

GIS NETWORK ANALYSIS IN RESCUE OF COAL MINE

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KEY WORDS: Geometry Network, Polygon Based Model, Net work analysis, Coal mine safety, Fire, Flood

ABSTRACT:

Coal industry is one of a country's base supports. It is one of powers which make the economy of China developing fast. But at the same time, Coal industry is such a kind of industry in which many people hurt or die. Recently, many coal mines established coal mine rescue system. They improved the results in rescue by using information technology. The GIS (Geographic Information System) technology was widely applied. But this kind technology was limited to display and query maps. Its really powerful analysis function wasn't used efficiently. There are flood, fire, gas disaster and etc in coal exploitation. Once the disaster happens, available escaping paths should be found immediately. Currently the administrators can accomplish this mission by using GIS function in coal mine rescue system, but in the rescue action, the time is very important. If GIS analysis function is used to find escaping paths automatically, the result of rescue action should be better. In coal mine, the laneways are used in transporting and ventilating. When the mine disaster happens, these laneway are escaping paths for the workers. So the escaping paths should be found in the laneways. To analyze the interlaced laneways by GIS method, a special model need to be built. It is a solution that constructing a network model which consists of junctions and edges by abstracting the laneways. So the problem of finding a escaping paths is converted to the path analysis of network. First, draw the network according to mine construction map strictly and build the correct topology relationship between them. Then add attributes to the network data, for example, the elevation of the junctions, the name of the laneways or the direction of the airflow. Being different from normal spatial data, network data has characters of connectivity and direction. Before network analysis, these characters should be set correctly. But these characters vary from the type and extent of disaster. For example, in the laneways of the same mine, when flood happens, the junctions and edges which are higher than the water level should be connective, whereas they are not connective; when fire happens, the air returning laneways are dangerous, they should not be connective. So the connectivity and direction of network data should be adjusted real-time according the input. When the above steps are finished, the information of network analysis is sufficient. Then after applying a network analysis on the data, correct escaping paths will be found.

1. INTRODUCTION

Recently, GIS is applied in the area of safe production of coal mine widely. It gains remarkable economic benefit and society benefit. Many coal mines have built up information management systems. Through those systems, the administrators can monitor the safe production of coal mine. But the functions of those systems are limited to the display and query of the coal mine map. In China, the accidents of coal mine happen frequently. For those real-time accidents, current systems can only improve the efficiency of query information and give a more direct result. But these can't help the administrators make any decision. To apply the analysis function of GIS, coal mine information management system could satisfy the safe production of coal mine further, at the same time, improve the abilities of the administrators to make decisions.

2. SPATIAL MODEL OF COAL MINE SAFE PRODUCTION

The working environment consists of laneways and working face. Working face is exploitation face on which workers dig. Laneway is a passage which workers walk through and coal is carried out from. To make sure of the worker's safety is making sure the safety of the laneways and the working-face. Considering that the working-face is actually a special part of laneways, building a spatial model of coal mine safe production is actually building a model for the safety of laneways. When

the accident in coal mine happens, the administrator could gain the best path of the calamity avoiding through the analysis of safety model.

2.1. Geometry network based model

At present, geometry network model is applied in many GIS which are built up in different industry. For example, in the query system of public traffic, people solve the best path finding problem by using the geometry network model. (Liu Yuefeng, Xu Yiqin, 2005)

The geometry network can represent a set of path which is connected to each other. It abstracts the paths of real world. It uses edge and node to represent and analyze the paths. The laneways of coal mine is similar to the paths of the geometry network. So, the geometry network can be used to represent the laneways. The passages in the laneways are the edges of the network, and the points which the passages joint are the nodes. In geometry network, the edge has attributes of orientation and weight, while the node has attributes of connection. In coal mine production, workers are able to walk through the laneway in both directions. According to the type of the calamity, the weight of the edge which represents the laneway varies. And the connection of node is the same. So, the laneway can be abstracted to "a non-direction network whose edge weight and node connection can be changed dynamically". (Michael Zeiler, 2001)

When the accident happens, the model can compute the best path of the calamity avoiding between two nodes by point out the “calamity type”, “happening place” and “exit place”.

2.2. Polygon based model

The geometry network based model can be processed fast. But it is highly abstracted. In some special scene of coal mine, it is hard to use. To satisfy this requirement, the network model can be anti-abstracted. It builds up a polygon based model to represent the real-world laneways. This model can simulate the real situation of the laneways, and is benefit to represent the result of path of the calamity avoiding analysis.

In the polygon based model, all the laneways connected to each other are regarded as a whole polygon, and the laneways not connected to others belong to another polygon.

In network model, the connected laneways are like “Figure 1”.

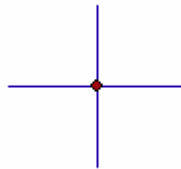


Figure 1 Connected laneways in geometry network

In polygon based model, the connected laneways are like “Figure 2”.

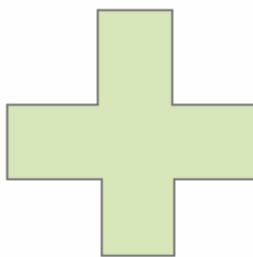


Figure 2 Connected laneways in polygon based model

In geometry network, the laneways that are not connected and cross laneway is like “Figure 3”.

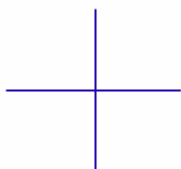


Figure 3 Cross laneways in geometry network

In polygon based model, the laneways that are not connected and cross laneway is like “Figure 4”.

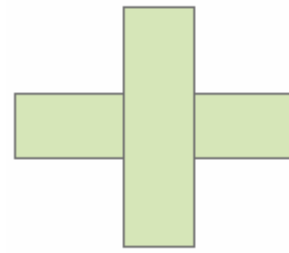


Figure 4 Connected laneways in polygon based model

It needs to add some points along the edge of the polygon, when the polygon based model is being built up. Among these points, the calamity related parameters are stored in. We call the points “assistant points”. The polygon that has been added points is like “Figure 5”.

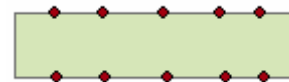


Figure 5 Polygon with assistant points

The model is used to analyze the best path of the calamity avoiding when the accident happens. First, according to the type of the calamity, the points are selected by judging the related value stored in the point. Then, the points are connected to form a line. Divide the polygon into two parts by the line. According to the rule of the model, that the laneways belongs different polygon are not connected, the polygons are removed from results, which represent the laneways that workers can't walk through. Last, the result polygon forms. The divided polygon is like “Figure 6”.

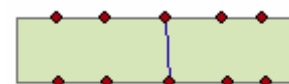


Figure 6 Divided polygon

3. THE APPLICATION OF THE MODELS IN RESCUE IN CALAMITIES

Fire and flood happens frequently in coal mine. We will explain how do the two model analyze these two kind calamity. We take example for a simple laneway map. It is like “Figure 7”.

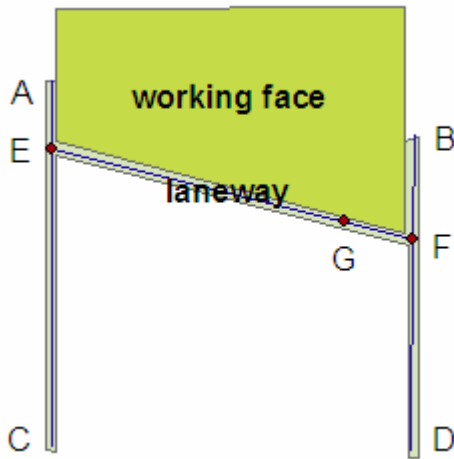


Figure 7 Coal mine map

In the map, points C, D are exits. The directions of the air flowing are C→D, C→B, D→A. The elevations of each point are shown in “Table 1”.

Point	Elevation(meter)
A	30
B	10
C	60
D	20
E	40
F	20
G	20

Table 1 Elevations of points

3.1. Fire

If a fire takes place in point G, point C is windward to point G, while point D is leeward to point G. To avoid poisoning of coal gas like carbon monoxide, workers must leave from point C immediately.

3.1.1. Geometry network based model. The single line in the map is the network that represents the laneways. The lines AE, BF, CE, DF, and EF are edges of the network. The points E, F are nodes of network.

Network analysis is used to get best path of the calamity avoiding. The length of the edge is assigned as the weight of the edge. But at this time, the edge FD is leeward to the place where fire happens. Worker can't walk through the laneway FD. So the weight of edge FD is set to ∞ . After set the weight dynamically, we can get result from the model. The best path is G→E→C.

3.1.2. Polygon based model. The polygon that contains the single line represents the real situation of the laneways. If fire happens in point G, we need find the two nearest assistant points. Then use them divide the polygon. The polygon that has been divided is like “Figure 8”.

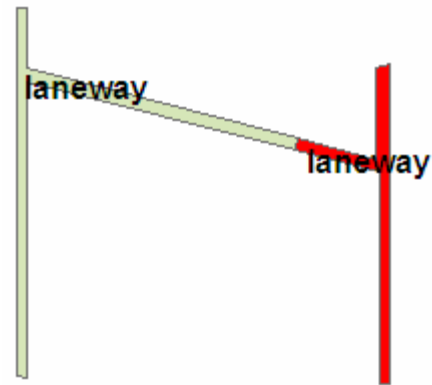


Figure 8 Fire avoiding path in polygon based model

So we have two laneways, the left part and the right part. According the rule of the model, these two laneway is not connected. Then we could find the right path directly in map.

In network model, the laneway FD is removed from results. This model doesn't show the path of the right side of the fire place. But actually lane FD is leeward to the fire place though, workers in right side could leave form exit D because the distance to exit D is not very long. In polygon based model the right polygon is still integrated. It means the right laneway is still connected. Worker can work through in it. It points out that workers in right side could leave form exit D. It is obvious that the model based on polygon could give out full-scale solution when the path of fire avoiding is analyzed.

3.2. Flood

If flood takes place in laneway, the worker in point G need choose the path of flood avoiding according to the water level.

3.2.1. Geometry network based model. If the water level is lower than 20 meters, the network is still connected. The length of edge is assigned to edge. By the model, we can get the best path is G→F→D. If the water level is higher than 25 meters, the node F has been submerged. The node F should be set not connected. Then we can get the path is G→E→C.

3.2.2. Polygon based model. If the water level is lower than 20 meters, the laneways polygon is divided according to the value of the assistant points. The result is like “Figure 9”.

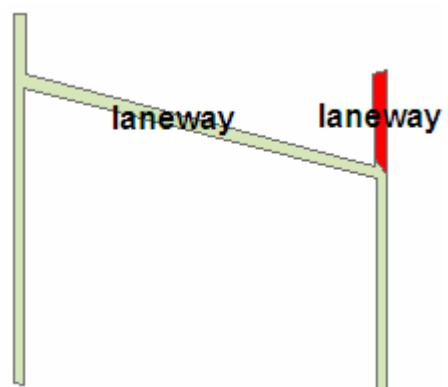


Figure 9 Flood avoiding path in polygon based model (Water level < 20m)

The polygon is divided into two parts: the one is lower than 20 meters and the other is higher than 20 meters. Actually, workers can walk through all the laneways that is higher than 20 meter. So they could leave from exit C and D.

If the water level is higher than 25 meters, the laneways polygon is divided. Divided polygon is like Figure 10.

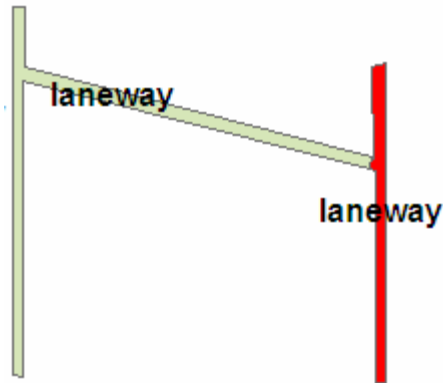


Figure 10 Flood avoiding path in polygon based model
(Water level > 25m)

The right polygon is lower than 25. It means the right part laneway has been submerged. Workers can only leaves from point C.

CONCLUSION

This article discusses the GIS network analysis in rescue of coal mine. It brings forward a polygon based model. Then it compares the geometry network model to this model. It is difficult to process the complex safety management by using the normal geometry network, while it is easy to solve such kind problem by using the new model cited by this article. But this model also has some limitation. It is hard to building the model and it is complex for the data preparation. The future work should study combining the polygon based model with the geometry network based model.

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