An Autonomous Parking Lot Administration with a Variety of Parking Permits

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Abstract:
Urbanization and population growth are stretching the transportation infrastructure of the cities. University campuses are feeling intense pressure of providing adequate parking spaces for operation, staff, faculty members, students, and visitors. Commuters are faced with trouble of finding a suitable parking space causing stress, wastage of energy and loss of productive time on a daily basis. On one end, drivers are forced to violate the parking rules and on the other end authorities are forced to spend numerous man-hours, considerable amount of money and other resources in monitoring parking violation. A promising solution could be an intelligent, self-monitoring parking lot which can play a vital role in Intelligent Transportation Systems(ITS) by reducing parking related problems, and problems associated with human errors. Internet of Things (IoT) and smart devices are transforming and revolutionizing every possible aspect of our lives. In this research, IoT and detection technology are combined to design an autonomous parking lot capable of monitoring variety of parking permits, providing real time information about lot occupancy, and issuing violation penalty. The designed system will use Radio-Frequency IDentification (RFID) tags as various parking permits. In-ground RFID readers along with vision system will identify a vehicle. Information infrastructure will exchange information among devices and central database to monitor and execute the functional aspects of parking lot management. A scaled prototype is developed to verify the design concept and integration of selected technology.

KEYWORDS:
Smart Parking System, RFID (Radio Frequency Identification) detection, Parking Violation.

1. Introduction:

Internet of Things (IoT) is the network of variety of physical end systems connected via different layers allowing to share data among subsystems. IoT allows objects to be sensed or controlled remotely across existing network infrastructure creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit with reduced human intervention[1]. IoT's ability to connect larger number of heterogeneous objects enabling the concept of

Smart City [2]. One of the major subsystem in a Smart City IoT is the management of traffic congestions. Intelligent parking system management and seamless integration to Smart City-IoT is essential to address the growing congestion problem. Recently development in the literature suggests deployment of sensor-based technology connected over an IoT framework has the potential for addressing the parking related problems.

Large university or corporate parking lots pose additional problem of monitoring various types of parking permits. This paper proposes a smart design for autonomous parking management system for a typical university parking lot. The autonomous parking lot will be able to detect type of permit for each parked vehicle, determine parking violations and issue penalty, administer time-based and/or pay-to-park slots, and provide occupancy information to the approaching traffic.

In the following section relevant state of the art is presented. Rest of the paper is organized as follows. In Section 3 the design methodology and the conceptual design of the system is described. This is followed by the technology search and selection, system architecture and prototype implementation. In the last section the paper has been concluded with future work scopes and suggestions for full-scale implementation.

2. Background:

Magnitude of the parking problem and development in the relevant technology has attracted considerable attention to the field. In the recent years, numerous research works have been published. Also, several patents have been issued on automatic parking monitoring and management system. Xiao et al.in their patent claim that autonomous parking lot management system maintains a parking space inventory of one or more parking lots and let the commuter know about the availability of a nearby parking space [3]. A patent is also issued to a proposed wireless LAN based parking space information system connected to an interface and then to the Internet [4]. In this patent parking condition detection devices and wireless LAN mobile station are installed in a mobile object. The information is managed by a server via an IP network so that the parking lot management system can provide the information for a user who is in the parking lot. Also,a patent is issued for a system with option for parking space reservation. The system can receive space reservation request online and allocate appropriate parking spaces for the customer [5].

Smart parking system based on field sensors and real time display helps the driver locate a free space [6]. This type of smart system may provide optimum path to the parking space thereby reducing carbon emission and environment pollution. Most of such systems have vehicle presence detection technology. Hence these systems are capable of displaying empty spaces available in the parking lot. However, such systems do not attempt to identify the unique ID of a car in a particular parking slot. If there are different categories of parking spaces, e.g. a typical university parking lot, it is necessary to know whether a car is parked in the allowable space or not.

A generic concept of cloud based intelligent parking system management system is proposed [7] which can be integrated to the Smart City-IoT. In this work a detail design of middle-ware for a university parking lots is presented. A survey of recent works on the smart parking system based on IoT is available [8].

Short-range communication technology like RFID can be used with parking permits to electronically identify each specific car that provide legitimate use of parking space and promptly find out parking rules violation. In automatic vehicle identification and detection system RFID reader ensure the unique number containing RFID tag location as well as the car location holding that RFID tag [9].

A RFID based vehicle detection system will include an RFID reader along the parking array and will be configured to interrogate the RFID tags contained in the vehicle in that space. To be practicable components of such systems must withstand harsh weather condition. Recently, the U.S. Federal Aviation Administration (FAA) has buried more than 1,000 RFID-enabled marker balls around a new runway at the Hartsfield-Jackson Atlanta International Airport which have been used by the contractors with handheld RFID interrogators to locate utility cables and pipes buried 5 feet underground, as well as determine the type of infrastructure they represent, and who owns that infrastructure [10]. This development makes RFID as a feasible choice for smart parking system.

Most of the proposed parking systems only obtain the availability information of parking spaces based on the deployed sensor network. Also, they propose sensor-based entrance control mechanism. However, if a typical university parking lot is considered, each day the parking management faces vehicles with a variety of permits, such as student permit, faculty permit, visitor permit or guest permit. This situation gives rise to the need of a parking system that can detect which particular car is parked at which spot. Besides there are different types of violations based on the permit, for example: parking at a wrong spot or parking time violation or even parking without a permit. Monitoring and keeping track of all sorts of permits and violations is tedious, error prone, and costly. This paper proposes an autonomous parking management system to address these issues.

3. System Concept:

This research followed systematic design methodology [11] in developing the design for a typical university parking lot. First, the system requirements are determined by conducting multiple surveys and interviews of the stake holders, namely, commuters, parking lot operators, and parking lot administrators. The information obtained through this mechanism were analyzed and following system requirements were recognized:

- should be capable of detecting various type of permit
- should display real time parking space availability information
- should be able to manage visitors and guests
- should be able to detect permit violation - no permit or wrong type of permit
- should be able to manage paid parking slots
- should be able to detect time violation
- should be robust to withstand harsh outdoor weather and rough use
- no additional physical space
- no large structural component(s) in the middle of the lot
- the implementation cost should be justifiable

Based on the system requirements and scope of automation the structure of a typical parking lot has been divided into the following subsystems:

1. Entrance
2. Exit
3. Individual Slot Management
4. Information Infrastructure

The entrance and exit subsystems are placed side by side at the front side of the parking lot, and each parking spot is equipped with individual slot management subsystem. All of the detection and sensing outputs of these three subsystems are remotely connected to information infrastructure that maintains a database of vehicles and violations. Following is the overall big picture of the concept developed for the system.

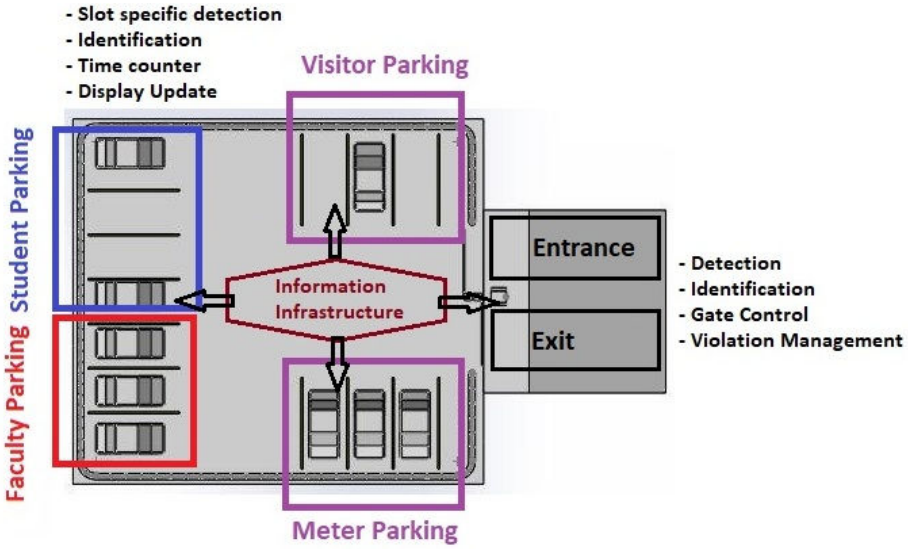

Figure 1: Typical University Parking Lot Structure with Suggested Sections

3.1 Entrance:

Entrance is the subsection where initially the vehicle permit will be detected. In case of a vehicle with no permit, a dispenser system before the entry gate will provide temporary permit upon request of the commuter, which will then read at the entry gate. The dispenser system will have option for two types of visitor permit: Long term (for the entire day) or short term (metered or time restricted parking). This sub system ensures the tracking of vehicles entering the lot based on their permits. Also, this subsystem will communicate with the central database for monitoring and management purposes.

Besides detecting and issuing permit, a vision system will identify the plate number of the approaching vehicle and associate the vehicle to the permit by storing the information in the database.

Another part of this subsystem is the display, where the real time availability of a variety of parking slots will be displayed. The display will be automatically updated based on the output of the individual slot management subsystem.

3.2 Exit:

This subsection consists of gate control mechanism based on the presence of a car. Being informed by the individual slot management system, this system will issue parking violation tickets or charge for the paid parking slots prior to opening the gate. The ticket/charge information will be reported to the central database which already contains the identifying information about the vehicle. Also, for visitor cars there will be a dispensing mechanism for the retrieval of the visitor tags provided at the entrance.

3.3 Individual Slot Management:

This subsystem contains sensor network that will detect the presence or absence of cars at each particular slot. Depending on the sensor network data, display unit at the entrance subsystem will be updated. Also, due to permit variations, it is required to monitor which particular car is at which spot. This subsection will ensure the tracking of vehicles at each parking spot and detect violations based on their permits.

In case of time restricted parking slots, this subsystem will include a time counter that will keep track of the time in and time out. Based on the counter output, violations or parking charge will be detected and necessary steps like issuing ticket will be performed at exit subsection.

3.4 Information Infrastructure:

This subsystem is connected with all the other subsections for the management of parking rules. In this subsystem all the controllers will be connected to a master controller. The master controller will be remotely connected to the central database. The database will be maintained to keep track of the cars entering and exiting the parking lot. Also based on the detection sensor and time counter outputs, database will be interrogated to determine parking violations and to control gate mechanism.

4. Technology Investigation and Selection:

Based on the subsystems following technologies are investigated in the automation of the proposed parking system:

Figure 2: Technology Subsystems

For detection RFID technology has been selected at both entrance and parking subsystem. For keeping track and monitoring vehicles entering and exiting the parking lot, a camera with license plate analyzing algorithm and a central database has been taken into consideration. Finally, for the enforcement part, based on violations gate control and ticket issuing mechanism has been implemented.

4.1 RFID technology:

There are several sensors available for detection technology, such as ultrasonic sensor, IR sensor, Sonar sensor, Magnetometer, RFID. Ultrasonic sensor can be a cheaper and easy to install detection sensor. Though it can detect the presence or absence of a car, this technology will not be able to detect able which particular car is at that spot. Also due to the indoor only

compatibility of IR sensors, it cannot be used for an open parking environment. Magnetometer has also been cancelled out due to the calibration and alignment complexity. Finally evaluating the performance of different detection sensors in an open parking lot environment, RFID has been selected as the final detection technology. Since RFID technology has the capability to automatically identify and track tags attached to objects, and RFID tags can contain electronically stored information, this technology has been selected over the other available options.

In the designed system RFID tags will be issued to the user and the database will contain the information of permit type related to the RFID tag. The entrance and Exit gate will be controlled by the output of RFID reader [12]. RFID system will be used in conjunction with servo motor to control the time the gate will open or to control the closing of the gate once the vehicle has cleared.
The RFID tag number in conjunction with the plate number of the vehicle will work as unique identification number for parking rights of individual vehicle. RFID readers will again be installed at each parking spot to detect which specific car is coming to or leaving from that particular spot.

4.2 Camera System:

Another part of the detection technology is license plate recognition to keep documentation of the vehicle in case of violations. License Plate Recognition (LPR) systems are usually designed to read vehicles license plate and automatically recognize license plate number in ASCII[13]. Systems are readily available for mass surveillance that utilizes optical character recognition (OCR) and hardware capable of reading license plates of moving vehicles[14]. The LPR system receives the image in one of two ways: either the image is captured by an LPR camera and fed to the integrated system or alternatively the image can be delivered electronically to the LPR engine and remote processing is performed. In all these systems a fixed or moveable camera is an integral part that will only able to scan the vehicle passing through a particular point.

After the image acquisition using a camera, the extraction of license plate can be done with edge detection, texture detection or character detection [15]. For the prototype implementation of the designed system, cameras compatible with Arduino master controller have been considered [16] which has been connected and controlled by the central processing unit.

In this designed system, in order to detect and keep track of the vehicles entering the parking lot, a camera will be set up at the entrance along with RFID reader. Here the camera trigger will be turned on to take the license plate picture only when a car is entering the parking lot. The entrance right of a car will be determined by the output of the RFID reader at the gate. Afterwards the capture of the camera will be sent to the central processing unit where the license plate number will be retrieved via image processing and will be stored to the database against the RFID reader output at that time. In this way a particular RFID tag number will be stored in the database with a particular license plate number. Based on the database entries, later on, violation tickets will be enforced to that particular license plate vehicle, while the car is at the exit.

4.3 Communication Technology:

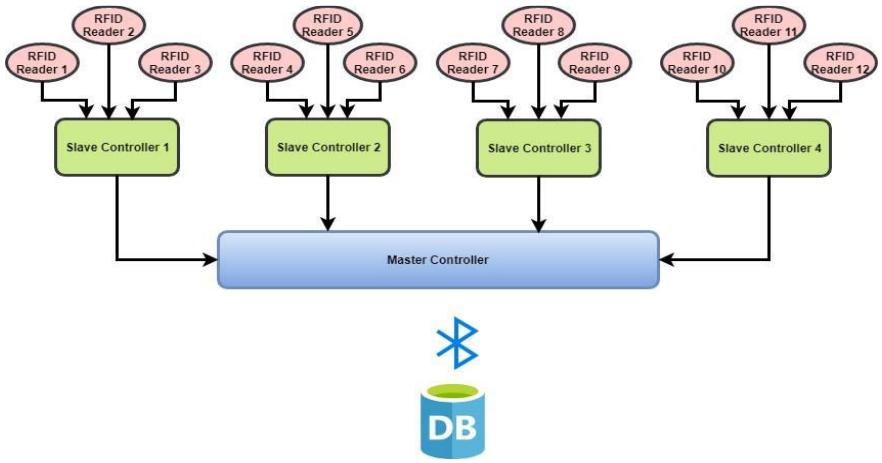

Figure 3: Communication Architecture of Sensors, Controllers and Database

4.3.1 Wired communication, I^2C:

The Inter-Integrated Circuit (I^2C) protocol allows multiple "slave" controllers to communicate with one or more "master" controllers. Most I^2C devices communicate at 100KHz or 400KHz. It requires two wires, serial clock (SCL) and serial data(SDA) lines like asynchronous serial [17].

Asynchronous serial ports where receiver and transmitter of one device is connected to transmitter and receiver of another device do not transmit clock data which causes garbled data transfer. Additionally, they require hardware overhead at either end of devices which is complex. At least one start and stop bit is required for each 8 bits of transmission. On the other hand, Serial Peripheral Interface(SPI) requires four lines makes it undesirable for connecting lots of slave devices to master [18].

In our research Arduino mega controllers were used as slave and master controllers. RFID readers are connected to slaves which detects the unique ID when vehicle is parked in a parking space. This ID is transferred to the master controller through I^2C protocol.

4.3.2 Wireless Communication-Bluetooth:

Generally, the sensor network and the back manager (Database) will be placed at long distances which makes wired connections complex. Therefore, the communication between the master controller and database is shifted to wireless and is implemented using Bluetooth technology assuming low communication range in our prototype. Wi-Fi technology can be implemented in real time monitoring system for long distance range of communication between controller and database. This system is illustrated in figure 3.

4.4 Gate Control and Visitor Tag Issuing Mechanism:

Entry and exit will be control by stepper motor operated gate. In the entry gate visitor tags will be issued from RFID tag dispenser to the cars that don't have RFID tag permits. As soon as the car with RFID tag approach the entry gate, it will detect by the RFID reader placed in the gate. Confirming the tag number in the system data base entry gate will open. Exit gate

mechanism will be also controlled by the RFID reader, placed near the exit gate, which will instantly read the tags attached to vehicles. By checking the tag ID with the database, it will ensure whether that is a visitor car or a permit holder car. If it is a regular commuter car (having previously issued permit) that have not violated any parking rules while being in the lot, the gate will open immediately. For a car that violates any rules like, parked in a wrong spot or time violation, a ticket will be issued in the exit gate. After dispensing the ticket, gate will open. If the reader detects a visitor tag holder car at the exit gate, it will not open the gate until the driver drops the tag in a particular box placed at the exit. This retrieval box will also contain a short-range RFID reader that will detect the retrieved card. After getting signal from the Reader in the drop box, exit gate will open for visitor cars that have not violated any rules. For visitor cars with parking violations, the same rule as regular commuters will be applied. After dispensing violation ticket, the database will keep track of the ticket issued car based on its license plate number and steps will be taken by management in case the ticket amount is not paid.

5. System Architecture:

The detailed architecture of the system is described in figure 4. The flowcharts of operations, while the car enters, parks and exits are presented.

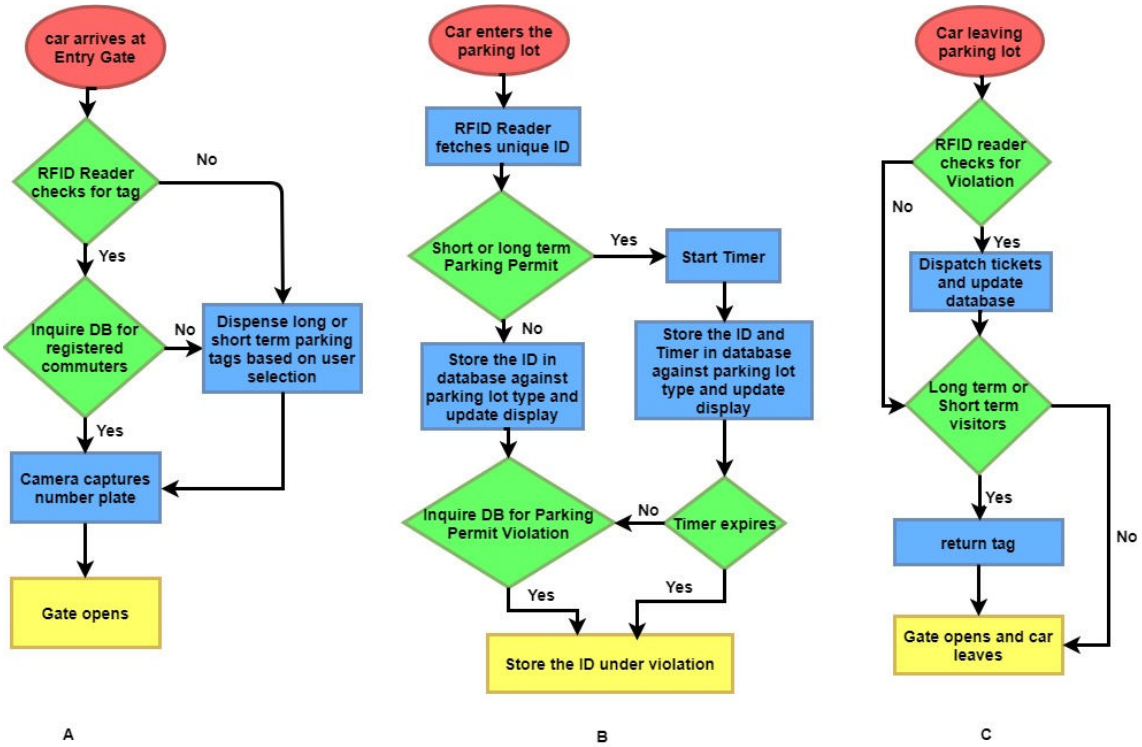

Figure 4: System Architecture. (A)Entrance(B)Slot Management(C) Exit

6. Prototype Implementation:

A 1:24 scaled prototype has been developed to mimic a Grand Valley State University parking lot with various parking restrictions. Figure 5 shows the layout of the parking lot and an actual picture of the implementation.

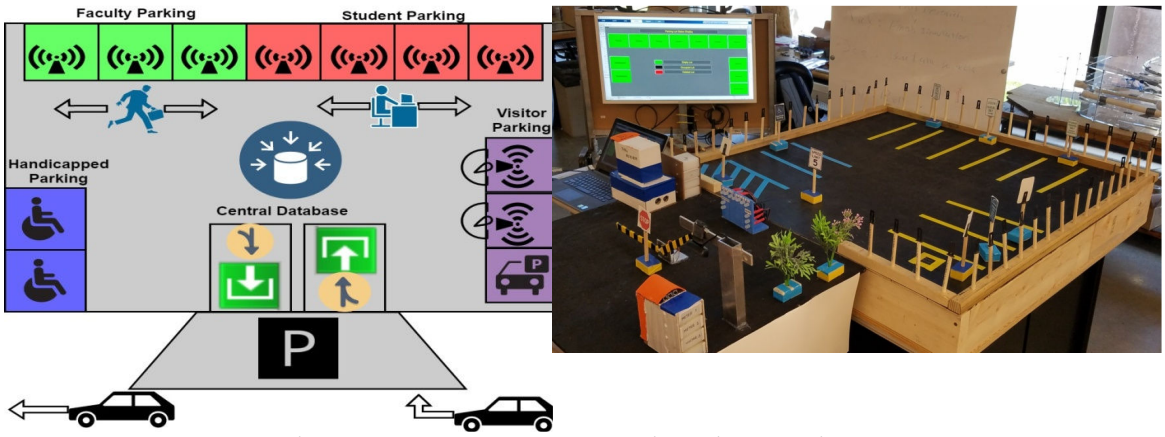

Figure 5: Prototype Layout and Implementation

Specific car detection at each parking slot and counter for time restricted parking slots have been implemented. A network of sensors is connected to the information infrastructure via master-slave communication of multiple Arduino controllers. For this implementation RFID ID20LA reader has been used which has a tag reading range of 20 cm. In the presence or absence of a car, the central display at the entrance shows slot availability (Fig. 6.a). Along with the centralized display unit, a display at the parking management office will also display the availability and parking violations. Here Green, Black and Red color demonstrate Availability, Occupancy and Violation accordingly. Using the I^2C communication of multiple Arduino controllers, the permit tag ID is sent to the central database.

RFID controlled entrance gate opens for a car with valid tag (Fig. 6.b) and allows visitors to obtain an appropriate permit from a dispenser. RFID reader and the camera at the entrance gate associates each car with a tag number. At the exit, backbone system computes for any violation by reading the RFID tag of the car. The gate opens for no violation (Fig. 6.c) and dispenses ticket for the violators. For visitors the gate opens only after the tag is returned into a bin.

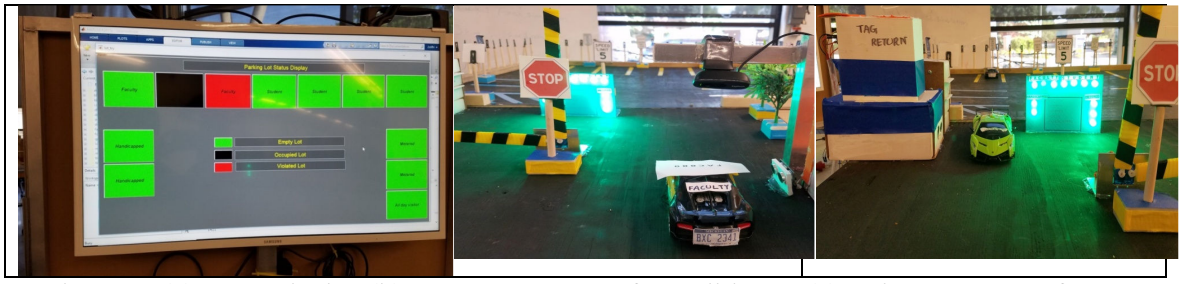

Figure 6: (a) User Display (b) Entry Gate opens for Valid Pass (c) Exit Gate Opens for no Violation

7. Conclusion:

In this research project a systematic design methodology is followed to find the best solution for an autonomous parking management system for a typical university parking lot. Design process started by gathering user input to determine the system requirements. The vehicle identity detection is executed by a camera at the entrance. In-ground RFID readers at the parking slots are used to identify the RFID tag in the vehicle and thereby determine the permit type. The sensor network has been connected through a master controller to a remote

management system. Based on the real time database analysis the management system provides occupancy information, determines violations, and takes necessary actions for violations and issue tickets. The systematic design method led to a robust design which will fulfill the system requirements. For the prototype implementation a short range ID20LA RFID has been used, however, for full scale implementation RFID with appropriate range will be implemented, and Bluetooth connection will be replaced by Wi-Fi connection. Also, for real life implementation, legal issues related to the scanning of vehicle License plate at the entrance, along with tracking vehicles inside parking lot should be checked accordingly by considering the rules and regulations of Parking Lot Management System and Privacy Act. In future such autonomous monitoring system can be extended and combined to self-driven cars for full automation of future parking system.

Acknowledgement: Authors express their gratitude to The Graduate School of Grand Valley State University for awarding the presidential Research grant to pursue this project.

8. References:

[1] R. H. Weber and R. Weber, Internet of things, vol. 12. Springer, 2010.

[2] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of things for smart cities," *IEEE Internet Things J.*, vol. 1, no. 1, pp. 22–32, 2014.

[3] Hong Xiao,Dongchen Wang, Rahul Khushoo, Andre Turner, Afshin Moshrefi. "Parking lot management system." Application No.US20120299749A1, 29 Nov 2012.

[4] Noguchi, Kazushige. "Parking lot management system using wireless LAN system." U.S. Patent No.US7253747B2 Aug. 2007.

[5] Goldman, Stuart O., and Susan A. Feyerabend. "Dynamic parking place location system." Application No. US20100302067A1. 2 Dec 2010.

[6] S. Lee, D. Yoon, and A. Ghosh, "Intelligent parking lot application using wireless sensor networks," International Symposium onCollaborative Technologies and Systems, 2008, pp. 48–57.

[7] Z. Ji, I. Ganchev, M. O'Droma, L. Zhao, and X. Zhang, "A cloud-based car parking middleware for IoT-based smart cities: Design and implementation," *Sensors*, vol. 14, no. 12, pp. 22372–22393, 2014.

[8] Y. Vishwanath, A. D. Kuchalli, and D. Rakshit, "Survey paper on Smart Parking System based on Internet of Things," Int. J. Recent Trends Eng. Res., vol. 2, no. 3, 2016.

[9] B. B. Roesner, "Vehicle Detection System with RFID-Based Location Determination." Google Patents, 08-Nov-2012.

[10] Mark Roberti, "Can RFID Tags Be Read When Buried Underground?"[Online]. Available:http://www.rfidjournal.com/blogs/experts. Accessed on 03/04/2018.

[11] G. (Gerhard) Pahl, K. Wallace, and L. Blessing, Engineering design : a systematic approach. Springer, 2007.

[12] Ray Floyd, "RFID for Access Control ," 2014. [Online]. Available: https://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/7668/RFID-for-Access-Control.aspx,Accessed on 02/27/2018.

[13] Jadhav, Ganesh R., and Kailash J. Karande. "Automatic Vehicle Number Plate Recognition for Vehicle Parking Management System." Computer Engineering and Intelligent Systems, ISSN: 2222-1719.

[14] J.-K. Tyan and C. Neubauer, "Character segmentation method for vehicle license plate recognition." U.S. Patent No.US6473517B1, 29-Oct-2002.

[15] Makwana Maulin, R., and Dharmesh Bhalodia. "Survey on License Plate Recognition (LPR) System."ISSN: 2349-6002,2014.

[16] "A Guide to Arduino Based Video Camera | Open Electronics," 2017. [Online]. Available: https://www.open-electronics.org/a-complete-guide-to-arduino-based-video-camera/,Accessed on 03/10/2018

[17] D. Paret and C. Fenger, *The I2C bus: from theory to practice*. John Wiley & Sons, Inc., 1997.

[18] F. Leens, "An introduction to I 2 C and SPI protocols," *IEEE Instrum. Meas. Mag.*, vol. 12, no. 1, pp. 8–13, 2009.