Intelligent Control of Tunnel Lane Indicator under Fire Condition

Shiwei WU, Zheng ZHOU
School of Civil Engineering, Chongqing Jiaotong University, Chongqing 400074, CHINA

Abstract: With the development of traffic cause, tunnel number increased year by year. At the same time, the tunnel fire accidents at home and abroad in recent years has caused a large number of casualties and property losses. The study of intelligent control of tunnel lane indicator is urgent and necessary. Propose the intelligent control mode of tunnel lane indicator from the perspective of induction of personnel and cars escape under fire condition. Write a PLC program for 1km long tunnel as an example. Simulate the tunnel lane indicators' automatic control under the condition of tunnel fire.

Keywords: Tunnel fire; Tunnel lane indicator; Evacuation and rescue; PLC

1. Introduction

With the development of traffic cause, the mileage of traffic tunnels built by various countries in the world increased continuously. Because of the special structure of tunnel space, it is difficult for vehicles and the car personnel to evacuate. In the event of fire, it will be a serious threat to human life and property safety. In recent years, the tunnel fire accidents are common at home and abroad, there are some typical cases: Lin Jia Chuan tunnel fire is on June 12, 1993 [1]; The English Channel tunnel fire is in 1996; Mont Blanc Tunnel fire is in 1999; Salzburg states in Austria Kitts Stanford Huo County mountain tunnel fire is in 2000; Guang Dong Dabaoshan Tunnel fire is in 2008; Shanxi Yanhou Tunnel fire is in 2014; And so on. All have caused great casualties and property losses.

From the statistical data shows that both at home and abroad, the risk of highway tunnel fire is much smaller than the risk of ground vehicle fires, but the consequences of a fire in the tunnel is much more serious. Evacuation is the most serious problem [2]. The tunnel space is narrow and it has longer depth. The tunnel is relatively closed and has a few exports and entrances. Once the fire happened, evacuate the personnel is very difficult due to the large concentrations of smoke and low visibility.

Many studies have shown that, many victims of tunnel fire are suffocated to death rather than directly burned by fire. This shows the importance of emergency evacuation. The longitudinal size of tunnel is much bigger than the lateral size of tunnel. It needs relatively long time for flames and smokes to spread along the longitudinal. So people in the accident have time for an emergency escape. But our people have less knowledge of reasonable fire evacuation in road tunnel. In the face of tunnel fire, a lot of people's behavior is to stay in the car and to be at a loss. Some people may watch others' behavior in the car and then make a decision. There are also some people who turn around the car and drive to escape. These are the wrong way to escape. The propaganda of tunnel fire safety knowledge should be strengthened [3].

2. Intelligent Control Method of Tunnel Lane Indicator

In case a fire occurs in a tunnel, tunnel lane indicators should quickly and accurately provide guidance information for the affected vehicles and personnel. Make personnel quickly clear the current correct driving route and escape direction. It is very meaningful for evacuation.

In normal working conditions, the traffic lights out of the tunnel are all green. It means cars are allowed to pass. The lane indicators pointing to straight in face of the driving direction all show green arrows. It means open to traffic. The lane indicators pointing to left in face of the driving direction all show red forks. It means Banning of turning movement.

Under fire conditions, the traffic lights out of the tunnel are all red to control the size of fire accidents. It means ban to traffic.

For the downstream of fire point: The lane indicators pointing to straight in face of the driving direction all show green arrows. It means open to traffic. The driver should drive out of the tunnel. The lane indicators pointing to left in face of the driving direction all show red forks. It means Banning of turning movement.

For the upstream of fire point: The lane indicators pointing to straight in face of the driving direction all show red forks. It means ban to traffic. The lane indicators pointing to left in face of the driving direction all show green arrows. It means a change of direction is allowed. If there is lane indicator in the line of sight range that allows turn left, the driver should drive through the transverse traffic tube and then drive away from another tunnel without fire. If there is no lane indicator in the line of sight range that allows turn left, the vehicles should be parked on the right, and personnel should departure from the fire point and escape from pedestrian crosswalk and transverse traffic tube.

As for another tunnel without fire, the lane indicators of the right lane show green arrows except for the entrance zone (The lane indicators at the entrance show red forks, it means ban to traffic.). Vehicles in tunnel should drive out along the lane on the right side. The lane indicators of left lane pointing to straight or left all show red forks. Set aside the channel for vehicles of another tunnel with fire. And avoid the car suddenly drive out of the transverse traffic tube and collide with vehicles on the left side of the driveway.

3. Example of the Control Method for 1 km Long Tunnel

With 1 km long two-track tunnels as an example. Assuming that the driving direction of tunnel A is from small to big coordinate and the driving direction of tunnel B is from big to small coordinate. Assume that the coordinate of the entrance of tunnel A is K000. The layout and running states under normal conditions of lane indicators and traffic lights are shown in Figure 1.

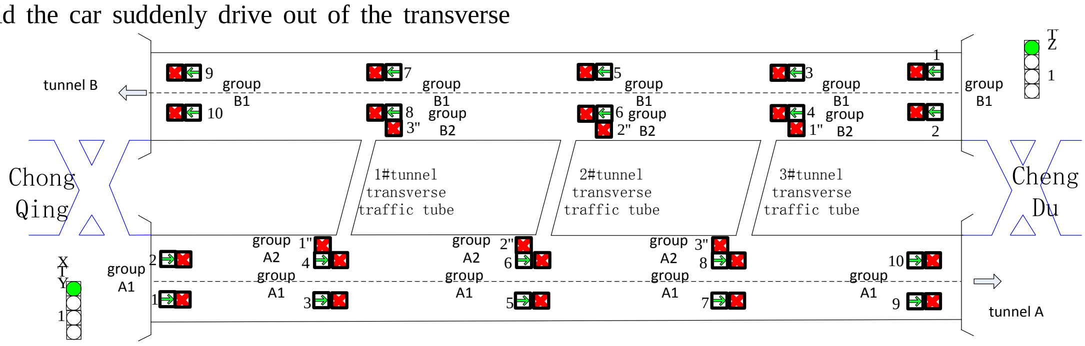

Figure 1. The layout and running state of lane indicators and traffic lights

There are A1, A2 two sets of lane indicators in tunnel A. There are B1, B2 two sets of lane indicators in tunnel B.

Group A1 contains No.1~10 tunnel lane indicators. The coordinate of No. 1, 2 tunnel lane indicators is 50; The coordinate of No. 3, 4 tunnel lane indicators is 275; The coordinate of No. 5, 6 tunnel lane indicators is 500; The coordinate of No. 7, 8 tunnel lane indicators is 725; The coordinate of No. 9, 10 tunnel lane indicators is 950.

Group A2 contains No.1~3 tunnel lane indicators. The coordinate of No. 1 tunnel lane indicator is 275; The coordinate of No. 2 tunnel lane indicator is 500; The coordinate of No. 3 tunnel lane indicator is 725.

Group B1 contains No.1~10 tunnel lane indicators. The coordinate of No. 1, 2 tunnel lane indicators is 950; The coordinate of No. 3, 4 tunnel lane indicators is 725; The coordinate of No. 5, 6 tunnel lane indicators is 500; The coordinate of No. 7, 8 tunnel lane indicators is 275; The coordinate of No. 9, 10 tunnel lane indicators is 50.

Group B2 contains No.1~3 tunnel lane indicators. The coordinate of No. 1 tunnel lane indicator is 725; The coordinate of No. 2 tunnel lane indicator is 500; The coordinate of No. 3 tunnel lane indicator is 275.

Group C contains traffic lights YTX1 and ZTX1.

When the fire happened, automatic fire alarm system will send the detected fire signal to control center. After receiving the fire signal, the system will automatically run the program according to the tunnel fire location information. The state of tunnel lane indicators will be adjusted according to the PLC program.

The coordinate of fire address is X; the coordinate of No. i tunnel lane indicator of A1 is Li (i=1, 2…10); the coordinate of No. j tunnel lane indicator of A2 is Lj (j=1, 2, 3); the coordinate of No. m tunnel lane indicator of B1 is Lm (m=1, 2…10); the coordinate of No. n tunnel lane indicator of B2 is Ln (n=1, 2, 3).

When the fire broke out in tunnel A, If $X-Li>0$, the corresponding tunnel lane indicators display ban; If $X-Li<0$, the corresponding tunnel lane indicators display allows; If $X-Lj>0$, the corresponding tunnel lane indicators display allows; If $X-Lj<0$, the corresponding tunnel lane indicators display ban; The corresponding tunnel lane indicators of Lm (m=1, 2, 4, 6, 8, 10) display ban; the corresponding tunnel lane indicators of Lm (m=3, 5, 7, 9) display allows. The corresponding tunnel lane indicators of Ln display ban; Group C of the traffic lights display ban.

When the fire broke out in tunnel B, If $X-Lm>0$, the corresponding tunnel lane indicators display allows; If $X-Lm<0$, the corresponding tunnel lane indicators display ban; If $X-Ln>0$, the corresponding tunnel lane indicators display ban; If $X-Ln<0$, the corresponding tunnel lane indicators display allows; The corresponding tunnel lane indicators of Li (i=1, 2, 4, 6, 8, 10) display ban; the corresponding tunnel lane indicators of Li (i=3, 5, 7, 9) display allows. The corresponding tunnel lane indicators of Lj display ban; Group C of the traffic lights display ban.

4. PLC Control Program and Simulation

The PLC control program is shown as follows

If Warning = 1, then the fire broke out in tunnel A; If Warning = 2, then the fire broke out in tunnel B.

Programming is as follows:

```
CASE warning OF 1:
    n :=REAL_TO_INT((Mileage-50)/225+1);
    Var1 :=2*n;
    FOR iCounterA:=1 TO 10 DO
IF iCounterA <=Var1
    THEN IntArrayA_a[iCounterA] :=0 ;
            IntArrayA_f[iCounterA] :=1;
    ELSE intArrayA_a[iCounterA] :=1 ;
            IntArrayA_f[iCounterA] :=0;
    END_IF;
END_FOR;
    FOR iCounterB:=1 TO 10 DO
    IntArrayB_a[1] :=0; IntArrayB_f[1] :=1;
IF (iCounterB>0) AND (iCounterB MOD 2 =0)
THEN IntArrayB_a[iCounterB] :=0; IntArrayB_f[iCounterB] :=1;
ELSE IntArrayB_a[iCounterB] :=1; IntArrayB_f[iCounterB] :=0;
    END_IF;
END_FOR;
FOR iCounterA2 :=2 TO 4 DO
IF iCounterA2 <= n
THEN
IntArrayA2_a[iCounterA2] :=1;IntArrayA2_f[iCounterA2] :=0;
    ELSE
IntArrayA2_a[iCounterA2] :=0;IntArrayA2_f[iCounterA2] :=1;

END_IF;
END_FOR;
IntArrayB2_a[2] :=0;IntArrayB2_a[3] :=0;IntArrayB2_a[4] :=0;

IntArrayB2_f[2] :=1;IntArrayB2_f[3] :=1;IntArrayB2_f[4] :=1;
AX1_a :=0;AX1_f :=1;
BX1_a :=0;BX1_f :=1;
2:
    n :=5-REAL_TO_INT((Mileage-50)/225+1);
Var1 :=2*n;
    FOR iCounterB:=1 TO 10 DO
IF iCounterB <=Var1
    THEN IntArrayB_a[iCounterB] :=0 ;
            IntArrayB_f[iCounterB] :=1;
    ELSE intArrayB_a[iCounterB] :=1 ;
            IntArrayB_f[iCounterB] :=0;
    END_IF;
END_FOR;
    FOR iCounterA:=1 TO 10 DO
    IntArrayA_a[1] :=0; IntArrayA_f[1] :=1;
IF (iCounterA>0) AND (iCounterA MOD 2 =0)
THEN IntArrayA_a[iCounterA] :=0; IntArrayA_f[iCounterA] :=1;
ELSE IntArrayA_a[iCounterA] :=1; IntArrayA_f[iCounterA] :=0;
    END_IF;
END_FOR;
FOR iCounterB2 :=2 TO 4 DO
IF iCounterB2 <= n
THEN
IntArrayB2_a[iCounterB2] :=1;IntArrayB2_f[iCounterB2] :=0;
ELSE
IntArrayB2_a[iCounterB2] :=0;IntArrayB2_f[iCounterB2] :=1;
END_IF;
END_FOR;
IntArrayA2_a[2] :=0;IntArrayA2_a[3] :=0;IntArrayA2_a[4] :=0;

IntArrayA2_f[2] :=1;IntArrayA2_f[3] :=1;IntArrayA2_f[4] :=1;

AX1_a :=0;AX1_f :=1;
BX1_a :=0;BX1_f :=1;
ELSE
FOR iCounterA:=1 TO 10 DO
    IntArrayA_a[iCounterA] :=TRUE;
    IntArrayA_f[iCounterA] :=FALSE;
END_FOR;
IntArrayA2_a[2] :=0;IntArrayA2_a[3] :=0;IntArrayA2_a[4] :=0;

IntArrayA2_f[2] :=1;IntArrayA2_f[3] :=1;IntArrayA2_f[4] :=1;

FOR iCounterB:=1 TO 10 DO
    IntArrayB_a[iCounterB] :=TRUE;
    IntArrayB_f[iCounterB] :=FALSE;
END_FOR;
IntArrayB2_a[2] :=0;IntArrayB2_a[3] :=0;IntArrayB2_a[4] :=0;

IntArrayB2_f[2] :=1;IntArrayB2_f[3] :=1;IntArrayB2_f[4] :=1;
AX1_a :=1;AX1_f :=0;
BX1_a :=1;BX1_f :=0;
END_CASE;
%QX0.0 :=IntArrayA_a[1];
%QX0.1 :=IntArrayA_a[2];
%QX0.2 :=IntArrayA_a[3];
%QX0.3 :=IntArrayA_a[4];
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%QX0.4 :=IntArrayA_a[5];
%QX0.5 :=IntArrayA_a[6];
%QX0.6 :=IntArrayA_a[7];
%QX0.7 :=IntArrayA_a[8];
%QX1.0 :=IntArrayA_a[9];
%QX1.1 :=IntArrayA_a[10];
%QX1.2 :=IntArrayA_f[1];
%QX1.3 :=IntArrayA_f[2];
%QX1.4 :=IntArrayA_f[3];
%QX1.5 :=IntArrayA_f[4];
%QX1.6 :=IntArrayA_f[5];
%QX1.7 :=IntArrayA_f[6];
%QX24.0 :=IntArrayA_f[7];
%QX24.1 :=IntArrayA_f[8];
%QX24.2 :=IntArrayA_f[9];
%QX24.3 :=IntArrayA_f[10];
%QX24.4 :=IntArrayB_a[1];
%QX24.5 :=IntArrayB_a[2];
%QX24.6 :=IntArrayB_a[3];
%QX24.7 :=IntArrayB_a[4];
%QX25.0 :=IntArrayB_a[5];
%QX25.1 :=IntArrayB_a[6];
%QX25.2 :=IntArrayB_a[7];
%QX25.3 :=IntArrayB_a[8];
%QX25.4 :=IntArrayB_a[9];
%QX25.5 :=IntArrayB_a[10];
%QX25.6 :=IntArrayB_f[1];
%QX25.7 :=IntArrayB_f[2];
%QX48.0 :=IntArrayB_f[3];
%QX48.1 :=IntArrayB_f[4];
%QX48.2 :=IntArrayB_f[5];
%QX48.3 :=IntArrayB_f[6];
%QX48.4 :=IntArrayB_f[7];
%QX48.5 :=IntArrayB_f[8];
%QX48.6 :=IntArrayB_f[9];
%QX48.7 :=IntArrayB_f[10];
%QX49.0 :=IntArrayA2_a[2];
%QX49.1 :=IntArrayA2_a[3];
%QX49.2 :=IntArrayA2_a[4];
%QX49.3 :=IntArrayA2_f[2];
%QX49.4 :=IntArrayA2_f[3];
%QX49.5 :=IntArrayA2_f[4];
%QX49.6 :=IntArrayB2_a[2];
%QX49.7 :=IntArrayB2_a[3];
%QX72.0 :=IntArrayB2_a[4];
%QX72.1 :=IntArrayB2_f[2];
%QX72.2 :=IntArrayB2_f[3];
%QX72.3 :=IntArrayB2_f[4];
%QX72.4 :=AX1_a;
%QX72.5 :=AX1_f;
%QX72.6 :=BX1_a;
%QX72.7 :=BX1_f;

"Mileage" signifies the coordinate of fire address.

Programming is shown in Figure 2. When Y = 1, X = 370, the control state of tunnel lane indicators is shown in Figure 3. The simulation results are shown in Figure 4.

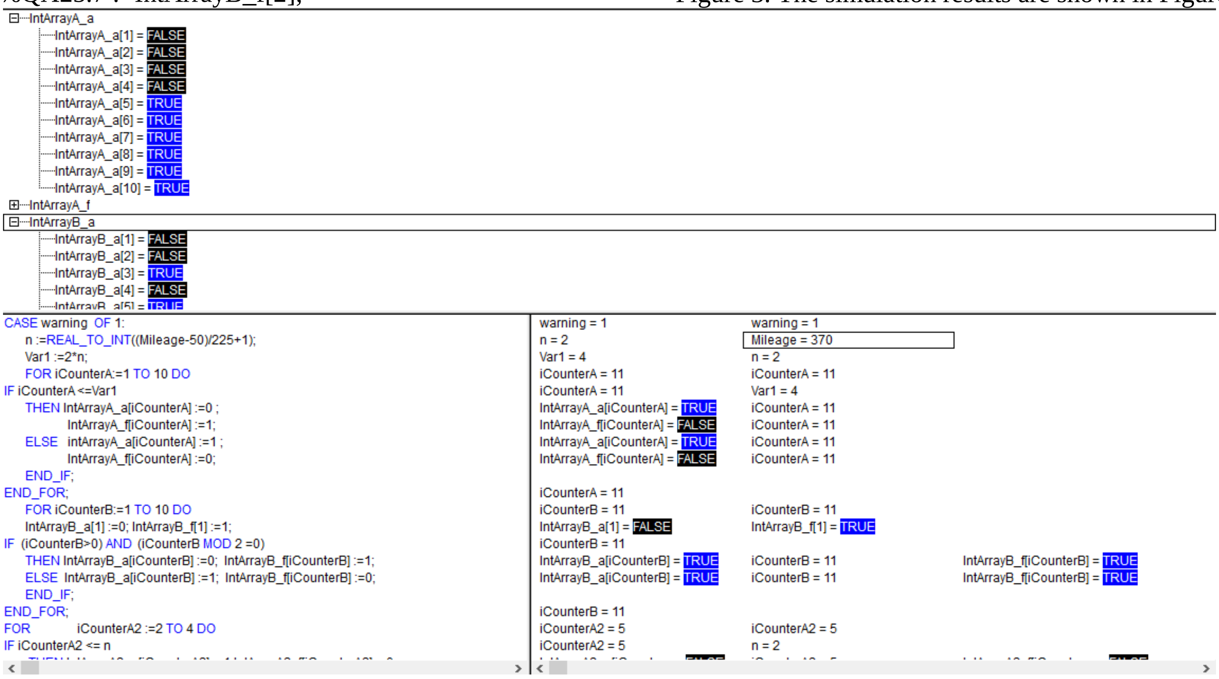

Figure 2. Programming

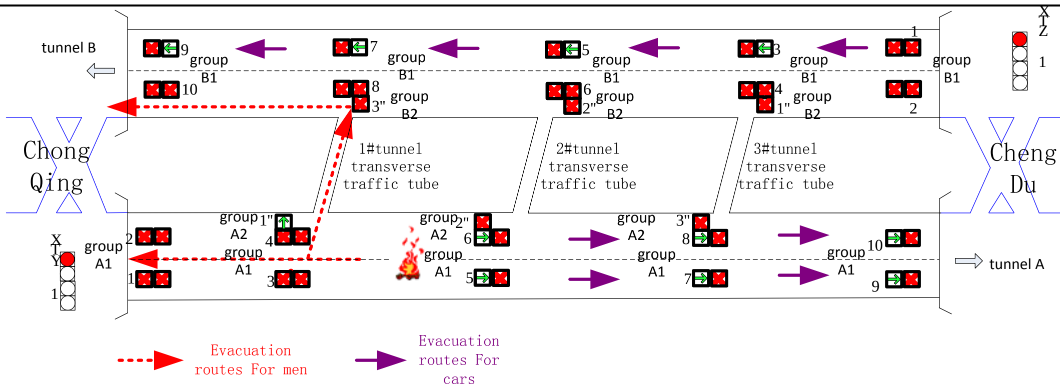

Figure 3. The control state of tunnel lane indicators

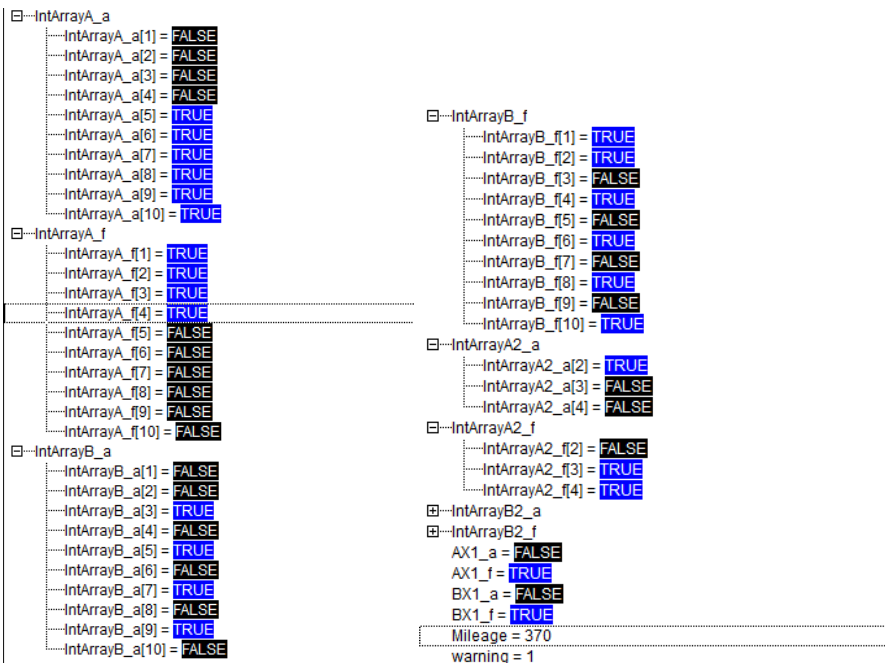

Figure 4. The simulation results

5. Conclusion and Recommendation

This method can save time and provide important evacuation information for the men. Personnel can quickly and accurately judge the escape route according to the state of tunnel lane indicators. It is very meaningful for evacuation under fire condition.

References

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