TECHNOLOGY FOR IMPROVED OPERATION AND MAINTENANCE OF VIDEO-BASED AUTOMATED INCIDENT DETECTION SENSORS

As presented at the 6th International Conference on Applications of Advanced Technologies in Transportation Engineering
28-30 June 2000 - Singapore

Dr. Durga P Panda
Image Sensing Systems, Inc.

Mr. Hung Kwong Chan
Flow Traffic Ltd.

ABSTRACT

Machine vision technology has emerged as an excellent alternative to inductive loops for traffic sensing. Acceptance of machine vision systems by traffic engineers is constantly on the rise. The technology has been used for automated freeway incident detection in cities worldwide. Recently, there has been further advancement of this technology that helps improve the reliability and maintainability of the video sensors. A new sensor system design has been introduced which takes advantage of the advancement in the miniaturization of digital electronics to integrate the opto-electrical transducer and the computing electronics into an integrated vision sensor. The resulting video sensor system offers the users many advantages not previously available. The integrated vision sensor is supported by a new communications architecture that offers optimal routing of the machine vision detection results, full motion video as well as digital imagery, and supervisor control over a wide-area network suitable for central management of the network. Standard Internet protocol and user interface format are adapted for this sensor network offering intuitive, user-friendly navigation. The paper will discuss the technology in detail and give examples of recent field implementations.

INTRODUCTION

Inductive loop detectors have been the predominant sensors of choice for traffic management and control. The inductive loop sensors detect vehicle presence but are fixed in location and require intrusive installation in the roadbed. Because of the limitations of these sensors, researchers have been continually exploring alternative sensing technology. In 1978, the Federal Highway Administration (FHWA) conducted a study, prepared by the Jet Propulsion Laboratory of Pasadena, California, USA, which concluded that machine vision technology offers a feasible alternative for traffic video detection (Federal Highway Administration, 1978). This technology used a camera and a machine vision processor (MVP) to process the camera output.

Several years later researchers at the University of Minnesota (Michalopoulos, 1991) developed an enhanced system with then state-of-the-art industrial computers. Testing of the system in field conditions demonstrated the feasibility of outdoor operation and the feasibility of real-time operation. Researchers in Japan and Europe were also developing machine vision systems for traffic control. Some examples include the works by Versavel et al (Versavel, 1989), Takatoo et al (Takatoo, 1989), and Blosseville et al (Blosseville, 1989). *Advanced Traffic Detection* is a recent publication that includes a very good brief summary of the various imaging sensor technologies being applied to traffic management problems (Fenichell, 1998).

Over the last decade the evolution of the traffic video detection system has been marked by several key evaluation reports. In 1991, researchers at the California Polytechnic Institute (Cal Poly) conducted an evaluation of the technology for highway applications (California Polytechnique State University, 1991). This report was quite extensive in cataloging different existing and emerging machine vision systems for traffic vehicle detection. Subsequently, in a recent paper Cal Poly indicated that some of the machine vision systems with exotic techniques requiring complex computation are less reliable for practical application (Chatziioanou and Sullivan, 1997). In 1994, Hughes Aircraft Company reported a comparative evaluation study of several video, as well as other, detector technologies (Klein and Mills, 1994). This study, although it did not explicitly conclude so, implied that the status of machine vision is ready and mature enough for traffic signal application. This was followed by a similar, but more rigorous and extensive, comparative study, done by the Minnesota Department of Transportation (Mn/DOT) for the FHWA (SRF, 1997). This study, concluded in 1996, indicated that video detectors, in general, do offer reasonably high accuracy for practical use. One of the conclusions of this test was that illumination conditions had significant impact on the video sensor performance.

While these evaluations were proceeding, FHWA was further advancing the video technology to measure additional traffic parameters, such as approach queue length and approach stops at intersections (Jet Propulsion Laboratory, 1997).

CURRENT STATUS

Today video sensors are used for traffic management and control on freeways and in tunnels in several major cities (Michalopoulos, 1998) such as the Olympic Road freeway in Seoul, Korea; the Gowanus Expressway in New York; I-40 freeway in Albuquerque, New Mexico; I-610 and other freeways in Houston, Texas; I-105 and other highways in California; and in the Lautau fixed crossing and in the Hong Kong Airport Tunnel in the Hong Kong Special Administrative Region. Traffic video sensors were also installed on the I-75 freeway in Atlanta, Georgia for the 1996 Olympic Games (Culver, 1997) and are currently being expanded for broader roadway coverage in the Atlanta metropolitan area.

Different installations use video sensors differently for incident detection. Video sensors sometimes offer built-in incident detection algorithms for the convenience of the users. One such algorithm is Automatic Incident Detection Algorithm (AIDA), which is used at various installations, including the Olympic Road Freeway in Seoul, Korea; the Gowanus Expressway in New York; and Hong Kong Airport Tunnel.

AIDA uses temporal variations in the traffic parameters, such as volume, occupancy, and speed, to detect shock wave from an incident (see Figure 1.). It can also detect stopped vehicles in its field-of-view. This allows automatic detection of vehicles pulled over to the pavement shoulder due to an emergency.

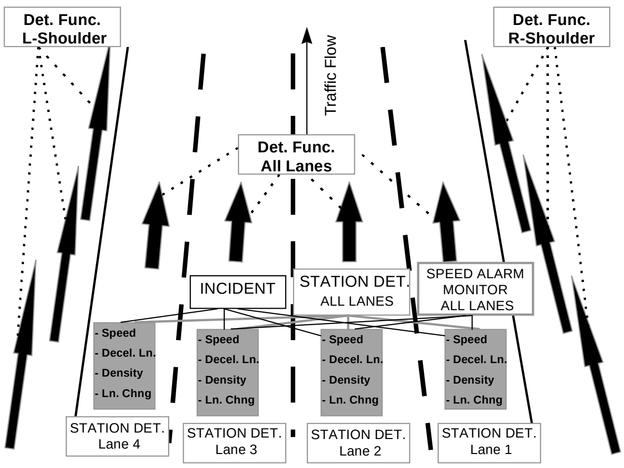

Figure 1. AIDA – Incident Detection Detector Configuration (shown here for 4-lanes)

RECENT ADVANCEMENTS IN SENSOR TECHNOLOGY

Although the current state-of-the-art has received broad acceptance, it is desirable to further advance the sensor technology in two categories: reliability and maintainability. Adaptation to illumination is a major area of reliability improvement. Another area of reliability concern is the degradation of video quality due to transmission. Often video is transmitted from the camera to the MVP over buried coaxial cable or wireless transmitter. Electro-magnetic interference (EMI) and transmission loss combine to degrade the image quality at the MVP. In addition, this degradation is intermittent, caused by external factors not easily modeled in the vehicle detection algorithms. Minimization or elimination of this cause of the reliability problem is desirable.

These motivations for improved reliability have led to a new design of video sensors. The design integrates camera optics and processing electronics into one compact package. The integrated sensor not only offers improved operational reliability but improved maintainability as well, as described in the following sections.

INTEGRATED SENSOR HARDWARE

The integrated sensor system consists of two hardware subsystems: the Machine Vision Processor (MVP) and the communication network.

Figure 2 shows the integrated sensor. To improve reliability under varying illumination conditions the CCD camera control was integrated with the processor. This allowed the processor to perform closed-loop gain and bias control of the images.

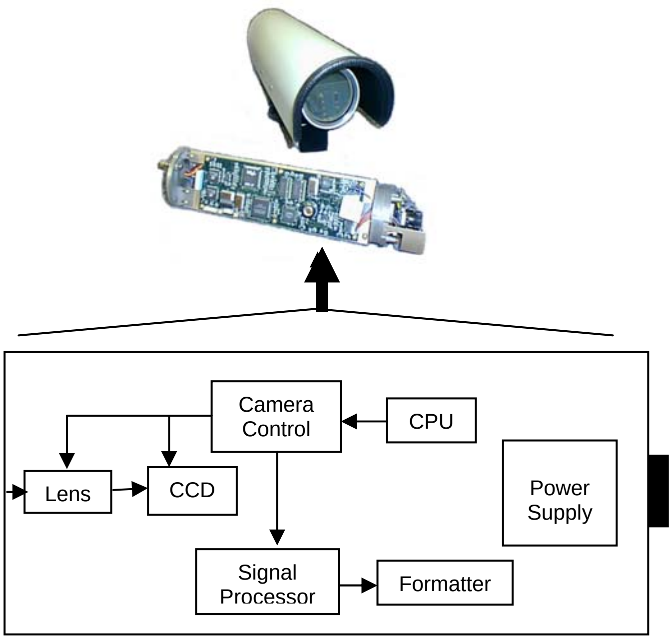

Figure 2. Integrated Video Sensor

The sensor hardware has the following input/output:

- Vehicle detection decision
- Traffic data
- Supervisory control
- System status
- Analog imagery
- Digital imagery

The system consists of a special communication hub to facilitate low cost management of the sensors from a Traffic Management Center (TMC) or some other similar central facility. The hub has three major communication functions:

- Data Multiplexing
- Video Multiplexing
- Hub-to-Hub Interconnection

Data and video from multiple sensors is multiplexed at a hub for the long haul transmission to the TMC.

Figure 3 shows the block diagrams for sensor network management from the TMC. At each node in the network, a hub multiplexes data and imagery from several sensors. Twisted-pair wires or other media link one communication hub to the next. The final hub is connected to a desktop PC through its communication ports. This desktop PC functions as a communication server (Comserver). The users may perform sensor management functions from this Comserver PC or any other PC connected to the Comserver over Local Area Network (LAN).

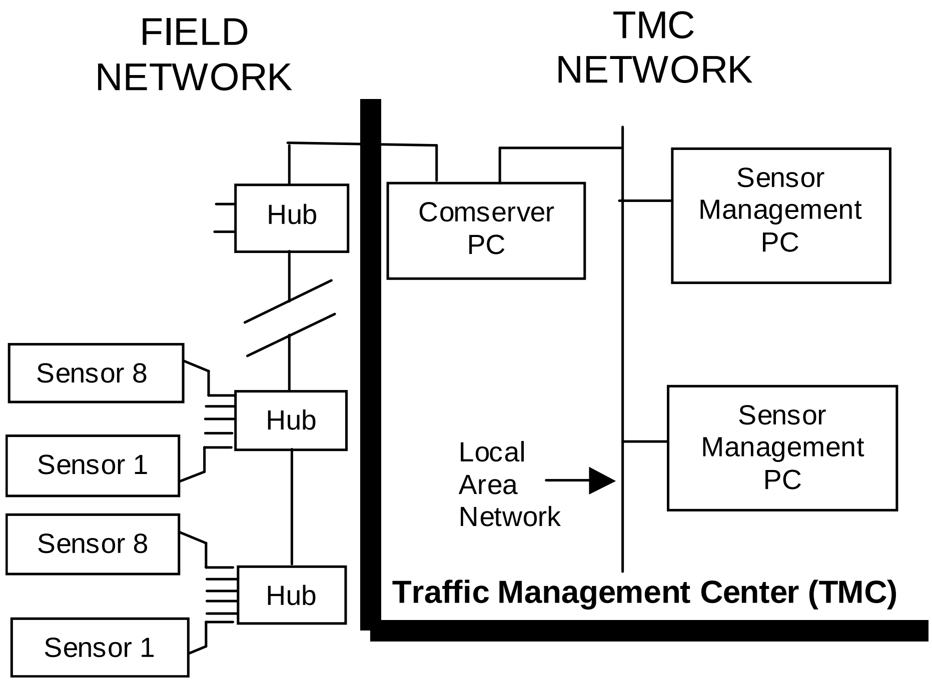

Figure 3. Sensor Network Architecture

SENSOR MANAGEMENT SOFTWARE

Referring to Figure 3, the Comserver is central to all the sensor management functions. The Comserver allows an operator at the central facility to establish communication with any of the sensors or the communication hubs in the field network. A user at the TMC can access any video sensor in the field network through the Comserver. The Sensor Network Browser software, similar to an Internet Browser, is available on the PC workstation of the operator for easy graphical interface with the sensors. Any desktop or notebook PC with appropriate Windows operating environment connected to the local area network (LAN) linking the Comserver PC in the operation center can execute the Sensor Network Browser. The Comserver is designed to communicate with the client applications and other sensor management software using industry standard TCP/IP communication protocol.

The sensor manager software consists of the following modules:

- Network Configuration Management: Includes defining, modifying, and verifying the communication servers and channels and the network topology.
- System Test: Performs diagnostics of the video sensors and the communication hub equipment.
- Software Installation: Includes automated software installation from the TMC in all the sensors in the field.
- Operational Log Review: The video sensors continuously perform self-diagnosis during their operations. The self-diagnosis log of any sensor can be remotely accessed, reviewed, and documented at the TMC.
- Traffic Data Archival and Display: From the TMC the sensors can be requested to collect and save any desirable traffic data (see Figure 4) accumulated over desired intervals.
- Video Management: Digital snapshots, as well as full motion video with flashing detector operation from any of the sensors in the network, can be accessed and displayed that the TMC.

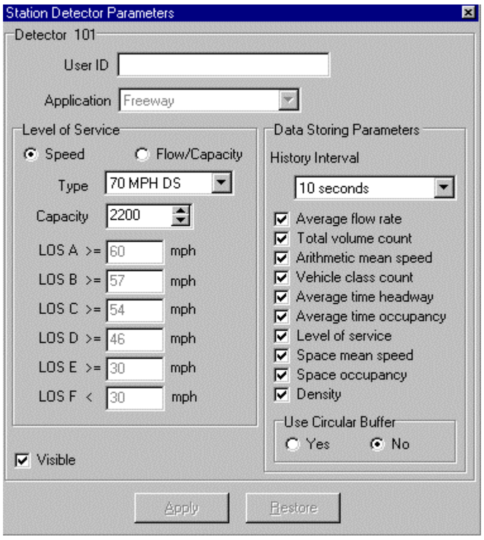

Figure 4. A List of Traffic Parameters Provided by the Sensor

RECENT IMPLEMENTATIONS

The new integrated sensor is well suited for several other transportation applications besides incident detection on motorways and in tunnels. Following are some examples of recent, special applications of the sensor.

ADAPTIVE TRAFFIC CONTROL: In Minneapolis, Minnesota, USA, a network of the integrated sensors is used for adaptive traffic control using a twisted-pair wire network. SCOOT adaptive control is being used in the central business district. The sensors are installed upstream to the traffic at each approach of an intersection adhering to the strict detection requirement of SCOOT. Both image snapshots and full motion video are transmitted to the TMC over the twisted-pair wire network.

ARTERIAL TRAFFIC STATUS: In St. Paul, Minnesota, USA, a network of the sensors is used for monitoring arterial traffic status using a combination of twisted-pair wires and fiber optic cable. The sensors are installed mid block on major arterial roadways to monitor traffic in both directions. The sensors provide real-time traffic measurements, which are then transmitted to a central facility in St. Paul.

VIRTUAL TRAFFIC OPERATION COMMUNICATION CENTER: The integrated sensor is being used in the virtual traffic operation communications centers (VTOC) in Duluth/St. Cloud, Minnesota. VTOC is a new concept that will allow a traffic engineer to monitor and manage traffic even when away from the central office. This is especially beneficial during severe winter storm or off-hour traffic emergency conditions. The integrated sensors will be used for the collection of traffic data and traffic image and for monitoring alarm conditions in tunnel traffic and other key locations. The communication path may include a combination of dial-up telephone line, twisted wire pair, ISDN, and spread-spectrum channels. Compressed video images will be transmitted and displayed at a VTOC using Advanced Streaming Format (ASF).

CONCLUSION

An innovative video sensor design is presented. The sensor combines transducer electronics and MVP electronics into one compact integrated package. This integrated video sensor has many features and resulting benefits for the users. Integration of the transducer and the MVP into one compact unit improves detection reliability and lowers susceptibility to EMI, lowers installation costs, reduces installation time, enables rapid deployment, and makes the system more readily portable. Direct real-time control of the transducer allows for precise adjustment of illumination based on detection zones and enables control of illumination.

Twisted-pair wire communication makes the sensor more cost-effective and simple to use and allows longer distance data transmission and deployment at more locations because twisted-pair is more readily available. Industry-standard TCP/IP protocol allows for multiple access capability from within the local area network at the TMC. An Internet browser-like user interface makes it easy for traffic engineers to configure detectors, collect traffic data, and manage the sensors. The compact integrated video sensor offers improved reliability and maintainability for traffic management and control applications.

REFERENCES

Blosseville, J.M.,(1989). Titan: A Traffic Measurement System Using Image Processing Techniques, IEE Second International Conference on Road Traffic Monitoring, London.

California Polytechnique State University, San Luis Obispo, California, (June 1991). Final Report, Evaluation of Image Processing Technology for Applications on Highway Operations, Technical Report TR 91-2, Department of Transportation, State of California.

Chatziioanou, A. and E.C. Sullivan (February 1997). Traffic Video Image Processing Systems Installations—An Examination of VIPS Standardization, Proceedings of IFAC Transportation Systems Conference, Chania, Greece.

Culver, M. (January 1997). Video Detection: The Atlanta Experience, *Traffic Technology International*, pp 40-43.

Econolite Control Products, Inc. (1995). Autoscope User's Guide.

Federal Highway Administration, Washington, D.C. (February 1978), Wide Area Detection System, Conceptual Design Study, Report No. FHWA-RD-77-86.

Fenichell, D. (1998). Advanced Traffic Detection Emerging Technologies and Market Forecast, Transport Technology Publishing.

Jet Propulsion Laboratory, Pasadena, California (March 1997). Sensor Development Final Report, *Traffic Surveillance and Detection Technology Development,* Federal Highway Administration, U.S. Department of Transportation.