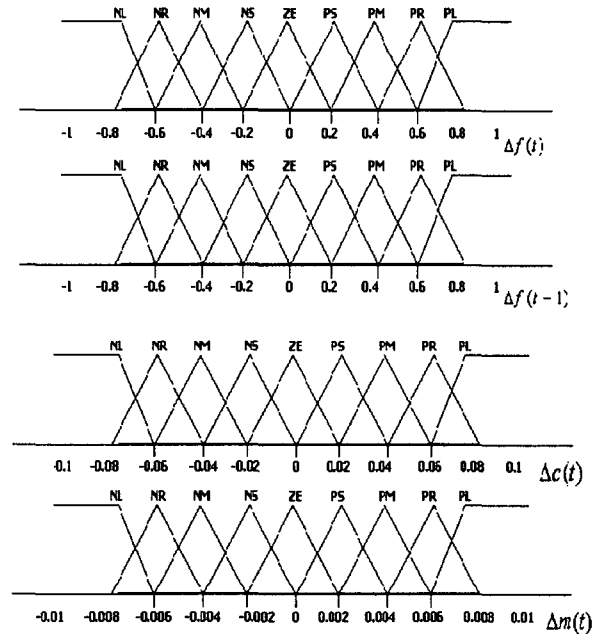


Figure 3 - Membership Function

### (3) Fuzzy Control Rules

Based on a number of experiments and domain expert opinions. When the change in average fitness is in the proximity of zero, the element in fuzzy control rules for mutation takes the linguistic value of PR.

### (4) Look up table for control actions

The look-up table is formulated as shown in table 1.

Table 1 and 2 are a look-up table for actions of the crossover and mutation fuzzy logic controller. So, PR has the value of 3 in case of mutation fuzzy logic controller. The outputs of the crossover and mutation in the fuzzy logic controller are formulated in equation (1), (2).

Table 1 - Look-up table for crossover

$\begin{matrix} x \\ z \\ y \end{matrix}$	-4	-3	-2	-1	0	1	2	3	4
-4	-4	-3	-3	-2	-2	-1	-1	-0	-0
-3	-3	-3	-2	-2	-1	-1	-0	+0	1
-2	-3	-2	-2	-1	-1	-0	+0	1	1
-1	-2	-2	-1	-1	-0	+0	1	1	2
0	-2	-1	-1	-0	2	1	1	2	2
1	-1	-1	-0	+0	1	1	2	2	3
2	-1	-0	+0	1	1	2	2	3	3
3	-0	+0	1	1	2	2	3	3	4
4	+0	1	1	2	2	3	3	4	4

Table 2. Look-up table for mutation

$\begin{matrix} x \\ z \\ y \end{matrix}$	-4	-3	-2	-1	0	1	2	3	4
-4	-4	-3	-3	-2	-2	-1	-1	-0	-0
-3	-3	-3	-2	-2	-1	-1	-0	+0	1
-2	-3	-2	-2	-1	-1	-0	+0	1	1
-1	-2	-2	-1	-1	-0	+0	1	1	2
0	-2	-1	-1	-0	3	1	1	2	2
1	-1	-1	-0	+0	1	1	2	2	3
2	-1	-0	+0	1	1	2	2	3	3
3	-0	+0	1	1	2	2	3	3	4
4	+0	1	1	2	2	3	3	4	4

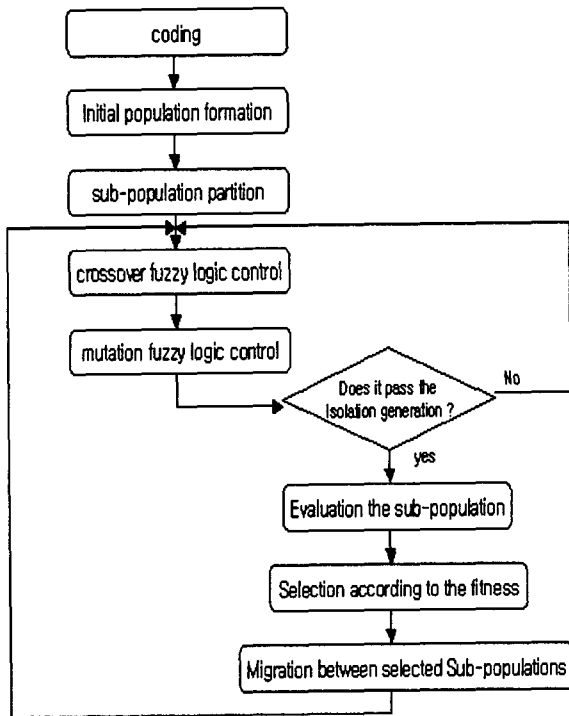


Figure 4 - Coordinated strategy between fuzzy logic control and multi-population genetic algorithms

$$\Delta c(t) = \text{look-up table}[i][j] \times 0.02 \times \alpha \quad (1)$$

$$\Delta m(t) = \text{look-up table}[i][j] \times 0.02 \times \alpha \quad (2)$$

Where  $i, j \in \{0,1,2,3,4,5,6,7,8\}$ , the contents of the

look-up table $[i][j]$  are the values of  $z$  in Table 1,  $\alpha$  is another adaptive coefficient which is less than 1.0 when the changes in fitness of whole populations are less than 0.02.[2]

The combination strategy in this paper between fuzzy logic control and multi-population genetic algorithms is shown in Figure 4.

## Simulation

The performance of the proposed method is then tested by a function optimization problem. The reason to use a lot of the optimization functions as the test of parallel genetic algorithms are because of the reasonable multi-model as an example the minimum point of the region. [6][7]

Optimization problem of three-dimensional function is tested as follow.

$$\begin{aligned} \max f(x_1, x_2) &= 21.5 + x_1 \sin(4\pi x_1) + x_2 \sin(20\pi x_2) \\ -3.0 &\leq x_1 \leq 12.1 \\ 4.1 &\leq x_2 \leq 5.8 \end{aligned} \quad (3)$$

The simulation parameters are as follows.

Whole population = 100 ;

The number of subpopulation = 10 ;

The individual number into sub-population = 10 ;

Migration individual number = 10 ;

Evolution generation = 100 ;

Crossover rates = 0.25 ;

Mutation rates = 0.01 ;

Coding method = binary coding ;

Selection method = roulette wheel.

In this simulation, we compared the group migration scheme and proposed method. This made subpopulations of 10groups and then tested. The individual number of each subpopulation is the 10. During the evolution to the whole 100 generations, we adopted the migration scheme the individual of 10 groups each 10 generations. And we show the best good result during having the simulation of 50 times.

Following Figure 5 is shown a maximum fitness according to the number of the generation.

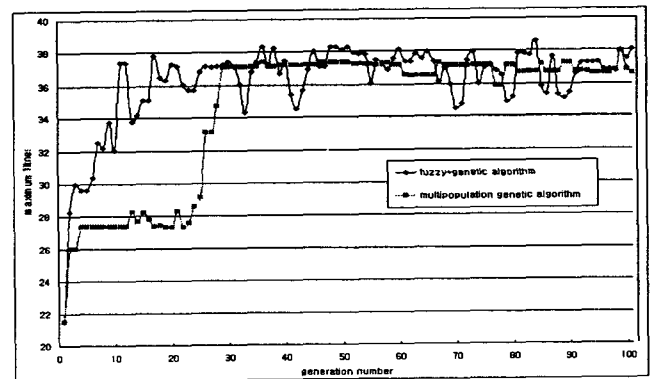


Figure 5 - Comparison the maximum fitness of two methods

We know that the proposed method has a much better performance as this shows a large difference of fitness between subpopulations in the initial generation.

Following Figure 6, the result of the test increases as the size of the whole population is 300, and the individual number in the sub-population is also 30.

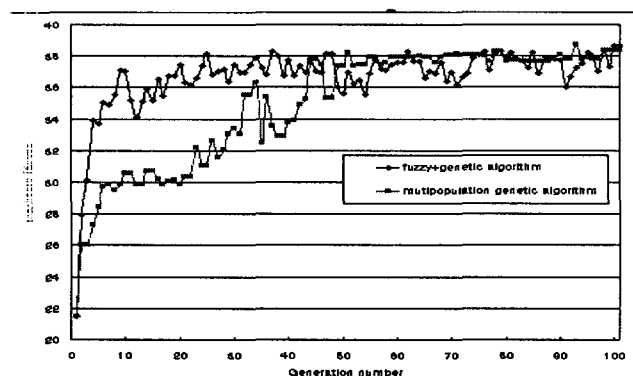


Figure 6 – Comparison the maximum fitness of two methods

Similar to the result both Figure 5 and Figure 6, the values can generally show to improve as an increase of the size of the population. This differs greatly from the initial generation, but we can show how to keep good value after middle-generation.

## Conclusions

We have looked around the area of the migration scheme in the multi-population genetic algorithms and the migration scheme using the crossover, and mutation in the fuzzy logic control and the existing method and proposed method. We can compare the proposed method with the existing method.

The result of the simulation, the proposed method has much better performance from the initial generation, and searches the optimization values to keep the good values from middle generation which are know similar to the existing method.

The proposed method can be applied to a wide range of systems and control problems because the performance of exhortion of taxes improves from the moment it decreases to be in danger of the regional optimum values. [2][5]

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