ITS SUPPORTED PARKING LOT MANAGEMENT

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Abstract: In recent decades the number of vehicles in urban areas has rapidly increased causing problems such as traffic congestion and prolonged parking space search time. To overcome the problem of parking place search, large ground/underground parking lots have been built in city centres and other areas with high demand for parking space like office buildings, shopping malls, airports, etc. Driver information systems based on technologies developed within the intelligent transportation systems (ITS) have been implemented to inform the drivers about the number of free parking spaces and their distribution between different parking lots or between different levels in a particular parking lot. Such ITS based information systems use different sensors to detect car presence on a parking space like magnetic, infrared or ultrasonic sensors and belong to classical parking lot management systems. These sensors must be mounted on every single parking space and require significant installation and maintenance effort. Many parking lots also have installed cameras that cover most or all parking places used for surveillance purpose. To reduce parking lot management cost, installed cameras are being more and more used for parking lot management tasks like incoming and outgoing car counting, parking place occupancy detection, incident detection, parking lot security, and parking payment via license plate recognition. Such camera based systems have several advantages: high reliability (comparable to infrared sensors), one camera can cover a relatively large parking lot area, relatively small numbers of cameras are needed to cover the entire parking lot (number of classical sensors is equal to number of parking spaces), intelligent cameras with integrated embedded computer vision systems perform vehicle detection locally thus enabling easy integration into existing parking lot management systems, video footage can be used for additional purposes like person counting and recognition, surveillance, security, etc. This paper gives a review of existing computer vision based parking lot management systems. Implementation possibilities of additional ITS functionality (driver informing, driver navigation to a free parking space, parking lot usage statistics) are being analyzed. Problems of such systems are being investigated and possible solutions are evaluated. Comparison of vision system complexity to classical management systems is also given.

Keywords: ITS, parking lot management, computer vision, driver navigation system.

1. Introduction

Rapid economic and technical development enabled people all over the globe private ownership of a vehicle. While enabling people more freedom, shorter travel times and better utilization of their working and leisure time, mass ownership of vehicles is also constantly producing challenges for urban, traffic and road planers. Demand for wider and higher quality roads rises, crossroads have to be controlled, traffic rules have to be augmented, etc. One of the challenging demands, that today has still room for improvement, are places where vehicles can be left when not used or parking lots. They have to be placed in areas with high parking space demand and offer appropriate capacity (Maršanić et al. 2010).

Parking lots can be owned by several persons (every vehicle owner has its own parking place in the parking lot) or by only one person or company. When a large parking lot is owned by only one person or company, economic revenue of that parking lot is crucial. Therefore they are built in areas with high vehicle and people circulation like shopping malls, airports, business centres, tourist resorts, intermodal traffic junctions, etc. Parking lot owner and user share the same goal, i.e. to provide/find free parking space at the most convenient place. Both have a need for a parking lot control system that monitors and informs about the quantity of free parking spaces, ensures safe usage, navigates individual users to reserved parking space or parking lot nearest to the final goal, and ensures accurate payment according to time the vehicle spent on the parking place.

Such parking lot control systems have to work individually and as part of a wider urban parking system. They are usually built under the measure->process->react control framework to bring the whole system into desired reference state. In this case, the desired reference state is a road traffic area with satisfied traffic users (drivers and pedestrians), traffic without congestion at parking lot entry or exit area and minimal traffic induced by vehicles searching for a free parking space. It is necessary to mention here that traffic induced by vehicles searching for free parking space can present a significant amount in dense urban areas - up to 30% or more in extreme situations. Poor management of large parking lots can also cause traffic congestion and significant vehicle queues in parking entrance or exit area. In closed, underground parking lots this can lead to potentially dangerous situations for drivers' health due to vehicle exhaust gases.

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Integration of individual parking lots in an urban wide traffic control system is crucial in applying the intelligent transport system (ITS) framework in traffic control (Shaheen et al. 2005). The idea is to control the traffic in such a way as to reduce the build-up of significant traffic congestion or queuing areas or prevent it completely. For this functionality, measurement of driver behaviour, creating models for forecasting problematic situations and archiving traffic measurements for future examination is very important. Desired result is urban traffic with less congestion and fewer incident situations, less environment pollution, satisfied traffic users, etc. Drawback is that large areas have to be monitored in order to obtain data about traffic speed, traffic flow density, vehicle types, duration of peak traffic hours, including interval start and end time, significant number of various sensors, archiving large amount of data, etc.

To overcome mentioned drawbacks, starting in the last decade, vision systems are being more and more used for mentioned traffic parameters measuring tasks (ARH Inc., 2012). Statistical and artificial intelligence based methods are also being applied for reduction of representative data set archive size. Vision based traffic monitoring system have the advantage that one sensor can be used for various tasks like vehicle detection, traffic density measurement, traffic speed measurement, vehicle (license plate recognition) or pedestrian (face recognition) identification, detection of incident situations, origin-destination matrix generation in crossroads, and road condition measurement. Additional benefit is that such a system can also cover a larger area. This advantage is significant when relatively slow traffic, like the one in parking lots, has to be monitored. Cameras equipped with pan-tilt units and a night-vision system can be utilized to their maximum which will be commented in continuation of this paper.

This paper is organized as follows. Second chapter describes parking lot management problems followed by the third chapter that gives an overview of existing parking lot management systems. Fourth chapter describes possibilities of computer vision based parking lot management systems and the fifth chapter presents ITS functionality that can be applied with computer vision based parking lot control systems. Paper ends with a conclusion and authors' ideas for future work.

2. Parking lot management problem

The parking lot management problem can be viewed from several angles. Parking lot owners want to ensure appropriate economic revenue and protect their investment; drivers want to have a secure guarded place to leave their vehicle at a reasonable price; and authorities want the surrounding road traffic to be without congestion, moderate density and with minimal incident situations caused by the parking lot. Drivers are mostly interested in finding of a parking lot with free parking spaces near to their travel goal. Owners and authorities are much more interested in the influence of the parking lot on surrounding road area traffic, users' safety, and ensuring optimal usage of the parking lot (enough available parking places in peak traffic hours and profitable parking lot occupancy in off-peak traffic hours).

To achieve this goal, each parking lot has to be equipped with a control system that enables monitoring of the number of free and occupied parking places and informing potential parking lot users about the parking lot status (open with/without free available parking spaces or closed) locally and in a wider area. Additionally, it is preferable that the systems contains driver navigation to a parking lot with free parking spaces in an urban area and driver navigation to a free parking space in a parking lot, tracking of parking lot occupancy during parking lot working hours for further analysis, parking service payment according to parking time duration, and security monitoring of the parking lot to prevent damage from fire, air pollution or criminals. It has to be also ensured that the parking lot area is in a state suitable for safe usage by their users. There is also the feature of universality that has to be fulfilled so parts like RFID tags or radio transponders that require their placement on every vehicle that is using the parking lot, have to be avoided if possible. The term universality denotes here the possibility that every vehicle can use the parking lot without making any specific changes on it. Special cases are parking lots related to high security areas (government, financial, research and military facilities) where only certified users can access a certain part of the parking lot.

Such parking lot control system consist of a sensor module, measurement data processing module, control module, driver and authorities informing module, parking lot data archiving module, security module, and actuator module as given in Fig. 1. All modules are connected by a local communication network. Sensor module consists of various sensors that can measure needed parking lot management parameters. Measurement data processing module collects data from the sensor module and extracts crucial parking lot status data (number of free parking places, CO_2 concentration, temperature, lighting conditions, etc.). Control module processes measured data and makes decision about parking lot management (information signs data, data archiving, payment status, etc.). Driver informing module forwards relevant data to authorities and parking lot users.

Data archiving module saves relevant parking lot management data for further analysis regarding authority's investigations or parking lot owner optimization procedures. Security module is connected to prevention and processing of criminal acts in one part and in ensuring safety in the parking lot area in the other part. Actuator module consists of elements that can influence parking lot parameters like entrance and exit ramps, ventilation system, lighting, and fire extinguisher system.

Regarding mentioned demands on a parking lot management system, a system with several sensor, actuator and informing categories has to be used always.

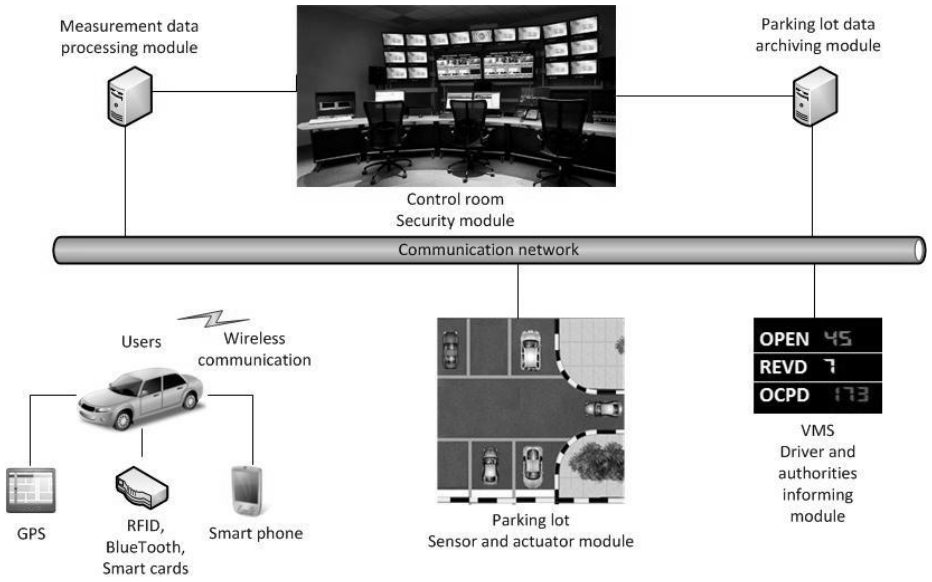

Fig. 1.
Parking lot management system modules

3. Existing Parking Systems

Parking systems can be divided into five major categories: Parking Guidance and Information Systems (PGIS), Transit Based Information Systems (TBIS), smart payment systems, E-parking and automatic parking systems (Shaheen et al. 2005). Every category uses various sensors regarding vehicle detection for parking lot status monitoring, driver informing and parking usage payment related tasks.

3.1. Parking Guidance and Information System

PGIS use variable message signs (VMS) to provide drivers with information on the location and the availability of parking spaces in parking lots (Sakai et al. 1995). Every PGIS consists of four mayor components: information gathering module, information disseminating module, control centre, and telecommunication network. The implementation of PGIS can include an entire city area or only a particular car park facility. Both implementations provide information which aids the decision making process of drivers in reaching their destination location and in locating a vacant parking space within a parking lot. The city wide PGIS is indeed helpful in assisting drivers navigating to a parking lot with vacant parking spaces via the information occupancy status for various parking lots around the city. PGIS implemented within a parking lot provides guidance in locating a vacant parking space within the parking lot (Shaheen et al. 2005). Vehicle and parking space detectors used in booth PGIS implementations include loop detectors, machine vision, ultrasonic, infrared, microwave and laser detectors (Idris et al. 2010).

3.2. Transit Based Information System

TBIS provides parking space information and public transport schedules in Park and Ride facilities. The systems main purpose is to encourage commuters to park their vehicles and use other public transport modes for their transit. This in turn reduces traffic congestion, pollution, and fuel consumption. Transit Based Information System is very similar to PGIS regarding used vehicle detectors. It also uses VMS to provide information. The difference exists in the fact that the TBIS concentrates on guiding drivers to park-and-ride facilities (Idris et al. 2010).

3.3. Smart payment system

The smart payment system presents an advanced payment system to replace conventional parking meters and payment systems. Conventional parking lot usage payment methods cause delays and inconveniences for the users and personnel as they have to deal with cash. So the usage of a smart payment system reduces maintenance and staffing requirement for payment handling purposes as well as for parking lot management (Chinrungrueng et al. 2007). The smart payment system can be based on contact or contactless methods. Contact methods involve using smart, debit or credit cards. Contactless methods involve using smart cards, RFID technologies, automated vehicle identification technology, and mobile communication devices. Contactless methods are much faster but require appropriate infrastructure by both, parking lot management system and users.

When this payment system is used, conventional vehicle detectors are not necessary. These systems have security issues regarding the fact that some of used technologies like RFID are vulnerable to exploits, malwares and worms attacks (Idris et al. 2010). Additional data encryption can minimize this drawback. Smart payment systems are usually used as a module integrated as part of an existing parking lot management system.

3.4. E-parking

E-parking systems provide information about car parking space availability and allow parking space reservation at a desired parking lot. A driver can ensure the availability of a vacant car park space when he arrives at the desired parking lot. Accessing the system can be done using a smart phone, personal digital assistant, short message service or through Internet. The system must be able to identify the customer that made the reservation or its vehicle and allow them access to reserved parking space (Chinrungrueng et al. 2007). There are many different implementations of the user identification process. Some examples are a confirmation code access received on the customer cell phone, printed receipts, smart cards, magnetic cards and Bluetooth based identification. E-parking has additional benefits like simpler payment mechanism of aforementioned smart payment system whereby payments by the parking lot users are made hassle free using e-payment technologies discussed previously (Idris et al. 2010).

3.5. Automatic parking system

Automatic parking systems use computer controlled mechanisms which allow users to drive up to the entrance bay, place their car in a specially designed cradle, lock their car and let the system automatically place the vehicle in allocated parking space. To retrieve their car, users only have to insert a code and password. The mechanical system retrieves their vehicle automatically. Goal of an automatic parking system is the efficient use of expensive and limited parking lots in dense populated urban areas. Because vehicles are moved and placed in an assigned container-like parking place by manipulators, the whole parking lot needs a relative small building area. Needed area used in conventional parking lots for car driving can be mostly used for additional parking places. Automatic parking systems are very popular in developed countries such as Japan, United States and Canada (Shaheen et al. 2005). As the car park facility is designed with conveyer belts, rotatable lifts and shuttles, whole system has to be coordinated to ensure successful and safe placement and retrieval of the vehicles (Idris et al. 2010). Such systems use a variety of vehicle detectors ranging from infrared, ultrasonic, microwave to laser detectors. Since vehicle cradles are made of metal, inductive and magnetic sensors are inappropriate due to significant magnetic interference. Vision sensors are mostly used for surveillance purposes.

3.6. Analysis of existing parking systems

The parameters used in the comparative analysis of existing parking systems are sensors, efficient use of parking space, financial investments, driver informing and customer satisfaction.

Initial implementations of PGIS in the early 1970s provided only information about free parking zones around the city using an inductive loop for tracking available parking spaces. In recent implementations, PGIS provide more specific information such as directions to empty parking lots and precise location of available parking places for city zones, parking facilities, and on-street parking. Infrared, ultrasonic, microwave and laser detectors are used for the detection of available parking places. Some PIGS implementations have also the ability to learn from historical data to forecast parking demand by time of day. The characteristics of this parking lot management category are reduced parking queues; relatively high understanding of driver information signs; and visitors to a city are more likely use PGIS than regular commuters. Drawback of such systems is that travel time and corresponding economic benefits are relatively small for such a complex system.

Transit Based Information System are designed and implemented to increase the benefits of PGIS, including increased use and revenues of transit systems, and reduced vehicle travel and air pollution. Small number of parking space at suburban rail stations may be a significant constraint to transit ridership. For that reason en-route information on parking space availability at transit stations may have a significant effect on transit ridership. Except information about number of available empty parking spaces, this system provides information about next public transportation departure time. Additionally, suggestion information type, whether it is better to use transit when alternate roadway routes are congested can also be provided. Such suggestions help drivers to decide in advance if they should leave their car and complete their journey by public transportation or continue all the way by car. For the detection of available parking spaces such systems uses sensors like PGIS systems and can also forecast parking demand by time of day using historical data. Apart from providing information to drivers, these systems also enable the reservation of parking space via Internet or phone.

Traditional parking payment methods typically have high operational and maintenance costs. The smart payment system has the advantage of available technology as to reduce operation, maintenance and enforcement costs as well as to improve customer convenience and make parking payment simpler. It also efficiently uses existing parking spaces to facilitate fast, convenient and reliable reservations and parking payment.

E-parking is an innovative business platform, which allows drivers to acquire parking availability information for a given destination, reserve an available parking space and pay for parking upon departure, without ever leaving their cars.

An automated parking system has a high initial cost but price is competitive considering the provided quality of service. The savings in required building space are about 50% compared to conventional parking lots in areas where parking space is scarce and expensive. This kind of parking lot management does not require special ventilation systems for vehicle emissions, because the vehicles are transported with the car engines turned off and the parking area is without human presence. The highest advantage of this system is security. Users avoid walking through empty parking lots or unsafe streets at night, crashes caused by improperly parking and car thefts are avoided. Furthermore, this kind of parking lot is also suitable for persons with disabilities without extra cost. The parking lot is equipped with vision sensors for surveillance purposes, and if any unusual motion is detected like a child or pet that was forgotten in the back seat, the parking systems will warn the user and refuse to operate until the unsafe situation is resolved.

4. Computer vision based systems

Computer vision based systems for parking lot management are currently active areas of research. As mentioned above, existing parking management implementations use such systems to a certain extent and in combination with other sensors. Computer vision based systems became particularly important in parking lot management systems mainly due to their fast response, easy installation, operation, maintenance, and their ability to monitor wide areas when information gathered at one camera location can be linked to another camera (Bong et al. 2008). In early systems, video cameras were used only for basic video surveillance of the parking lot which is today a standard part of nearly every parking lot. Today's parking lot management systems use video image processing to automatically analyze the scene of interest and extract information regarding parking lot occupancy, license plates and other traffic data of interest. A video image processor (VIP) system usually consists of one or more cameras, a microprocessor-based computer for digitizing and processing of the imagery, and software for image interpretation. Addition of a VIP provides additionally management and information functionality to parking lots with basic vision surveillance systems (Idris et al. 2010).

A vision based parking system enables the surveillance of a whole parking lot and can additionally count occupied and empty parking spaces. Furthermore, it also has the possibility to monitor the status of each individual parking space and to guide a car to a vacant parking space in an intelligent way. Thus it increases the efficiency of parking lot management systems and enables drivers to quickly park their vehicles without too much effort. Second thing which this technology can enable is tracking of time spent at a parking lot for every individual vehicle. Consequently it is necessary to recognize license plates for unique identification of every vehicle, saving arrival time and time of departure. It allows integration of smart payment systems into an existing parking lot.

To ensure high profitability of video surveillance, every video camera should cover as many parking spaces within its field of view as possible. However, the problems with indoor parking lots are numerous barriers which can reduce the camera's field of view. For that reason, the number of necessary cameras is usually increased.

Video surveillance is more useful at outdoor parking where cameras are placed at higher mounting locations ensuring a wider field of view over the parking lot. Major problem of outdoor surveillances are variable weather conditions which influence performances of such a system. Other problems are shadow effects, occlusion effects, change of lighting conditions and perspective distortion. Variable light intensity is one of the major challenges in a vision based detection system (Fleyeh, 2010).

4.1. The complexity of the system

Vision based parking system faces the challenges of multi scale information gathering, contextual event detection and the deployment of large systems (Hampapur et al. 2005). System complexity is related to the hardware and software part. Hardware part consist of several camera sensors, network and server infrastructure. Several servers are needed for image processing, data archiving and information dissemination. The majority of computational power is used for image processing and high level data extraction (vehicle and incident situations recognition, parking lot occupancy computation, license plate recognition, etc.). This presents a drawback of such a system which can be overcome by the usage of parallel and distributed computing. Unlike classical parking lot management systems, computer vision system generates large amounts of various data. Such data are in the form of raw video footage or extracted high level data. Cloud based data storage presents a very efficient solution for storing significant amount of video data.

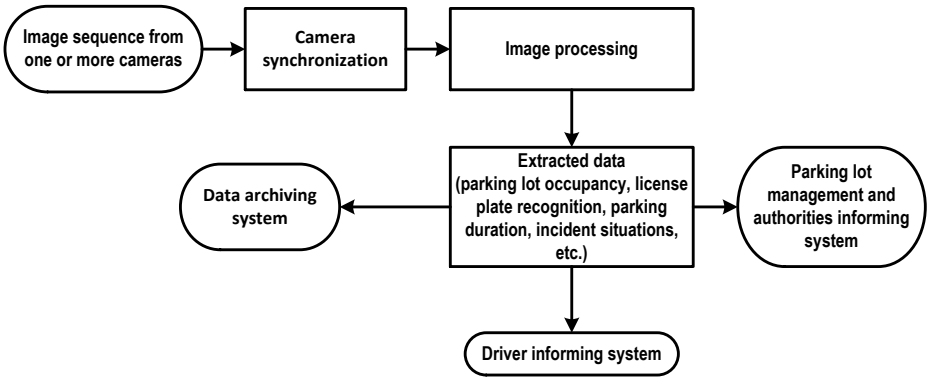

Fig. 2.
Flowchart of a vision based parking lot management system

Basic flowchart of a vision based parking lot management system is shown in Fig. 2. Due to the limited field of view, a camera synchronization algorithm is used to integrate visual cues from multiple cameras to make a panoramic scene construction of the whole parking lot. Such an approach is needed if more than one camera is used. After that, software for image processing and data extraction computes variables of interest using the parking lot panoramic scene. For possible further analysis, extracted data are stored in an archiving system. Last step consists of information dissemination to parking lot management, authorities and to the driver information system.

4.2. Existing systems based on computer vision

Basis for every computer based parking lot management system is the occupancy parking lots recognition, also known as the Car Park Occupancy Information System (COINS). After processing the information about parking lot occupancy and collected archiving data on a central computer system, extracted information is forwarded to a driver information system. Most popular driver information systems are display panels that are located at strategic locations in the parking lot but nowadays they can be provided by using smart phones, web technology, etc. COINS can be based on four different categories of technology: counter-based, wired sensor-based, wireless sensor-based and computer vision-based (Bong et al. 2006). In contrast to other technology, computer vision-based system have the possibility to provide exact information about location of a vacant parking place without installing a sensor at each individual parking space.

4.3. License plate recognition

Unique identification of every single vehicle can be made universally available by using license plate recognition (LPR) systems. LPR plays an important role in numerous applications such as unattended autonomous parking lot surveillance, security control of restricted areas, traffic safety enforcement, statistical analysis, etc.

A typical system for LPR consists of four parts: vehicle image acquisition, license plate localization and segmentation, character segmentation and standardization, and license plate characters identification (Anagnostopoulos et al. 2008, Romić et al. 2012). The license plates localization processing step is crucial for the entire system because it directly influences the accuracy and efficiency of all subsequent recognition steps. Researchers have proposed many methods for license plates localization in order to extract the license plate areas. Some of them are: edge detection methods, line sensitive filters, the window method and the mathematics morphology method. For the license characters identification also a large number of techniques, such as Bayes' classifiers, artificial neural networks, support vector machines, and K-nearest neighbour classification are used (Wen et al. 2011). These algorithms can also process the license plate segmentation part and recognize license plate characters.

First LPR systems were problematic due to low resolution analog video signal, small available computational power and license plate configurations not suitable for computer based vision recognition. With technology advancement of computational power, usage of intelligent cameras that include built in basic image processing functions and adaptation of license plate configuration these problem are now overcome. Current LPR systems are suitable for real-time application with vehicle speeds up to 250 km/h (ARH Inc., 2012).

5. ITS functionality

There exists an interconnection of standard ITS and parking lot management functional modules. Both systems share the functional modules related to traffic state measurement, measured data processing and archiving, payment system, and traffic user information. From this interconnection arises the need for integration of both systems. Most significant importance regarding ITS based integration of parking lots into a wider urban traffic area is related to driver information and navigation systems. Such driver information systems have two modes: (i) mode related to informing and navigating drivers searching for a parking lot, and (ii) mode related to informing and navigating in a parking lot to a free parking space. For both purposes variable message signs presenting number of free parking spaces and distance to particular parking lot/space are used. These systems are today common in larger cities or larger parking lots.

Today's increased traffic density and time efficiency demands additional functionality regarding general traffic control and parking lot control. One such driver assistant functionality is automatic assignment of a free parking place to a vehicle when it enters a parking lot. Camera vision sensor combined with vehicle license plate recognition present a good combination for such a task. Each vehicle has a unique license plate which can be recognized using a computer vision based license plate recognition system. Each vehicle can then be tracked when driving to assigned parking space and informed on crucial turns to stay on the optimal route to prevent unnecessary time and fuel waste in searching for assigned parking space. Also, control system can easily detect driver error and change the variable message signs display to help the driver to correct its error without violating traffic rules or to guide him to a different assigned parking place. Additionally, such a control system can recognize frequent users or users with special needs like disabled persons, woman drivers or families with children. After recognition, control system can assign appropriate parking place near elevators, guarded areas, shopping or entertainment areas.

Authorities and parking lot owners have the need to include functionalities related to traffic incident detection and monitoring of the parking lot. This functionalities are also part of ITS because today's vehicles are still driven by humans and incident situations due to driver error can occur. Such situations are related to speeding, illegal turns, illegal parking, driving in wrong direction, minor accidents and abuse of parking lot purpose. Vision system combined with data archiving module and license plate detection systems is a significant help to authorities and drivers in prevention or solving incident situations and damage compensation related to minor accidents, especially regarding the fact that in a parking lot vehicles are parked closely together and the probability for finding a witness for incident reconstruction is very low. Another important issue is helping parking lot users in cases of medical or similar emergencies. Vehicle stopped in a driving area longer that a certain amount of time can be recognized by the control system and appropriate action can be taken. Parking lot personnel can then inspect the incident vehicle using a pan tilt camera with zoom function, contact the driver and dispatch appropriate assistance.

A significant problem to parking lot owners can be the abuse of parking lot purpose. This can often happen in parking lots close to shopping malls, touristic resorts and large companies where control system is kept rather simple to cut costs and alleviate its usage. Drivers searching for a free parking place and a different destination occupy the parking lot and its designated users are left without a parking space.

Again, usage of the surveillance video footage in combination with a license plate recognition system connected with a designated user data base can be used for statistical analysis of parking lot usage. Individual user behaviour can be monitored during longer periods thus creating trends needed for planning purposes without significant financial investment.

6. Conclusion and future work

This article gives an overview of parking lot management systems with emphasis on computer vision systems. Requirements for such systems are discussed in terms of ITS and their application possibilities regarding universality. In this term, universality means that no additional components have to be added or mounted on a standard road vehicle. Current state of the art of parking lot management systems provides today's drivers with a more comfortable travelling experience and with less time spent in an appropriate parking lot search. Comparison of different parking lot management systems relying on non-vision sensors reveals that a significant economical, construction and maintenance effort is needed in order to retrofit or build a controlled parking lot. The effort is mostly related to the number of necessary sensors and their wiring.

Computer vision systems for parking lot management and corresponding driver information systems enable a relative economical and fast upgrade of uncontrolled parking lots. The used vision sensor camera, with or without a pan-tilt unit, can cover a larger parking area while also providing additional high level information. Therefore the needed number of necessary sensors and amount of wiring can be reduced. Drawback of such systems is that individual parking places have to be labelled manually in the system commissioning. Outdoor environment influence can also be problematic for such systems and further robustness on lighting condition change, wheatear influence, and high level object recognition improvement is needed.

Authors future work will be related to building a simulation environment for a computer vision managed parking lot. It will consist of a small scale testing model for indoor usage, and a full scale outdoor parking lot. Aims of the author future research include creation of a video footage data base of typical situations in parking lots (different weather conditions, driver behaviour, different lighting conditions, etc.), automatic detection of individual parking places in a parking lot, incident detection, and system robustness regarding outdoor usage improvement.

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References

Anagnostopoulos, I.E.; Psoroulas, I.D.; Loumos, V.; Kayafas, E., 2008. License Plate Recognition from Still Images and Video Sequences: A Survey. *IEEE Transactions on Intelligent Transportation Systems* 9 (3): 377 - 391

ARH Inc., 2012. CARMEN FreeFlow ANPR/LPR Software Technical Specifications. Available from internet: <http://www.arhungary.hu/contleft/1011/content.htm >.

Bong, D.B.L.; Ting, K.C.; Lai K.C., 2008. Integrated Approach in the Design of Car Park Occupancy Information System (COINS), *IAENG International Journal of Computer Science* 35 (1): 7 -14

Bong, D.B.L.; Ting, K.C.; Rajaee. N., 2006. Car-park occupancy information system, In *Proceedings of 3rd Real-Time Technology Application Symposium*, 65 -70.

Chinrungrueng, J.; Sunantachaikul, U.; Triamlumlerd, S., 2007. Smart parking: an application of optical wireless sensor network. In *Proceedings of the 2007 International Symposium on Applications and the Internet Workshops (SAINTW'07), Hiroshima, Japan*, 66-69.

Fleyeh, H. 2010. *Traffic Sign Recognition.* Lambert Academic Publishing AG & Co. KG, Germany. 239 p.

Hampapur, A. L.; Brown, J.; Connell, A. E.; N. Haas et al., 2005. Smart video surveillance: Exploring the concept of multiscale spatiotemporal tracking. *IEEE Signal Processing Magazine* 22: 38-51.

Idris, M. Y. I.; Leng, Y. Y.; Tamil, E. M.; Noor N. M.; Razak, Z., 2009. Car Park System: A Review of Smart Parking System and its Technology, *Information Technology Journal* 8 (2): 101-113.

Maršanić, R.; Zenzerović, Z.; Mrnjavac, E., 2010. Planning model of optimal parking area capacity, *Promet – Traffic&Transportation* 6 (22): 449-457

Romić, K.; Galić, I.; Baumgartner, A., 2012. Character recognition based on region pixel concentration for license plate identification. *Tehnički vjesnik – Technical gazette* 19 (2): 321-325

Sakai, A.; Mizuno, K.; Sugimoto, T.; Okuda, T., 1995. Parking guidance and information systems. In *Proceedings of Vehicle Navigation and Information Systems Conference in Conjunction with the Pacific Rim TransTech Conference, 6th International VNIS*, 478-485.

Shaheen, S.A.; Rodier, C.J.; Eaken, A.M., 2005. Smart parking management field test: A bay area rapid transit (BART) district parking demonstration. Available from internet: <http://pubs.its.ucdavis.edu/download_pdf.php?id=44>.

Wen, Y.; Lu, Y.; Yan, J.; Zhou, Z.; von Deneen, K.M.; Shi, P., 2011. An Algorithm for License Plate Recognition Applied to Intelligent Transportation System, *IEEE Transactions on Intelligent Transportation Systems* 12 (3): 830-845