

A fire fighting robotic system for road and railway tunnels

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Abstract

The problem of safety in tunnels is considered in this paper, with particular attention to the vulnerability to fire. In close environments like tunnels, a prompt and effective intervention is a very difficult task and the fire may easily become non-controllable, as in the 1999 Monte Bianco disaster. In this scenario, robotics may play a crucial role for permanent monitoring and fire fighting in railway and road tunnels.

Keywords: *fire fighting, environmental monitoring, road and railway tunnels, robots*

1 Motivation

The problem of safety in road and railway tunnels and, in particular, the risk connected to fires has become of particular concern after some recent tunnel disasters. The impressive images of the 1999 fire in the Monte Bianco tunnel (see Fig.1), connecting Italy to France, are still on people's mind.

The lesson learned is that the capability of intervention of firemen in tunnels is very limited because of the extreme environmental conditions (high temperature, intense smoke, gas emissions, traffic, rails and other obstructions) which delay or preclude the action of men and machines. On the other hand, a prompt and effective intervention is crucial to keep the fire under control and contain the damage.

Tunnels are important infrastructures for the European Union and play a crucial role for the development of the regional economies [1]. However, most of the existing tunnels in Europe do not have a safety system adequate to the actual traffic volume, which is continuously increasing. For this reason, the risk of serious tunnel disasters is significantly higher than in the past years and their costs become more and more relevant.

The problem of tunnel safety must take into account the geometric characteristics (i.e., length, section, altimetric profile and planimetric development) as well as the functional characteristics (number of



Figure 1: Image of the Monte Bianco disaster.

passages, number of ways, illumination, ventilation, traffic signs, visibility, etc.) of the tunnels [2]. The first element of risk in road tunnels is represented by the reduced visibility and by the not adequate safety distance taken by drivers; moreover, in case of accidents, the presence of other vehicles may facilitate propagation of flames.

From the prevention point of view, different solutions have been adopted in European tunnels. They are essentially based on distributed monitoring systems including fire detection systems (based on smoke and temperature sensors and on infrared cameras) and traffic monitoring systems. Examples can be found both for the case of road tunnels [3] and railway tunnels [4]. In some cases, vehicles are subject to a thermal control at the entrance of the tunnel, as for the thermographic portal of the Monte Bianco tunnel [5].

From the intervention point of view, several tunnel fire protection systems have been realized. The most adopted solution in long tunnels is based on fixed installations composed by fire foam emitters distributed along the tunnel, which is divided into sections; in case of detection of fire or high temperature smoke, the interested section is invaded by foam in order to facilitate the intervention of firemen.

It should be remarked, however, that the prevention and the fixed intervention plants allows to mitigate but not eliminate the crucial problems connected

to fires in existing tunnels, i.e., difficulty of access, difficulty on continuous water supply, and critical environmental conditions. In this respect, technology may play an important role to augment safety. Tunnels can be made more and more "intelligent" by installing distributed sensors to measure significant variables (temperature, humidity, wind velocity, presence of smoke or other gas, etc.) that can be collected and suitably elaborated to facilitate human intervention or to guide the operation of automatic devices [6]. In particular, robots can replace or support men in monitoring and intervention in case of fire.

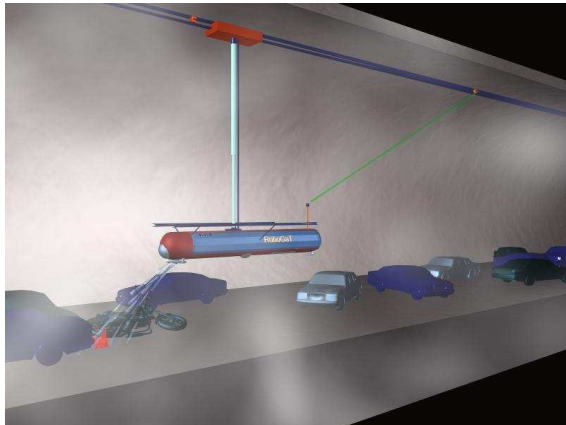


Figure 2: A sketch of the fire fighting robotic system.

2 Fire fighting robotic system

The robotic system presented in this paper derives from the ROBOGAT patent [7] and is the subject of a National Operational Program (P.O.N.) financed by the Italian Ministry of Education, University and Scientific Research. The research consortium includes three industrial partners and three Departments of the University of Naples Federico II (Department of Computer and Systems Engineering, Department of Transportation Engineering, Department of Industrial Design and Management).

The basic idea of ROBOGAT was that of designing a robotic system able to perform operations similar to those of the firemen, without the limitations evidenced above. The system is composed by:

- a self-cooling monorail which guarantees continuous water supply;
- a mobile base moving on the monorail;
- a telescopic hose that allows to deploy the cabin of the robot near to the floor to make rescue operations and to attack the fire from a low position (where the smoke is usually less dense);
- a robotic arm carrying a fire fighting monitor;

- enhanced sensors as infrared video cameras, pyrometers, gas chromatographs.

The above solution overcomes the accessibility problem, because the monorail may be installed on the side or on the ceiling of the tunnel, depending on the room available. Hence, the robot may reach any point of the tunnel in short time, guaranteeing a prompt intervention. For example, considering a cruise velocity of about 50 km/h, the robot will employ about six minutes to traverse the whole Monte Bianco tunnel. For long tunnels, it could be convenient to install two or more robots at both sides or in intermediate positions, so as to reduce the intervention time and to guarantee a more effective action.

The robotic system is built to resist to high temperatures (up to 1000 degrees) and is tele-operated from a remote control room; moreover, it is able to perform some autonomous operation. The mobile base is guided to the place of intervention, where is automatically connected to a fire hose (fire hoses are suitably disposed along the monorail at a distance of about 30 m). After the connection to the water supply, the robot may slide in both senses along the monorail, or may move along the vertical direction thanks to the adoption of telescopic tubes. The robotic arm is suitably controlled to drive the water jet on the hot spots located by the infrared cameras.

Besides the fire fighting application, the above robotic system may be employed in many other useful tasks, as diagnostics and environment data transmission, people assistance and rescue, power shuttle, tunnel vault maintenance, post-fire wall treatment. Hence, it is believed that such a system represents a valid instrument for disaster prevention and intervention in tunnels.

References

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