

APPLICATIONS AND EVALUATION OF
AUTOMATED LICENSE PLATE READING SYSTEMS

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ABSTRACT

Many technological advances have enabled new methods of collecting transportation data that can be used to plan and maintain effective roadway policies. Automated license plate reading technologies are beginning to gain acceptance because of the wide range of applications to which they can be applied. Typically, automatic license plate reading (ALPR) systems are used for enforcement type applications and data collection applications including parking lot management, origin-destination studies, traffic flow studies, high occupancy vehicle analysis, and weigh in motion systems. An ALPR system consists of three main components; a device for detecting vehicle presence, a digital video camera and an image processor. The image processor identifies the license plate according to embedded pattern recognition algorithms. The accuracy of the pattern recognition algorithms used in the image processor is an important concern when evaluating ALPR systems. The required accuracy depends on the application. For example, an enforcement application may require a high degree of accuracy while a traffic flow study may only require that an image obtained at an entry point be matched to an image obtained at an exit point. Other issues for consideration when evaluating ALPR systems are mobility and simplicity of use, range of vehicle types that can be read, necessary lighting conditions, range of states of origin that can be read, range of vehicular volumes and speeds that do not overload the image processor, and human impact/public relations.

INTRODUCTION

Intelligent Transportation Systems (ITS) are characterized by technological solutions that integrate information processing, communications, control, and electronics with transportation management systems (1). Examples of ITS solutions include Automatic Vehicle Location (AVL) systems, Automatic Passenger Counting (APC) systems, Automated Toll Collection (ATC) systems and Automatic License Plate Reading (ALPR) systems. ITS solutions give transportation engineers the ability to collect meaningful data in real-time and assist in improving the operational performance of the transportation application.

The purpose of this paper is to review ALPR systems in order to assist practitioners in understanding the capabilities of these systems. This paper will first cover the basic architecture of ALPR systems and then discuss several current applications of ALPR systems. Next, we will present several alternative suppliers of ALPR systems. Finally, we suggest a possible method for evaluating the systems.

ALPR System Architecture and Operation

Transportation planning and infrastructure developments are major issues in the expanding global network. Many technological advances have enabled new methods of collecting transportation data that can be used to plan and maintain effective roadway policies. Automated license plate reading technologies are beginning to gain acceptance because of the wide range of applications to which they can be applied. These units typically consist of the following components (2): an illumination source, a camera, a vehicle sensing device, an image processor, a power source, and a host computer for saving images and interpretations. The light source must be able to overpower sunlight and eliminate shadows.

A color digital camera with exceptionally fast shutter speeds must be triggered from an internal or external device that senses the vehicle. The image processor is the heart of the system and identifies the license plate according to its embedded pattern recognition algorithms.

The following is a summary of how a typical ALPR system operates from ITS World, January - February, 1997:

As a vehicle enters a system's field of view, it triggers a complex processing cascade. Vehicle presence can be detected by an external trigger, such as a trip wire, in-ground loop, or cross-traffic light beam, or an internal trigger, wherein the signal from the video subsystem alerts the processor that an object may be present. The video camera, with its synchronized shutter and illuminator, then captures an image or series of images of the passing vehicle.

Once the image is digitized, the next job is to determine if and where a license plate is located. The system must search for a plate among a sea of similar objects such as bumper stickers, fleet identification numbers, manufacturers' labels, dealer logos, and parking permits. Usually, several tests isolate and confirm that a plate is present and submit it for character recognition.

Once the characters are recognized, their *font*, or particular style of lettering, and syntax can aid in refining the determination. The interpreted data and imagery can then be retained locally for query against an established database or transmitted to a remote file system server for further processing or storage.

Character recognition is one of the most critical issues associated with ALPR systems. Typically, the consumer is free to choose from a number of commercial video imaging subsystems. (1) The pattern recognition algorithms used in the imaging systems are the most important component in the ALPR system. The correlation matching approach takes each character, and attempts to match it to a set of predefined standards. With this approach, any change from the norm could cause a questionable identification. Structural analysis uses decision trees to comprehend the character's geometric shapes. This method is a little more tolerable for changes in the license plate's environment. Finally, neural networks are trained by examples of previous plates. Statistical models are built each time a new character is seen by the system. This is the most accurate method, although it can be time consuming as the system continually expands its library. (1)

ALPR TRANSPORTATION APPLICATIONS

Typically ALPR systems are used for enforcement type applications and data collection applications including parking lot management, origin-destination studies, traffic flow studies, high occupancy vehicle analysis, and weigh in motion systems.

ALPR systems have been used in paid parking lot systems in order to overcome most of the shortcomings of normal parking systems. When a car enters a lot, the system captures the license plate number, and logs the time and date. When the car later exits, the system again captures the license plate number, and computes the fee. This system eliminates problems with lost or swapped tickets, cashier fraud, and stolen cars. (3) This system will require a high accuracy rate. Whenever enforcement issues are involved, the accuracy of the system is very important.

Three of the most common uses of license plate imaging technologies are Origin - Destination Studies/Trip Surveys, Cordon Studies, and Travel Time Studies. The purpose of Origin-Destination

Studies is to determine the travel patterns along a given transportation network. Often Trip Surveys are used to implement these studies. Trip surveys require three main parts. First of all, the license plates chosen for the study should be randomly selected. Second, there can be no incorrect interpretations of the license plates by the imaging system. Third, the database must be readily available for use by analyzers. This type of use does not require a high level of accuracy. As long as the system is consistent in its plate identification, it will be successful. In a Cordon Study, the traffic patterns into and out of a given area are analyzed. The key to these studies is correct placement of the imaging equipment at pertinent locations on the boundaries of the area being studied.

Another common application is Travel Time studies. License plate recognition systems are used to record the location of a vehicle at two different points in time; from this data an average speed can be acquired. (2) The feasibility of using license plate images for these types of studies was first realized in Great Britain. (4) Since then studies have been conducted to further test the reliability and effectiveness of this technology for such studies. It has been concluded that this technology can “reduce the cost and greatly facilitate the conduct of travel time and small area origin-destination studies.” (4)

Shuldiner et al. (1996) discuss the use of video and machine vision license plate matching to measure origin-destination and travel time patterns. Shuldiner et al. (1996) concluded that “the estimates of mean travel times produced by machine vision analysis are essentially identical to the estimates resulting from an exhaustive manual analysis and that both the manual and machine vision analysis of videotaped license plate images produce very accurate and precise estimates of mean travel times.” (4)

Traffic flow studies are another application of ALPR's. A license plate reader can eliminate some of the problems faced when attempting to conduct a traffic flow study. For example, shutting a road down in order to install an inductive loop detector may be required. A license plate reader can quickly and easily be installed on both ends of the desired corridor and the study can begin immediately. This type of study does not require high accuracy. A study by Craig A. Anderson, Panos G. Michalopoulos, and Richard D. Jacobson entitled “Cost Benefit Analysis of Video Based Vehicle Detection” uncovered a few interesting points that are mentioned here, but apply to many applications. First of all, they present two ways to place the camera along the road. Their first alternative was to configure the cameras in the median in order to detect cars in all mainline directions and on the ramps. Their second alternative involved placing the cameras along the outside shoulders of each mainline direction. (5) These alternatives show some of the issues to be dealt with when using an ALPR system. The second important aspect the study identified was a list of factors and comparisons of ALPR's versus loop detectors. ALPR systems allow for year round installation and maintenance. In addition, their installation typically does not cause lane closures. ALPR are able to perform visual detection, measure speeds, detect wrong way vehicle movement, measure queues and other performance measures, detect incidents, and provide visual surveillance capabilities.

ALPR systems can also help determine relevant information for HOV lanes. They can determine the potential demand for such a lane through matching license plates at enter and exit points of such a facility, and, subsequently, determining the traffic volume.(4) Furthermore, ALPR's can help with the enforcement of an HOV lane. This second application, however, is more difficult than most because it requires error free and verifiable results, not normally necessary. (4)

Weigh stations provide an opportunity for enforcement personnel to check a vehicle's weight, dimensions and credentials and to ensure that the vehicle is safe to operate. The inspection process,

however, can be time consuming and is costly. Time spent waiting in line, being weighed or inspected, or reviewing paperwork is non-productive time that results in inefficiency. The added deceleration, acceleration and idle time of the trucks add to fuel consumption and air pollution. Finally, the excess merging of trucks is an obvious safety hazard along a highly traveled route. A current approach to weigh in motion systems is the use of transponders. These small devices are placed in each truck. A reader can read the transponder and refer to a database to see whether or not the truck has already passed inspection.(6) An ALPR system is a logical choice to eliminate the inadequacies of transponder based systems. The trucks require no extra hardware, therefore there is less cost and all trucks can be monitored, as opposed to only those with transponders installed.

In Iowa, a weigh in motion system is in use. In this system, the trucks actually exit the main highway and enter a ramp at 30 to 50 foot intervals. The license plates are read and a signal is given to inform the driver of whether or not he/she needs to go to the scale, or if he/she can continue back to the highway. Ideally the trucks should be scanned on the highway and told whether to enter the weigh station from the highway; however, the system will be dependent upon accurately reading license plates at highway speeds. An alternative is to use other aspects of the vehicle such as the USDOT (or ICC) number. (7)

SYSTEM ACCURACY

Accuracy is another important issue involved in these systems. It is often difficult to quantify the performance of a system. One method is to measure the percentage of license plates correctly identified by the machine that can be verified by a person. (1) Nelson (1) illustrates the challenges of measuring the accuracy associated with an ALPR system via an example, which shows that one cannot simply measure individual character accuracy and extrapolate total system accuracy. Nelson defines the system accuracy as:

$$A = (T \times I) \times 100 \tag{1}$$

where

A = total system accuracy

T = rate of successful plate recognition, expressed as a decimal number

I = rate of successful interpretation of entire plate content

By measuring and interpreting each character's accuracy individually, he further refines the system accuracy as:

$$A = (T \times I_1 \times I_2 \times \dots \times I_n) \times 100 \tag{2}$$

where

A = total system accuracy

T = rate of successful plate recognition

I₁ = rate of successful interpretation of first character

I_n = rate of successful interpretation of second character

I_n = rate of successful interpretation of nth character

Nelson then discusses an example with the ALPR system recognizing and identifying 10,000 license plates with seven characters on each plate, a total of 70,000 characters. As Nelson points out “if the system reads the first six characters correctly on each plate but misses the last character on every plate, one might be inclined to state the overall accuracy as $(60,000/70,000) \times 100$, or 85.7 percent; however, using Equation 2, the true system accuracy in this case is zero.”

Different applications require different levels of accuracy. As higher accuracy is required, the price of the system rises because better cameras are necessary. For example, a system designed to enforce HOV lanes must be 100% accurate or else innocent people could be charged. The equipment for this application can be more costly. On the other hand, studies only involving traffic in and out of a corridor do not need to be as accurate. The system will identify the plate at the entrance and exit to the corridor. Correct identification depends on correctly matching license plates at both ends of the corridor. It does not matter if the plate was identified correctly, as long as it was identified the same at both ends of the corridor. Therefore, researchers still know how fast the vehicle traveled through the corridor as well as other relevant information. The equipment for this use would not be as expensive. Shuldiner et al. (1996) shows that machine vision is capable of matching license plates, which is the only requirement for many of the above applications.

ALPR ALTERNATIVES

Transformation Systems, Inc. (Transfo) works jointly with Computer Recognition Systems, Inc. (CRS) to provide Intelligent Transportation Systems (ITS) and services to the North American transportation industry. Together they installed the first license plate reader in 1979. (8) Examples of recently completed or current systems include: a border crossing traveler information system, an automated real-time traveler information system, video detectors to control intersections, travel time studies, license plate based surveys, and a commercial vehicle license plate study. Transfo and CRS’s main systems include the Traffic Analysis System (TAS2), the Image Capture System (ICS), and the Numberplate Reading System (NRS2). Transfo is the leader in this industry. With CRS, they developed the first license plate reading system in 1979. CRS conducted the first traffic surveys using machine vision in 1991 to determine vehicle travel times and origin/destinations. CRS also developed one of the first open highway electronic toll systems in the world during 1993 in Singapore. (9)

Perceptics’ license plate readers have been applied to many functions. They monitor border crossings, do electronic toll collections, commercial vehicle operations, registration enforcement, revenue collection, access control and security, and emissions testing. (10) AlphaTech, founded in 1979, can provide a number of ALPR systems. (11) They currently have systems in Illinois, New York City, Phoenix, Denver, Korea, South Carolina, Coleman Bridge, VA, and Maryland. AlphaTech boasts that it can read a full range of license plate design variations, with vehicle speeds up to 100 miles per hour. Racal’s *Talon* system, as it is called, currently is applied to five applications. These are security, car parking, enforcement, traffic surveys, and road tolling. (12) The enforcement application is most relevant to weigh in motion systems. The Talon system provides “rapid and accurate identification of vehicles, 24 hours a day” for these types of applications. (12) Racal’s Plate Recognition Unit (PRU) is a highly modular device with a power supply, hard and floppy disk drives, and five slots for recogniser modules. A recogniser module is a single board with a camera multiplexer, a frame grabber, a PC

interface and a Digital Signal Processing (DSP) Unit. The DSP runs the algorithms which identify the license plates. Extra recogniser modules can be added to work with a greater number of cameras. (12)

SYSTEM EVALUATION

There are many factors involved in deciding which system to obtain. Some of the main aspects are the following: mobility and simplicity of use, range of vehicle types that can be read, necessary lighting conditions, range of states of origin that can be read, range of vehicular volumes and speeds that do not overload the image processor, and human impact/public relations. French et al. (1997) recommend specifications for a general purpose ALPR for transportation planning.

Any system that is not being outfitted in a permanent location must have the ability to be transported easily and cost-efficiently. Optimally, the entire system should be able to be moved in one vehicle. During transport, the system should not be suspect to damage. Set-up should be as simple as possible and should require a limited number of technicians. An arduous set-up program will waste time and money. Set-up time limits should be determined in a case-by-case basis. (2) An ideal system can read the plate of any vehicle but reading the plates of heavy vehicles can be especially difficult because of their size and the fact that, according to John Keyhart of Racal, the front license plate must be read. One study indicated only 30-35% accuracy in this type of situation. (2) As a result of the added difficulties of correctly identifying the plates of heavy vehicles, a more costly camera is often needed. This added cost should be included in the assessment of a system.

Another aspect on this topic is the recognition engine a system uses to identify plates. This engine should be sufficient for one's needs. The conditions at the time of the test should be identified when a vendor claims a certain accuracy rate. There are a number of factors that can lead to less accuracy in an ALPR system. Some of these include: vehicle speed, volume of traffic flow, ambient illumination, inter-vehicular spacing, weather, vehicle type, plate mounting, plate variety, plate jurisdiction, camera-to-plate distance, plate tilt, rotation, and skew, presence of a trailer hitch, communications pathway (1) In addition to these factors, there are other circumstances to consider. In some states, laminated graphic plates are being used to customize license plates with pictures, backgrounds and foregrounds. This presents an added challenge to an ALPR system. (1) A vendor should be aware of all of these factors and should be prepared to attempt to account for them.

Systems are generally externally or internally triggered. An externally triggered system uses a vehicle detector to tell the camera that a vehicle is present. The camera must then take a picture in the field of view most likely to contain the plate. If the plate is not in this field of view, the camera will not capture the plate. If the system utilizes an internal trigger, constant illumination is necessary. This often necessitates additional power requirements. Furthermore, the light needs to be infrared. Any system being purchased should have the capability of ultimately identifying all the different plate types in the United States. The system should be easily updateable for new plate types.(2) The most effective method for achieving this is a neural network with decision trees as another alternative. The ALPR system should be capable of handling 2300 vehicles per hour per lane of traffic covered. (2)

An additional factor involved in implementing a license plate reading system is public impact and resistance. These components are generally the same no matter which system is chosen, but should still be mentioned. The primary factor is safety. Studies have shown that often people tend to steer away from any roadside machinery they see. (2) This potentially could lead to hazards as people accustom themselves to video equipment along the roads. Another factor is that people may feel that their privacy

is being violated by video cameras placed along the highways. It needs to be clearly stated to the public that the equipment will only be used for license plate identification, and not for spying on people, tracking their travel habits, or any other uses. If people fear they are being spied on, they may resort to traveling along back roads that are not meant to support heavy traffic. Complicated legal issues could potentially evolve from a license plate reading system. In some cases people have used the data gathered with these systems to make money through selling the data to marketing firms. The appearance of impropriety must be avoided at all costs. Finally, there is the possibility of computer hackers and other causes of false information. If inaccurate information begins to cause problems amongst the public, again resistance will surface. (13)

The two main effects that camera equipment along the road for a weigh in motion system will have are speed reductions and lateral shifts. Motorists tend to slow down and move away from unfamiliar objects. This is a potential safety hazard. Therefore, the equipment should be placed as inconspicuously as possible. A system that is not capable of such placement is potentially dangerous. The best solution for this is a system that can be placed behind a guardrail, or some other roadside barrier. Another aspect of this is that the accuracy of the system will diminish as vehicles move away from the cameras. (2) The cameras are aimed at a certain section of the road and if vehicles move away from this area, some accuracy will be sacrificed. Acquiring images on larger vehicles poses a difficult problem for ALPRs. The surface area of the vehicles is larger, thus there is more opportunity for error. In one test, the ALPR system was only accurate 30-35% of the time in correctly interpreting the entire license plate, both state and number. (2)

CONCLUSIONS

Automated License Plate Reading systems have shown their worthiness as traffic data collection tools. Through image capturing and processing, ALPR's can give a user quick, and inexpensive data. As the field of automated data acquisition expands, more and more uses begin to arise. In choosing a system, one should consider mobility and simplicity of use, range of vehicle types that can be read, necessary lighting conditions, range of states of origin that can be read, range of vehicular volumes and speeds that do not overload the image processor, and human impact/public relations. All of these performance issues should be considered when purchasing this high-priced equipment.

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