LOW COST REMOTE MANAGEMENT OF VIDEO DETECTORS

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ABSTRACT

Video detection technology has matured to the level of reliability where it is now increasingly being used for traffic management, control, and monitoring applications. This paper describes new technology now available for remote management of video detectors from traffic operation centers. With this technology, video sensors can be synergistically controlled from the same traffic operation centers managing surveillance, traffic control, or traveler information equipment. Remote management includes network-wide sensor operation and maintenance functions such as monitoring of the communication network, diagnosis of the sensor system, installation of software, set up of the detectors and monitoring of the detectors' operations. The technology allows the use of low-cost communication infrastructure such as a twisted-pair copper wire network, which exists in many transportation communities.

INTRODUCTION

Video detection system technology has matured to the level of reliability where it is now increasingly being used for traffic management, control, and monitoring for large applications (1-3). For large installations involving many video sensors spread out over a broad region, cost-effective management of the network of sensors is important.

Management of the video sensors may require traffic engineers to reconfigure the vehicle detectors during road construction, install software upgrades, review detector performance, and retrieve status information. Ordinarily, to perform these functions would require that a technician drive to each intersection or freeway camera site in the field.

Remote management of the sensors from a central facility saves money and time and minimizes operational downtime. Remote management allows the management of the traffic control system and the video sensor system to coexist at one location, thereby achieving operational synergy. Additionally, operators can augment traffic surveillance cameras by viewing video from the video sensors.

The technology that provides convenient remote management was installed as a part of an adaptive signal control system in the central business district of Minneapolis, Minnesota (4). The system includes 138 video sensors configured to provide the vehicle detection required for Split Cycle Offset Optimization Technique (SCOOT) traffic control. The communication network used to manage these sensors consists primarily of existing, low-cost, twisted-pair copper wires.

The following sections describe the components of the management system including a brief background of the video sensor. Brief examples of freeway, arterial, CBD and virtual operation center applications are given.

SENSOR BACKGROUND

The new video vehicle detection sensor integrates the camera optics and the image processing electronics into one compact, single-camera machine vision processor (MVP) unit, eliminating the need for separate cameras and MVPs. In addition, co-located electronics and optics allow the image processor to control the camera gain, brightness, and illumination directly. The new integrated machine vision system, called the Autoscope Solo™ MVP, offers significant benefits:

- Eliminates the need for high bandwidth video transmission between a camera and a separate MVP. This lowers installation cost, eliminates transmission-induced loss of image quality, and makes the deployment more rapid.
- Makes the system more readily portable by eliminating a major physical component and long, bulky, coaxial video cables.
- Enables closed-loop control of the camera optics, such as illumination, gain, and brightness, by the vision processor itself.
- Improved detection performance is enabled through improved video quality and the closed-loop control of the camera optics.

There are four sets of input/output to the sensor: power, video, data, and control. The power options are 24 volt DC or AC. The video output from the sensor is transmitted over a twisted pair and includes the detector layout superimposed on it. The superimposed detectors flash when a detection occurs, indicating sensor operation to the viewer. The data and control signals are available in RS-485 or RS-232 formats.

This design makes the video sensor a more cost-competitive alternative to in-pavement loops for many applications. The twisted-pair input/output makes the sensor deployment more affordable, enabling direct integration of the sensor into the pre-existing, low-cost, twisted-pair wire communication infrastructure.

COMMUNICATIONS NETWORK ARCHITECTURE

In a compact package, Autoscope Solo MVP provides all of the following input/output:

- Supervisory control of the MVP -- This includes setting up the required detector configuration, monitoring sensor diagnostics and other utility functions.
- Detector actuation status
- Traffic data -- this includes all the traffic data typically required by a traffic engineer such as volume, occupancy, speed, headway and several others.
- Traffic image -- this includes individual snapshots as well as full motion video.

The above functions can be exercised either in a stand-alone mode or in a network mode of Autoscope Solo. Stand-alone mode is where a single MVP is used for an application without any interconnection with another MVP or with a central facility. The network mode of operation allows interconnection of multiple MVPs and, if desired, communication to a central facility for remote management of the sensors. (See Figure 1.)

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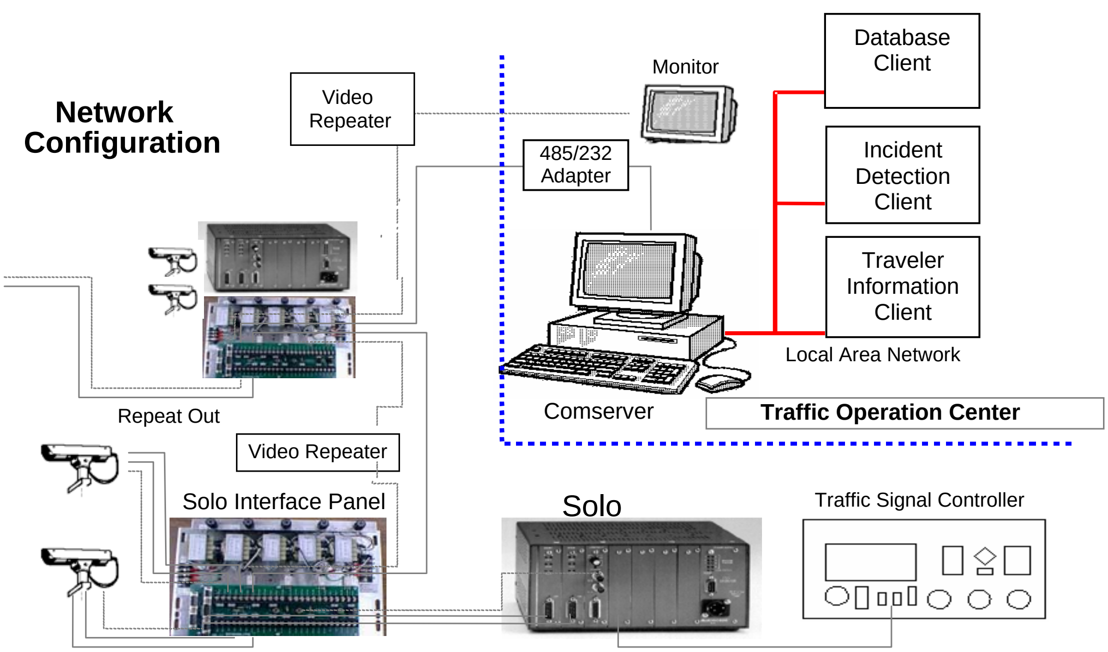

Figure 1. Communication Network for Remote Video Sensor Management

Applications in stand-alone mode include advanced detection at an intersection, queue detection at a freeway ramp, or portable traffic management at a freeway work zone. For stand-alone application involving a traffic controller, the Autoscope Solo system includes a communication card called Mini-Hub that fits in NEMA type C or D detector rack or 170 style input rack. The Mini-Hub provides the necessary TS1 or TS2 detector output from the MVP to the controller and any desired controller information, such as the signal phase, as input to the MVP. The Mini-Hub provides an RS232 output for desired local supervisory control of the stand-alone MVP. BNC video output is also provided for the display of traffic images. Alternatively, in applications such as a work zone, a computer may be programmed to have direct access to the detector actuation output of the MVP without the Mini-Hub card and actuate a variable message sign (VMS) based on the traffic condition.

The network mode of operation of Autoscope Solo provides low-cost operation of a large network of sensors from a central facility. Applications in the network mode include freeway traffic management, tunnel or bridge traffic management, coordinated control of a network of intersections, traffic responsive or adaptive, as well as the control of a single intersection with multiple approaches with or without advanced detection. To facilitate operation of a sensor network over a low-cost infrastructure, such as twisted pair copper wire, a modular and flexible communication hub is available.

For networks where broad band infrastructure such as fiber optic backbone is available, there may not be the need for the Hub. For example, in a freeway network with fiber, the MVPs may be connected to the backbone with RS-485 to fiber transceivers and coax to fiber transceivers for interconnection with the Traffic Management Center.

Each Hub functions as a node in the user's communications network and facilitates communication with multiple MVPs at that node. The Hub provides networking of data, video, and supervisory control to the multiple MVPs at that node, to the Hubs at other nodes in the network, and to the central communication server. A user may select one or more of several different functional modules to configure the desired Hub. The modules include:

- RS-485 module
- RS-232 module
- Video Mux module
- External Interface Module - Parallel (EIM-P)
- External Interface Module - Serial (EIM-S)

The RS-485 module supports two primary functions. First, it provides connectivity to the MVP for supervisory control, connectivity to the detector actuation status in the MVP, and traffic data collection. Second, it provides both long-haul relay and routing of the communication message to another node in the network. Multiple RS-485 cards can be used in a Hub to provide the combination of these functions.

The RS-232 module provides dual port serial communications for Data Communications Equipment (DCE) devices, such as modems, and Data Terminal Equipment (DTE) devices, such as notebook computers.

The Video Mux module provides software or hardware selection of the video output from any one of the multiple MVPs connected at a node in the network. Software selection allows a traffic engineer at a central facility to select live video from any of the sensors in the network for display, storage, or verification of the operation of the detectors. Hardware selection allows local selection of a video at the Hub itself in the field. The Video Mux module provides BNC output of the selected video. Additionally, an auxiliary video input BNC connector is provided which can be switched to the output, as well. This facilitates the integration of other video sources, such as from a pan-tilt-zoom surveillance camera. The module also performs long-haul relay of the video signals to other Hubs in the network or to the central facility.

The EIM-P module provides NEMA TS1 interface between MVPs and a traffic signal controller. It provides detector actuation output of the MVP to the controller as well as controller state input to the MVP. The EIM-S module similarly provides NEMA TS2 SDLC interface between MVPs and a traffic signal controller.

NETWORK MANAGEMENT SOFTWARE

The communication network connects the video sensors to a PC-based communication server (Comserver) at the traffic operations center (see Figure 1). As mentioned above, communication hubs are available for connecting and multiplexing several machine vision sensors and an auxiliary camera at any point in the network. Multiple communication links from different sections of the deployment region can be brought into the Comserver PC through separate communication ports.

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 over the twisted-pair network.

A user at the traffic operations center can access any video sensor in the field network through the Comserver. The sensor Network Browser software, similar to an Internet Browser, runs on the PC workstation of the operator for easy graphical interface with the sensors (see Figure 2).

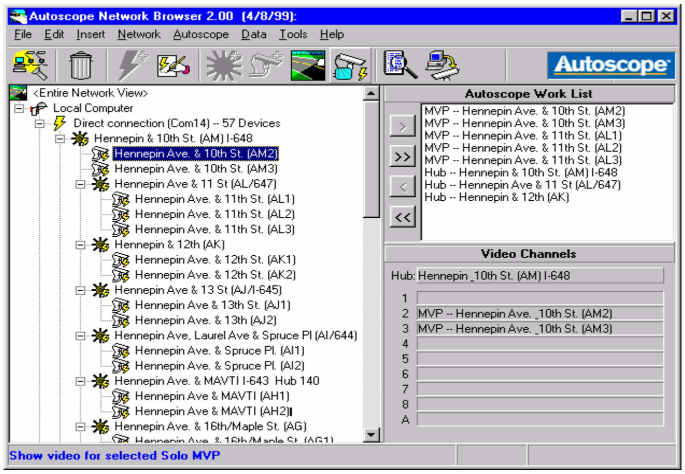

Figure 2. Network Browser includes Explorer Style menus, tools, and displays for convenient network management interface

Any desktop or notebook PC with appropriate Windows operating environment connected to the local area network (LAN) linking the Comserver PC in the operations center can execute the sensor Network Browser.

The sensor network management software system performs the following functions:

- Network Configuration Management: Used to define, modify, and verify the communication servers, communication channels, communication hubs, video sensors, and the network topology.
- System Test: Used to perform system tests via the video sensors and the communication hub equipment for system integration.
- Software Installation: Performs automated software installation for all the sensors and hubs in the field network. New sensors in the field can have software installed from the traffic operation center, as well as software upgrades for the existing sensors. The software can install to one unit (sensor or hub) or perform automatic batch installation for an entire set of units.
- Detector Editor: Used to create and modify detector layouts and make detector output assignments.
- Operational Log: The video sensors and the communication hubs continuously perform self-diagnosis during their operations. Any anomaly or deviation from the normal operation is automatically stored in the unit's Operation Log. The Operations Log of any sensor or hub can be retrieved and examined at the traffic operations center.
- Traffic Data Archival and Display: From the traffic operations center the sensors can be configured to collect and save traffic data accumulated over selected time intervals. An operator can schedule the traffic data to be automatically uploaded and archived. Archived data can be displayed for review and analysis.
- 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 at the traffic operations center.

INSTALLATION EXAMPLES

This remote video sensor management system is currently deployed and in use in Minneapolis, Minnesota for adaptive traffic control in a grid network of CBD intersections. The system is also installed in St. Paul, Minnesota as a part of Minnesota's ORION Model Deployment Initiative for the monitoring of arterial traffic status. And, it is currently in use with a freeway application test on I-94 between St. Paul and Minneapolis. It is also included with the video sensor system selected for use in the recently awarded Traffic Operations

Communication Center (TOCC) project in Duluth under the state-wide initiative of Minnesota Department of Transportation to spread ITS to rural Minnesota.

ADAPTIVE TRAFFIC CONTROL

In Minneapolis, Minnesota an Autoscope Solo sensor network is used for adaptive traffic control using a twisted-pair wire network. SCOOT adaptive control is being used in a section of the central business district consisting of a sports facility and traffic distribution from several freeways and arterials. Autoscope Solo sensors are installed upstream to the traffic at each approach of an intersection adhering to the strict detection requirement of SCOOT. The Autoscope Solo sensors provide real-time detector actuation to local controller units in the cabinet, which then transmit the information to the central control computer at the Traffic Control Center (TCC). In addition, interval traffic data from the sensors is also made available at the TCC. Supervisory control of all the sensors is also available at the TCC. Both image snapshots and full motion video are transmitted to the TCC over the twisted-pair wire network. The sensor network is fully operational and on-line. The adaptive control system is currently undergoing evaluation. Initial evaluation indicates noticeable improvement in traffic flow and reduction in number of stops and delays (5).

ARTERIAL TRAFFIC STATUS

In St. Paul, Minnesota, a network of Autoscope Solo sensors is used for monitoring arterial traffic status using a combination of twisted-pair wires and fiber optic cable. Autoscope Solo 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 through 170 controllers to a central facility in St. Paul. There the sensor output will be used to display real-time traffic status information for traffic engineers responsible for day-to-day traffic operations on the arterial roadways. As of this writing, the sensor network is installed and partially on-line. The complete system is expected to be fully on-line and rolled out later this year.

FREEWAY TRAFFIC SENSING

Autoscope Solo is used on Interstate Highway I-94 near Snelling Avenue in Minnesota to measure freeway traffic parameters. The freeway has three lanes in each direction. (See Figure 3.) Vehicles are detected and tracked within the tracking zone in each lane. The tracking information is used to measure speed of the detected vehicle and extraction of other typical freeway traffic parameters, shown in Figure 4. In addition, video from the freeway sensor can also be viewed, supplementing surveillance video from pan-tilt-zoom cameras.

PLANNED VIRTUAL TRAFFIC OPERATION COMMUNICATION CENTER

Autoscope Solo sensor was also selected for use in the recently awarded Traffic Operation Communications Center Project of Minnesota Department of Transportation (Mn/DOT) in Duluth/St. Cloud, Minnesota. As part of Mn/DOT's statewide ITS initiative, virtual TOCCs will be developed that will allow a traffic engineer, away from the central office, to monitor and manage traffic. This is especially beneficial during severe winter storm or off-hour traffic emergency conditions. Autoscope Solo 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 virtual TOCC using Advanced Streaming Format (ASF).

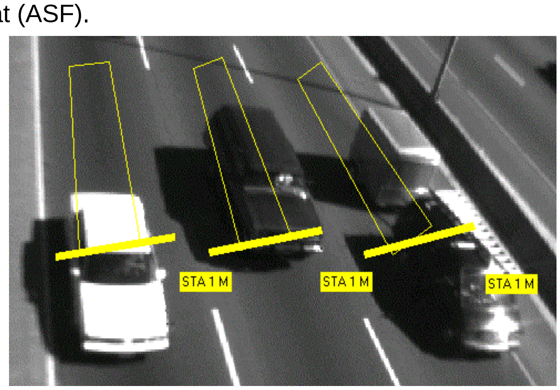

Figure 3. Autoscope Solo tracks vehicles and uses speed for enhanced accuracy

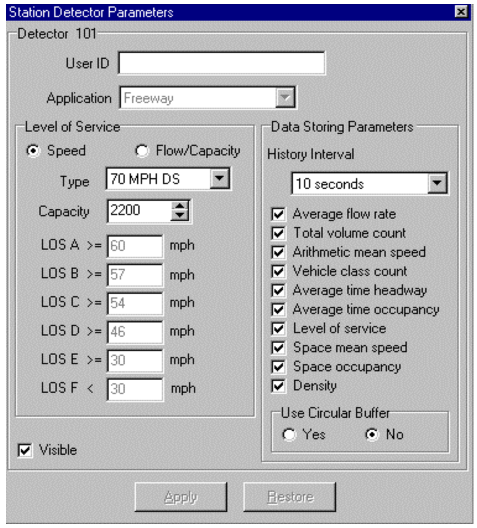

Figure 4. Autoscope Solo provides a large number of traffic parameters for traffic management and control

CONCLUSION

A new technology has emerged to provide low-cost management of deployed video detectors from a traffic operations center. For video sensors deployed over large areas this technology offers savings in cost and time by significantly reducing or eliminating travel to the field.

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