APPLICATION OF DEPTH-FIRST SEARCH METHOD IN FINDING RECIRCULATION IN MINE VENTILATION SYSTEM

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ABSTRACT

Recirculation of airflows in a mine ventilation system can cause concentration of contaminated air which results in an unsafe working environment for people working in an underground mine. Due to the difficulty in finding the recirculation of airflows in complicated mine ventilation system, depth-first search method is proposed to find the recirculation of airflows in complicated mine ventilation systems. The searching procedure of a simply depth-first search method is introduced briefly. Then the depth-first search method is modified for searching recirculation of airflows in complicated mine ventilation systems. The proposed method is implemented through MATLAB in the form of storing ventilation information in a matrix. A few recirculation of airflows are found and are confirmed by the mine ventilation simulation result. It is concluded that the proposed method is a valuable tool in finding recirculation of airflows in a complicated mine ventilation system.

KEYWORDS

Mine ventilation, Recirculation, Booster fan, Depth-first search method

INTRODUCTION

Nowadays, booster fans are widely employed in an underground mine, which help to balance the air pressure and quantity distribution to provide a suitable working environment for human being[1, 2]. However, booster fans installed underground can cause recirculation of airflow in the mine ventilation system. Recirculation in a mine ventilation system makes it possible to induce concentration of contaminated air, including dust and gas, which make the people who work underground taking a risk. Therefore, it is imperative to find the reticulation of airflows in a mine ventilation system and to control them. Figure 1 shows an example of recirculation of airflow in an underground mine. All the roads of the mine are depicted in the figure 1 and the red arrows represent the directions of the airflows. A fan is installed underground as indicated by the green arrow. As can be seen, there is a recirculation of airflow as indicated in the white box. The air in the white area is circulating in a few connected roads instead of all the air flowing to the return roads, which significantly reduces the volumetric efficiency. It is easy to find the recirculation of airflows in a simple ventilation system as shown in figure 1 while it is difficult to find the recirculation in a complicated ventilation system which has dozens of booster fans installed underground and hundreds or thousands of roads.

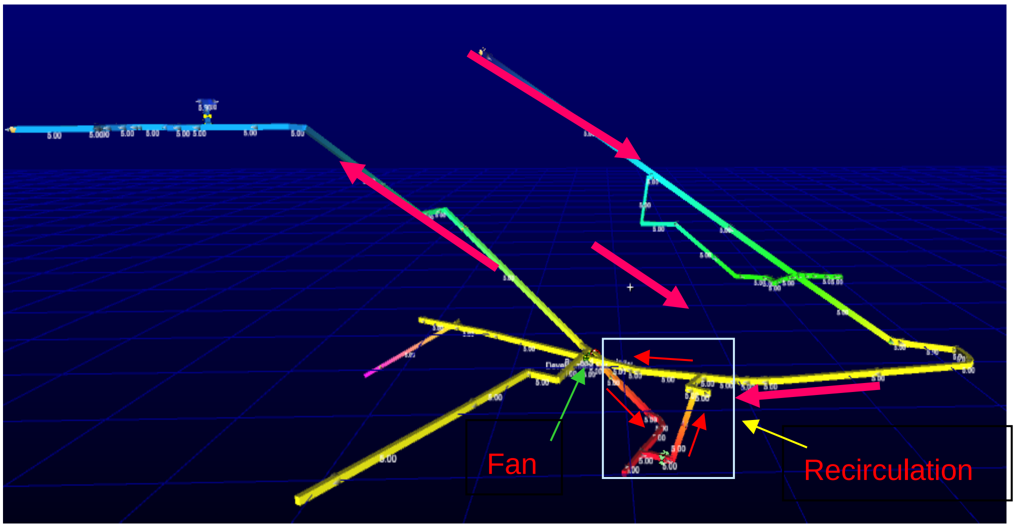


Fig. 1 - An example of recirculation airflow in an underground mine

In terms of mine ventilation, many numerical or experimental researches have been done [3-7]. However, as for the recirculation of airflows, rare study has been focused on it. With the fast development of the computer technology, researchers have begun to study the recirculation of airflows on basis of computer technology [8]. Since it is of great importance to eliminate the recirculation of airflows and it is difficult to find the recirculation of airflows in a complicated ventilation systems, this paper provides a mathematical method, i.e. depth-first search method, for finding the recirculation in a complicated mine ventilation system and applies the method in a copper mine to search the recirculation of airflows.

DEPTH-FIRST SEARCH METHOD

In this section, the simple depth-first search method is introduced first. Then the simple depth-first search method is modified for suitable finding the recirculation of airflows in a complicated mine ventilation system.

Simple Depth-First Search Method

Depth-first method has been applied in many fields [9-14]. Since the simple depth-first method had been introduced in detail by Rao and Kumar (1987) [11], the method herein is introduced briefly and the modified depth-first search method for finding the recirculation of airflows in a complicated mine ventilation system is introduced in detail.

Depth-first search method is used to find a path in a directed graph from an initial node to a goal node [11] . The search begins by expanding the initial node, i.e. by generating its successors, and ends when a goal node is found [11] . Consequently, the solution path is constructed by following the path from the initial node to the goal node. Figure 2 illustrates a step-tree generated according to the depth-first method. In figure 2, the numbers in the boxes indicate the order of the boxes generated while the expanding order of the boxes follow the alphabet order as shown in the boxes. As can be seen in figure 2, the first box, i.e. A1, on the top is the initial node which generated three nodes, i.e. 2B, 3I and 4L. Then 2B expands and generates two boxes, 5C and 6D.

After that, the tree generates and expands following the previous rules. More details can be found in the reference [15].

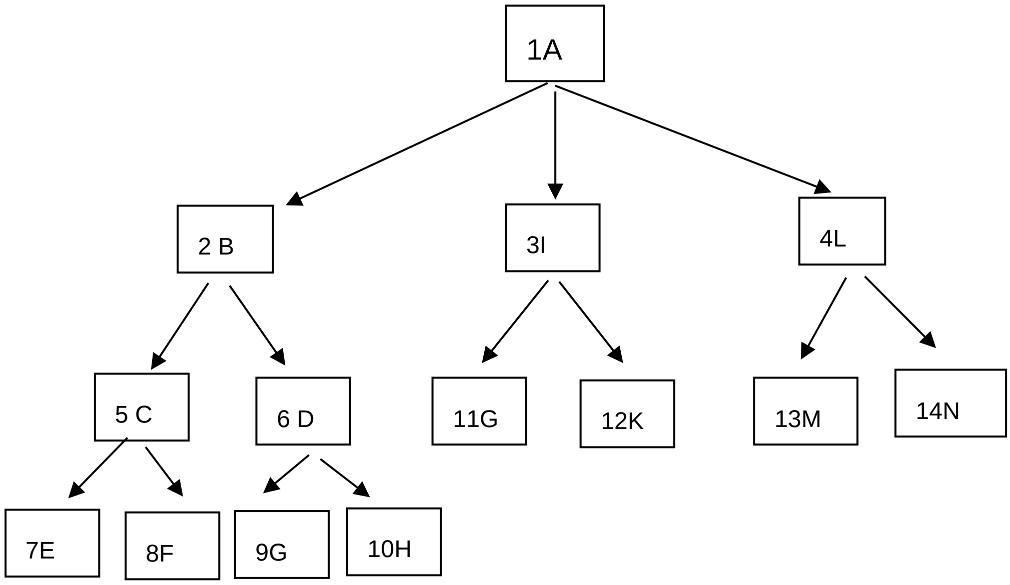


Fig. 2 - Example of Depth-first search method producer. Each number in the box represents the order of generation while the order of expansion follows the alphabet order in the box. After Rao and Kumar (1987)

Modified Depth-First Search Method for finding Recirculation in Mine Ventilation System

The simple depth-first search method mentioned above is modified for searching recirculation of airflows in complicated mine ventilation system. The basis searching rules follow simple depth-first search method while a few new rules are added for searching.

The procedure for the modified depth-first method is as follows.

1) The initial node is put in a stack first.
2) The search begins by searching adjacent nodes of the initial node along the arrow directions.
3) The search will visit the searched adjacent node with smaller number if there are more than one adjacent nodes and put the visited number in the stack.
4) The search repeats the rule 2 and 3 untill the initial node is visited again. Then the visited path represents one recirculation.
5) The search will pop backwards to find a visited node which has unvisited adjacent node.
6) The search will repeat step 2 to 5 until all the recirculation paths beginning from the initial node are found.

Figure 3 shows the initial state of a network. The search will start from node 1. Figure 3 represents part of ventilation network in which all the roads are connected. It should be noted that, in Figure 3, the node 1 and node 1`represent the same node. We put the initial node in two circles for conveniently drawing and explaining the searching procedure in the network.

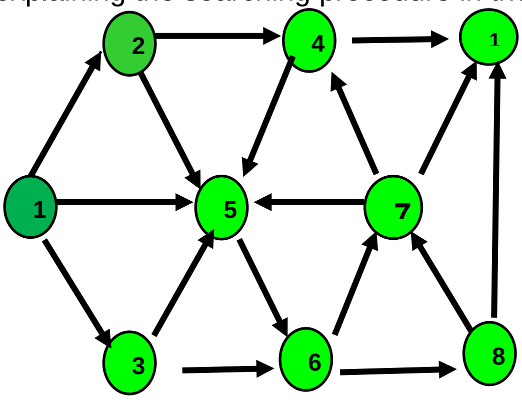
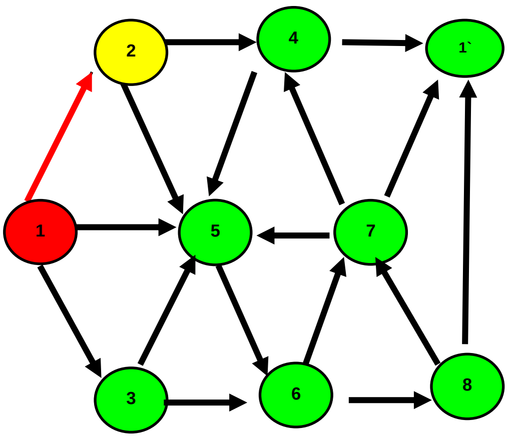
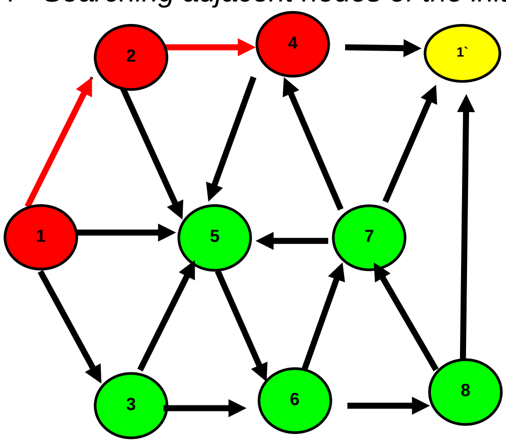


Fig. 3 - Initial state of a network



Stack	1	2							

Fig. 4 - Searching adjacent nodes of the initial node



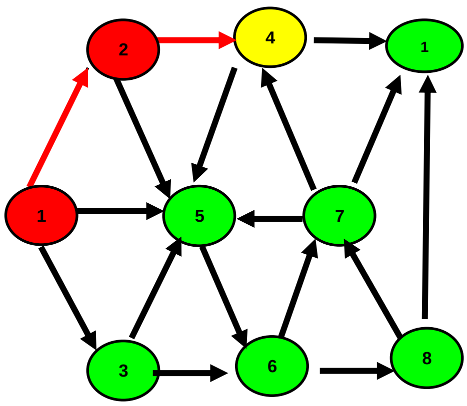
Stack	1	2	4	1`					

Fig 5 - First recirculation in the network

As illustrated in Figure 4, the initial node, i.e. node 1, is put into the stack first according to rule 1. Then, the depth-first search method begins to search the adjacent nodes of node 1 along the arrow direction, i.e. the direction of airflow in a ventilation system, according to rule 2. Two nodes are found, i.e. node 1 and node 3.

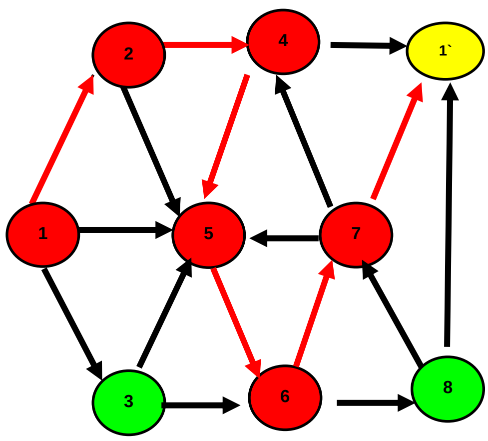
The node 2 is visited and put the number into the stack according to rule 3, i.e. visiting the smaller node with smaller number. After that the node 1 and node 2 are marked using red color and yellow color, respectively. In this paper, the red color represents initial node or visited nodes while the yellow color represents the current visiting nodes. Additionally, the green color indicates unvisited nodes.

Figure 5 shows the first recirculation found in the network. After node 2 is visited, the search then continues to find the adjacent nodes of node 2, i.e. node 4 and node 5. Since the search will choose the node with smaller number to visit first, the node 4 is visited put into the stack. The rule 2 and rule 3 are repeated until the node 1` is visited. In the next step, the node 1`, i.e. node 1. Thus a recirculation of airflow is found and the numbers are put into the stack.



Stack	1	2	4						

Fig. 6 - Popping back to node 4



Stack	1	2	4	5	6	8	7	1`	

Fig. 7 - Second recirculation in the network

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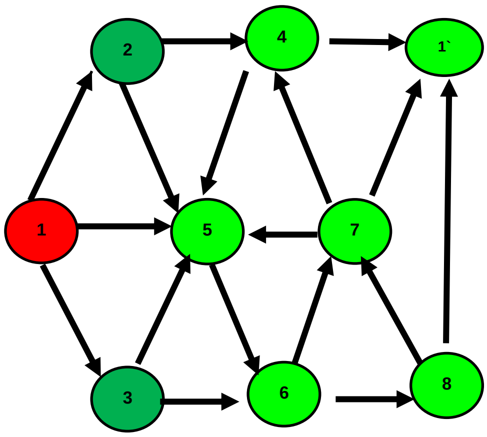
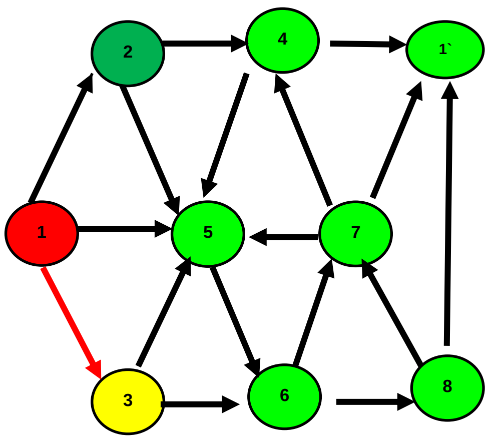
Since the recirculation of air flow is found, the search will pop backwards to found a visited node that has unvisited adjacent nodes. As shown in Figure 6, the search pop back to node 4 and finds that there are two adjacent nodes, i.e. node 5 and node 7, which are not visited yet.

Then the search continues to travel from node 4 as shown in Figure 7. The search follows rule 2, 3 and 4. Finally, the second recirculation of airflow is found and the nodes of the recirculation are put into the stack.



Stack	1								

Fig. 8 - Popping back to the initial node



Stack	1	3							

Fig. 9 - Search from the initial node again

According to rule 5, the search will pop backwards and find that only the initial node has unvisited node. Therefore, the search continues to go from node 1（Figure 8. The node 3 is visited. Since there are not unvisited adjacent nodes for node 3, the search will pop back again. The search pops back to node 1 and the node 1 does not have any unvisited nodes (Figure 9). Therefore, the search has finished and two recirculation of airflows are found.

APPLICATION OF THE MODIFIED METHOD IN FINDING THE RECIRCULATION IN VENTILATION SYSTEM

In this section, the proposed modified depth-first search method is applied in a complicated copper mine ventilation system for finding recirculation of airflows near at the booster fan areas.

All the rules mentioned in Section 2 are made for suitable finding recirculation in ventilation system. The initial node in ventilation system represents the place where the booster fan is. Since the recirculation of airflows is mainly caused by the booster fans installed in underground mine, we mainly focus on finding recirculation of airflows around those areas where booster fans are installed. In section 2, the node with smaller number has the priority to be visited. This is because in our ventilation system the air flow from the ends with smaller number to the ends with bigger number. In another word, the search will follow the directions of airflow. In Section 2, when the initial node is visited again, a recirculation of airflow is found. This means the air flow from the intake air road and return to the intake road again instead of passing the return road to the outside. Then, it represents a recirculation of airflow.

According to rules of the depth-first method, application of the method needs to know the airflows of the ventilation system, the position of booster fans and number of the two ends of roads. With the development of the computer technology, a lot of of mine ventilation software are available at this moment. In our research, WENTSIM [16] is adopted for simulating the ventilation system and adding numbers to the two ends of each road.

The implementation of the depth-first method is then use the MATLAB [17] software, which is good at storing matrixes. All the roads will be shown in figure induced by the MATLAB software. The recirculation of airflows in the ventilation system will be marked as red color.

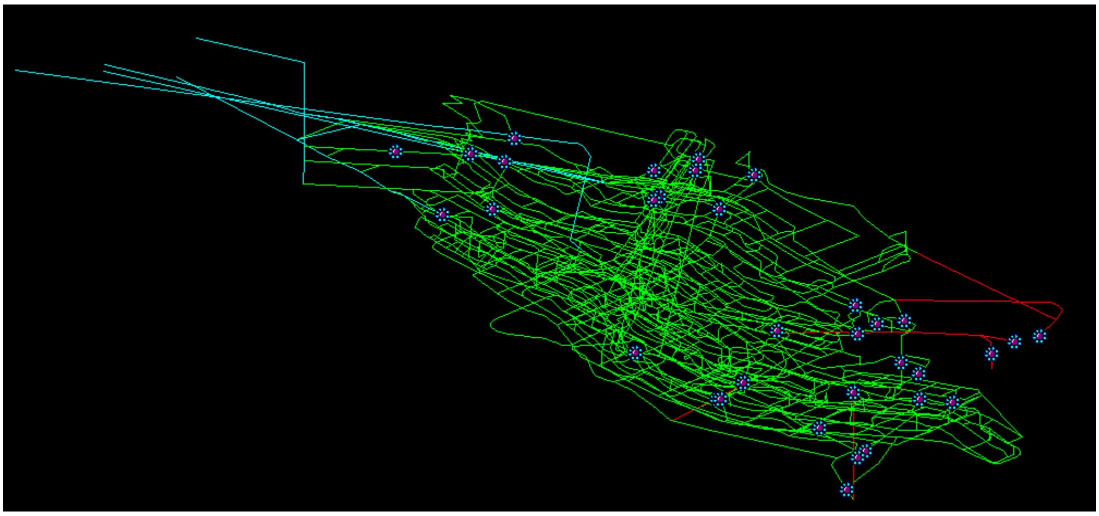


Fig. 10 - Mine ventilation system of a copper mine

Figure 10 shows a copper mine ventilation system. The blue lines represent the intake air roads while the red lines indicate the return road for the contaminated air. The fan is denoted by the fan symbols. The copper mine currently has thousands of roads and 38 fans installed underground.

The simulated results of mine ventilation system, i.e. the airflow directions and the denoted numbers on two ends of each roads are stored in the MATLAB in the form of matrix. Then the depth-first search begin to search from the initial nodes, i.e. the position of a booster fan, and follows the directions of airflows, i.e. from smaller number to big number. All the nodes which

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indicate the booster fan positions are used as the initial nodes for searching the recirculation of airflows at the fan areas.

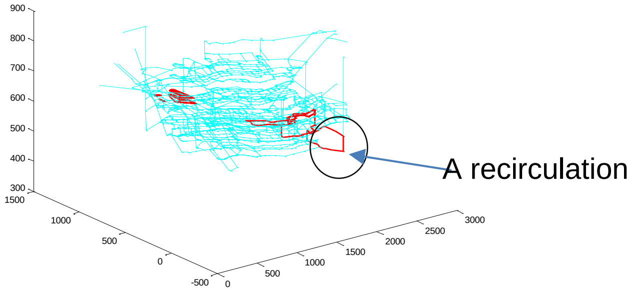

Fig. 11 - Recirculations marked in red colour in a ventilations systém

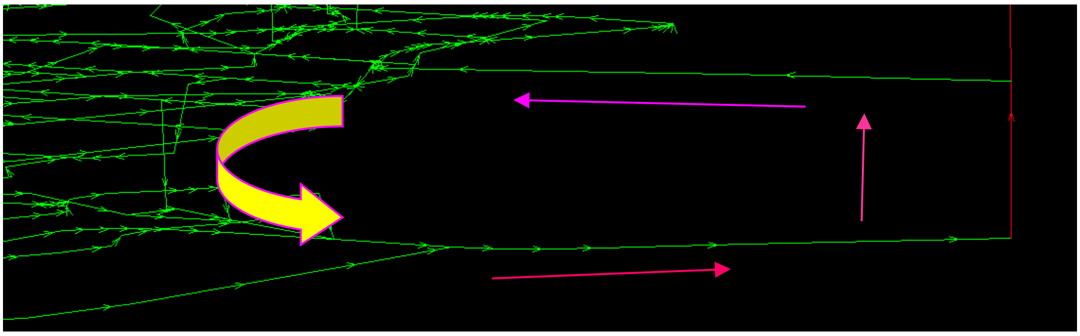

Figure 12. Corresponding recirculation circled in Figure 11

Figure 11 illustrates the searched results in which the recirculation airflows are denoted using red color. It can be seen that a few recirculation of air flow are found. The recirculation of airflow at the circled area is compared with the ventilation simulation result in Figure 10. Figure 12 shows the corresponding recirculation circled in Figure 11.It is confirmed that the depth-first search method can find the recirculation of air flows. Other recirculation of airflows illustrated in Figure 11 is also compared with the mine simulation results and all the recirculation of airflows found by the depth-first method are correct.

DISCUSSION

The implementation of the depth-first search method for finding recirculation of airflows in mine ventilation system in this research is still a little complicated. The ventilation system should be simulated for getting all the airflows information firs. The simulated airflows information is then stored in a matrix. Finally, the depth-first search method is used to search recirculation of airflows in the network stored in the matrix.

More work need to be done to simplify this process. The depth-first search method could be combined in the mine simulation software. Thus, while simulating the ventilation system, the recirculation of airflows is also denoted on the ventilation network.

Although recirculation of airflows mainly occur at the booster fan areas, there are also recirculation of airflows in other places. Therefore, it is necessary to study a method to find those recirculation of airflows.

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CONCLUSION

Since the recirculation of airflow in a complicated mine ventilation system makes the contaminated air concentrated and people who work in such an environment take a risk, depth-first method is introduced to find the recirculation airflows in a complicated mine ventilation system for controlling or eliminating the recirculation of airflows. The simple depth-first method is introduced first. Then the modified depth-first method for finding recirculation of airflows is then introduced in detail. The proposed method is implemented through MATLAB by storing the ventilation simulation results in the form of matrix. After that, a copper mine ventilation system is introduced and the proposed method is applied to find recirculation of airflows in this complicated copper mine ventilation system. A few recirculation of airflows are found and compared with the simulation results. The compared results show that the searched recirculation of airflows by the depth-first search method agrees with the simulation results.

It is concluded that the depth-first search method is able to find recirculation in complicated mine ventilation system. Although depth-first search method shows its capability in finding recirculation in complicated copper mine, more work still need to done to simplify the application.

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