APPLICATION OF GENETIC ALGORITHMS TO ESTABLISH FLOODING EVACUATION PATH MODEL IN METROPOLITAN AREA

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Abstract. This research has shown the difficulties associated with the GIS and the flooding evacuation path search through the huge searching space generated during the network analysis process. This research also presents an approach to these problems by utilizing a search process whose concept is derived from natural genetics. Genetic algorithms (GAs) have been introduced in the optimization problem solving area by Holland (1975) and Goldberg (1989) and have shown their usefulness through numerous applications. We apply GA and GIS to choice flooding evacuation path in metropolitan area in this study. We take the region of Shiji city in Taiwan for case. That could be divided into four parts. First, is to set the population of GA operation. Second, is to choose crossover and mutation. Third, is to calculate the fitness function of each generation and to select the better gene arrangement. Fourth, is to reproduce, after evolution, we can establish Flooding Evacuation Path that more reflect really human action and choice when flood takes place. However we can apply GA to calculate different evacuation path in different time series. Final, we compare and establish real model of evacuation path model to choosing flooding evacuation path. Keywords: Disaster, Flooding Evacuation Path, Genetic Algorithm, Network Analysis, GIS.
1. Introduction

Along with the economy grows up and urbanization, the metropolis gathers the most part of population and property. However influence of the Taiwan geography location and meteorological condition, flooding resulting from typhoons was frequently and greatly impacted the cities located in the river basin in Taiwan, for example, the typhoon Xiang-Shen in October 2000, the typhoon Tao-Zhi in August 2001 and the typhoon Na-Li in September 2001 (Zhang 2000). It threatens people’s life and property tremendously. Because of that, we need to provide proper Evacuation Path Model (EPM) to people, and decrease the damage; however, in the process of analyzing the EPM, we usually plan it as the shortcut. Although obtaining shortest distance, but it is not necessarily the best path, and it lacks the dynamic consideration (Li 1997).

When the flood occurs in the metropolitan area, the range of the inundation will change along with the time status (Breaden 1973). Thus, on the planning of evacuation path and precaution node, there are something need to be considered. First, the dangerous degree of flood in the area needs to be examined. Second, the time efficiency of evacuation path needs to be evaluated. In order to achieve the function of flood-avoided, not only the condition of the location itself but also the condition of the environment need to be considered (Djokie 1996). Besides, the successful rate of the evacuation action will be influenced by not only the environment and the time situation, but also the decision-making behavior of the people who under the pressure. Therefore, it is much important to design an optimal path but not the shortest path. Then, other choices of the evacuation path need to be provided in order to adapt to the human behavior.

The traditional researches of Evacuation Path (EP) in Geographic Information System (GIS) were seen as a kind of problem solving of productive searching with rules of IF...THAN. Those concepts are finding all probable answers so must face difficult problem of combine explode. Usually, those problems are straightened out by some heuristic rules and search strategy (Anderson 1996).

The EP is thought as a production tree (Gero and Ding, 1997). It was believed that a reasonable tree existed could be mapping. The goal of EP is finding out the reasonable tree could be matched. The context of EP knowledge is controlling and searching the paths and the nodes to conform to EP need on tree. The only way to find out the tree just is try and error. There are two questions in a good answer of EP, one is how are the rules decided in the EP process, and other is how is evaluated process or answer of good EP. These are the important subjects in this study.

In the primary stage we can’t judge the result is the best only by the better judgment. In fact the most events we can’t judge the better or worse in early
days until the final stage. But in the final time we want to choose is not any change, the path could be determined. The nodes were existed in the searching processes might be the best solution paths, that were deleted by some heuristic rules and search strategy (Wen 2001). So we can search the EP by the GAs that is the natural choose process to find the optimization model to help us soon get the global optimum in this study (Blanco 2000).

2. Theory

The theoretical basis of the research included GA, GIS, Network Analysis and disaster prevention theories. The biological evolution aroused GA, which is a kind of optimization search model within natural choice process. It operates by the way of the encoding gathered by parameter and gets rid of restrictions of seeking space analysis. For this reason, we can get the Global Optimum faster, and prevent it become the Local Optimum. Therefore, the study uses the dynamic process of the Genetic calculation, and goes on the choice of the flooding evacuation path. Receiving the batter population, we combine the function of the GIS Spatial Analysis, under the disaster prevention theories, it can present a more safe model that near to the behavior of the really evacuation in mankind. The structure of combined GA with GIS like figure 1.

![Figure 1. The structure of combined GA with GIS](image-url)
2.1. GENETIC ALGORITHMS

John Holland proposed genetic algorithms (GAs) in 1795. This is an optimization of problem solving and technologic of machine learning. It is enlightenment from creature evolution process. The answer of every problem expresses a chromosome that present an individual creature. A group of creature were evolution by Darwin's evolutionism compete and select. The fitting creature exists that present the good solution survival the bad eliminates through competition. The new solution of new generation also to model creature propagate by survival's individual copulation and mutation (Bullock, 1995).

There are four different points between GAs and traditional way of optimization and search. (1). GAs deal with whole set of solution, not only solution itself. (2). The search of GAs starts from a group of population fitting well and scattering beginning, not from a point. (3). GAs is objective function, not differentiation or others assist knowledge. (4). GAs leads the direction of search only by hands around rule of probability (Woodbury, 1993).

It is a series process of self adjusts in search control of design reasoning of GAs (Jo and Gero, 1995). The combination of design reasoning rules could be a chromosome of one of EP solution. Every set of chromosome is whole result of inference path generated by probability. These evolution from parents and generate next generation were selected by environment conditions. Those are constantly adjusted through heuristic rules and search strategy, stop until solution fit need. The whole process of evolution is the process of finding out answer. The final result of inference paths, evaluative rules and solution is important knowledge of EP. There are three process follow:

1. Reproduction
   The probability of copy from parents is derived from fitness degree of the chromosome. The common method is Roulette Wheel Selection by the percentage of its fitness degree of the chromosome over summarization of all fitness degree. That is the more high fitness degree the more opportunity to duplicated from parents.

2. Crossover
   After reproduction the crossover provide for exchange chromosomes between mother generations in order to get the befitted chromosome from parents (Chan 1994).

3. Mutation
   It may change some genes form some chromosomes to avoided lost the befit information by reproduction and crossover in the genetic process. So we can extend the searching space to escape from the local optimum to the global optimum.
2.2. PERSON STREAMING THEORY

The walk speed will be close to normal speed if there is enough space. On the contrary, if there is not enough space, walk speed will be slow down even closed to stop depending on the increasing density. Dr. Tanaboriboon and Dr. Guyano think about that walk speed and body characteristics of western is differ with oriental. At the center street of Bangkok city in Thailand it was studied to survey location the ambulation of people (Tanaboriboon and Guyano 1989). They divide service level of ambulation into 6 rankings (A, B, C, D, E and F). And they convert walk speed base on the relationship of density and discharge like Table 1.

<table>
<thead>
<tr>
<th>Services level</th>
<th>Density (Person / Square metre)</th>
<th>Velocity (Metre /Second)</th>
<th>Flow (Person / Metre * Second)</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≦0.42</td>
<td>≧1.12</td>
<td>≧0.47</td>
<td>* Don’t generate conflict each other</td>
</tr>
<tr>
<td>B</td>
<td>0.43–0.63</td>
<td>1.06–1.11</td>
<td>0.48–0.67</td>
<td>* The velocity and flows become slightly slow</td>
</tr>
<tr>
<td>C</td>
<td>0.64–1.02</td>
<td>1.00–1.05</td>
<td>0.68–1.02</td>
<td>* The pedestrian needs to adjust the velocity and directions</td>
</tr>
<tr>
<td>D</td>
<td>1.031–1.54</td>
<td>0.88–0.99</td>
<td>1.03–1.35</td>
<td>* Difficult to change the direction and cross</td>
</tr>
<tr>
<td>E</td>
<td>1.55–2.70</td>
<td>0.62–0.87</td>
<td>1.36–1.68</td>
<td>* Extremely difficult to change the direction and cross</td>
</tr>
<tr>
<td>F</td>
<td>&gt;2.71</td>
<td>&lt;0.61</td>
<td>&gt;1.69</td>
<td>* Can’t reverse direction and cross</td>
</tr>
</tbody>
</table>

3. Knowledge Representation

The knowledge representation is the key of whole system of Evacuation Path Model (EPM). There are chromosome, environmental parameters and fitness function. These derived from path table, node table, choose table, dynamic function and GA table in GIS.

3.1. CODE OF CHROMOSOME

The concept is developed by initial EP’s idea. The result of chosen path could be transformed a serious genes to combine chromosome. Assuming one area has many nodes (for example… P1, P2, P3, …, Pn.), each node has a lot of path to be chosen. The figure 2 shows the node P1 has two paths can be chosen, there are two chosen method. As the same way, the P2 has three
chosen method. Thus we can establish the attributes of choose table (like table 2) from node table.

<table>
<thead>
<tr>
<th>Method</th>
<th>Node</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10</th>
<th>P11</th>
<th>P12</th>
<th>…</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>P4</td>
<td>P1</td>
<td>P2</td>
<td>P1</td>
<td>P4</td>
<td>P5</td>
<td>P6</td>
<td>P10</td>
<td>P8</td>
<td>P16</td>
<td>P4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>P2</td>
<td>P3</td>
<td>P8</td>
<td>P5</td>
<td>P13</td>
<td>P2</td>
<td>P14</td>
<td>P9</td>
<td>P7</td>
<td>P13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>P6</td>
<td></td>
<td>P12</td>
<td>P6</td>
<td>P7</td>
<td>P10</td>
<td>P3</td>
<td>P16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. The method of node choose

The table 2 presents the spatial relationship and chosen method of each node of the figure 2.

TABLE 2. Choose Table.

Choose gene code

<table>
<thead>
<tr>
<th>Id</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gene</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

Transform to dynamic path node code

Code of chromosome

Figure 3. The dynamic function to transform the gene code into the EP
The dynamic function is to transform the gene code into the EP (like figure 3). The gene code follows the id to be a chromosome in the GA. The id just the sequence number there is no any means in this table. If we decide the start node is (P1) and the end node is (P14) of EP. The first id just is in the name of start node (P1), the gene code is (0). Then we can choose the next node by index the gene code from choose table. For the start node (P1, 0) we can index P1 choose the (0) method to find out the P4. So the next node is P4, we transform the gene code from (1, 0) to (P1, 0) to (P1, P4). Then repeat the steps above until the next node is just equal the end node. Final we can spatial join table to GIS to draw out the EP (like the red line in figure 3).

The rule of crossover between two chromosomes is before we cut any segment by random, after we crossover them.

Before crossover => PathA: 1,1,2,⋯⋯,3 1  PathB: 1,1,4,⋯⋯,2
After crossover   => PathA: 2,1,4,⋯⋯,2 1  PathB: 2,1,2,⋯⋯,3

3.2. ENVIRONMENTAL PARAMETER

DF: Degree of Fitness. The value was calculated by the fitness function. Then it transfers each case’s subsistence probability. The function follows:

\[ \text{ALIVE}_i = \frac{\text{DF}_i}{\sum_{j=1}^{n} \text{DF}_j} \]

\( i \): the \( i \)'th case

PN: Population Number. The numbers of total individual, the max living numbers of controlled environment

RR: Reproduction Rate is the copy rate of mother generation. Whether the individual child will be reproduction, it depended on its subsistence probability. If the subsistence probability is higher, it will be more chance copied. It will have more opportunity to evolve.

CR: Crossover Rate is the exchange percentage between any two chromosomes of parents.

MR: Mutation Rate is self-change probability of any chromosome.

3.3. FITNESS FUNCTION

The fitness function is the rules to estimate cases and give weight score. It is the tool to judge the better or worse one. It can decide to eliminate the unsuitable case. It including evaluation the rank of EP, the successive nodes of EP, the number of nodes, the length of EP and the number of repeat path in EP choose.
4. Computing evacuation path in Shiji area

This chapter will take the Shiji City in the Keelung River Basin for case in this study. The boundary is like figure 4. We apply river digital topographic map, Digital Elevation Model, Traffic Network Data, Urban Planning Map, etc. According the functions required. We can analyze the demand of data, and build database.

4.1. WORKING DATA AND PARAMETER SETTING

We adopt Taipei Disaster-Prevention Planning for the setting of road class. The roads were classified into four classes: emergency path system (20m), rescue transport path system (15m), fire control path system (8m) and assist path system (8m). To define the boundary of Urban Disaster Prevention & Rescue Refuge Rings, we take the service radius (600m) of high school elementary schools, and the range of refuge rings is about 300m~500m. The walk time of refuge rings is about 5~10 minutes and to consider other resource of Disaster Prevention & Rescue. The construction of the disaster prevention network model is like figure 5.
Before process the GAs calculation, we must to precede the pattern of Gene Coding. Let the variables indicate the suitable sequence in the computer operating. Finally, we decoding it and return the result (like figure 6).

![Figure 6. The refuge node coding](image)

Final we set the parameter like Initial population, crossover rate and mutation rate. After we coding the refuge node, we can create initial population and choose the start node. This study on GA’s parameter set up 500 initial populations, and it has 0.5% crossover rate and 0.1% mutation rate.

To search EP, we use GA technique to get an answer belong to the problem form of the limited type model. The region of answer could be very small. The result could be segment to several areas. It would have low rate to get optimization answer with this model, and the rate of best answer also obvious level down. Generally speak the best answer often appearance on cape area that on the boundary region of the feasible solution. If we only adopt the information of the feasible solution, it would increase search time and difficulty. Gen (1997) use GAs to solve the limited type of problem model, it will often appear the result that not falls into feasible solution region. Gen solve these problems by four kinds of strategy, we use two kinds of methods in the following.

1. Reject Strategy: Once the answer of GA output in not feasible solution region, we throw down that chromosome right away. Make sure the chromosome that making duplicate always in the feasible solution region.

2. Penalty Strategy: At original target function, increase a penalty item. The penalties items will check by the level of individual act against restrict. The degree of act against is more. The penalty function is bigger. Whereas is
smaller. These study give different degrees of penalty function with have inundation or not. So we can make the limit question into in limit.

4.2. OPERATION INTERFACE AND PROCESS

On the process of searching the best evacuation path, we adopt two different methods to find the solution. First, it is on the condition of evacuation path continuous each other and processes the optimization of path. Second, it is on the unlimited condition, so all influential factor proceed in different indicators weights. The first method has better searching speed, the second method has longer time to calculate, but it is flexible. In this study, we take the first method to simulating. The operation interface is like figure 6. The Population Results and Progress Graph like figure 7.
4.3. THE SIMULATING RESULT ON DYNAMIC TIME

In the Figure 8, it is the flood area on the precipitation of 300mm in the 10 hours rainfall. The blocks have less effect by flood, and there is less separation of road. We can reach to refuge node directly by GA operating.

In the Figure 9, it is the flood area on the precipitation of 300mm in the 20 hours rainfall. As the increase of the effect blocks, the condition of separating roads is more severe, so it needs to make a detour to reach rescue refuge.

Figure 8. The simulation of the initial stage in Shiji flood area

Figure 9. The simulation of the middle stage in Shiji flood area
5. Conclusion

In this study, we establish disaster databases to proceed with case study and bring up the preliminary analysis result, it will consider in a specific way to search evacuation path in city. Combining GAs and GIS to deal with the dynamic time space data, we point on the different time state and dynamic selection of the path, the simulation can offer the better hermeneutic capability to process dynamic flooding evacuation path modal.

After the more physical computing result, calculating the minimum of node number at first has batter time efficiency than calculate the minimum length or time. Consider the minimum node point number then consider time factor batter than only consider one influence factor.

A. We constructing the database of dynamic time and spatial and the pattern of analyzing evacuation path, and to propose the method of combination further, and analyze the process of the combination of spatial and time information.

B. To make use of Decision Support System, we can plan and manage flooding evacuation path and disaster rescuing and refusing space, and decrease the damage.

C. Researching the combination of GIS and GA, and we hope to promote the technique of GIS

This evacuation path operation still adopts the one-to-one search method at the present time, however in realistic environment, refuge place and path will generate more complicated relation, there will be many situations like different location in complex number refuge personnel toward same refuge place. So the study will consider the complex person to select evacuation paths toward different refuge place on next stage.

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