FUSION OF FUZZY SYSTEMS AND GENETIC ALGORITHMS

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Abstract: In this paper we study the fuzzy systems and genetic algorithm techniques .Ganetic Algorithm(G.A.) are complementary to Fuzzy Systems(F.S.) while the F.S. are easy to understand; the G.A. are not although they have the ability to learn, and so on. Our aim is to introduce the fusion of these two techniques.

Key words: Fuzzy systems, Genetic Algorithms, Artificial networks, chromosoms, Encoding scheme.

Mathematical Subject Clssification: 2000

Introduction: Genetic algorithm can be viewed as general purpose search method, an optimization method or a learning mechanism. This algorithm was developed by Goldberg with inspired by Darwin's theory of biological evolution: reproduction and "the strongest spices that survives" or "Select the best, discard the rest' .GAs are probabilistic optimization methods which try to imiate the process. This concept was introduced in 1967 by J.D. Bagley in his PhD thesis "The Behavior of Adoptive systems which Employ Genetic and Correlative Algorithms" [Bagley, 1967]. The theory and applicability was strongly influenced by J.H.Holland, a pioneer of GAs (1992). The first text book on GAs, which has become a standard reference work, was written by D.E. Goldberg [Goldberg, 1989]. Another useful standard work is the collection of Devis [Devis, 1991].

The genetic algorithms mentain a set of candidate solutions. The set is called a population and candidate solutions are called individuals or chromosomes. Chromosomes are usually represented by binary string of fixed length. The string which are candidate solutions to the search problem are reffered to as chromosomes. A chromosome is composed from gens and its value can be either numerical, binary or symbols. The chromosoms will undergo a process which is known as fitness function to measure the suitability of solution generated by GA. It work with coding of parameters, rather than the parameters themselves.

Fuzzy sets are the basic concept for supporting fuzzy theory. The main area of fuzzy theory are fuzzy logic and fuzzy measure. Fuzzy control is an application of fuzzy reasoning to fuzzy control. We here to discuss how the output of fuzzy system is calculated by fuzzy rules and fuzzy reasoning. The feature of fuzzy systems is the ability to realize a complex non-linear input-output relations as a synthesis of multiple input-output relations. The system output from one rule area to next area gradually changes. This is the essential idea of fuzzy systems and the origin of term 'Fuzzy'. The fuzzy systems modify fuzzy rules when logic should be changed and modify membership function which define fuzziness when fuzziness should be changed.The atemps to obtain fusion between FS and GA can be classified into two groups:

1. the control of parameters in GA with FS
2. The identifying of FS with GA.

We know, the FS are not learning algorithms but GA can be used as such learning algorithm for FS. The presence of parameters in GA makes its modification during the process possible.

This paper is organized as follows: In 2.1 presents general stracture of GA and 2.2 gives brief overview of the method of evolution of GA. Section 2.3 presents the fusion of GA and FS and these can be classified in two groups. Lastly we solve some problem using GA.

Genetic Algorithms:

General Stracture of Genetic Algorithms: The genetic algorithms have been shown to be an effective search method on difficult optimization problems.

Operatios: A typical genetic algorithm performs a sequence of operations on a population:

a) Initialize a population of chromosomes(population size =n)
b) Evaluate the fitness of each chromosome in the population.
c) If the stop condition is satisfied, stop and return the best chromosome in the population;
d) Select n/2 pairs of chromosomes from the population. Chromosomes can be selected several times.
e) Create new n chromosomes by mating the selected pairs by applying the crossover operator.
f) Apply the mutation operator to the new chromosomes
g) Replace the old chromosomes with the new chromosomes.
h) Return to the step no. (b).

This make a cycle which ends when we reach a predetermined limit.

Encoding Scheme: It is the scheme to represent the chromosomes into binary systems.We use GA into binary strings so the chromosomes are need to represent into binary systems.

Since chromosomes represent the candidate solutions, the encoding scheme should be designed so that it can cover the possible solution space. Also, it should be designed so that the modification of chromosomes through Genetic operators such as cross over and mutation, is easy and effective.

For example, if any integer greater than 0 and less than 255 are used, a triplet of (15, 25, 13) can be enclosed as follows: 000011110001100100001101.

The first 8 bits 00001111 are binary representation of decimal 15, also 2^{nd} 8 bits 00011001 represent decimal of 25 and 3^{rd} 8 bits 00001101 represent 13.

Evolution of Genetic Alogorithms:

Fitness function and evaluation: It is fitness function which is to evaluate solutions during the operation. A fitness value is assigned to each solution depending on how close it is actually to the optimal solution of the problem. Thus, the fitness function should be designed so that it gives higher fitness values to better solutions.

That is, a optimized function is usually used as a fitness function.

For example, if the maximum of $f(x)= -2x^2+6x-3$, on $\{0\le x\le 2\}$ are to be found and the value x is encoded,then the function f(x) can be directly used as the fitness function. The fitness value of a chromosom representing 1.5 is f(1.5)=1.5.

If we have no such function, we evaluate the quality of the solution. For example, a case of building a decesion tree with given data we should design a fitness function based on the variables which can reflect the quality of a decsion tree (such as number of nodes, the correctness of outputs).

Selection: Selection is an operation to choose parent solutions. New solution vectors in the next generation are calculated from them. The selected chromosomes are called parents. For the selection, first the possibility for each chromosom to be selected. Since it is expected that better parents generate better offspring, parent solution vectors which have higher fitness values have a higher probability to be selected. There are several selection methods.

- Roulette Wheel method: It is a typical selection method.The selection probality of a chromosome is the ratio of its fitness value to the sum of those of all chromosomes. From this analogy, the Roulette Wheel selection gives the selection probability to the individuals in proportion to their fitness values. The scale of fitness values is not always suitable for the scale of selection probability. Suppose there are a few individuals whose fitness values are very high, and others whose are very low. Then, the few parents are almost always selected and the veriety of their offspring becomes small.
- Rank Based Selection: The above mentioned method, the selection probability is linearly proportional to the fitness values. But Rank Based selection method, the selection probability is fixed according to the rank of fitness. For example, if the selection probabilities are given as follows :(0,3,.25,.20,.15), the chromosom with the maximum fitness always has a selection probability of .3, the chromosome with 2^{nd} largest has .25.

One merit of this method over the Roulitte wheel method is preventing fast convergence to a local maximum. The chromosomes with high probability are almost always selected and this most offsprings are generated from them. It makes the variety of a population low.

Crossover: Crossover is an opration to combine multiple parents and make offspring. The crossover is most essential operation in GA. Crossover operator produce two new chromosomes by exchanging information of the selected chromosomes. There are several ways to combine parent chromosomes. The simplest crossover is called one-point crossover. The selected chromosomes are cut on the randomly choosen point and the cut parts are exchanged. These are shown in figure 1.

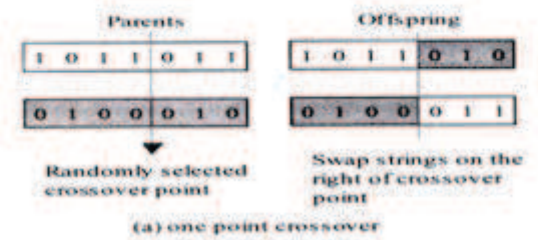

Fig.1

Crossover that uses two cut points is called two-point crossover [figure 2]. Their natural expansion is called multi-point crossover or uniform crossover [figurer 3].

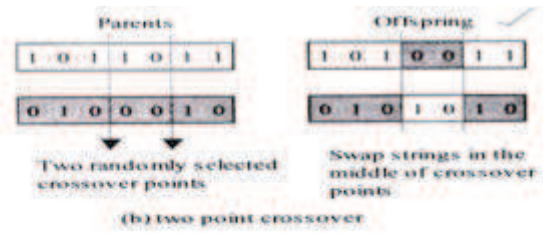

Fig.2

The simplex crossover combine two better parents and one poor parent and makes one offspring. When both are better parents having same bit 0 or 1 at a certain bit position, the offspring copies the bit into the same bit position. When better parents have different bit, then a complement bit of the poor parent is copied to the offspring. This is the analogous to learning something from bad behavior. [figure 3]

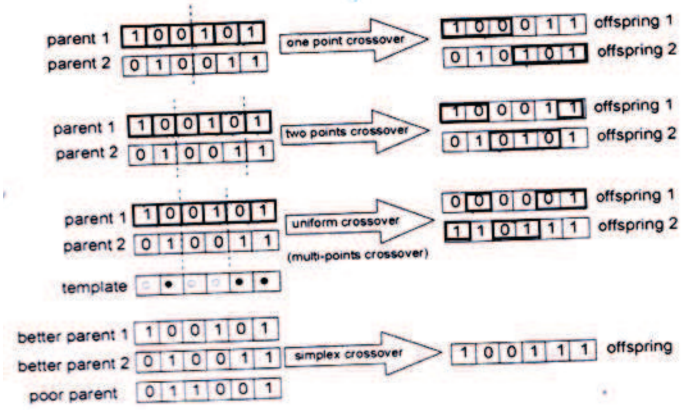

Fig 3

Mutation: Mutation operators changes some randomly selected bits of chromosomes. If the chromosomes are binary strings, then 'o' are changed to 1 and 1 are to 'o'. It plays the secondary role after the crossover operator in GA. For the change of bits making an offspring genetically different from parents.
Mutation introduces in new features occasionally into the solution of the population to maintain different from the parents to offspring. In order to escape from local optimum, a kind of jump operation is needed. So, by using the mutation operator, we can get some offsprings differ from their parents.
However, if the mutation operator is often applied to chromosomes, then most of newly created chromosomes are randomly different from their parents, so that the searching process may loss its direction. Thus, the mutation probability of a bit should be very low.
Replacement: A GA totally replaces the old population with new created chromosomes, but it is not mandatory.
For, example, after reproduction, the old and new popuplations are taken together, and among them the best n-chromosomes are selected as the next population.
The elitist strategy is an approach that copies the best k-chromosomes into the population and other chromosomes of new population are reproduced from the old population.

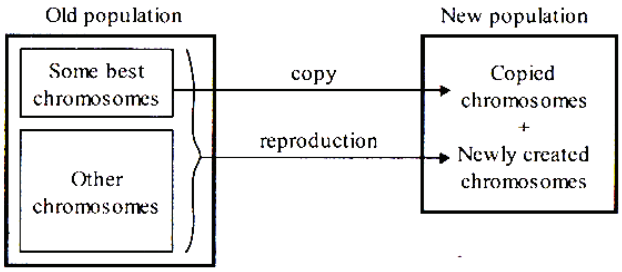

Fig.4

Figure 4 is graph of elitist strategy. If the total replacement is performed, the chromosomes of the best fitness in the new population may be worse than that of old population. Thus, elitist strategy is effective.
Fusion with Genetic Algorithms: Ganetic Algorithm (G.A.) are complementary to Fuzzy Systems (F.S.) while theF.S. are easy to understand; the G.A. are not although they have the ability to learn, and so on, that is, the fuzzy system do not have learning algorithms so the GA can be used as a learning algorithm of the fuzzy systems. GA have some parameters to be set. In searching process fuzzy system can be used to change these parameters. Now, the fusion of them are classified into two categories:

1. Identifying of fuzzy systems with Genetic Algorithms.
2. Controlling parameters of Genetic Algorithms with Fuzzy systems.

Identifying of fuzzy systems with Genetic Algorithms: Fuzzy systems have been using the control of a number of systems, it is very difficult problem and is to be taken adequate selection of the fuzzy membership function. Since this admits many subjectivety aspects and perhaps the need of too much time, yet FS are very useful indeed, in the control of systems.
The scheme of identification in figure 5

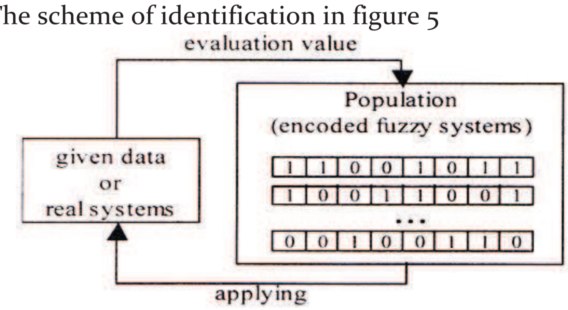

Fig. 5

The researchers can be categorized into two groups.

Tuning an existing FS: The investigating in the first category modify the parameters of an existing FS. Generally the tunned parameters ar the membership function and, or fuzzy rules. Tunning the membership functions with GAs are analogue to neuro FS. We encoded the membership function in chromosomes, and the search of better membership function is reached by GA.

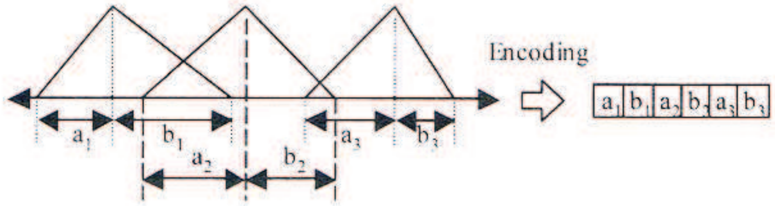

Fig. 6

Figure shows an example of encoded fuzzy sets into chromosomes.The shape of a triangular membership function is defined by three parameters: Left.Centre and Right. The consequent part is also parameterized. Ie, the center of triangular fuzzy sets is fixed, and only the left and the right points of each fuzzy set are variables and thus encoded. To modify the fuzzy rules, their consequent parts are usually encoded.

For example, there are four fuzzy rules:

IF X is I_1 THEN Y is o_1.
IF X is I_2 THEN Y is o_2.
IF X is I_3 THEN Y is o_3.
IF X is I_4 THEN Y is o_4.

Then they are encoded as a string of linguistic terms like $O_1O_2O_3O_4$ The Genetic operators will change it but not their membership functions. That is, $O_1O_2O_3O_4$ may changed into $O_1O_3O_4O_1$ after genetic operations.

Building a FS with GA.: The 2nd procedure is made by the construction of a FS through GA. Therefore, we do not need a pre-existing FS. So, the determination of the parameters by GA, is fixed directly. The chromosomes used in this method usually include most of the parameters and the membership functions of linguistic terms.

Controlling parameters of Genetic Algorithms with Fuzzy systems: Genetic Algorithm need some parameters such as population size and probalities of crossover and mutation. These parameters are very important for the performance, and the interaction between them is known to be complex. Thus, there have been many researching on how these parmeters effect on the performance and how to set them to improve the performance.

GA use a fuzzy knowledge-based system to dynamically control the parameters, such as population size, crossover rates and mutation rates.

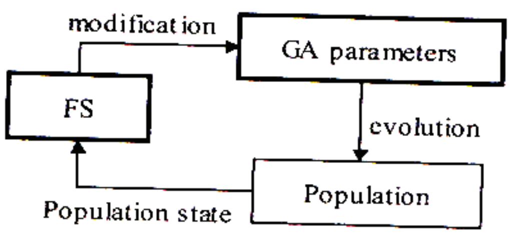

Fig. 7: Schemetic diagram of controlling parameters Gas and FSs.

Figure shows the schematic diagram of this method.

For example, fuzzy rules for those systems can be described as follows:

1. IF average fitness is high THEN population size should be increased.
2. IF best fitness is not improved THEN mutation rate should be increased.

One question of this approach is how to obtain the knowledge to build fuzzy rules. It can be solved in the ways: an expart on GAs can describe his/her own knowledge or an automatic fuzzy design technique can be applied.

An example of this approach is dynamic parametric Genetic Algorithm (DPGA) proposed by 'Lee and Takagi'. The DPGA has a fuzzy system which controls the parameters of GA according to the population state.

Actually DPGA was manually built from empirical knowledge, but it do not show good performance. Thus an automated method to built fuzzy systems was used.

Encoding Scheme: To build a FS which can control the parameters of GA well, parameters of the FS are encoded into chromosomes. The inputs of FS are average fitness/ best fitness, worst fitness/average fitness and change of fitness.The outputs are the changes of population size, crossover probability and mutation probability. All the 1 and 0 variables are represented by these fuzzy sets in figure.

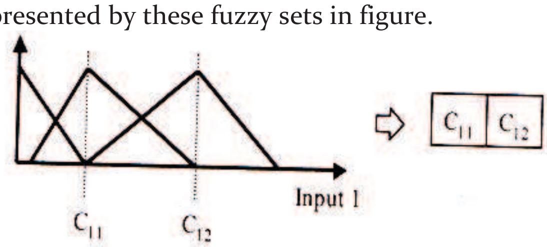

Fig. 8

Evaluation: For the evaluation of chromosomes, Dejong's five functions are used. The fitness of chromosomes is evaluated based on how much Dejong's functions are optimized by DPGA. This DPGA may not show a good performance in other applications because it is optimized with respect only Dejong's functions.

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