MOTORWAY SURVEILLANCE THROUGH STEREO COMPUTER VISION

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ABSTRACT

The demand for traffic monitoring systems is growing very quickly. The public transportation authorities have a clear need of these systems to gather as much traffic data as possible so that the proper solutions to congested road and motorways can be adopted. This paper presents a stereo computer vision system for traffic monitoring, developed within the European ESPRIT 8819 VICTORIA project. The system is based on stereo vision technology, which provides clear benefits and advantages with respect to conventional systems based on classical inductive loops or pneumatic tubes. Additionally, and compared to existing monocular vision based sensors, the VICTORIA system has the advantage of providing real world three dimensional information that allow vehicle classification. This is a requirement in some applications such as automatic tolling systems.

1. INTRODUCTION

The demand for traffic monitoring systems is becoming higher everyday. The cost (in terms of money) of congested roads due to bad designed junction points, motorways unable to absorb the incoming vehicles, and traffic collisions can be easily quantified by the direct effects: people fail to reach their jobs on time or even fail to reach them at all, huge amount of consumed combustible, material damage due to collisions, pollution, noise ...The European Union is really concerned about this problem. In the Citizens' Network Green Paper [8], the Commissioner Neil Kinnock provided some guidelines for estimating these costs: *... congestion is estimated to cost the European Union some two per cent of the Gross Domestic Product (GDP) every year; accident costs borne by other people of society as a whole [cost] another 1,5 per cent and air pollution and noise at least 0,6 per cent. All this amounts to some Euro 250 billion per year throughout the European Union. More than 90 per cent of these costs are related to road transport. ...* The situation in the rest of the world is not different, although figures may differ from the ones previously given. It is clear then that some procedures have to be established in order to reduce as much as possible the road congestion problem. And the first step to be accomplished is the traffic data gathering, by the use of automatic traffic monitoring systems.

Current technology applies several procedures to obtain traffic data. The traditional techniques used for road monitoring are based on pneumatic tubes and magnetics loops, whose robustness and versatility is well proven. The current research work is mainly focused on two new approaches: piezoelectric sensors and, with a wider acceptance, video systems. Traffic monitoring video systems provide many added features compared to other techniques: simple non-intrusive installation and maintenance, access to spatial and temporal traffic variables, monitoring of large areas, and obviously visual control.

This paper presents the results of an European project devoted to the development of a computer vision system for traffic monitoring in motorways: the ESPRIT 8819 VICTORIA project.

2. THE VICTORIA SYSTEM

The VICTORIA project run from November 1994 to April 1998. The Consortium was composed of two different groups: the development partners and the end users partners. The development partners included the companies ELIOP S.A. (Spain), Robert Bosch GmbH FV/SLH (Germany) and the Grupo de Tratamiento de Imágenes of the Universidad Politécnica de Madrid (Spain). The end user partners, in charge of performing the system test on field, were Autopista Concesionaria Astur-Leonesa AUCALSA (Spain) and the Bun-

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desanstalt für Strassenwesen Bast (Germany).

2.1. Objectives of the VICTORIA project

Basically, the objectives of the VICTORIA project were to develop, build and test a stereo computer vision system able to determine the geometrical and kinetic parameters of the passing vehicles in the region of interest observed by the system cameras. The provided data include the speed and dimensions of each vehicle (length, width and height), and the traffic flow per lane. From this data, additional events are directly obtained, such as vehicle stop detection, vehicle classification, inverse direction and road congestion. Moreover, the VICTORIA system is able to provide, upon request, live images of the area under observation.

2.2. Hardware architecture

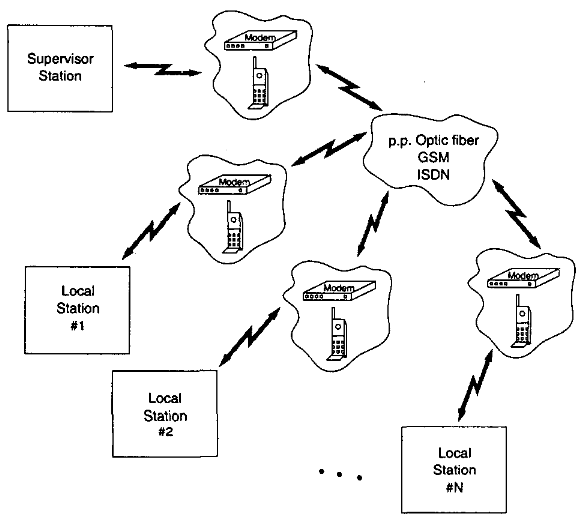

Figure 1: Major components and communication links of the VICTORIA system.

The VICTORIA system is composed by:

- A Supervisor Station, located at the traffic control centre, and connected to
- Several Local Stations, installed by the motorways, that acquire and process the stereo video images to generate the traffic parameters.

The Supervisor Station is based on a PC platform, running SunSoft's Solaris 2 SDK 2.5 (Open Windows based GUI). The provided functionality is the following:

- Control of the operations of the Local Stations: start-up, shutdown, adjustment of the real-time clock, remote modification of the configuration parameters, etc.
- Obtaining, storage, and display of the data that define the state of every Local Station under supervision. Every Local Station will store data describing the different events detected during its operation. These data are collected and store by the Supervisor Station to allow inspection by the system operator.
- Collection, storage, and display of the traffic data obtained by the Local Station.
- Request of live images of the measurement area of a particular Local Station. Upon demand, of the system operator, these images are transmitted in compressed format and presented in the monitor of the Supervisor Station.

The data communication link between the Supervisor Station and every Local Station (Figure 1) is an asynchronous serial line, at a maximum data rate of 64 kbs. The data communication protocol is an extension of the standard CEI/IEC 870-5 *Telecontrol equipment protocols*. The extension includes a set of functions to the application level of the protocol for the transmission of the compressed live images.

The Local Station (Figure 2) is based on a multiprocessor system (Figure 3), able to provide the required computational power for the stereo computer vision algorithms. It relies on commercially available hardware components (3 PowerPC single board computers mounted on a rack, plus two RS-485 remote controlled analog video cameras), and a specifically developed image acquisition subsystem that support the functional an attribute requirements of the VICTORIA system. The video cameras are deployed on a gantry, over the motorway, acquiring the back side of the vehicles. This configuration allows for artificial illumination during night operation, without disturbing or dazzling the vehicle drivers.

The provided functionality of the Local Station is:

- To obtain the speed and dimensions (length, width, and height) of each vehicle passing the observation area.
- To obtain the accumulated data of traffic flow per lane at specific time intervals.
- To generate compressed live images of the observation area upon request of the Supervisor Station.

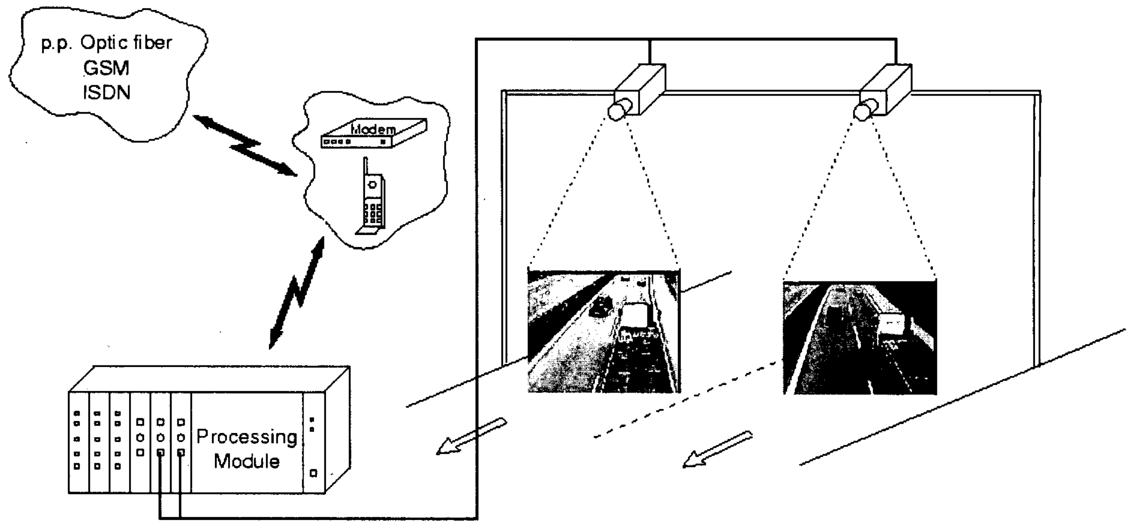

Figure 2: Local station components.

- To transmit all the data to the Supervisor Station upon request.

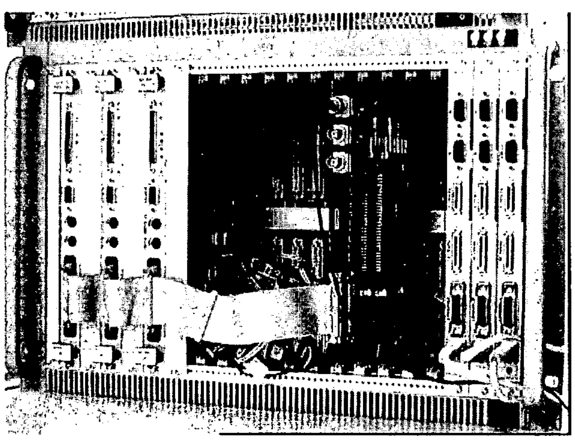

Figure 3: Local Station processing module.

2.3. Software architecture

Figure 4 shows the block diagram of the main software subsystems included in the Supervisor Station. Their functionality is the following:

Overall control: Manages all the actions of the whole VICTORIA system: start-up, shutdown,

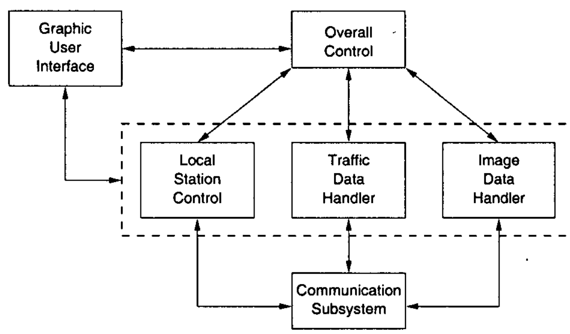

Figure 4: Software Architecture of the Supervisor Station.

status of the system, global actions to be performed, etc.

Local Station control: Keeps track and manages the independent status of every Local Station connected to the Supervisor Station.

Traffic Data Handler: Module that requests and stores the traffic information from the different Local Station for further display or printing.

Image Data Handler: Module that request and stores compressed live images of the observation area for further display.

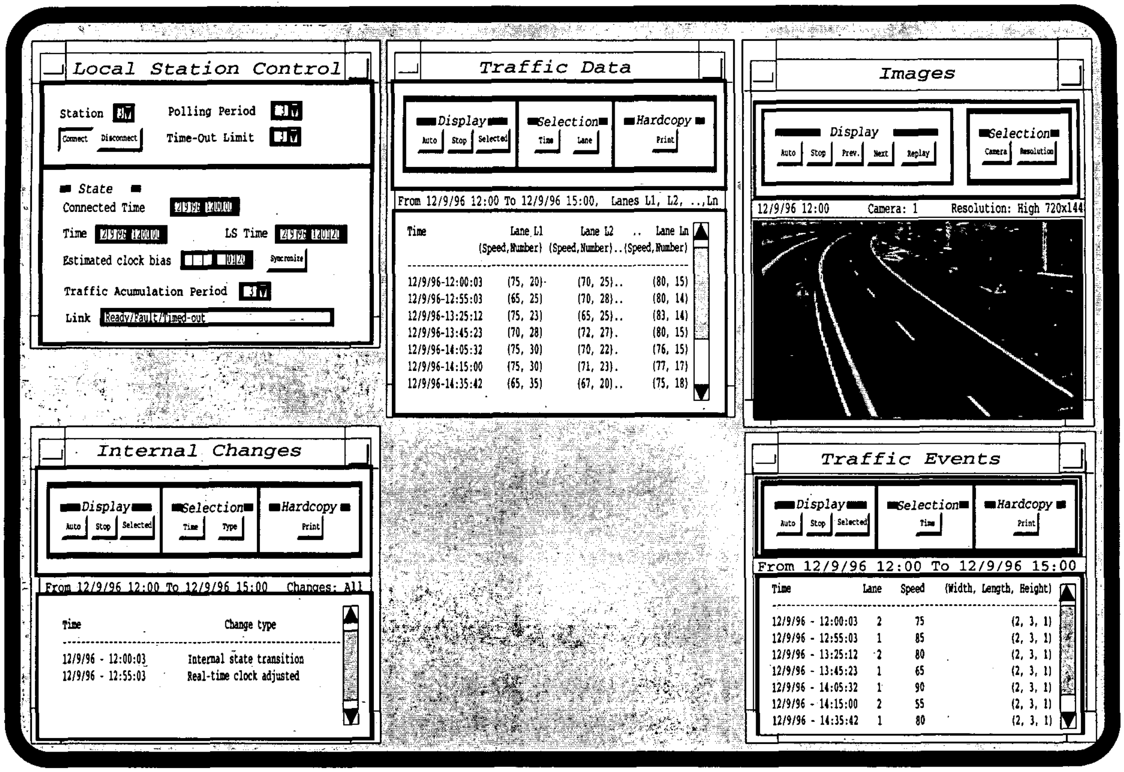

Figure 5: Supervisor Station screen layout.

Communication Subsystem: Module devoted to information exchange between the Supervisor Station and every Local Station.

Graphic User Interface: Displays information about the status of the Supervisor Station, the addressed Local Station, and the exchanged traffic and image data. Figure 5 shows the screen layout.

Figure 6 shows the block diagram of the software subsystems of one Local Station. The main components are:

Local Station Control: Intelligent module that manages all the subsystems of the Local Station and dispatches the requests from the Supervisor Station.

Image Grabber: Module that digitises the video images coming from the stereo acquiring cameras.

Image Compression: Upon request from the Supervisor Station, this module compresses images for transmission through a narrow-band communication channel.

Camera Control: Module that communicates with the acquiring cameras through a RS-485 serial port to independently modify each video camera parameters: iris, shutter, focus, etc.

Vehicle Detection and Tracking: This module detects the presence of every incoming vehicle and tracks its trajectory through the observation area.

Vehicle 3D Parameters Estimation: For every detected vehicle, the dimensions (length, width and height) and speed is estimated.

Camera Calibration: This module allows the establishment of correspondences between the 2D image world and the actual 3D world from which the images are acquired.

Statistical Analysis: All the traffic data is gather by this module in order to generate the accumu-

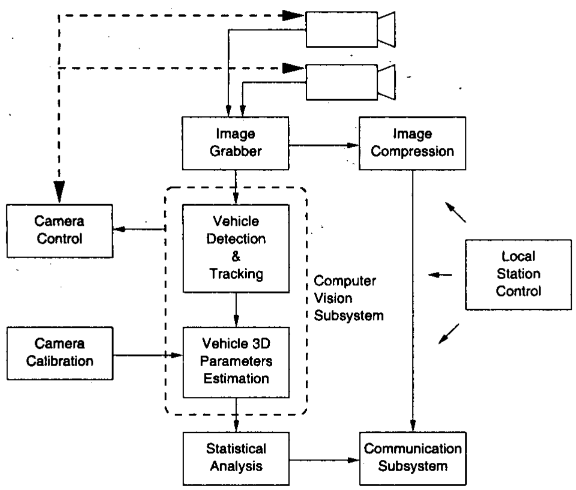

Figure 6: Software Architecture of the Local Station.

lated traffic statistics: traffic flow per lane, average speed per lane, etc. The integration period is configurable by the Supervisor Station.

Communication Subsystem: Module devoted to information exchange between the Local Station and the Supervisor Station.

3. FIELD TEST RESULTS

Two different types of test were applied to the VICTORIA system: laboratory tests and field tests. The laboratory test took place during the last three months of 1997. For this purpose, a 1:32 scale car circuit was used, allowing the acquisition of real time images with passing vehicles in a controlled environment. During this phase a final tuning was applied to the system to guarantee time stability and robustness against sudden changes in the illumination conditions or unexpected events (temporal failure of one subsystem, unavailability of the image information coming from one of the cameras, etc).

The field test were applied during the first four months of 1998, both at the German and at the Spanish end user facilities. Different kind of test were performed in order to check the different functionalities of the system:

Detection test: The success rate of detected vehicles was higher than the 97% during day operation, decreasing to the 95% by night with artificial illumination. These good results were really surprising if we take into account that the tested algorithms had not been especially conceived for night operation. The detection rate decreased to the 92% in case of heavy rain, falling to the 70% under snow conditions.

Speed test: The results obtained showed the robustness of the system independently of the weather conditions. The errors in the estimation of the vehicle speed were below the 8%, most of them with negative sign. This offset might probably be corrected with a careful system calibration.

3D Measures: The system was able to provide confident 3D measures of the detected vehicle only during day operation. Under these conditions, the error rate was between the 3% and 7%, increasing to the 12% with rain or snow. At night, the vehicle lights induced a smear effect in the acquired images that made difficult the estimation of the vehicle 3D borders. This problem might be overcome with the use of non-smearing cameras.

4. CONCLUSIONS

This paper presents a stereo computer vision system for traffic monitoring, developed within the European ESPRIT 8819 VICTORIA project. The system provides clear benefits and advantages with respect to conventional systems based on classical inductive loops or pneumatic tubes:

- It is a non-intrusive system, and therefore do not hamper the traffic flow, as no road works are required for the installation and setup on site.
- The system provides live images of the monitored area. This is a clear advantage, even with respect to systems based on alternative technologies such as radar or laser.
- It is a long lifetime system, allowing for long maintenance intervals.
- The system has mobility: it is possible to easily change the place of installation, if required.

Additionally, and compared to existing monocular vision based sensors, the VICTORIA system has the advantage of providing real world three dimensional information that allow vehicle classification. This is a requirement in some applications such as automatic tolling systems.

The companies involved in the VICTORIA pilot system development are currently enhancing and adapting the output of the project to their own market areas: event detection, vehicle classification, automatic tolling, etc.

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