VITUS: VIDEO IMAGE ANALYSIS FOR TUNNEL SAFETY

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ABSTRACT

This paper summarises work undertaken on the VITUS project. The main aim of VITUS project is to build and implement a prototype for an automatic video image analysis system in order to increase safety in tunnel roads. A feasibility study about video image analysis in tunnels was carried out, and the implementation of the prototype and evaluation of the system is work on going. Experiments on real sequences using innovative image processing algorithms display promising results.

Keywords: Tunnel safety, video image analysis and vision enhancement systems, traffic surveillance, traffic control systems, real world applications.

1. INTRODUCTION

This paper describes work undertaken on the VITUS (Video Image analysis for TUnnel Safety) project. The main aim of this project is to build and implement a prototype for an automatic video image analysis system in order to increase safety in tunnel roads.

Tunnels play a crucial role in the importance of the transport sector for Europe's economy. Austria is one of the leading countries in Europe when it comes to the total number and length of street and motorways tunnels. Controlling traffic tunnels is a complex task which imposes serious requirements. When an incident is detected by the tunnel operator, the tunnel operator has to proceed to the incident verification including the notification to the proper personal (e.g. roadway authorities, hospital, police). Examples of incident verification are crashes between vehicles, lost cargo, objects on the road, and fire among many others. Thus, it is required that operators pay careful attention during the monitoring task, and tunnel monitoring has to be resolved by them within a very tight timeframe.

Besides, the tunnel control centre has to coordinate the incident detection and verification, utilization of emergency response actors and on-scene actions, traffic management, and evacuation. As consequence, tunnel operators have a high degree of responsibility on tunnel monitoring and emergency management, and effective incident management completely depends on fast incident detection and fast incident verification. Many road tunnels are already equipped with video systems, mostly analogue CCTV-Systems. Such systems allow operators the supervision of tunnel activities and the guidance of emergency activities.

However, these video systems generate a huge amount of information, which clearly can not be completely supervised by tunnel operators the whole time.

On the other hand, after the fire disasters occurred in the "Mont Blanc" tunnel located at the frontier between France and Italy (1999, 39 died), "Tauern" tunnel in Austria (1999, 12 died), and the "Gotthard" tunnel located in Switzerland (2001, 11 died) the European authorities reviewed the safety standards for tunnel operation. Such tragedies have provided the impetus for a major re-appraisal of fire safety in European road and rail tunnels. In 2001, the European Union launched the White Paper [Commission European Communities, 2001], which proposes 60 specific measures to be taken at Community level under the transport policy, including, among others, a directive on safety standards in tunnels. The EU Directive launched in 2004 provides institutional, organizational, operational and technical measures addressing tunnel safety. This directive determines the major stakeholders that are involved in the Tunnel Safety Management and their objectives and responsibilities. The Transport Committee of the Economic Commission for Europe formed a multidisciplinary group of experts on safety in tunnels [UNECE].

As a consequence, development and implementation of automatic or semi-automatic interpretation tools to aid human operators (not to replace them) to detect unexpected events, and abnormal behaviour is desirable and necessary. Implementation of advanced applications might increase safety, and it may play an important role in the performance of economy. ASFiNAG, as road authority of the motorways and fast-highways in Austria, is interested in offering safety, and highly efficient ways of transport in an enlarged Europe [ASFiNAG, 2004].

Over the last decade, increasing interest in the field of visual surveillance has led to the design of a plethora of systems for automated visual video surveillance systems. Considerable efforts have been spent on the computer vision area to develop algorithms for detecting and tracking moving objects in the image, for object classification and detection of unexpected events and abnormal behaviour. Recent advances in hardware and computing power helps in the development of visual surveillance applications. A combination of computer vision methods with video technology is able to detect all major incidents: stopped vehicles, slow moving traffic, and statistical information such as speed, and vehicle classification. Different models and techniques to detect moving objects, follow trajectories and extract statistical information have been proposed by different authors [Boyd et al., 1999], [Buzan et al., 2004], [Coifman et al., 1998], [Cucchiara et al., 1999], [Remagnino, 1997], [Viola, 2001]. Commercial systems like ABT2000 [Artibrain], INVIS [Ascom], MediaRoad [Citylog], Traffic Analysis System [Crs], Autoscope [Image Sensing Systems], Vantage [Iteris], Mavis [Mavix], Video Trak 910 [Peek Traffic], SiADS – SITRAFFIC [Siemens], and Traficam [Traficon] demonstrate these abilities. Certainly, this list is not complete.

However, to the best of our knowledge, no work has been reported on digital image video analysis and pilot projects in tunnels. VITUS (Video Image analysis for TUnnel Safety) project aims at building and implementing a prototype for an automatic video image analysis system for tunnel safety. To achieve their objectives, VITUS is divided into two subprojects called VITUS-1, and VITUS-2 respectively, and partners coming from diverse areas such as road authority (ASFiNAG), industry (ETM and PTV), government (ASTL and BMVIT), academic (ICG), and research (ARC Seibersdorf and ACV) are involved in the project.

The remainder of this paper is as follows: Section 2 summarises the tasks carried out among VITUS-1 project. Section 3 is the main core of the paper describing VITUS-2 project in detail and its current status. Conclusions and future work are drawn in Section 4.

2. VITUS-1: THE FEASIBILITY STUDY

The feasibility study VITUS-1 defines a concept mainly based on automatic incident management based on digital video image analysis. During this feasibility study, a concept that enables (1) automatic recognition of dangerous situations through video sequence analysis, (2) warning of tunnel operators, (3) warning of road users upon necessity through the tunnel control system, and (4) the automatic archiving of the relevant video sequences has been defined. Among VITUS-1, following tasks were carried out:

- 1. user requirements and models of tunnel scenarios have been defined,
- 2. a revision and evaluation of video sensor technologies,
- 3. a market study about current products,
- 4. a revision and evaluation of image processing algorithms and the possible computer vision techniques to be applied,
- 5. a compilation of the state-of-the-art algorithms (both areas, scientific and commercial),
- 6. recording of test sequences considering different situations and events, and
- 7. a specification of system's architecture, and a design of the prototype.

More information about VITUS-1 can be found in [Schwabach et al., 2005].

3. VITUS-2: A PILOT PROJECT

The demonstration project VITUS-2 implements a prototype based on the user requirements, including a description of the tunnel activities while considering the tunnel's infrastructure and it also addresses the evaluation of the system. Results of VITUS-1 provide an assessment of the pilot and demonstration project VITUS-2 with regard to its feasibility, the necessary system resources and the expected effort under the defined conditions. To achieve VITUS-2's objectives, seven work packages (WP) have been defined. Figure 1 summarises each work package and the topics related to.

Work packages and related activities are:

1. Installation of test-site: This WP covers the necessary hardware, mechanical and electronic components for the acquisition, transmission, and storage of the data. Electronic components, dedicated recorder equipment and the sensor network for intelligent surveillance will be installed in the Plabutsch tunnel in near future. Analogue cameras were installed during 2004 when the tunnel was closed for maintenance purposes. Figure 2 depicts the system architecture.



Figure 1. VITUS-2: Work packages and their responsibilities.



Pilot system - Tunnel Surveillance

Figure 2. VITUS-2: System architecture.

2. *Video database*: Along the whole project, representative scenes were defined and recorded. As result a representative database was built. Current database consists of almost 10 hours of video material distributed into 176 scenes covering various possible scenarios, (normal traffic,

presence of persons), different environment conditions (normal illumination in tunnel, emergency illumination in tunnel, dry floor, wet floor), and abnormal and dangerous situations (traffic in wrong direction, fire and smoke, lost cargo).

Situation	Illumination	Roadway
Normal traffic	Normal, low	Dry, wet
Traffic in wrong direction	Normal, low	Dry, wet
Presence of people	Normal, low	Dry, wet
Lost cargo	Normal, low	Dry, wet
Fire and smoke	Normal	Normal

Tabl	e 1.	Recorded	situations.
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Table 1 shows which situations were recorded, and Figure 3 depicts some representative scenes taken from this video material.

Building this database is not an easy task. Normal traffic situations are relatively easy to record, but consider traffic in wrong direction or presence of fire. It might be possible to obtain such scenes in normal operation of the tunnel. However, these situations are very dangerous. In this case, the scenes were simulated which has many and not trivial implications: The tunnel has to be closed, people have to take part of the simulation (drivers, police, firemen, etc.) and a coordination task with tunnel operators has to be done. Almost 20 people were involved during each test (in case of presence of fire and smoke more people like policemen and firemen were necessary), and people acting as drivers drive more than 1200 km.

3. Algorithm development: This WP concerns the development of image processing algorithms and the analysis and understanding of the data. Along VITUS-1 three main topics were identified as the most relevant: Object detection and object tracking (recognition of stopped objects; detection of persons at unauthorized places; detection, recognition of lost objects, etc.), detection and management of several traffic situations (normal traffic, recognition of traffic jam; classification of objects, statistical analysis), and detection and management of dangerous traffic events (detection of vehicles in wrong direction, fire and smoke detection). The algorithms have to process the video data to achieve an automatic understanding of current situation in tunnel to comply with the users' needs. Results delivered by image processing algorithms provide the information required for event recognition and behaviour analysis in order to interpret current situation. An assessment of the reliability of the image analysis algorithms is of utmost importance. Up to now, image processing algorithms for background modelling, tracking, and classification were developed. The tracking algorithm is based on a statistical analysis of current frame [Alefs et al., 2005], and classification of lost objects is mainly based on feature based methods [Grabner et al., 2005]. These algorithms were evaluated using different sequences of aforementioned database to check their response under tunnel conditions.



Figure 3. Typical tunnel scenes from our test database: (a) Normal traffic behaviour, (b) Traffic in wrong direction, (c) Fire and smoke, (d) Presence of persons, (e) Presence of persons, (f) Lost cargo. (a-d) dry roadway; (e-f) wet roadway.

Ongoing work is concentrated on an increase of robustness in order to reduce false positives and false negatives. While the former is a critical factor for the acceptance of tunnel operators, the latter refers to the misdetection of situations which must to be detected.

Figure 4 depicts some results of image processing algorithms developed up to now. Results of object detection (a), object classification (b), object detection and tracking (c), and trajectory of the objects (d) are depicted. Integration of these algorithms into the prototype is the next step in this WP. Our current database provides important material to check and evaluate the response of the algorithms.



Figure 4. Results of image processing algorithms. (a) Object detection, (b) Object classification, (c) Object detection and object tracking, (d) Trajectory of the objects.

4. *Prototype*: This work package implements the prototype, i.e. it represents the central point for implementing all produced software and algorithms. This work package covers the software application, the necessary communication between the different modules and the necessary data communication. Figure 5 shows a prototype of the Graphic User Interface (GUI) of the application. It is well known, a clear system design is critical to both its acceptance and use for users. Thus, it is necessary that the GUI has a very simple design to facilitate its use by tunnel operators. We are working on a redesign in order to manage various cameras simultaneously.

By using current GUI, the user can choose the source of data (video stream coming from an analogue input, video stream coming from a digital input, and sequences saved in different formats like RTP stream, MPEG-2, and AVI files), the processing task to be performed (video image analysis, live), and the kind of event to be detected (traffic jam, wrong way driver, lost cargo and strange objects, all of them). Besides, it is possible to restart the application, to load the previous configuration, to store the current configuration, to edit the current configuration and to display the log event file. We are planning to compress the data using MPEG-4 codec and its integration in the application. Ongoing work is concentrated in the development of the necessary modules for data communication and event management.



Figure 5. GUI of the application.

5. *Evaluation*: Current work package is responsible for the evaluation of the prototype in terms of selected scenes and normal operation of the tunnel. The evaluation verifies the achievements of the prototype.

6. Documentation and dissemination: This work package is in charge of the whole documentation and the dissemination of achieved results of the project. To do that, a users group will be formed. The actions to be taken are led along the project in close collaboration with the others partners.

7. *Project management*: The last package runs during the whole project, and it concerns the complete documentation of the project, meeting's organisation, etc. The project management concerns the administrative and financial review, scientific innovated research and industrial results management.

4. CONCLUSION

Tunnel safety is a challenging task with very serious requirements, due to special tunnel conditions and a tight timeframe for recognition purposes.

This paper has reported work undertaken on VITUS Project. VITUS project aims to build and implement a prototype for an automatic video image analysis system in order to increase safety in tunnel roads. A feasibility study about video image analysis in tunnels was carried out. The system's architecture of the pilot project was determined for the integration of video

analysis into the tunnel infrastructure of the tunnel control system, which enables a systematic and comparative evaluation of the video analysis in the pilot project. Experiments on real sequences using innovative image processing algorithms have shown promising results. The installation of the components, the implementation of the prototype and evaluation of the system is work on going.

Future work is mainly concentrated on following tasks:

- 1. Installation of all the components in the tunnel,
- 2. integration of the software components in the pilot system,
- 3. complete testing of the system considering hardware equipment and mechanical components (cameras, PCs, data transmission, integration in the operator's room) and software systems (image processing, compression, module test, integration test),
- 4. comparison of response of the algorithms using analogue data and digital data,
- 5. evaluation of the influence of compressed data on the system.

It is expected that VITUS project is aimed at bringing transparency to tunnel operators and helping them to monitor tunnel activities. It is hoped that the results of this research will provide an increase in tunnel safety, and it should help to form the basis for future efforts. The efforts will continue beyond the project period until their final completion during 2006.

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Current paper does not constitute a standard, specification, or regulation.

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