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Genetic Algorithm for Finding Shortest Path in a Network

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Abstract. This paper presents a genetic algorithm based on a strategy to find the shortest path in a network with variable length chromosomes (strings) and their genes have been used for encoding the problem. Crossover and mutation together provide improved quality of solution. Even though shortest path algorithms are already well established, this paper proposing a simple method of finding shortest path in a network using genetic algorithm.

Keywords: Genetic algorithm, shortest path, triangular fuzzy number

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1. Introduction

The problem of searching the shortest path is very common and is widely studied on graph theory and optimization areas. To achieve the best path, there are many algorithms which are more or less effective; depending on the particular case. Shortest-Path Problems play an important role in routing messages efficiently in networks. Each method has got independent merit of its own address, different types of path searching in different situations. These algorithms of path searching are not always based on precise data. So to deal with uncertainty fuzzy logic will be the appropriate tool. This is used to simultaneously associate more costs to those arcs, but this new feature increments computational efforts.

The fuzzy shortest path problem was first analyzed by Dubois and Prade [3]. He used Floyd's algorithm and Ford's algorithm to treat the fuzzy shortest path problem. Although in their method the shortest path length can be obtained, maybe the corresponding path in the network doesn't exist. Okada and Soper [7] developed an algorithm based on the multiple labeling approaches, by which a number of non-dominated paths can be generated. Besides, the multiple labeling approach is an exhaustive approach, and it needs to compare all the possible paths from the source node to the other nodes. Klein [5] proposed a dynamical programming recursion based on fuzzy algorithm. Lin and Chen [6] found the fuzzy shortest path length in a network by means of a fuzzy linear programming approach. Chuang and Kung [1], proposed fuzzy shortest path length procedure that can find fuzzy shortest path length among all possible paths in a network.

Many human inventions were inspired by nature. Artificial neural networks are one example. Another example is Genetic Algorithms (GA). GAs search by simulating evolution, starting from an initial set of solutions or hypotheses, and generating successive "generations" of solutions. This particular branch of Algorithms was inspired by the way living things evolved into more successful organisms in nature. The main idea is survival of the fittest, by the natural selection. A chromosome is a long, complicated thread of DNA (deoxyribonucleic acid). Hereditary factors that determine particular traits of an individual are strong along the length of these chromosomes. Changes occur during reproduction. The chromosomes from the parents exchange randomly by a process called crossover. Therefore, the offspring exhibit some traits of the father and some traits of the mother. The rare process called mutation also changes traits.

In nature, the individual that has better survival traits will survive for a longer period of time. This in turn provides it a better chance to produce offspring with its genetic material. Therefore, after a long period of time, the entire population will consist of lots of genes from the superior individuals and less from the inferior individuals. In a sense, the fittest survived and the unfit died out. This force of nature is called natural selection.

In dealing with fuzzy shortest path problem these genetic algorithms by the computation of more number of generations with the operators (crossover and mutation) will give the existing number of paths with the best fitness and fittest of survive leads to the minimal path.

This paper is organized as follows. In section 2, some basic definitions are discussed. Section 3 explains the execution of genetic algorithm, section 4 defines algorithm, in section 5 Network terminology, and in section 6 numerical example is given for the proposed method.

2. Concepts

Definition 2.1. (Fuzzy set [8]) Let X be the Universe of discourse, then a fuzzy set is defined as:

$$A= \{[x, \mu_{\tilde{A}}(x)], x \in X\}$$

This is characterized by a membership function: X → [0 1], where, $\mu_A(x)$ denotes the degree of membership of the element x to the set A.

Definition 2.2. (Triangular fuzzy number) A fuzzy number $\tilde{A}$ is said to be a triangular fuzzy number, if its membership function is given by

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{(x-a)}{(b-a)} & a \leq x \leq b \\ 1 & x = b \\ \frac{(x-c)}{(b-c)} & b \leq x \leq c \end{cases}$$

where a, b, c ϵ R.

Definition 2.3. Let $\tilde{A}$ = (a_1, a_2, a_3) be a triangular fuzzy number. Then an accuracy function of a fuzzy number can be defined as follows

$$H(\tilde{A}) = \frac{a_1 + 2a_2 + a_3}{4}$$

3. Genetic algorithm

Genetic Algorithm (GA) is based on an analogy to the phenomenon of natural selection in biology. First, a chromosome structure is defined to represent the solutions of the problem. A GA can be implemented in a variety of ways. The excellent books by Goldberg [4] and Davis [2] describe many possible variants of GAs. Here, we describe the encoding scheme used by the GAs. Genetic operators (initialization, crossover and mutation) specific to this encoding scheme are also defined.

3.1. Coding Solutions

The individual (chromosome) is represented by the collection of edges, and each e_i is the distance between two nodes. Our aim is to find the minimal path between the source node to destination node.

3.2. Representation of an individual (chromosome)

Here we are representing a chromosome as a random collection of edges and each edge is represented in a binary coding (4 bits string).

3.3. Initialization

The initial population is randomly generated and each individual is the random collection of edges. The edges are represented by a fuzzy number and the accuracy value of each fuzzy number is represented by a four bit binary string.

3.4. Crossover

Crossover combines information from two parents such that the children have a resemblance to each parent. Here we used two point crossover for generating the off springs.

3.5. Mutation

The Traditional mutation operator mutates the genes value randomly according to a small probability of mutation.

3.6. Selection

Considering population chromosome, a path for each chromosome is determined and the path length is considered as the chromosome value. The minimum will survive by comparing the chromosome values.

4. Algorithm

The main steps of the proposed algorithm are listed below:

Step 1 Randomly initialize the population (chromosomes).

Step 2 Update the chromosomes by crossover and mutation process

Step 3 Calculate the chromosome fitness

Step 4 Repeat step 1 and 2 until the minimum path exists.

5. Network terminology

Consider a directed network G (V, E) consisting of a finite set of nodes V={1,…,n}and a set of m directed edges E ⊆ V×V. Each edge is denoted by an ordered pair (i,j) where i, j ϵ V and i ≠ j. In this network, we specify two nodes, namely source node and the destination node. $\widetilde{d}_{ij}$ denotes a triangular fuzzy number associated with the edge (i,j). The fuzzy distance along the path P is denoted by $\tilde{d}$ (P) = $\sum_{i,j\epsilon \text{ P}} \tilde{d}_{ij}$

6. Numerical Example

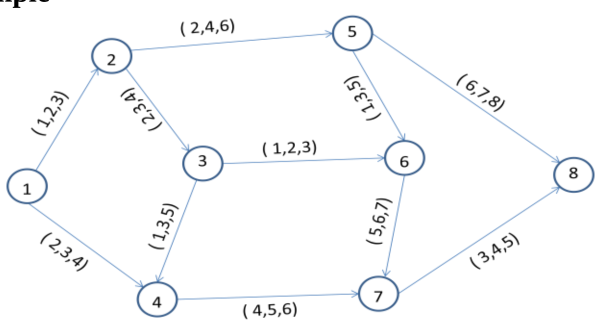

Figure 6.1

Represent the edges of the network by e_1 = (1,2,3), e_2 = (2,3,4), e_3 = (2,3,4), e_4 = (1,3,5), e_5 = (2,4,6), e_6 = (1,2,3), e_7 = (4,5,6), e_8 = (1,3,5), e_9 = (5,6,7), e_{10} = (6,7,8) e_{11} = (3,4,5).

6.1. Coding of Solutions

Each edge is represented by a four bit string. Suppose one such chromosome is (solution) (e_1, e_2, e_5, e_6, e_7) then it can be represented by 0010 0011 0100 0010 0101. The total length of the chromosome is represented as a 20 bit string.

6.2. Initialization

Randomly initialize the population let it be

{ e_2,e_4,e_3,e_5,e_7}, { e_1,e_2,e_5,e_6,e_7 }, { e_4,e_7,e_3,e_{11},e_6 },{ e_1,e_3,e_6,e_2,e_7 }

e_2	**e_4**	**e_3**	**e_5**	**e_7**		
(2,3,4)	(1,3,5)	(2,3,4)	(2,4,6)	(4,5,6)	———	18

0011	0011	0011	0100	0101	
e_1	**e_2**	**e_5**	**e_6**	**e_7**	
(1,2,3)	(2,3,4)	(2,4,6)	(1,2,3)	(4,5,6)	——— 16
0010	0011	0100	0010	0101	
e_4	**e_7**	**e_3**	**e_{11}**	**e_6**	
(1,3,5)	(4,5,6)	(2,3,4)	(3,4,5)	(1,2,3)	——— 17
0011	0101	0011	0100	0010	
e_1	**e_3**	**e_6**	**e_2**	**e_7**	
(1,2,3)	(2,3,4)	(1,2,3)	(2,3,4)	(4,5,6)	——— 15
0010	0011	0010	0011	0101	

6.3. Crossover

Before Crossover

0011 0011	0011 0100	0101
0010 0011	0100 0010	0101
0011 0101	0011 0100	0010
0010 0011	0010 0011	0101

After Crossover

0011 0011 0100 0010	0101	——— 17
0010 0011 0011 0100	0101	——— 17
0011 0101 0010 0011	0010	——— 15
0010 0011 0011 0100	0010	——— 14

6.4. Mutation

The first and the last four bits are mutated by the source node and the destination node.

0010	0011	0100	0010	0100	——— 15
0010	0011	0011	0100	0100	——— 16
0010	0101	0010	0011	0100	——— 16
0010	0011	0011	0100	0100	——— 16

6.5. Selection

The minimum path length after mutation is 15 [0010 0011 0100 0010 0100]
(e_1 e_4 e_5 e_6 e_{11})

It is not a continuous path. Hence select the minimal path by some more executions. Along with this path randomly initialize some more chromosomes and continue the process until the minimum path reached.

7. Conclusion

Here we considered the problem of finding a shortest path problem from source node to destination node in a network. The lengths are represented by a triangular fuzzy number, and the accuracy function is defined for the same. Then we investigate the possibility of finding the shortest path using genetic algorithm.

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