DETECTION OF RISK BEARING VEHICLES BEFORE ENTERING TUNNELS

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ABSTRACT
Tunnel safety can experience an innovative advance due to an increased awareness of dangerous goods vehicles and the monitoring of potentially dangerous overheated vehicles before the tunnel entrance. The overhead 3D vehicle classification system with laser scanners and conventional digital and infrared cameras enables the automatic generation of highly accurate and reliable data on risk bearing vehicles for the first time. Various installations in Germany and Switzerland have shown that complex applications can be solved with an all-in-one system without intrusion into the road surface. The 3D model-based vehicle information provides comprehensive traffic and safety information which supports tunnel management authorities and emergency services.

Keywords: dangerous goods recognition, hotspot detection, overhead vehicle classification

1. INTRODUCTION
The increase in traffic volume on roads and motorways and in heavy goods vehicles in particular highlights the need for new traffic management and monitoring solutions. High traffic density, especially in road tunnels, requires automatic sensor systems for the detection and monitoring of risk bearing vehicles in order to prevent possible incidents. These systems enable the emergency services and traffic management authorities to provide an immediate and appropriate reaction in case of an event. Tunnel safety can experience an innovative advance due to an increased awareness of dangerous goods vehicles and the monitoring of potentially dangerous overheated vehicles before the tunnel entrance.

Furthermore, the latest guidelines in various European countries require a risk and safety assessment for tunnels. Substantial high quality statistical data on risk bearing vehicles provides the information required for a long term tunnel safety evaluation.

The newest sensor technologies permit the automatic acquisition of highly accurate data on risk bearing vehicles with an overhead system based on laser scanner technology in combination with conventional digital and infrared cameras. Without any intrusion into the road surface, information about traffic flow and composition, overheight monitoring, dangerous goods vehicles and vehicle hotspots can be generated from a single system which will be presented below. This comprehensive traffic data is transmitted and visualized in the tunnel management headquarters in order to conduct an efficient and safe tunnel operation.
2. OVERHEAD VEHICLE CLASSIFICATION WITH LASER SCANNERS

Laser scanner technology using the time of flight measuring principle provides precise traffic information and vehicle specifications (Hirst, 2009). A 3D model of each vehicle, representing the vehicle's outline is generated and permits the derivation of traffic data such as speed, vehicle class, travel direction and distances between vehicles (see Figure 1).

In addition to standard vehicle classification systems (e.g., inductive loops), precise information on the vehicle's height, length and width can be measured leading to an overheight monitoring and detection system. Lane changing vehicles are identified and correctly classified thus providing accurate traffic statistics for a given cross-section.

![Figure 1: Overhead vehicle classification with laser scanners on the A99 motorway in Munich and the 3D model of a vehicle on the right](image)

The 3D model classification differentiates between 28 vehicle classes which can be assigned to the standardized TLS8+1 classes. The classification results obtained on the four lane A99 motorway in Munich satisfy the requirements of the TLS2002 norm with level A1 for the TLS8+1 and F1 for the TLS5+1 classification, including all lane changing vehicles.

Due to the precise vehicle speed measurement, the classification system is especially suitable for "stop and go" traffic on city motorways with heavy traffic during rush hours. The self-calibrating system can be mounted over a four lane motorway within less than one hour allowing fast relocation of the classification sites.

The overhead vehicle classification system with laser scanners represents the basic detection system which can be combined with other sensors for further and more sophisticated applications in a fully modular approach (e.g., travel time forecast, dangerous goods detection, hotspot detection, weigh-in-motion, axle counting, etc.).

3. DETECTION AND MONITORING OF DANGEROUS GOODS VEHICLES

As a large part of heavy goods traffic transports dangerous materials it is becoming more important to acquire reliable data throughout the transport infrastructure but especially in hazard areas like tunnels (Feldges et al., 2009).

Vehicles carrying dangerous goods by road must attach an orange dangerous goods plate in accordance with the UN directive (The European Agreement concerning the International Carriage of Dangerous Goods by Road – ADR 2009). The plate contains a UN code and a dangerous goods code which identifies the goods being transported. If several different hazardous goods are transported on the same vehicle, the orange plate will be blank (see Figure 2).
Standalone automatic sensor systems which have been developed in the past (e.g. video surveillance) have not been able to produce sufficiently accurate data for the detection of dangerous goods vehicles to be useful to tunnel management authorities. Since the dangerous goods plates represent a highly inhomogeneous data set because of different weather conditions, mounting positions and plate types, either the detection rate or the false detection rate were not satisfactory with regard to the previous systems. In addition to this, a solitary OCR (Optical Character Recognition) sensor system is not able to read blank dangerous goods plates which constitute up to 40% of all plates. Furthermore, so-called A-plates which indicate waste transportation vehicles and which have the same dimensions as dangerous goods plates must not be detected.

These reasons are leading to a new multi-sensor approach using the overhead 3D vehicle classification system together with a conventional OCR camera. This offers more possibilities of reaching higher detection rates required to satisfy the high expectations of the tunnel management authorities (see Figure 3).

Both, blank and numbered plates are automatically identified and read with high accuracy by this new dangerous goods plate identification system. It is based on laser scanner technology in combination with a camera and an OCR algorithm which identifies the UN codes. The laser scanners deliver the exact position and speed of each vehicle at a given time and thus are used to precisely trigger the camera and the infrared flash. The images are assigned to the corresponding vehicle without ambiguity and the additional information from the vehicle classification together with the 3D model is used in further validation algorithms.

Each vehicle's data set, including a coloured overview picture, can be transferred to the tunnel management headquarters in real time, enabling emergency services and traffic management authorities to react to an incident in an appropriate and timely manner.
The practical results obtained in January 2010 at three independent locations, one lane each, on the A99 city motorway in Munich before the entrance to the Allach tunnel show very satisfactory results despite the difficult weather conditions during the measurement campaign. The detection rate (detected plates over actually present plates) is 84% together with a false detection rate below 5% (falsely detected plates over all detected plates). The read rate reaches 97% (correctly read plates over all detected plates).

**Figure 4:** Distribution of dangerous goods being transported in one week (1300 vehicles)

**Figure 4** shows an example of the statistical distribution of the dangerous goods transported during one week on the A99 motorway in Munich. The analysis of the time gap between two successive dangerous goods vehicles has shown that in 13% of cases this gap is below one minute and in 2% of cases it is even below five seconds, representing an increased safety risk. This high quality statistical data on dangerous goods vehicles provides the information needed for a long term tunnel safety evaluation.

## 4. DETECTION OF OVERHEATING VEHICLES

Vehicles with potentially dangerous hotspots such as overheated wheels, axles and exhausts represent a high risk to the transport infrastructure, especially to tunnels. Potentially risk bearing vehicles must be detected before entering a tunnel in order to prevent a possible fire incident caused by temperature violations on vehicle parts.

The difficulties for a hotspot detection system reside in the correct hotspot localisation and assignment to the corresponding vehicle which resulted in presenting a major problem for solitary infrared cameras.

**Figure 5:** 3D model with the vehicle's temperature distribution on the right

The hotspot detection system combines measured temperature data from a thermal imaging camera with the 3D model from the overhead vehicle classification system with laser scanners (see **Figure 5**). An additional side scanner provides detailed 3D information on the wheel zone of each vehicle enabling axle counting without any intrusion into the road surface.

The 3D model approach offers new possibilities to precisely localise and identify each present heat source and to translate this information into a risk evaluation algorithm. With the clear positioning of the hotspots on the vehicle geometry, the system can automatically identify the type of the heat source (e.g. wheel). This allows authorities to react not only to absolute temperature violations of single hotspots with different thresholds but also to initialise an
alarm when relative temperature differences, for example between two wheels of the same vehicle (e.g. due to load shift), are detected. Furthermore, the vehicle's temperature distribution can be visualized on the 3D model providing tunnel operators with an increased awareness of risk bearing vehicles enabling an efficient and safe tunnel operation.

Figure 6: Vehicle hotspot detection at the Gotthard tunnel in Switzerland

Practical results have been obtained on the A1 motorway in Switzerland at the Gotthard tunnel in January/February 2009 (see Figure 6). Before the entrance to this single tube road tunnel with a length of 17km, risk bearing vehicles were identified and monitored at normal speed (80km/h). The results have shown maximum wheel temperatures over 90°C and tyre temperatures of about 40°C (ambient temperature: -5°C). The overall maximum temperature measured on the exhaust pipe of a vehicle was above 350°C.

5. CONCLUSION

Combining the overhead 3D vehicle classification system with conventional digital and infrared cameras allows the automatic collection of highly accurate and reliable data on risk bearing vehicles such as dangerous goods transporters and potentially overheated vehicles.

The system can be fully integrated into the tunnel management headquarters. It supports emergency services and tunnel authorities in preventing possible incidents and in providing an immediate and appropriate reaction in case of an event.

6. REFERENCES


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