Intelligent Remote Monitoring of Parking Spaces using Licensed and Unlicensed Wireless Technologies

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Abstract: Short and long range wireless communication is imperative for many remote monitoring applications such as industrial automation, digital health, smart cities. Remote monitoring is one of the components of complex systems that can be optimized with the use of machine learning-based techniques. In this article, an intelligent parking system is presented. The system exploits the benefits of a synergy between licensed and unlicensed wireless technologies, Internet of Things (IoT), computer vision, and artificial intelligence. We discussed how an end user can interact with the system and manage it with a user interface. The user interface provides a range of dashboard facilities that provide various statistics about car park utilization and optimization facilities. Our proposed solution is comprised of a range of sensors including high-resolution cameras, that are distributed throughout a car park. The cameras are connected using different types of wireless communication. The data is processed in real–time by the sensors and sent to a cloud server, where it is analyzed, stored and presented to the end-user. The object detection, tracking and optical character recognition (OCR) system executed by the vision sensor which utilizes a combination of convolutional neural networks and a proprietary deep-learning based object detection algorithm. This solution has achieved high levels of classification accuracy (99.97%) and high image processing speeds (66 ms).

Keywords: Smart parking, computational intelligence, wireless communications, deep learning, unlicensed spectrum

1. Introduction

Nowadays there is an identified need to enhance interoperability between licensed and unlicensed spectrums and corresponding wireless technologies to enable the transfer of higher data volumes and fuel the development of effective applications such as remote monitoring applications. One emerging remote monitoring application area is the development of smart parking systems. Smart parking systems continue to gain popularity due to their benefits for drivers, car park owners and managers, as well as the environment. These benefits include: the exploitation of the accumulated data for informing managerial decisions and optimizing pricing strategies, the reduction of air pollution caused by vehicle emissions; decrease in fuel consumption due to reduced vehicle travels; reduction of traffic congestion [1].

Smart parking applications have a significant impact in the economy. The parking turnover in the UK alone is valued at £1,500M per annum for local authorities, while the private sector market is estimated to be even higher. Modern advances in wireless technologies and big data analytics provide the base for developing a new generation of smart parking application.

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The main motivation for this work is to propose a robust and novel solution to a problem of automated remote monitoring of parking spaces with the use of wireless and machine learning technologies.

In this article we present an innovative solution to monitor car parking availability in car parks of all shapes and sizes. This solution will alleviate the frustration of crawling around a car park looking for a space, optimize billing and parking allocation as well as allow businesses to intelligently manage their own car park. Smart parking will become the latest of many services to benefit from the use of smart wireless and machine learning technologies.

The novelty of the approach presented in this article results from a unique combination of sensors, wireless technology and data processing techniques that enables accurate detection of parking space occupancy and high accuracy predictions of the future utilization of car park spaces. The combination of deep learning techniques exhibits high performance in a license plate and object detection with IoT technology, and solves an established challenge of linking a parking space with a specific car in an innovative fashion. Additionally, the utilization of parking sensors to identify the number and movement of people in a given area have not been applied before in this context.

This article initially provides an overview of smart parking technologies, describes wireless technologies which can be used for developing smart parking applications, and presents the machine learning techniques and big data methodologies. Later the authors describe the proposed smart parking solution. Finally, the benefits of deploying this solution are highlighted, and future research directions are discussed.

2. Background

2.1 Smart parking technologies

Recent research combined sensory equipment and wireless technologies to deliver effective smart parking systems. In [2] the vehicle is connected to the Wi-Fi network of a specific parking space. IR sensors are used to send the status of the parking slot to a microcontroller. Finally, this information is uploaded to a webpage that is used to inform the driver of the vacancy of a particular space [2]. In the smart parking system presented in [2] an IoT technology is used to monitor the status of parking spaces. A mobile application is used to inform the driver to check availability and pre-book a parking space [3]. Other researchers combined intelligent algorithms and network architectures to develop smart parking systems that enable drivers to automatically find the most suitable parking space by considering the distance and space availability [4]. Recently research combined Wi-Fi and wireless network technologies (geomagnetic sensors) to detect parking space availability and navigate the driver to an available space [5].

JustPark is a commercial smart parking system which offers a car park search and location service for all local sites, while it provides a reservation facility and allows individual users to register with the service and offer their private spaces for rental. Clearview Intelligence is another solution which offers bay monitoring using a combination of infrared and magnetic field detectors to determine occupancy. The method of communication is 868MHz radio with approximately 35m range. The devices are laid out in a mesh-type network. Repeater units are used on the surface of the road. Finally, Appy Parking provides parking sensors and general information regarding parking space prices. The sensors use Bluetooth for short-range communication. The sensors are glued onto the road.

Smart parking applications are divided into the following categories:

- Parking Guidance and Information Systems (PGIS). These systems help the drivers to reach their destination and locate an available car park and a vacant space within the car park.

- Transit based information systems. These systems differentiate from the PGIS by guiding drivers to park and ride facilities.
- Smart payment systems. These systems are designed to overcome the delays and limitations caused by conventional payment methods.
- E-parking. E-parking systems check the availability of parking spaces in a car park, enable parking space reservations, and ensure the availability of parking space before the driver arrives at the parking area.
- Automated parking. These systems include computer-controlled mechanisms which are responsible to automatically place the car in the designated parking space.

The most crucial part of a car parking system is car park occupancy detection. Towards this goal a multitude of sensory equipment has been used. The choice of equipment relies on the car park type and layout. Sensory equipment includes sensors which are invasively installed on the parking area such as: active infrared, inductive loops, magnetometers, magneto resistive sensors, pneumatic road tubes, piezoelectric cables and weigh in motion sensor; and non-obtrusive sensors and technologies such as microwave radar, passive acoustic array sensors, passive infrared sensor, RFID, ultrasonic and computer vision [6]. These sensors are connected together with different wireless technologies for which we provide a brief description in the next section.

The application of smart parking technology presents a number of challenges that are a barrier and a reason why the solutions are still not very popular and widely used. The first challenge is the actual price of a device ranging from £150 to £1000 per unit. This and a support contract make it inaccessible and not viable solution for many companies. Another challenge is the high power consumption of those devices that are mainly battery based. This means that the power units have to be replaced frequently which adds to the maintenance and utility costs. In addition to that the usefulness of the data generated by those devices is highly reduced by the lack of a high-performance generative algorithm that can make predictions and model car park utilization. Next challenge is the integration between the different sensor and technologies to achieve a seamless functionality and optimize the value for end customer. Finally, the challenge of an integration with a robust automatic payment system, that ensures customers are charged correctly and do not need to waste unnecessary time using physical money and accessing payment stations.

2.2 Wireless Technologies

The short, and medium range communication has become crucial for a number of applications related to vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and infrastructure to user (I2U). Its usefulness results mainly from how it improves the accessibility and data collection capabilities of many systems. In V2V for example, the data collected by vehicle’s embedded sensors and cameras described by specific characteristics of the data such as heterogeneity, redundancy, incompleteness and size make the analysis and extraction of valuable information very challenging. This challenge requires the application of new mechanisms that can process the data efficiently. One of the challenges in data collection therefor is the volume of data that makes the communication exchange between all parties via V2Vand V2I very difficult, sometimes impossible. This is due to the opportunistic, occasional and not long lasting characteristics of these communication capabilities. Furthermore, the security aspect pose another challenge that has been for a long time considered one of the most important tasks of data collection. This is especially true in wireless communication because open wireless connections to others expose the data and its holder to various kinds of attacks. The ease of data exchange in short, and medium range communication makes it vulnerable to malicious behaviors and an easy target to attackers mainly due to the sensitivity of information they hold.

In this section we briefly present the most popular wireless technologies, which are currently being used by smart parking applications. We highlight the main features of wireless technologies that can be used to exploit both licensed and unlicensed spectrum, and develop state of the art smart parking applications as the one described in this article.

2.2.1 Bluetooth

Bluetooth is one of the most common wireless communication systems, and is used mostly to exchange data over short distances. Bluetooth is specifically designed for short-range and low-cost devices, and it is based on two network topologies, namely the piconet and the scatternet. The maximum number of devices in a Bluetooth network building cell is 8 [7]. Bluetooth features short wavelength radio transmission in 2400–2480 MHz which is unlicensed spectrum in most countries, frequency hopping with 79 channels and 1 MHz bandwidth, and features low power consumption, fast data exchange, wide spread availability and limited effect on battery life [8].

2.2.2 Wireless Fidelity (Wi-Fi)

Wi-Fi includes IEEE 802.11a/b/g standards for wireless local area networks (WLAN). Wi-Fi Wi- is oriented to about 100m, and enables Internet access at broadband speeds when there is a connection to an AP or in ad hoc mode. Wi-Fi protocols have spread spectrum techniques in the 2.4 GHz band which is known as the industrial, scientific, and medical (ISM) band. Wi-Fi nominal transmission power is estimated to be 20 dBm. Wi-Fi utilizes transmission power control and dynamic frequency selection, DSSS, complementary code keying, or OFDM modulation with 14 RF channels and a bandwidth of 22 MHz. The basic cell of an IEEE 802.11 LAN is basic service set. The basic service set is a set of mobile or fixed stations. In the cell there could be a maximum of 2007 devices for a structured Wi-Fi BSS. Wi-Fi consumes more power than Bluetooth and Zigbee since it is designed for a longer connection and supports devices with a substantial power supply.

2.2.3 LTE-U

Towards enabling users to effectively use both licensed and unlicensed spectrum under a unified LTE network infrastructure. LTE-U is able to support improved coverage and greater capacity than cellular/Wi-Fi interworking. At the same time LTE-U enables smooth data flow between licensed and unlicensed spectrum through a single Evolved Packet Core (EPC) network. As reported in recent research studies LTE-U performance shows some instability especially when there is interference by Wi-Fi activities. This reality makes it difficult for LTE-U applications to guarantee quality of service. LTE-U is focused on providing multimedia services and operates on the 5 GHz band. LTE-U devices utilize Dynamic Frequency Selection, clear channel assessment (CCA) or listen-before-talk [9].

2.2.4 ZigBee

ZigBee can be described as a wireless mesh network which is based on the IEEE standard 802.15.4. Zigbee is a reliable, cost effective, long battery life and low power solution for an operating space of approximately 10m. ZigBee utilizes a direct sequence spread spectrum with a bandwidth of 2 MHZ and 16 channels. Zigbee’s data rates are low (250kbps/channel in the 2.4 GHz band, 40kbps/channel in the 915MHz band and 20kbps/ channel in the 868MHz band). As described in the comparative study by Mahmood et al. in a Zigbee network all connections can be optimized and updated dynamically and each of the network nodes can be reached by multiple links, features that make Zigbee a resilient network which can deal with node and link failures. Zigbee also provides IP functionality and offers interoperability and compatibility by supporting communication with IPv6 based nodes using other network architectures like Wi-Fi, Ethernet.

2.2.5 Ultra-Wideband-UWB

Ultra-wideband technology can use a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum. One of its key characteristics of UWB is that it can support demanding applications, such as video, and its bandwidth can be up to 480 Mbps. Therefore, UWB usage is suggested for short-range and high data rate applications. Basic cell of UWB is the same as for the Bluetooth the piconet with a maximum of 8 cell nodes. UWB has a frequency band 3.1-10.6 GHz, a range of 10m, a max signal rate of 110Mb/s and has a number of 1-15 RF channels with a channel Bandwidth of 500 MHz- 7.5 GHz. UWB uses adaptive frequency hopping, modulation type BPSK or QPSK and DS-UWB, MB-OFDM.

2.2.6 6LoWPAN

The concept of 6LoWPAN stems from the need for a protocol to enable small low power devices participate in the IOT. As described in (Mahmud, 2015) 6LoWPAN enables IEEE 802.15 and IPv6 to work together in order to achieve IP enabled low power networks of sensors, controllers etc. 6LoWPAN is an emerging technology in the market that aims to replace Wi-Fi. 6LoWPAN is mostly used in home automation systems that utilize open IP standard, mesh routing and multiple PHY support. As presented in [10] 6LoWPAN is able to connect the devices within a network wirelessly at low power while maximizing the diversity and flexibility of the interconnections and communications. This technology enables the interactions between devices to be configured remotely by the user connected to a local network with remote access control [10]. 6LoWPAN features low power consumption, long lifetime and transparent internet integration. These features can support the development of effective IoT applications. In addition, this technology is a license free standard for IoT and provides a better Quality of Service (QOS).

2.2.7 Relative comparison between the protocols.

The number and variety of the wireless communication protocols described above makes it necessary to briefly discuss their advantages and disadvantages. Thus for example Bluetooth is cheap to implement easy to install and connecting the devices is relatively simple. It is however vulnerable to security breaches and can connect only two devices at once. It is therefore more desirable to use Zigbee protocol instead in application where security and connectivity are required. Another advantage of using Zigbee is the low power consumption and the ease of access. The disadvantage however is their cost and speed, the price of the Zigbee module is sometimes 10x then the price of Bluetooth module. In applications where the communication distance and speed are important the right choice would be to use 3G/4G. They however are much more expensive and not suitable for small distributed sensor networks.

2.3 Deep learning for data analytics and computer vision

Deep Learning is an artificial intelligence technique that imitates the human brain in processing data and creating patterns to be used in decision making. It utilizes multiple levels of artificial neural networks to deliver its machine learning services. Deep Learning has been the computational base for developing innovative solutions in many scientific domains and for setting new records in machine learning tasks, such as image recognition, speech recognition and sentiment analysis, where it has achieved superior forecasting and classification performance.

Recently Deep Neural Networks (DNNs) have shown outstanding performance on image classification tasks. Convolutional Neural Networks (CNN) are the most successful architectures. CNNs are a special type of multi-layer neural networks that take an inspiration form how a human brain processes visual sensory information. They are designed to recognize visual patterns directly from pixel images with minimal preprocessing to an input image. Despite the differences in the neural network architectures and their compositions they all share a number of common features. They are structured in a layer wise fashion with each consecutive layer learning more complex representations of hidden features that are composing an image. The neural network training is performed by iteratively adjusting the parameters called weights of the model to reduce an error of a cost function that expresses how well a model fits the data. Finally they all use a concept of receptive fields, which is a region of the input space that affects a particular unit of the network. CNNs are used to solve a wide range of computer vision problems such as: classification - classifying an image into one of many different categories, localization - finding the location of a single object inside the image, instance segmentation - not only fining objects inside an image, but also find a pixel by pixel mask of each of the detected objects, object detection – combines the problem of localization with object classification. Although the application of DNN to the problem of object detection is well established, the use of linear filters and standard computer vision techniques is still the norm in the context of vehicle license plate detection.

3. Smart parking system

In this article, we integrate a short-range unlicensed wireless communication, with long-range licensed wireless communication in a novel application of a remote car parking monitoring system. This combination of wireless communication allows for a synergy in technologies that achieve a robust, easy to maintain, and inexpensive network of IoT devices. The proposed system (shown in Fig. 1) is an innovative way to track car parking availability in car parks of all shapes and sizes.

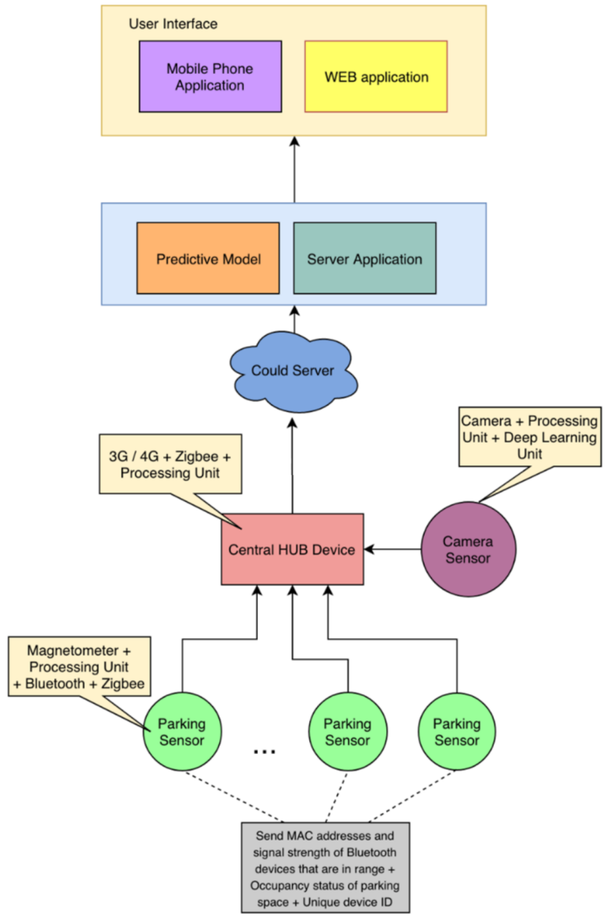

Figure 1. Smart parking system architecture.

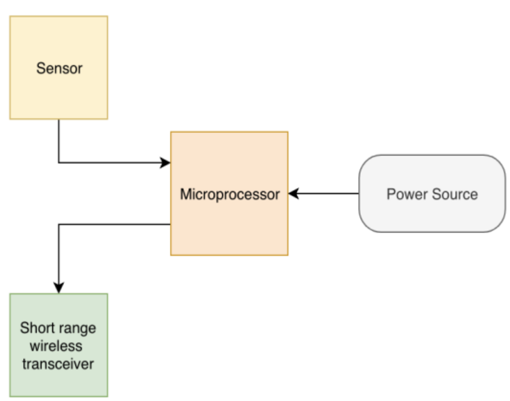

Figure 2. Device diagram.

The proposed solution is based on the use of small sensors mounted in each parking space. The sensors are designed in such a way to reduce the power consumption to the minimum with the use of low power circuit which is powered with solar energy and rechargeable battery. This design ensures that the device can run with no interruption or a need of maintenance for many years. The very low cost of the individual sensors, means that the devices can be used in high volumes and cover large areas. The sensor, in the most simplistic form, contains a processing unit, a sensor, short-range wireless transceiver and a power source (Fig. 2). The devices are in sleep mode for most of the time and they are enabled on an interruption generated by the sensor. This interruption executes the part of a firmware device that is responsible for analyzing the continuous signal generated by the sensor, and with the use of previously trained artificial neural network it can detect a unique pattern that indicates a movement of a car. The movement of a car can be classified into two classes "car moving into a parking space" or "car leaving the parking space". When the sensor detects the movement, it identifies and saves all the Bluetooth devices in its vicinity, together with the strength of their signals. The positive verification of the signal indicating that a car has parked or left a parking space together with a set number of the closest Bluetooth devices and a unique device identification is transferred to a wireless transceiver that sends the information to a central hub. The information is further transferred from the hub to a cloud server with the use of long-range wireless communication protocol. The server application stores the occupancy information in a database together with the date/time stamp and a list of Bluetooth devices for further data processing. The list of Bluetooth devices is also compared with the list of all subscribers to the automated payment system. On a positive data filtering and identification of an individual system user, the server sends an information to a mobile phone application for that specific user. The client has the option to select the amount of time he/she plans to use the parking space and arrange the payment for the car park usage.

The above described functionality also helps to identify people's movement and a "business" for a given location that can be defined as the number of people per a defined fixed area of space. This is achieved by using the sensor to scan passively and identify nearby signals every fixed interval of time for all wireless devices accessible to that particular sensor. By coordinating the readings from different sensors and using a triangulation algorithm one can track the movements of individual people with high precision. This information can be used to better design public space, business outlets, and other access points.

In order to detect a car's presence, the device uses a magnetometer sensor. This sensor detects the strength of the magnetic field it is exposed to. When the metallic body of the car is in a way of the earth's field, the flux lines are absorbed into the metal, creating non-uniformity in the distribution of flux lines. By measuring the output of the sensor in a continuous way it is possible to identify those distortions to the magnetic field and detect car presence. With the use of a sensitive enough sensor, it is possible, not only to identify the presence of a car but also to identify the type of car by looking at the individual footprint generated by that car.

The individual sensors are assembled into a network. The network of sensors is organized in a star topology where all nodes are individually connected to a central connection point, a dedicated mini-hub that combines the simplicity and low cost of short-range wireless communication with long-range 3G/4G wireless mobile telecommunications technology. Central hub keeps track of the occupancy status of a group of sensors using a short-range wireless protocol. This information is transmitted using Wi-Fi /GPRS to the main server for further processing.

In addition to the network of sensors and a central hub, the proposed system integrates a number of automated vision inspection devices that are connected to the central hub via Wi-Fi communication protocol and which are capable of identifying vehicles, tracking them between individual video frames and performing number plate recognition. The IoT automated vision inspection devices are designed in such a way to perform all the vision and relating data processing tasks on the actual device. In order to enhance functionality, the devices consist of a high-resolution camera, a processing unit in a form of a system on a chip (SoC), a machine learning processor and a Wi-Fi transceiver. The object detection, tracking and optical character recognition system is based on deep learning, and utilizes a combination of convolutional neural networks and a proprietary deep-learning based object detection algorithm [11, 12].

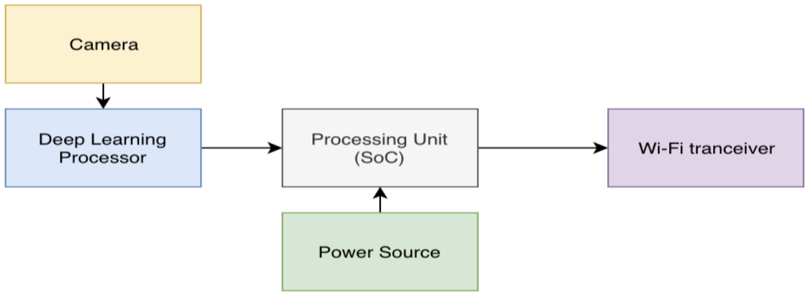

Figure 3. IoT vision inspection device diagram.

The raw image from the camera is processed with the use of a previously trained deep learning algorithm that is stored and executed on a deep learning processor. The annotated data is then sent to the main processing unit which in turn sends it with to the cloud server. This information is processed by the server and stored in the database (Fig. 3). The main use of this information is to facilitate the automated payment system or allow a selective access to a gated carpark. In this case, unlike in the previous example where a sensing device is used, there is no need to run a separate application on a mobile phone but rather use the information acquired by an automatic OCR system. The IoT vision inspection devices can also count the traffic in a given area and identify a driver's undesirable behavior, for example, automatically report fly-tipping or illegal waste dumping. The proposed automated object detection (AOD) system uses deep neural networks to accurately identify and exact position of an object in a field of view of an imaging sensor. The system for any given input image or a video sequence outputs a probability mask corresponding to each pixel of an input image or a current video frame. The probability mask is defined as an output vector where each element of that vector is in a range between 0 and 1 and represents a probability of a corresponding element of an input vector belonging to the object that is being detected. In practice this means that all elements of an input vector that do not belong to the target object are assigned value of 0 and all the pixels that belong to that object have value 1. The deep neural network is built in a symmetrical way such that the inputs are fed to multiple blocks of convolution and pooling layers, each time reducing the size of a block. When the convolution layer is small enough the process is reversed and the outputs are fed through multiple blocks of de-convolution and up-sampling to the point where the convolution layer is of the same size as the input. The deep neural network is trained using one of the gradient descent optimization algorithms. The loss function used is mean square error (MSE).

4. Comparative Evaluation

We compared our OCR results with state-of-the-art research and development [13, 14]. Pahani et al. utilized CCA and RANSAC as a detection method and a probabilistic SVM for recognition, and as it can be seen in the comparative study in [13], they managed to outperform other existing methods. Pahani et al. achieved a plate detection accuracy of 98.7% with a processing time of 180ms [13]. Tarigan used a GA optimized backpropagation neural network. Tarigan et al. achieved 97.18% for character recognition accuracy with average pre-processing time 229.88ms and average feedforward time 2.50ms [14]. The proposed algorithm has outperformed the existing approaches for classification accuracy. The method discussed in this article is based on DNNS and integrated with proposed IoT hardware architecture, and improves the accuracy rate to 99.98% with an image processing speed of 66ms. The comparative results are shown in Fig. 4.

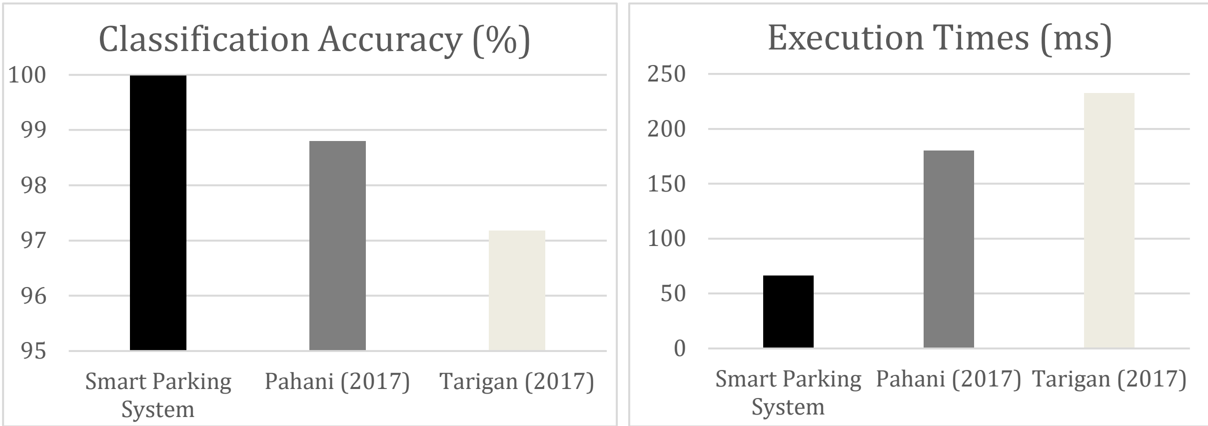

Figure 4. OCR recognition classification accuracy and execution time comparison.

5. Conclusions and future work

In this article, we have presented an innovative smart parking solution based on IoT, deep learning and wireless technologies. This solution can be used by municipal authorities and private companies owning parking areas, as well as individual drivers in order to: eliminate the stress of driving around and reduce the time looking for a space by finding the best suitable available space for each driver and direct them to it; support local businesses and authorities to maximize their parking capacity and profit through predictive analytics; promote driver's wellbeing and parking management through providing functions such as automate payment, pre-booking, automatic vehicle location detection and others. Autonomous vehicles can benefit from real-time information about car spaces availability to plan their routs more effectively [15].

Our future work will involve integrating the system with other services such as satellite-navigation systems, local council information systems and traffic management systems to provide the users with real-time information. The richness of data acquired during the operation of the car park monitoring system will help to improve the predictions of space utilization and improve the access to the services, buildings and the infrastructure.

References

[1] T. Maniak, R. Iqbal, and F. Doctor, "Traffic Modelling, Visualisation and Prediction for Urban Mobility Management", *Advances in Hybridization of Intelligent Methods*, 2018, pp. 57-70.
[2] Y.R. Rao, "Automatic smart parking system using Internet of Things (IOT)". Int. J. Eng. Tech. Sci. Res, vol 4, 2017, pp. 2394-3386.
[3] A. Khanna, and R. Anand, "IoT based smart parking system", International Conference on Internet of Things and Applications (IOTA), 2016, pp. 266-270.
[4] T.N. Pham et al., "A cloud-based smart-parking system based on Internet-of-Things technologies", IEEE Access, vol. 3, 2015, pp. 1581-1591.
[5] C. Yuan et al., "A smart parking system using WiFi and wireless sensor network", IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW), 2016, pp. 1-2.

[6] M.Y.I. Idris et al., “Car park system: a review of smart parking system and its technology”, Information Technology Journal, vol. 8, no. 2, 2009, pp. 101-113.
[7] A. Mahmood, N. Javaid, and S. Razzaq, “A review of wireless communications for smart grid”, Renewable and sustainable energy reviews, vol. 41, 2015, pp. 248-260.
[8] J.S. Lee, Y. W. Su, and C.C. Shen, “A comparative study of wireless protocols: Bluetooth, UWB, ZigBee, and Wi-Fi”, *Industrial Electronics Society*, 33rd Annual Conference of the IEEE, IECON 2007, pp. 46-51.
[9] R. Zhang et al.. “LTE-unlicensed: the future of spectrum aggregation for cellular networks”, IEEE Wireless Communications, vol. 22, no. 3, 2015, pp. 150-159.
[10] T. Gonnot, and J. Saniie, “User defined interactions between devices on a 6LoWPAN network for home automation”, *Technology Management Conference* (ITMC), IEEE International 2014, pp. 1-4.
[11] T. Maniak et al., “Automated intelligent system for sound signalling device quality assurance”, Information Sciences, vol. 294, 2015, pp. 600-611.
[12] R. Iqbal et al., “Big Data analytics and Computational Intelligence for Cyber–Physical Systems: Recent trends and state of the art applications”, Future Generation Computer Systems, 2017
[13] R. Panahi, and I. Gholampour, “Accurate detection and recognition of dirty vehicle plate numbers for high-speed applications”. *IEEE Transactions on intelligent transportation systems”*, vol 8, no 4, 2017, pp. 767-779.
[14] J. Tarigan, R. Diedan, and Y. Suryana, “Plate Recognition Using Backpropagation Neural Network and Genetic Algorithm”, *Procedia Computer Science*, vol 116, 2017, pp. 365-372.
[15] L. Birek et al., “A novel Big Data analytics and intelligent technique to predict driver's intent”, Journal of Computers in Industry, vol. 99, 2018, pp. 226-240.

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