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Car Park System: A Review of Smart Parking System and its Technology

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Abstract: Due to the proliferation in the number of vehicles on the road, traffic problems are bound to exist. This is due to the fact that the current transportation infrastructure and car park facility developed are unable to cope with the influx of vehicles on the road. To alleviate the aforementioned problems, the smart parking system has been developed. With the implementation of the smart parking system, patrons can easily locate and secure a vacant parking space at any car park deemed convenient to them. Vehicle ingress and egress are also made more convenient with the implementation of hassle free payment mechanism. With vehicle detection sensors aplenty on the market, the choices made may defer due to the different requirements in addition to the its pros and cons. Subsequently, the various sensor systems used in developing the systems in addition to the recent research and commercial system on the market are examined as vehicle detection plays a crucial role in the smart parking system.

Key words: Car park system, intelligent transportation system, parking technology, smart parking system

INTRODUCTION

In the year 2006, 458,293 new registered vehicles were reported compared to the year 1999 where there were only 296,716 new registered vehicles, which makes it a rough estimate of 54.5% increase in a span of 7 years (Malaysian Ministry of Transportation, 2007). Referring to the aforesaid statistics provided by the Malaysian Ministry of Transportation, the current transportation infrastructure and car park facilities are deemed insufficient in sustaining the influx of vehicles on the road.

Therefore, problems such as traffic congestion and insufficient parking space inevitably crops up. In Asia, the situation are made worse by the fact that the roads are significantly narrower compared to the West (Inaba *et al*., 2001). Various measures have been taken in the attempt to overcome the traffic problems. Although, the problem can be addressed via many methods, the paper focuses on the car park management system introduced, which is the smart parking system. This study will review the evolution of vehicle detection technologies as well as the detection systems developed over the years.

SMART PARKING SYSTEM

The smart parking system implemented mainly in the Europe, United States and Japan (Shaheen *et al*., 2005) is developed with the incorporation of advanced technologies and researches from various academic disciplines. With its deployment in the car park, it is hoped that it would solve the aforementioned problems faced by the patrons within the car park.

Advantages of smart parking system implementation: The smart parking system is considered beneficial for the car park operators, car park patrons as well as in environment conservation (Shaheen *et al*., 2005; Chinrungrueng *et al*., 2007). For the car park operators, the information gathered via the implementation of the Smart Parking System can be exploited to predict future parking patterns. Pricing strategies can also be manipulated according to the information obtained to increase the company's profit. In terms of environment conservation, the level of pollution can be reduced by decreasing vehicle emission (air pollutant) in the air (Shaheen *et al*., 2005). This can be attributed to the fact that vehicle travel is reduced. As fuel consumption is directly related to vehicle miles travelled, it will be reduces as well.

Patrons are also able to benefit from smart parking system as parking space are able to be fully utilized (Kurogo *et al*., 1995; Sakai *et al*., 1995) with a safer (Shaheen *et al*., 2005; Chinrungrueng *et al*., 2007), optimized and more efficient system implemented (Sakai *et al*., 1995; Shaheen *et al*., 2005). The system is made more efficient as vehicle travel time and search time are significantly reduced due to the information provided

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by the smart parking system. With the information provided, drivers are able to avoid car park that are fully occupied and locate vacant parking spaces with ease elsewhere. The number of vehicles parked illegally by the roadside which leads to traffic congestion is also reduced as it is absorbed into the car parks (Kurogo *et al*., 1995). Most importantly, traffic congestion can be reduced. All this would eventually lead to convenience for the patrons.

Categories of smart parking system: The smart parking system can be divided into five major categories: namely, Parking Guidance and Information System (PGIS), transit based information system, smart payment system, E-parking and automated parking (Shaheen *et al*., 2005). Further discussion on the implementation and characteristic of each of the smart parking system category together with examples of its implementation around the world will also be provided.

Parking Guidance and Information System (PGIS): The implementation of Parking Guidance and Information System (PGIS) encompasses two major categories. The PGIS can either include the entire city area or function only within the car park facility (Shaheen *et al*., 2005). Setting aside the differences, both the PGIS implemented in many major cities in Europe, Japan, the United Kingdom and the United States (Kurogo *et al*., 1995; Sakai *et al*., 1995; Shaheen *et al*., 2005; Mouskos *et al*., 2007) offer similar advantages similar to those of smart parking system as discussed earlier. Both provides information which aids the decision making process of the drivers in reaching their destination location and aids them in locating a vacant parking space within the car park facility. The city wide PGIS is indeed helpful in assisting drivers to car park with vacant parking spaces via the information occupancy status for various car parks around the city as well as other relevant information. On the other hand, guidance in locating the vacant parking space within the car park is ultimately provided by PGIS implemented within the car park.

PGIS can be summarized as consisting of 4 major components: namely, information disseminating mechanism, information gathering mechanism, control center and telecommunication networks similar to the components stated by Mouskos *et al*. (2007). Static/dynamic Variable Message Signs (VMS) have been used in providing drivers with direction either on the road or within the car park. For guidance on the road, various implementation methods can be adopted. For example, the system in Shinjuku and Pittsburgh, Pennsylvania segregates the city area into color coded areas for in providing guidance (Kurogo *et al*., 1995; Shaheen *et al*., 2005). The PGIS in Pittsburgh, Pennsylvania also functions in directing drivers to special attraction in the area. Meanwhile, in Yokohama, Japan, the city is divided into four zones whereby the information specificity increases with each zone that the driver cross to arrive at the destination location. Additional information on traffic flow provided by the Aichi Prefectural Police Headquarters Traffic Control Center and Japan Highway Public Corporation Nagoya Department is also provided by the system implemented in Toyota, Japan (Sakai *et al*., 1995).

Mobile phones can also be used for guidance based on the research conducted by Idna and Tamil (2007) which utilizes Global Positioning System (GPS) for vehicle detection. A map of the driver's current position based on the GPS data along with the status of three of the nearby car park are sent to their mobile phones based on the patron's current location. The GPS technology used are discussed in detail by Tamil *et al*. (2007). Besides that, the parking guidance system developed based on web and GIS technology (Liu *et al*., 2006) are able to disseminate information to the users via internet, mobile phones and/or PDA. The guidance system can be with the conventional parking management system as well. In order to guide the patrons effectively, the car park map is printed on the parking ticket equipped with Radio Frequency Identification (RFID) tags for guidance (Idna *et al*., 2008) so that patrons can locate the assigned parking slot with ease. There are also no worries about forgetting the location of the assigned parking slot during exit.

Vehicle detection sensors are commonly installed at entrances, exits and/or individual parking space to detect vehicle occupancy. Indicator lights integrated with sensors are also sometimes installed at every individual parking space within the parking facility. The occupancy status detected by the sensors can either be occupancy of each individual parking space or in terms of vehicles counts in the car park depending on the installation of the sensors. Moving on, the control center gathers and processes the traffic and occupancy information as well as controls the display of information for drivers whereas the telecommunication network facilitates the transfer of information among the other three modules (Mouskos *et al*., 2007). With the advent of advanced technologies, the implementation of devices such as microcontroller and Field Programmable Gate Array (FPGA) are incorporated for faster information processing. Not only that, the telecommunication network no longer dependent on conventional electrical wiring but wireless technologies are able to be utilized. Researchers such as Wang and Chen (2004), Bi *et al*. (2006), Liu *et al*. (2006), Tang *et al.* (2006), Idna *et al.* (2008), Lee *et al.* (2008) and Seong-Eun *et al.* (2008) have all used wireless network for data transfer in the implementation of their proposed parking guidance system.

Transit based information system: The functionality of transit based information system implemented in countries such as France, Germany, Ireland, Japan, Switzerland, the United Kingdom and the United States (Shaheen *et al.*, 2005) is actually similar to PGIS. The difference exist in the fact the Transit Based Information System concentrates on guiding user to park-and-ride facilities. It provides real-time information on the status of each car park and public transportation such as the schedules and traffic condition to the public. The additional information provided enables the patrons to plan for transit in advance without getting into any inconvenience (Chinrungrueng *et al.*, 2007). Among its benefits includes increase in the utilization of public transportation as the primary means of transportation as they can leave their vehicle in the car park and switch to public transportation with ease. This will indirectly lead to an increase in the transit revenue (Shaheen *et al.*, 2005; Chinrungrueng *et al.*, 2007).

No doubt, for the transit based information system to achieve success in its implementation, proper planning must be conducted. This is especially true in selecting the location for the park-and-ride car parks that maximizes transit whereby the concept of catchment area/commutersheds are often used such as indicated by Horner and Groves (2007). In the network flow-based technique introduced, it improves on the conventional spatial model used in determining the park-and-ride facility location by taking into consideration the traffic flow and works in reducing the vehicle miles travelled by maximizing the interception of vehicle during the beginning stage of the journey.

There have been many research centered upon using Geographic Information System (GIS). Among them are the research conducted for siting park-and-ride car parks in Columbus, Ohio. Farhan and Murray (2008) incorporated multi-objective spatial optimization model in locating the park-and-ride facilities while considering numerous objectives and constraints as well as taking into consideration the existing system. While research by Farhan and Murray (2008) made no assumption on user demands, Horner and Grubesic (2001) used Principal Component Analysis (PCA) in representing the index of user demands which will be converted to demand points when coupled with information obtained via Geographic Information System (GIS). Subsequently, additional calculation conducted by Horner and Groves (2007) takes into account various other factors which includes: geographical, network, travel time from demand points to the location of the park-and-ride facilities and the constraints of computershed shapes are performed in determining the location and commutershed area for the park-and-ride lots.

Smart payment system: The smart payment system is implemented in the effort to overcome the limitation of the conventional payment methods by revamping the payment method via parking meter and introduce new technologies. This is because the conventional method causes delay and inconvenience for the patrons as they have to deal with cash. It also reduces maintenance and staffing requirement for payment handling purposes as well as traffic control (Chinrungrueng *et al.*, 2007). In general, the Smart Payment System implemented in places such as Finland, Italy, London and United States (Hinze, 2000; Shaheen *et al.*, 2005; Jones, 2006; Mouskos *et al.*, 2007) consists of contact method, contactless method and mobile devices. While the contact method involves the use of smart cards, debit cards and credit cards, the contactless method involves the use of contactless cards, mobile devices as well as Automated Vehicle Identification (AVI) tag whereby RFID technologies are utilized (Mouskos *et al.*, 2007). As contact methods requires contact of the cards with parking meter or payment machines in the facility, the latter offers more convenience to the patrons.

Parking meters have now been improvised with technologies which revolutionize the payment system via implementing various improvements such as the acceptance of various types of cards such as credit card, debit cards (Shaheen *et al.*, 2005) and smart cards (Hinze, 2000). It also incorporates other technologies such as having solar power source and wireless connectivity. The PhotoViolationMeter (Photo Violation Technologies, n.d.) which caters for various types of payment methods uses ground sensors in detecting vehicle presence. Most importantly, technologies such as WiFi connectivity (Photo Violation Technologies, n.d.), together with its ability in handling payment of fines and taking photos of vehicles which violates parking regulations for evidence are also incorporated (Ebling and De Lara, 2007). Personal parking meters which are essentially placed in the vehicle have also been introduced in Buffalo, New York and Aspen, Colorado after test studies have been conducted (Jones, 2006).

The incorporation of RFID technologies in making payments were implemented in commercial systems such as Mobipower Ltd., which utilized RFID-based cellular technology and EZPass system have also developed payment system via RFID for car parks and toll facilities (Mouskos *et al*., 2007). Similarity between the two systems exists in the requirement for placement of transponder unit in the vehicle. Moving on, the implementation of mobile devices such as mobile phones and PDA are normally seen to incorporate other devices such as parking meters and cards. For some systems such as those implemented in Groningen, Netherlands (Shaheen *et al*., 2005) and Oulu, Finland (Jones, 2006), prior registration via the internet is required. As mobile phones are utilized, the system implemented in Oulu, Finland also has the capability of sending Short Message Service (SMS) notification to remind the patrons that the time is almost due and allow them to settle the payment for the additional time extension required (Jones, 2006).

The main concern hindering the implementation of the Smart Payment System would have to be skepticism on the privacy and security issues. This is due to the fact that confidential data of the patrons such as personal information and probably account information are being dealt with which are highly confidential. With the emergence of various threats, it is justifiable to be worried. In RFID implementation alone, exploits, malwares and worms (Rieback *et al*., 2006a), as well as attacks such as sniffing, spoofing, replay attack and denial of services are just a fraction of it. Of course, methods have been developed in securing the data and overcoming the threats as is it discovered ranging from the cryptography, detection and evasion as well as temporary deactivation which are constantly improved from the conventional method implemented which dates back to World War II (Rieback *et al*., 2006b).

E-parking: E-parking provides an alternative for patrons to enquire the availability and/or reserve a parking space at their desired parking facility to ensure the availability of vacant car park space when they arrive at the parking facility. The system can be accessed via numerous methods such as SMS or through the internet. Some of the additional benefits of using the E-parking system aside from those collectively gained by smart parking system are that it can be extended easily to incorporate the payment mechanism of smart payment system whereby payments by the patrons are made hassle free using the technologies discussed previously. Customized information can also be provided to the patrons either before or during their trip to the car park (Shaheen *et al*., 2005).

In a study by Inaba *et al*. (2001), reservations can be made through the utilization of mobile phones or any reservation centers convenient to the patrons. On the other hand, the study by Hodel and Cong (2004) revealed

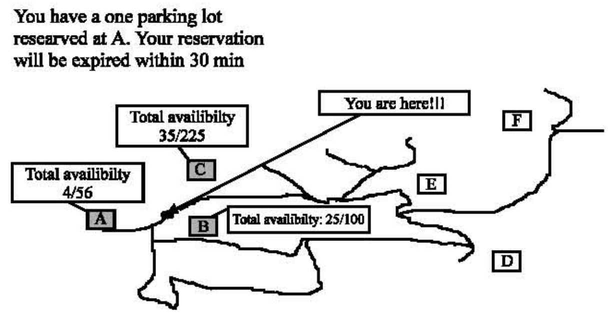

Fig. 1: Example of parking reservation system message

options of using the internet via Wireless Application Protocol (WAP) enabled mobile phones, Personal Digital Assistants (PDAs) and even conventional computer in addition to SMS service for the drivers in accessing the information as well as making reservations. Teodorovic *et al*. (2006) takes the implementation a step further by incorporating fuzzy logic in decision making whereby the parking reservation request can either accepted or rejected. It also facilitates the enforcement of tariff classes to enable the maximization of revenue for car park operators. The system discussed in (Idna and Tamil, 2007) is one of the systems integrating PGIS with E-parking system, where the patrons are able to reserve parking slots after reviewing the status of the car park and its proximity to the patron's current location. An example of the message to the patrons is shown in Fig. 1.

Thus far, numerous systems have been implemented online for city wide implementation, university campuses as well as complexes. Among the examples of companies involved in the development of E-parking system are companies such as ParkingCarma (ParkingCarma, n.d.), Click and Park (Click and Park, n.d.) and City and Suburban Parking Ltd., (City and Suburban Parking Ltd., n.d.). As the E-parking systems implemented online can also be considered as E-commerce applications, it has been proposed that the Unified Modeling Language (UML) is employed in modeling the system's performance. This can be achieved by converting the class diagram and sequence diagram to an execution diagram via an intermediary actor-event graph and combining it with other necessary information pertinent to the system (Geetha *et al*., 2007).

As observed, there are many different implementation methods that can be enforced by incorporating various technologies. Besides the difference in reservation method, different reservation types can also be enforced such as proposed by Inaba *et al*. (2001), whereby patrons can chose not to declare the exit time and park for an indefinite amount of time. To gain access in to the car park, printed receipts, permits or passes are utilized by the patrons. More sophisticated implementation proposed which requires the use of smart cards or magnetic cards (Inaba *et al*., 2001) and Bluetooth (Hodel and Cong, 2004) are also implemented in granting access to the patrons. It can also be implemented together with Smart Payment System payment schemes such as cards (Inaba *et al*., 2001; Hodel and Cong, 2004), pre and post paid methods as well as m-payment (Hodel and Cong, 2004) are utilized.

Automated parking: Automated parking involves the use of computer controlled mechanism, which allows patrons to drive up to the bay, lock the cars and let the machines automatically place the vehicle in the allocated space. This type of car park offers maximum utilization of space as it is machine controlled unlike conventional car park where space is needed for navigation of vehicle within the car park. Among its benefits are that the implementation works great in locations, where there are limited room for expansion due to its structure. Besides that, the Automated Parking System also offers efficiency in car storage as it allows car stacking and the patron does not even need to go into the car park which indirectly provides extra safety measures which covers both the vehicles and patrons (Shaheen *et al*., 2005).

Among the automated parking system reviewed in countries which includes Japan, Canada and United States (Shaheen *et al*., 2005) as well as the commercial system developed by companies such as automotion parking system (Automotion, n.d.), robotic parking (Robotic Parking, n.d.) and Fata SKYPARKS (Fata SKYPARKS, n.d.), it generally utilizes computer controlled mechanism in placing the vehicles in its storage bay within the parking facility. Automated parking can also be implemented in a conventional car park via additional equipments installed such as developed by Fata SKYPARKS (Fata SKYPARKS, n.d.). There are many variations whereby the automated parking system can be implemented, from the design of the car park structure to the workings of the computer controlled docks/lifts as well as the placement of vehicles whereby user participation are sometimes required.

The safety features are geared towards the vehicle whereby it is important to ensure that the vehicle remains safe and undamaged with all the handling by the computer controlled mechanisms. Research by Mathijssen and Pretorius (2007) introduced a three-level software design which includes: Logical Layer (LL), Safety Layer (SL) and Hardware Abstraction Layer (HAL) to enforce correct and efficient storage of vehicles in a safe manner. As the car park facility is designed with conveyer belts, rotatable lifts and shuttles, it has to be coordinated to ensure successful and safe placement and retrieval of the vehicle.

CAR PARK OCCUPANCY DETECTION

The smart parking system relies heavily on the car park occupancy information as it is not only used in assisting the drivers on the road, but in the management within the car park as well. There is abundance of sensor system that can be installed to provide this crucial piece of information. Having said that, there are many factors which can affect the occupancy detection such as sensor chosen car park type and layout, to name a few.

Vehicle detection technology: Vehicle sensors and detector system can be categorized into two main categories: namely, intrusive and non-intrusive sensors (Mimbela and Klein, 2007). Intrusive sensors are sensors which are typically installed in holes on the road surface, by tunneling under the road surfaces or anchoring to the surface of the road which leads to invasive procedures of installation whereas the latter can be installed easily by mounting the device on the ground or the ceiling of the car park. With the variety of sensors on the market, factors such as the cost, environmental condition, scale of implementation as well as the system design would have to be considered while selecting the sensors.

Examples of intrusive sensors include active infrared sensors, inductive loops, magnetometers, magneto-resistive sensors, pneumatic road tubes, piezoelectric cables and weigh-in-motion sensors. As denoted by its name, intrusive sensors typically requires pavement cut for installation which indirectly decreases pavement life. For installation and maintenance on the road, lane closure would have to be conducted, which would lead to inconvenience of the drivers (Chinrungrueng *et al*., 2006; Lenz and Edelstein, 2006; Mimbela and Klein, 2007; Mouskos *et al*., 2007).

On the other hand, non-intrusive sensors encompasses microwave radar, passive acoustic array sensors, passive infrared sensor, RFID, ultrasonic and video image processing. Non-intrusive sensors can easily be installed and maintained and does not affect the surface in the process. Unlike intrusive sensors, maintenance and installation for non-intrusive sensors can be conducted without invasive procedures and disruption of traffic (Kastrinaki *et al*., 2003; Mimbela and Klein, 2007). The description, strength and weaknesses of the various sensor technologies that are currently utilized in vehicle detection as compiled by Mimbela and Klein (2007) together with other research by Kastrinaki *et al*. (2003), Cheung *et al*. (2005), Chinrungrueng *et al*. (2006), Lenz and Edelstein (2006), Wolff *et al*. (2006), Mouskos *et al*. (2007) and Pala and Inanc (2007) will subsequently be scrutinized. Each of the sensors also has the ability to provide different detection parameters which are also discussed in the aforementioned studies.

Active infrared sensors: Active infrared sensors detects vehicles by emitting infrared energy and detecting the amount of energy reflected (Mimbela and Klein, 2007; Mouskos *et al*., 2007). By utilizing the active infrared sensors, multiple lane operations can be conducted. For an accurate measurement of vehicle position, speed and class, multiple beams are transmitted from the sensor. However, the drawback of the sensor would be its sensitivity towards environmental conditions such as fog or blowing snow which affects the operation of the sensors.

Inductive loop detectors: Inductive Loop Detectors (ILDs) are wire loops of various sizes which are exited with signals whose frequencies range from 10 to 50 kHz. The oscillation frequency of the inductive loop is directly controlled by the inductance of the loop which changes with vehicle presence. The sensor system proved to be a mature and well understood technology with large experience base and extensive research conducted. Besides that, its flexibility also allows for the implementation in a large variety of applications. The vehicle detection zone can be easily enlarged by combining the loops together. Compared with other commonly used techniques, ILD provides the best accuracy for count data. In fact, inductive loop sensors became the common standard for obtaining accurate occupancy measurements.

While the inductive loop detector has its advantages, it is not without flaw as it is expensive to maintain (Mouskos *et al*., 2007). Not only does it require multiple detectors to monitor a specific location, the Wire loops subjected to wear and tear due to stresses of traffic and temperature. Detection accuracy would also be compromised when design requires detection of a large variety of vehicle classes. While it is mentioned by Mimbela and Klein (2007) that it is insensitive to weather condition such as rain, fog and snow, Mouskos *et al*. (2007) has stated that the sensors are sensitive to element such as water, especially if the pavement is cracked.

Magnetometer (fluxgate magnetometer): Fluxgate magnetometers works by detecting perturbation (magnetic anomaly) in the earth's horizontal and vertical magnetic field. Fluxgate magnetometers provide the advantage of being insensitive to weather condition such as snow, rain and fog. It is also more accurate and less susceptible than loops to stresses of traffic. As the technologies for wireless transmissions evolves, wireless RF link are also used to transmit data in some models. Among the disadvantages of using fluxgate magnetometers are the small detection zones in some model which requires multiple units are required for full lane detection as well as the close proximity required for accurate detection (Cheung *et al*., 2005; Mimbela and Klein, 2007).

Magnetometer (induction or search coil magnetometer): Induction or search coil magnetometer identifies vehicle signature by measuring the change in the magnetic flux lines caused by the moving vehicle according to Faraday's Law of induction (Lenz and Edelstein, 2006; Mimbela and Klein, 2007). Like the fluxgate magnetometer, it is insensitive to weather condition such as snow, rain and fog. Besides that, it is less susceptible to stresses of traffic than loops. Special sensor layouts and signal processing software are required to identify stopped vehicles. While it is an intrusive sensor, some models can be installed without the need for pavement cuts.

Magnetoresistive sensor: As stated by Lenz and Edelstein (2006), magnetoresistive sensors encompasses: Anisiotropic Magnetoresistance Sensors (AMR), Giant Magnetoresistance Sensors (GMR), Magnetic Tunnel Junction Sensors, Extraordinary Magnetoresistance and Ballistic Magnetoresistance that are simply energized by providing a constant current (Lenz and Edelstein, 2006). The sensors are light and small which makes it versatile in placement (Wolff *et al*., 2006). Coupled with a wide range of temperature (-55 to 200°) and low cost, it has been widely used for vehicle detection. Wolff *et al*. (2006) have utilized the AMR sensor in their research for vehicle detection and has noted its sensitivity to position and orientation.

Piezoelectric sensors: Piezoelectric sensors are made from specially processed material that is able to convert kinetic energy to electrical energy when subjected to vibration or mechanical impact. Vehicle differentiation can also be conducted with extreme precision as additional information is gathered rather than the passing of vehicle alone. Not only that, it also provides a more accurate reading on vehicle speed and classification of vehicles based on weight and axle spacing with almost the same cost as ILD. Among the disadvantages would be the need to use multiple detectors to instrument a location. Besides that, it is also extremely sensitive to high temperature and traffic stress.

Pneumatic road tube: Pneumatic road tube detects vehicle via the air pressure created which closes a switch, producing signals when a vehicle pass or stop over the tube. While it offers a low cost solution as well as quick installation and easy maintenance, it has its disadvantages. Pneumatic road sensors are temperature sensitive. Inaccuracies in axle count are also bound to happen when bus and truck numbers are high. In addition, the tubes are prone to vandalism.

Weight-in-Motion (WIM) sensors: Weight-in-Motion (WIM) sensors are able to detect the weight of the vehicle whereby the data acquired are extremely useful to highway planner, designers and law enforcement agencies. The four technologies used in WIM system are: bending plate, piezoelectric, load cell and capacitance mat. Each of the WIM sensors has its own advantages and disadvantages. While bending plate WIM is more accurate and costly compared to piezoelectric WIM system, it is less accurate compared to load cell WIM systems and are considerable cheaper. Although capacitance mat can be used as portable or permanent, it is the least accurate WIM system. For accuracy, load cell WIM system would be preferable as it is the most accurate WIM system, with the disadvantage of it being the priciest. The cheapest WIM system in use is the piezoelectric system, with a weakness of sensitivity towards weather and speed variation. Its accuracy is behind load cell WIM and bending plate WIM system. Both the piezoelectric and capacitance mat WIM system can be used to monitor up to 4 lanes. All the WIM system requires replacement or refurbishment every 3 to 5 years.

Microwave radar: Microwave radar sensor transmits energy (1-30 GHz) through an antenna and detects vehicle by the energy reflected back towards the antenna. The two type of microwave radar sensors being implemented are: Continuous Wave Radar (CW) and Frequency Modulated Continuous Wave Radar (FMCW). Microwave radar sensors provide the advantage of being insensitive to inclement weather. It is also able to conduct multiple lane traffic flow data gathering as well as provide direct measurement of vehicle speed. Among its disadvantages is that the Doppler sensors would have to be equipped with auxiliary sensors in attempt to detect stopped vehicle.

Acoustic sensors: The acoustic sensors detects vehicle via the acoustic energy or audible sounds produced by the vehicle through microphones installed for vehicle detection. The advantages offered by acoustic sensors are support for multiple lane operation in certain models as well as passive detection. Not only that, it is also insensitive to precipitation. Its sensitivity towards cold temperature which affects data accuracy proved to be a drawback. Certain models are also not recommended with slow moving vehicles in stop and go traffic.

Passive infrared sensors: Passive infrared sensors identify the occupancy status of a parking space by detecting changes in the energy emitted by the vehicle and the roads (Mimbela and Klein, 2007; Mouskos *et al*., 2007). While the sensors are able to be implemented in a multizone environment to measure vehicle speed, the sensitivity of the sensor is reduced in heavy rain, snow and dense fog. Besides that, certain models are not recommended for presence detection.

RFID: The utilization of RFID as a method for vehicle detection in conducted in Mouskos *et al*. (2007). It is a universal, useful secure and efficient technology (Pala and Inanc, 2007) which consist of 3 units which are: transceiver, transponder and antenna. The transceiver is used to send and read information from the transponder unit which contains the coded information through the antenna. Active transponders are also re-programmable through wireless connection, while passive transponders have an unlimited lifetime. Radio signals eliminates the need for contact, no line of sight operation and are able to penetrate opaque structures. By using RFID sensors, it provides the means for low cost installation and maintenance as well as possible detection at high speed. The complication actually lies with the need to place transponders in every vehicle as well as privacy issues with the patron's personal details.

Ultrasonic sensors: Ultrasonic sensors transmits pulse waveforms between 25 to 50 kHz to the road by detecting transmitted energy which are reflected back the sensor. Together with a signal processing module, the reflected ultrasonic energies are analyzed to detect occupancy in a roadside controller. Its utilization brings the advantage of detecting vehicles that exceed certain height limit as well as multiple lane operation. The ultrasonic sensors are also easy to install without the need for facility closure. Degraded occupancy measurement on freeways with vehicles traveling at moderate to high speeds due to large pulse repetition period are one of the shortcomings of the sensor. Besides that, temperature changes and extreme air turbulence affects the sensor performance, although temperature compensation has been built into some models.

Video image processor: A Video image processor typically consists of: one or more cameras, software for image interpretation and microprocessor based computer for digitizing and processing. Careful analysis of continuous frames captured by the video image processor can be used in detection of vehicles as it reveals the differences between subsequent frames. The utilization of video image processor provides the ease of management (Kastrinaki *et al*., 2003) and implementation as it is readily available in most car park facilities with basic surveillance systems. Detection zones are also easily added and modified. Besides that, it can easily adaptable to space of any geometric shape for coverage optimization, with the detection zones easily added and modified (Mouskos *et al*., 2007). With the wide-area detection provided when information gathered at one camera location are linked to another, it caters for multiple lane detection and reduces the number of cameras needed for monitoring. The detection results garnered can also be verified offline and in real-time without the need for delay (Mouskos *et al*., 2007).

Although, it has many advantages, the CCTV cameras are only cost-effective if many detection zones are required within the field of view of the camera and good lighting available. Inclement weather, shadows, vehicle projection into adjacent lanes, day-to-night transition, vehicle/road contrast and water, salt grime, icicles and cobwebs on camera lens can affect performance, even though temperature compensation and built into some models. Camera motions due to strong winds might also affect some models. The height and layout of the car park facility might also pose a problem as occlusion (Mimbela and Klein, 2007; Mouskos *et al*., 2007) can occur at certain locations. While the video cameras are unaffected by construction or maintenance of the car park (Mouskos *et al*., 2007), the camera mounting height (in a side-mounting configuration) required for optimum presence detection and speed measurement are about 50 to 60" would definitely be a problem in car park facilities with low roof.

IMPLEMENTATION OF VEHICLE DETECTION TECHNOLOGIES IN SMART PARKING SYSTEM

By further examining the various smart parking system currently deployed as well as the commercial system on the market, it provides a brief idea on its implementation methods and sensor utilization. The different sensor placements as well as the implementation method of the particular system, albeit achieving the same end results of providing guidance to the patrons, are quite different. Information gathered on the various systems would definitely help in improvising and developing a better system.

PGIS: Ultrasonic sensors were employed in each individual parking space for vehicle detection in the Baltimore-Washington International Airport in the United States and Blagnac Airport in France (Shaheen *et al*., 2005). Over in the European continent, infrared sensor applications have been applied in Bristol, United Kingdom to identify vacant spaces and transmit the data to a central computer (Shaheen *et al*., 2005). In NJIT, inductive loops were deployed at the car park entrances and exits detection (Mouskos *et al*., 2007). It is mainly used in keeping track of the vehicle count in the car park. In the study proposed by the authors on PGIS within the car park, CCTV cameras were used in detecting the occupancy status of each of the parking space (Idna *et al*., 2008).

Moving on to commercial systems, industrial giants such as CODIC (http://www.parkingireland.ie/showart2.htm.), E and D (http://www.enctechgroup.com/E%20&%20D/xguide.html.), IDENTIPARK (IDENTIPARK, n.d.) and SIEMENS (SIEMENS, n.d.) have developed PGIS using ultrasound sensors for vehicle detection, whereas VehicleSense (VehicleSense, n.d.) are geared towards using magnetic sensors. All the commercial systems mentioned have the sensors placement location in common whereby the sensors are placed at each individual parking space for occupancy detection. It is also used to guide patrons to the respective vacant spaces through the overhead lights incorporated which changes according to the occupancy status. On the other hand, the system developed in Toyota guides patron through VMS to the available vacant space (Sakai *et al*., 1995).

Transit based information system: In the case of transit based information system, ultrasonic sensors and laser scan detectors were installed in Munich whereas inductive loops were deployed in the city of Cologne (Shaheen *et al*., 2005). The systems in Cologne and Munich, which is implemented city wide, both exploits the use of VMS in providing information to the patrons as well as guidance to car parks with vacant space. The guidance provided by the system in Munich proved to be more extensive whereby it continues to guide patrons to the vacant parking space with guidance system within the car park as well (Shaheen *et al*., 2005).

Smart payment system via RFID: Commercial systems such as EZPass as well as those developed by Mobipower Ltd are vastly different in implementation although RFID technologies are utilized. The only similarities are the requirement for the RFID device to be placed in the vehicle. System by Mobipower such as described by Mouskos *et al*. (2007), requires the patron to activate the RFID unit named Triffiq to start the transaction and deactivate it to indicate end of transaction. Charges will then be displayed although the actual payments are made when monthly bills arrive. On the contrary, EZPass system does not require any activation of the device and immediately deducts the payments from the patron's account although records of the patron's transaction are provided periodically.

IMPLEMENTATION OF VARIOUS VEHICLE DETECTION TECHNOLOGIES IN COMMERCIAL SYSTEMS AND RESEARCH

Subsequent discussion focuses on the implementation of various sensors vehicle detection both on the road and in the car park. As the sensors utilized are essentially the same, more focus will be emphasized on the different placements and any associated hardware devices used in conjunction with the sensors. Information on the different methodologies and hardware devices are provided whenever available in providing a brief overview on the various systems reviewed. Apart from the systems discussed a compilation of the commercial systems available on the market as well as those still in research is presented by Mimbela and Klein (2007) and Kastrinaki *et al*. (2003).

Magnetic sensor: Various researches have been conducted by utilizing the magnetic sensors which are typically used for vehicle detection whereby the complete listing of the type of magnetic sensors is provided in the research by Lenz and Edelstein (2006). In a research by Wolff *et al*. (2006), passive magnetoresistive sensors were installed both along the walls and on the floor. Microcontrollers were used to handle the communication with a master via connectivity through a RS485 bus so that the data can be transmitted to the PC for processing and displayed on the three VMS installed in the car park. The following research involves the implementation of magnetic sensors in a Wireless Sensor Network (WSN) environment. In the D-Systems Project by the Mobile Internet Systems Laboratory, University College York (Benson *et al*., 2006; Barton *et al*., 2007), the system consist of a microcontroller and antenna for communication in the communication layer, magnetic sensor in the sensing layer and lastly, 2 AA batteries in the power layer. As the hardware is implemented in a stackable platform whereby it can be easily combined and dismantled, a processing layer consisting of FPGA device were able to be added (Barton *et al*., 2007).

Unlike the D-Systems which concentrates on occupancy detection, implementation by Cheung *et al*. (2005) explored the functionality of vehicle detection, vehicle speed detection, vehicle classification and re-identification through installation in the car park and on the road. The sensor nodes consist of: microcontroller, magnetic sensors and radio which are powered by 2 AA batteries are implemented in a (WSN) environment. Both are similar in the fact that the sensors are installed at each individual parking space and implemented in a WSN environment. Besides that, the components utilized are similar with the exception of FPGA device utilization.

Optical sensor: In a research by Chinrungrueng *et al*. (2006, 2007), optoelectronic sensors which reacts to light are utilized in vehicle detection. Each sensor nodes consist of optical sensor, a microcontroller and radio-frequency transmitter connected in a star-based WSN topology environment (Chinrungrueng *et al*., 2006). Its implementation differs depending on the power constraints. The sensor nodes can either be scheduled in a round robin fashion to monitor traffic and report during predetermined time or put to sleep and only activated when performing the function of: vehicle detection or communication with the server node. Two sensor heads installed at a certain distance for vehicle detection to overcome the initial weakness in the system whereby it is unable to distinguish vehicles from pedestrians and motorcycles (Chinrungrueng *et al*., 2007).

RFID: The system developed by Pala and Inanc (2007) relied solely on RFID technology in detecting vehicles at the ingress and egress points. Vehicles can enter and exit the car park without the need stop as there is no need for the usage of parking tickets and payments are handled via RFID technology. The authorization on entrance to the car park depends on the registration of the vehicle. This is because the system will search the database for registered vehicle and confirm that it does not have any check-in or check-out records before updating the check-in information into the database and lifting the barrier for vehicle ingress. If the vehicle is not registered, it cannot gain entry to the car park. During egress, system updates the database with the check-out date and time.

Inductive loop and RFID: In terms of vehicle detection, the utilization of inductive loop sensors in occupancy detections have been conceptualized whereby inductive loop detectors are installed at each individual parking space (Shim *et al*., 2006). It further extends the application by incorporating RFID technologies in the implementation whereby a RFID tag is used to provide the vehicle information in a WSN environment using Zigbee communication technology. This is to facilitate the information gathering of the ingress and egress of a particular vehicle. Implementation by Ostojic *et al*. (2007) differs in the sense that it is used to perceive vehicle presence at the ingress and egress and the RFID tag have to be put in front of the reader for verification at the ingress and egress point.

Sensor board with multiple sensors: The sensor board for research conducted by Tang *et al.* (2006) is employed with a three-layer framework implementation. While the motes are used in gathering data, the gateway in the server layer is used to update information in the server which will be accessed by the client, which is the application on the client computer. It consists of three types of sensors: namely, light, temperature, acoustic sensors. The system is event driven and consists of five major types of events which are timer, car-in, driving status, car-out and field management which triggers the operation and interaction between the modules.

Ultrasonic sensors as well as temperature sensors are available in the sensor node equipped together with a microprocessor and wireless communication module for the system developed by Bi *et al.* (2006). The system also provides guidance via a guiding node which also operates through WSN in obtaining information. Both the implementation by Tang *et al.* (2006) and Bi *et al.* (2006) requires the sensor nodes to be placed at every individual parking space for detection.

Vision based: The deployment of surveillance system generally faces the challenges of multiscale information gathering, contextual event detection and the deployment of large systems (Hampapur *et al.*, 2005). Vision based system or surveillance systems have been utilized in the detection of both static vehicles and also vehicles in motion. The methods proposed by Hampapur *et al.* (2005) for object detection which includes adaptive background subtraction and salient motion detection are some of the methods that can be implemented in vehicle detection. As more researches are conducted, a vast variety of image processing algorithms can be manipulated for vehicle detection. The main difference between the vision based systems developed is essentially the image processing algorithm without regards of whether the camera is static or moving.

The manipulation of color image for detecting car park occupancies have been conducted using various image processing methods. While Principal Component Analysis (PCA) is widely implemented in vehicle detection, the overall approach is vastly different. Wu *et al.* (2007) delt with ROI region which are cropped to three parking spaces per patch and uses PCA for feature extraction while incorporating it with preprocessing, color histogram analysis and Support Vector Machine (SVM) for vehicle recognition. Conflict resolution and optimization were also implemented with Markov Random Field. On the other hand, Funck *et al.* (2004) used PCA in reconstructing the input image via eigenspace reconstruction based on earlier obtained model of empty car park pictures to obtain the differences between the both the images for vehicle classification.

Subsequent discussion focuses on the use of different segmentation techniques for vehicle detection in determining occupancy status of the car park space. In the research by Idna *et al.* (2005), if a certain percentage of the pixels are detected to belong to the floor after segmentation via thresholding, it will be classified as vacant. Character recognition using chain code and database are implemented for character recognition of the parking space number via the numbers painted on the floor. A three-layer Bayesian hierarchical detection framework which encompasses observation layer, labeling layer and semantic layer has also been introduced (Huang *et al.*, 2008). Here the entire row of car park space is extracted as ROI that will eventually be segmented to obtain the occupancy status for each individual car park space.

The Car Park Occupancy Information System (COIS) uses a bi-stream (Bong *et al.*, 2008) detection to overcome false detection caused by shadows. Color images were initially used (Bong *et al.*, 2006), whereby image subtraction which was subsequently converted into binary form. Later on, grayscale image was used from the beginning (Bong *et al.*, 2008) whereby the conversion of the image to binary form depends solely on the bit-7 of image pixels. Although, the methods are different, segmentation via thresholding is essentially performed on the image. Calculation with an accumulator is performed next with a threshold value set to determine the occupancy status. The second processing stream utilizes Sobel edge detection to eliminate false reading by shadows, with median filter were added later on (Bong *et al.*, 2008).

Although, SVM classification has been implemented in Wu *et al.* (2007), a method incorporating image homography was proposed by López Sastre *et al.* (2007). By altering the viewpoint of the car park camera to top- view before performing feature extraction using Gabor filter and classification via SVM, the region-of-interest extraction process will be made easier and misclassification due to occlusion can be minimized.

As noticed, different algorithm provides different advantages for the systems developed. PCA are often used to overcome the problem of illumination variance in the images captured and SVM are robust enough in dealing with occlusion. But more recent techniques which involve using Bayesian probability such as implemented by are Huang *et al*. (2008) robust enough to handle both the problem of occlusion and illumination invariance.

CONCLUSION

In this study, the various types of smart parking system and has been presented. From the various examples of the implementation of the smart parking system being presented, its efficiency in alleviating the traffic problem that arises especially in the city area where traffic congestion and the insufficient parking spaces are undeniable. It does so by directing patrons and optimizing the use of parking spaces.

With the study on all the sensor technologies used in detecting vehicles, which are one of the most crucial parts of the smart parking system, the pros and cons of each sensor technologies can be analyzed. Although, there are certain disadvantages in the implementation of visual based system in vehicle detection as described earlier, the advantages far outweighs its disadvantages.

REFERENCES

Barton, J., J. Buckley, B. O'Flynn, S.C. O'Mathuna and J.P. Benson *et al*., 2007. The D-systems project-wireless sensor networks for car-park management. IEEE 65th Vehicular Technology Conference, April 22-25, VTC2007-Spring, pp: 170-173.

Benson, J., T. O'Donovan, P. O'Sullivan, U. Roedig and C. Sreenan, 2006. Car park management using wireless sensor networks. Proceedings of the 31st IEEE Conference on Local Computer Networks, November 14-16, Tampa, FL, pp: 588-595.

Bi, Y.Z., L.M. Sun, H.S. Zhu, T.X. Yan and Z.J. Luo, 2006. A parking management system based on wireless sensor network. Acta Automatica Sin., 32: 877-968.

Bong, D.B.L., K.C. Ting and N. Rajaee, 2006. Car-park occupancy information system. Third Real-Time Technology and Applications Symposium, RENTAS 2006, Serdang, Selangor, December 2006. http://www.cs.ieeemalaysia.org/RENTAS2006/papers/Car-Park-Occupancy.pdf.

Bong, D.B.L., K.C. Ting and K.C. Lai, 2008. Integrated approach in the design of car-park occupancy information system. IAENG Int. J. Comput. Sci., 35: 1-8.

Cheung, S.Y., S. Coleri Ergen and P. Varaiya, 2005. Traffic surveillance with wireless magnetic sensors. Proceedings of the 12th ITS World Congress, November 2005, San Francisco, pp: 1-13.

Chinrungrueng, J., U. Sunantachaikul and S. Triamlumlerd, 2006. A vehicular monitoring system with power-efficient wireless sensor networks. Proceedings of the 6th International Conference on ITS Telecommunication, June 21-23, Chengdu, pp: 951-954.

Chinrungrueng, J., U. Sunantachaikul and S. Triamlumlerd, 2007. Smart parking: An application of optical wireless sensor network. International Symposium on Applications and the Internet Workshops (SAINTW'07), January 15-19, Hiroshima, pp: 66-69.

Ebling, M. and E. De Lara, 2007. New products. IEEE Pervasive Comput., 6: 11-13.

Farhan, B. and A.T. Murray, 2008. Siting park-and-ride facilities using a multi-objective spatial optimization model. Comput. Operat. Res., 35: 445-456.

Funck, S., N. Mohler and W. Oertel, 2004. Determining car-park occupancy from single images. IEEE Intelligent Vehicles Symposium, June 14-17, Dresden, Germany, pp: 325-328.

Geetha, D.E., C.R.M. Reddy, T.V.S. Kumar and K.R. Kanth, 2007. Performance modeling and evaluation of e-commerce systems using UML 2.0. Proceedings of the 8th ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD 2007), July 30 2007-Aug. 1 2007, Washington, DC, USA., pp: 1135-1140.

Hampapur, A., L. Brown, J. Connell, A. Ekin and N. Haas *et al*., 2005. Smart video surveillance: Exploring the concept of multiscale spatiotemporal tracking. IEEE Signal Process. Mag., 22: 38-51.

Hinze, D., 2000. Italians drive for smart card parking in major cities. Card Technol. Today, 2: 6-7.

Hodel, T.B. and S. Cong, 2004. PSOS, parking space optimization service. Proceedings of the 4th Swiss Transport Research Conference, March 25-26, Monte Verità/Ascona, pp: 1-22.

Horner, M.W. and T.H. Grubesic, 2001. A GIS-based planning approach to locating urban rail terminals. Transportation, 28: 55-77.

Horner, M.W. and S. Groves, 2007. Network flow-based strategies for identifying rail park-and-ride facility locations. Soc. Econ. Plann. Sci., 41: 255-268.

Huang, C.C., S.J. Wang, Y.J. Chang and T. Chen, 2008. A bayesian hierarchical detection framework for parking space detection IEEE International Conference on Acoustic, Signal and Image Processing, ICASP 2008, 31 March 2008-4 April 2008, Las Vegas, NV, pp: 2097-2100.

Idna, M.Y., N.M. Noor, Z. Razak and M.N. Ridzuan, 2005. Parking system using chain code and a-star algorithm. International Conference on Intelligent Systems, ICIS2005, (Endorsed by the IEE), December 1-3, Sunway Lagoon Resort Hotel, Kuala Lumpur, pp: 1-5.

Idna, M.Y. and E.M. Tamil, 2007. Parking information system using GPS and shortest path algorithm. Proceedings of the SCORED 2007, May 14-15, Universiti Tenaga Nasional, Malaysia, pp: 1-7.

Idna, M.Y., Y.L. Yong, E.M. Tamil and N.Z Haron, 2008. Parking guidance system using RFID and image processing techniques in WSN environment. 4th International Colloquium on Signal Processing and its Applications, March 7-9, Royale Bintang Hotel, Kuala Lumpur, pp: 1-6.

Inaba, K., M. Shibui, T. Naganawa, M. Ogiwara and N. Yoshikai, 2001. Intelligent Parking Reservation Service on the Internet. SAINT-W, Symposium on Applications and the Internet-Workshops (SAINT 2001 Workshops), Jan. 8-12, San Diego, CA, USA., pp: 159-164.

Jones, W.D., 2006. Parking 2.0. IEEE Spectrum, 43: 20-20.

Kastrinaki, V., M. Zervakis and K. Kalaitzakis, 2003. A survey of video processing techniques for traffic applications. Image Vision Comput., 21: 359-381.

Kurogo, H., K. Takada and H. Akiyama, 1995. Concept of a parking guidance system and its effects in the Shinjuku area-configuration, performance and future improvement of system. Proceedings of Vehicle Navigation and Information Systems Conference, 1995. In conjunction with the Pacific Rim TransTech Conference. 6th International VNIS. 'A Ride into the Future', 30 July 2 August, Seattle, WA, USA., pp: 67-74.

Lee, S., D. Yoon and A. Ghosh, 2008. Intelligent parking lot application using wireless sensor networks. International Symposium on Collaborative Technologies and Systems, CTS 2008, May 19-23, Irvine, CA, pp: 48-57.

Lenz, J.E. and A.S. Edelstein, 2006. A review of magnetic sensors. IEEE Sensors J., 6: 631-649.

Liu, Q., H. Lu, B. Zou and Q. Li, 2006. Design and development of parking guidance information system based on web and gis technology. Proceedings of the 6th International Conference on ITS Telecommunications, June 21-23, Chengdu, pp: 1263-1266.

López Sastre, R.J., P. Gil Jiménez, F.J. Acevedo and S. Maldonado Bascón, 2007. Computer algebra algorithms applied to computer vision in a parking management system. IEEE International Symposium on Industrial Electronics, ISIE 2007, June 4-7, Vigo, pp: 1675-1680.

Mathijssen Aad, A. and P. Johannes, 2007. Verified design of an automated parking garage. Lecture Notes Comput. Sci., 4346: 165-180.

Mimbela, L.Y. and L.A. Klein, 2007. A summary of vehicle detection and surveillance technologies used in intelligent transportation systems. New Mexico State University, Tech. Report, 2007. http://www.fhwa.dot.gov/ohim/tvtw/vdstits.pdf.

Mouskos, K.C., M. Boile and N. Parker, 2007. Technical solutions to overcrowded park and ride facilities. University Transportation Research Center-Region 2. City College of New York. Final Report, FHWA-NJ-2007-01. http://www.nj.gov/transportation/refdata/research/reports/FHWA-NJ-2007-011.pdf.

Ostojic, G., S. Stankovski, M. Lazarevic and V. Jovanovic, 2007. Implementation of RFID technology in parking lot access control system. 1st Annual RFID Eurasia, Sept. 5-6, Istanbul, pp: 1-5.

Pala, Z. and N. Inanc, 2007. Smart parking applications using RFID technology. 1st Annual RFID Eurasia, Sept. 5-6, Istanbul, pp: 1-3.

Rieback, M.R., P.N.D. Simpson, B. Crispo and A.S. Tanenbaum, 2006a. RFID malware: Design principles and examples. Pervasive Mobile Comput., 2: 405-426.

Rieback, M.R., B. Crispo and A.S. Tanenbaum, 2006b. The evolution of RFID security. IEEE Pervasive Comput., 5: 62-69.

Sakai, A., K. Mizuno, T. Sugimoto and T. Okuda, 1995. Parking guidance and information systems. Proceedings of Vehicle Navigation and Information Systems Conference in Conjunction with the Pacific Rim TransTech Conference, 6th International VNIS. A Ride into the Future, 30 Julu-Aug. 2, IEEE, Xplore, pp: 478-485.

Seong-Eun, Y., C. Poh Kit, K. Taehong, K. Jonggu and K. Daeyoung *et al.*, 2008. PGS: Parking guidance system based on wireless sensor network. 3rd International Symposium on Wireless Pervasive Computing, (ISWPC 2008), May 7-9, IEEE Xplore, pp: 218-222.

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

Shim, S., S. Park and S. Hong, 2006. Parking management system using zigbee. Int. J. Comput. Sci. Network Security, 6: 131-137.

Tamil, E.M., D. Salleh and M.Y. Idna, 2007. CaTSys 1.0-a mobile vehicle tracking system with GPS technology. Proceedings of the SCORED 2007, May 14-15, Universiti Tenaga Nasional,Malaysia, pp: 1-11.

Tang, V.W.S., Y. Zheng and J.N. Cao, 2006. An intelligent car park management system based on wireless sensor networks. 1st International Symposium on Pervasive Computing and Applications, SPCA-2006, August 3-5, Urumqi, pp: 65-70.

Teodorovic, D. and P. Lucic, 2006. Intelligent parking systems. Eur. J. Operat. Res., 175: 1666-1681.

Wang, Y.K. and S.H. Chen, 2005. A robust vehicle detection approach. IEEE Conference on Advanced Video and Signal Based Surveillance, AVSS 2005, Sept. 15-16, Taiwan, pp: 117-122.

Wolff, J., J. Heuer, T. Haibin, G. Weinmann, M. Voit and S. Hartmann, 2006. Parking monitor system based on magnetic field senso. IEEE Intelligent Transportation System Conference, (ITSC'06), Toronto, Ont., pp: 1275-1279.

Wu, Q., C.C. Huang, S.Y. Wang, W.C. Chiu and T.H. Chen, 2007. Robust parking space detection considering inter-space correlation. IEEE International Conference on Multimedia and Expo, July 2-5, Beijing, pp: 659-662.