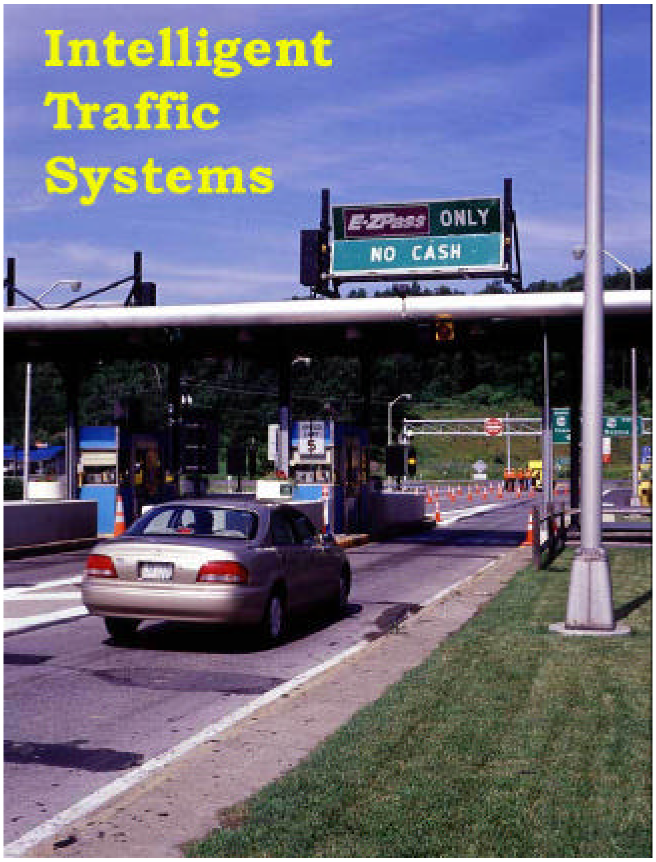

Figure 1: The E-ZPass system installed on the New York State Thruway is the first step in automating the collection of tolls. These automated toll gates reduce traffic congestion and the cost associated with collecting tolls. Future systems will allow much faster lane speeds.

As the machine vision industry matures, basic vision technologies are finding their way into ever new and diversified fields. Similar to early microprocessor and microcontroller developments, basic machine vision technologies are finding their way into a host of embedded applications that provide higher levels of functionality.

An interesting example of one such niche industry is that of the Intelligent Traffic Systems market. This industry employs a range of systems that use machine vision technologies, along with a host of other high tech gadgets, to perform a myriad of traffic and vehicle related functions with accuracy and assiduous resolve. These systems find their way into applications ranging from speed enforcement to parking lot security.

Over the past five years speed enforcement systems have proven their worth in many countries around the world, yet have not yet found a home in the United States due to a host of legal issues. Early adopter countries find them to be highly profitable revenue generators, in addition to improving safety and reducing fatalities. These systems incorporate machine vision and radar technologies that provide a turnkey solution for speed enforcement. The radar system monitors an approaching vehicle's speed, and if the measured speed is greater than an internally stored setting, an image of the vehicle is acquired. The image (or in many cases multiple images) form a record of the vehicle make and type, along with the license plate information. The information is then wired to ticket processing centers where hard copy tickets are printed and mailed to the offender. Typically these units are built into mobile platforms which can be randomly positioned in key problem areas.

Red light enforcement is another key application group that has benefited from improved vision technologies. Violation of traffic signals, most importantly the running of red lights, is a major safety issue and causes numerous fatalities each year. Systems are now capable of monitoring both the color of the traffic light and the movement of vehicles through the intersection. In the case of a vehicle moving into the intersection against a red light, the offender is imaged in full color revealing the traffic light, the make and model of the vehicle and the license plate. The information is automatically sent from these permanent intersection installations to ticket processing centers.

Parking lot security plays another significant role in a variety of applications. Rental car agencies can use automated systems to monitor vehicles that enter and exit their facilities. High security areas, including government, military, corporate or public facilities, can utilize license plate documentation systems for monitoring and archiving vehicle flow within certain specified areas. These systems promise to deliver higher levels of security and documentation for everything from grand larceny to terrorist activities.

Another area that has rapidly progressed is the automation of tollbooths and customs processing at border crossings. Automated imaging systems are already a part of many vehicle border-crossing checkpoints. These systems image the vehicle and acquire information regarding the make and model, the license plate number, and the border crossing time. Automation of this information allows it to be correlated with future information, particularly any discrepancy regarding length of stay. Collection of this data simplifies the analysis and improves efficiency in the overall system, minimizing the time and frustration experienced at these border-crossing stations.

Automated Toll Collection

Figure 2: Typical images acquired from high speed toll system on the New York State Thruway system. Both front and rear license plate images are acquired at full highway speed with sufficient resolution for the OCR engine to read the numerals. The plates may be located anywhere within the field of view. (The last numeral has been intentionally blacked out)

Analogous to the border crossing applications, many toll booths are now installing similar technologies for use on high traffic toll roads, bridges and tunnels. The push for tollbooth automation increases, especially in metropolitan areas, as traffic volume increases and the associated delays cause staggering traffic jams. In the United State, there are several successful preliminary installations including the SunPass system in Florida, and the E-ZPass system on the New York State Thruway Authority (NYSTA) system to name a couple. These systems use a variety of technologies to automate the collection of tolls and minimize the time spent at the toll collection booth. Currently these systems use radio tags within the vehicle that communicate with the tollbooth. Within milliseconds the approaching vehicle is identified and the toll is automatically withdrawn from the users prepaid account, allowing the user to exit in special 5 mile per hour lanes. Vision systems are used predominantly as enforcement tools for violators of these special automated lanes. If a user exits the automated lane without the special radio tag, or with an overdrawn account, an image is acquired of the license plate and the information is forwarded to a ticketing center.

Figure 3: Next generation high speed systems will be installed on overpass structures so that vehicles may remain traveling at full highway speeds. Camera and lighting systems may be located many kilometers from data collection centers.

The common denominator for all the above applications is the acquisition of the license plate image, and the subsequent reading of the plate information using OCR (Optical Character Recognition) techniques. Over the past decade these systems have been standardized to provide solutions for each of these varied application groups with minor variations to standardized hardware, software and lighting components.

These automated toll stations have already shown great promise, improving service to the user and providing increased profitability for the toll collection process. In North America, several progressive thinking organizations have already begun developing the next generation of systems that will allow for much higher speed toll collection. The Canadian providence of Ontario has installed what might be the first fully electronic high speed system on the 407 which utilizes a full vision-based system requiring no radio tags or other user registration other than the license plate information. Similarly in the United States, the NYSTA has been undergoing extensive roadside tests over the past 24 months to implement an automated toll collection systems which allow the user to continue at full highway speeds. The primary drive for this type of system is to eliminate tollbooths altogether in areas where major highways converge, allowing the driver to transfer on and off the tollway without ever slowing down.

While the benefits are obvious, high-speed toll collection provides a host of additional challenges over that of current systems. These systems require that all drivers on the throughway system be properly identified on both entrance and exit, not just the special group of pre-defined tag holders. This includes all forms of transport vehicles that range from motorcycle to large tandem trucks. Currently on the NYSTA, this requires the proper identification of travelers within 8 toll classes and 10 sub classes. Under real world high speed testing, the NYSTA testing has demonstrated laser-based systems that provide the proper information regarding length, number of trailers and overall number of wheels that provide for proper toll classification. Similarly, laser based systems also identify vehicle road and lane position necessary for camera based acquisition systems to acquire both front and rear license plates images for proper identification. From these images OCR software reads the plate and transfers the information to a centralized processing station.

System Hardware

The basic technology components common to these various applications involve tailored digital cameras and frame grabber hardware, specialized lighting devices and application specific software. While these components are similar to those developed for generic machine vision applications, they have been tailored to meet the specifics of these applications.

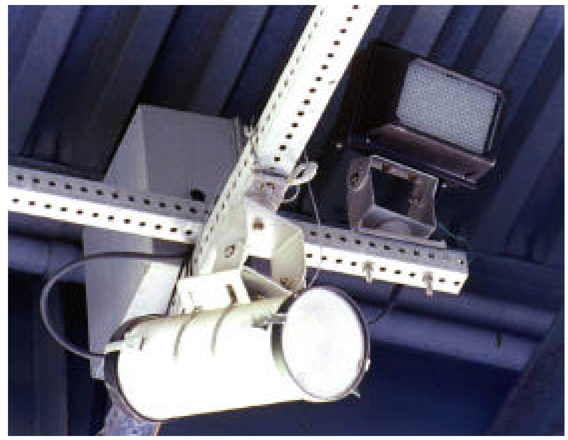

Figure 4: Proof of concept hardware includes camera, lighting and control modules. Hardware is mounted on the underside of an overpass or bridge and is triggered by a laser vehicle location system (not shown)

For the highly demanding NYSTA installations, turnkey license plate reader systems developed by Tecnicon International, Inc.[1] were installed and have exceeded specifications, exhibiting reliable operation for more than 18 months. The camera used within these systems is the Model 1015T Traffic Camera manufactured by Kodak. This fully digital camera was chosen for a number of reasons, the first being that it uses a 1K x 1K CCD sensor to deliver the required resolution over the field of view specified. Because the license plate can potentially be anywhere within the lane, the field of view must be over 12 feet in width, and yet the license plate characters must still be identifiable by the OCR algorithm. Another major consideration centers on the fiberoptic interface available. This camera can be operated on a gigabit fiberoptic ring network that allows up to 4 cameras per fiber pair to be operated at a full 15 frames per second per camera.

The fiber ring becomes an important factor in these type applications because of the inherent bandwidth and noise immunity. The typical installation requires long lengths of signal and control cables for successful operation of a multi-laned collection station. Copper based signal lines have a limit of about 30 meters for digital camera transmissions, while the fiberoptic solution has a range of up to 2 kilometers. In addition to be able to carry the digital output from up to 4 cameras simultaneously, the fiberoptic solution also has additional bandwidth for many of the potential I/O controls required including strobe triggers, camera controls and pan/tilt/zoom commands. While the fiberoptic link provides tremendous advantages for this niche application, it provided one serious drawback – at the time there were no commercially available frame grabbers with gigabit fiberoptic interfaces. To solve this problem Tecnicon developed a specialized framegrabber with the proper fiberoptic interface.

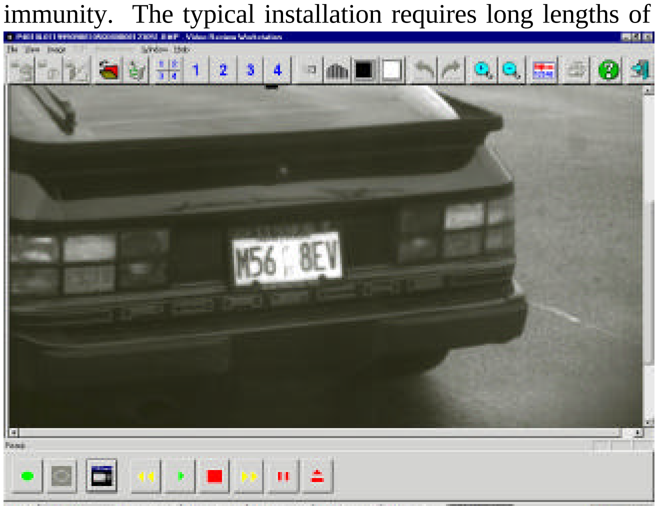

Figure 5: The Toll Enforcer™ software combines OCR processing with manual verification reports that link reports directly to DMV database protocols.

The software used in the NYSTA systems is the TollEnforcer™ product that uses ImageView32 to generate the citations and reports. The software kernel uses a proprietary back-end OCR processing system for plate recognition and a DMV database interface which is modified to match with the individual state or country protocol.

Lighting

The main technical issues surrounding the development of the lighting systems for these applications have to do with overall output intensity, spectral properties, working distance, field of view, lifetime, operational reliability, robust construction for outdoor operation, and overall power requirements. Through a creative technology partnership, Illumination Technologies[2] developed specialized LED lighting systems to meet the demands of these applications.

The intensity requirement is defined ultimately by the sensitivity of the camera, the reflectance of the license plate under investigation, and the integration time required in order to obtain a blur free image. The intensity required increases in direct proportion to the speed of the vehicle under inspection because the duration of the image acquisition must be reduced to eliminate blurring. High-speed plate reading has increased the intensity requirements significantly over earlier low speed systems.

One of the main issues surrounding successful implementation of these high-speed systems is how to produce enough light without creating a nuisance, distraction or potential safety issue for the driver. Earlier slow-speed or no-speed systems utilized large flood light type systems mounted close to the lane to illuminate the license plates. With high speed applications on the horizon it became apparent that more sophisticated high output lighting devices would be required.

The most logical choice for these applications would be the use of NIR (Near Infrared) illumination. A subset of this NIR illumination range from about 700nm to 900nm is completely invisible to the human eye, but is quite visible to most cameras using either CCD or CMOS sensor technology. Technically this type of illumination can be readily produced, in a highly desirable pulsed fashion, using LEDs (Light Emitting Diodes). These solid state devices provide the reliability and lifetime desired by such applications, with the covert nature desired by such applications. Early developments of this technology provided encouraging results and eventually led to the issuance of US Patent No. 5,591,972 to Illumination Technologies for these types of devices.

While NIR illumination is the defacto standard in many parts of the world, the wide variety of license plates manufactured in the United States continues to provide ongoing challenges. The variability of license plates and colors, combined with wide ranges of background reflectivity for these plates continues to increase as states add entire new lines of designer and vanity plates, each with unique color combinations and graphical layouts. Some states maintain sufficient license plate control (specifically absorbing numerals on retro-reflective backgrounds) and find that they still have quite a large latitude to develop quite a bit of artistic variation that can be made invisible under NIR light.

Figure 6: LPI 1000 provides high intensity strobed LED illumination for intelligent traffic applications. Robust outdoor units provide spectral options including NIR illumination

Many systems however, especially on the East Coast of the US, must be capable of reading plates from several different states. Testing has shown that the wide variety of plates currently available, especially in these regions make NIR illumination an impossible solution. In these areas overall system specifications dictate which plates are to be successfully read, and detailed spectral testing is conducted to determine the proper wavelengths which must be included in the strobe. The ever-increasing output of many of the visible wavelength LEDs has made it possible to supply solid state strobe units with two or three distinct spectral outputs necessary to solve the pending applications.

License Plate Standardization

The future of high-speed license plate detection and reading is petitioning for NIR illumination schemes. The liability issues alone demand an eventual move toward invisible and non-invasive schemes that do not distract vehicle operators. There are already several statewide developments pushing for national license plate standards which could make for equal quality detection under such invisible detection schemes.

Figure 7: Variation in images of sample plate showing the effects of different lighting schemes. The top plate is illuminated under white light, the bottom one using NIR illumination. For properly designed plates the contrast is greatly improved for automated OCR reading using NIR illumination. Note that proper design makes possible the use of visible graphics that make recognition difficult under white light schemes.

Proper standardization would provide many benefits for these systems without compromising the escalating demands for plate specialization and beautification. NIR components of the plate can be stored predominantly in the specialized retro-reflective background material, fairly independent of the graphical content within. If all states adopted the use of this material, combined with numerals that had NIR absorbing properties, these invisible detection systems would be feasible.

The added benefits to such NIR standardization would be that hidden codes could be placed in the background, visible only under NIR illumination and detectable only by specialized camera based systems. These codes could include specific toll classification information, eliminating the need for expensive electronic gear for determining vehicle class. They could also contain a host of other information stored on the license plate which could be stored in invisible bar or matrix codes. These codes might also provide heightened counterfeit measures, making printed plates more viable and eliminating the high costs associated with stamped plates. All of these benefits are pushing standardization efforts and may make the invisible detection scheme a reality in the not too distant future.

Conclusion

Futuristic systems are already showing progress in the area of intelligent traffic management, from the monitoring and management of traffic light signals at intersections, to smart camera systems that monitor congestion and suggest alternate routes via large message boards suspended over metropolitan highways.

The tools developed for basic machine vision continue to find their way into dedicated applications, providing fundamental building blocks for systems with higher levels of application specific functionality. Sight is arguably our most information abundant sense. Because of this reality, we should expect to see the kind of exponential growth in the embedded use of basic and specialized vision technologies well into the future.

---

[1] Tecnicon International, Inc.
Contact: Pamela Alonge
1981 Mountain Road
Haymarket, VA 21069 USA
TEL: 703-754-0449
pamela@tecnicon.com
www.tecnicon.com
Tecnicon manufacturers and markets turnkey visions based systems for the intelligent traffic control markets.

[2] Illumination Technologies, Inc.
Contact: Mike Muehlemann
5 Adler Drive
E. Syracuse, NY 13057 USA
TEL: 315-463-4673
www.illuminationtech.com
Illumination Technologies specializes in the design, manufacture and marketing of specialized lighting devices for the machine vision industry.