Research on mine fire rescue path based on hybrid algorithm of PSO

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Abstract. It is the most important thing to respond to mine fire that determining the optimal rescue path. This article is put forward the coefficient of accessing difficulty level by analyzing the factors which affecting underground fires, then constructing the optimal rescue path model of underground fire by calculating the equivalent length of roadway. Designing the hybrid particle based on PSO algorithm and ACO algorithm by analyzing the fundamental of PSO algorithm and ACO algorithm, and optimizing the basic flow of algorithm. Afterwards, searching for the optimal rescue path by using the hybrid particle. Finally, searching for the optimal rescue path with the shortest time by MATLAB software in the example. Not only providing a decision basis for determining the optimal rescue path in underground fires, but also providing the theoretical support of emergency relief system.

Introduction

In recent years, mining accidents are more frequent and larger extent of casualties, mine safety production management of national security is still a very important content [1]. While mine accidents decreases gradually in recent years, but because of the accident base, mine safety situation is still very grim. Mine Fire is one of the major natural disasters [2]. When an accident occurs, high-temperature and poisonous gases will attack many roadways, and then pose a great threat to the mine workers. Because multiple factors affecting the rescue, choosing a reasonable emergency rescue paths has great significance.

Determining a reasonable path of the emergency rescue is the primary task to deal with the underground fire. This article was constructed underground fire rescue path mode based on the rescue of roadway passable, roadway traffic and other factors solver equivalent length of roadway. Introducing the hybrid algorithm to determine the optimal path of underground fire rescue. Thereby shortened the rescue time of personnel in underground mines, as much as possible to avoid casualties and minimize the economic loss, improving the effectiveness science and practice of the emergency rescue system.

Construction of rescue path model of underground fire

The nature of the roadway's passage [3]. Ideal-type. The safe roadway of no or less high-temperature and poisonous gases affecting.

Passable-type. The safe roadway of high-temperature and poisonous gases affecting, Underground staff can through this roadway at a certain time. Available time:

$$\tau = 601.85\xi e^{-0.08t} \tag{1}$$

τ -Available time (min);

t-The temperature of roadway (℃);

ξ -The coefficient of roadway's Slope(The coefficient of horizontal and gently inclined slope- 1; The coefficient of upwardly inclined slope-0.2; The coefficient of downwardly inclined slope-0.36).

(3)Escape-type

The time passing through a roadway within the range of extreme temperature,The judgment is based on the maximum tolerated time of underground staff passing through a roadway.The maximum tolerated time:

$$T_{\max} = 1.812e^{-0.046t} \tag{2}$$

Tmax-The maximum tolerated time(min);

t-The temperature of roadway (℃).

The equivalent length of roadway [4]**.** The coefficient of accessing difficulty level. The factors which affecting pass speed are: the density of staff, the width and height of roadway, the slope, the toxic gases, the temperature, the wind speed, the difference of pressure, the obstacles, the transport and so on. We can use the coefficient of accessing difficulty level to express above factors, named βi. The coefficient of accessing difficulty level:

$$\beta_i(E_{ij}) = \frac{T(E_{ij}) - t(E_{ij})}{t(E_{ij})} \tag{3}$$

T (Eij)-The time of passing through the roadway “Eij” with the factors;

T (Eij) - The time of passing through the roadway “Eij” without the factors.

Calculate the equivalent length of roadway. The equivalent length of only one roadway

Set the actual length of the roadway “Eij” for “l (Eij)”, the coefficient of accessing difficulty level is named “βi (Eij)” which is based on the factor “i”. The equivalent length of roadway “Eij”:

$$L(E_{ij}) = l(E_{ij})\square[1 + \sum_{i=1}^{n} \beta_i(E_{ij})] \tag{4}$$

The equivalent length of the rescue path

“Pi” is expressed the passable path, it includes the rescue path “P”. The rescue path “P” which includes the quantity of roadways is n, “E_k” is the No. k roadway, so P= {E1, E2… E_k… En}.The equivalent length of this rescue path:

$$L_i = \sum_{k=1}^{n} L\left(E_k\right), E_k \in P \tag{5}$$

Hybrid design of PSO and ACO

The fundamental of PSO and ACO. PSO used to guide the next iteration position of particle by the current position , Pbest and Gbest. Because of its high searching efficiency and the simplicity of implement, it can be applied to a certain extent in many areas, such as the neural network training, parameter identification and task scheduling [5].

ACO algorithm is a heuristic algorithm to model the behavior of real ant colonies in establishing the shortest path between food sources and nests. The ant colony algorithm is versatile and robust．Due to its inherent search mechanism,it shows great performance in discrete optimization problems [6].

Algorithmic process. First of all, change the parameter optimization problem of ACO to continuous combinatorial optimization problem .Then abstract the problem of the optimal route search as the TSP problem of closed loop shortest path, named F(α,β,ρ). Regard the node of people trapped underground as the city we will traverse. Secondly, the characteristics of PSO specializes in solving the continuous problem can be used to search the optimal parameter combination of ACO,and then back to ACO. Use the high precision and parallelism of ACO to search the rescue path. In the end,we choose the shortest equivalent length and shortest time-consuming path after comparing. Obtain the optimal parameter combination and optimal rescue path min F(α,β,ρ).

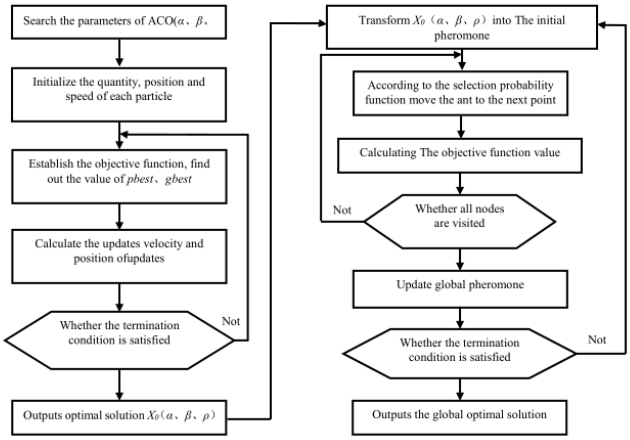

Fig.1 Algorithmic process

The application example

Constructing the model of roadways. Select one of the nodes as the fire place in a mine fire accident,then construct the rescue path model of underground fire.

The schematic diagram of Passable roadway,such as the Fig.2:

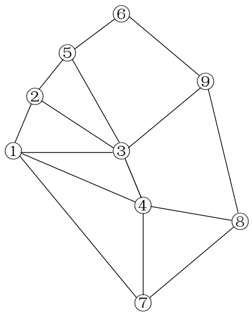

Fig.2 Passable roadway

Get the equivalent length of roadway,such as the table 1:

Table 1 the equivalent length of roadway

Eij	The actual length /m	β1	β2	β3	β4	β5	β6	β7	β8	The equivalent length /m
E12	188.4	0.1	0.2	0.1	0.1	0	0.2	0.3	0.1	395.6
E13	228.2	0.2	0.3	0.3	0.2	0.2	0.1	0.2	0.1	593.3
E14	371.3	0.1	0.2	0.4	0.1	0.2	0.1	0.3	0	891.1
E17	449.5	0	0.3	0.3	0.2	0	0.2	0.2	0	988.9
E23	194.8	0.3	0.3	0.4	0.5	0.1	0.4	0.1	0.2	642.8
E25	128.4	0.3	0	0.4	0.5	0.3	0.2	0	0.2	372..5
E34	159.4	0.2	0.2	0.1	03	0.2	0.3	0	0.2	398.6
E35	265.0	0.2	0.3	0.2	0.4	0.1	0.3	0.2	0.2	768.4
E39	274.7	0.2	0.2	0.4	0.3	0	0.4	0.1	0.1	741.7
E47	244.0	0.3	0.3	0.4	0.5	0.2	0.1	0.1	0.2	756.5
E48	228.8	0.4	0.2	0.3	0.5	0.3	0.2	0	0.3	732.2
E56	183.1	0.3	0	0.2	0.3	0.4	0.3	0.1	0.1	494.4
E69	223.3	0.3	0.3	0.2	0.2	0.3	0.2	0.3	0.3	692.2
E78	325.1	0.2	0.2	0.3	0.5	0	0.3	0.3	0.2	975.4
E89	385.6	0.2	0.4	0.2	0.1	0.3	0.3	0.1	0	1 002.5.

Eij-The roadway between nodes “i”and “j;

βk- The coefficient of accessing difficulty level which is based on the factor “k”,including the density of staff,the width and height of roadway,the slope,the toxic gases,the temperature,the wind speed and the difference of pressure.

The equivalent length of the impassable roadway is named “Inf”.

Solving the optimal rescue path by MATLAB software. The PSO algorithm is searched for the ACO algorithm parameters α,β,ρ by MATLAB software, the scope of the search: α∈[1.0,4.0], β∈

[3.0,5.0], ρ[0.4,0.6].Then back to ACO algorithm,the ACO algorithm is searched for the rescue path. Get the combination of parameters and the optimal path,such as the table 2:

Table 2 Combination of parameters and the optimal path

Number	α	β	ρ	length /m	Running time /s
1	1.041681	4.384328	0.492762	5791.5	21.09
2	1.094882	4.732991	0.502478	5791.5	24.01
3	1.1.3479	4.325773	0.479520	5791.5	22.57
4	3.496680	4.759632	0.485673	5791.5	25.32
5	1.009887	4.298647	0.496773	5 995.4	26.54
6	3.206893	4.978935	0.479550	5791.5	23.19
7	2.984339	4.873691	0.500338	5 995.4	23.78
8	1.070328	4.368912	0.488682	5791.5	28.46

The optimal combination of parameters: α=1.041681, β=4.384328, ρ=0.492762;

The optimal rescue path: 1→2→5→6→9→3→4→8→7→1 (The first group);

The equivalent length of the rescue path:5791.5m.

Conclusion

Constructing the rescue path model of underground fire by calculating the equivalent length of roadway. The optimal rescue path is the shortest equivalent length of the rescue path. The objective function:

$$Z = \min \sum_{E_k^* \in P^*} L\left(E_k^*\right);$$

This article is put forward the hybrid particle based on PSO algorithm and ACO algorithm.Using PSO algorithm searched parameters α,β,ρ of ACO algorithm,then backed to ACO algorithm and searched for the optimal rescue path.

In the example,searching for the optimal rescue path with the shortest time by MATLAB software.

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