"Implementation of a License Plate based Road Toll Collection and Management System"

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Abstract

The aim of this research paper is to design a prototype of a license plate recognition-based road toll tax collection system. The system will use a self-designed Automatic Vehicle License Plate Recognizer (AVLR) to detect the license plate of incoming vehicles from a threshold distance. This AVLR will be programmed to literally read characters on any given vehicle's license plate. The output of this AVLR will be fed to the system's algorithm which will check for available funds in the license plate owner's bank account/accounts or other linked digital wallets. If sufficient funds are found the toll gate would simply swing open allowing the vehicle to pass through the express lane without any need for stopping. If not, the gate would stay shut and the vehicle's driver will be alerted about the same early enough for him/her to switch to the normal lanes where he/she could pay the toll tax using traditional methods (cash/card). Approximately, the implementation of this system can double the upper limit of the volume of traffic that can pass through a given toll station per unit time. It would truncate long waiting queues while curbing air pollution caused by running engines. The system would concur with Digital India and Digital World Initiatives. Primarily, it will make the management and working process of a toll station simpler for all the involved parties. On a separate note, the system could also be used to track and locates stolen vehicles or catch fugitives evading in vehicles. As a corollary, the system would require all the vehicles to have a standardized license plate which will further assist in attaining a normalized traffic system.

Keywords *- Toll Plaza, Arduino, Toll Tax, E-Payment, Automobiles, Vehicles, License Plate Detection, Traffic Flow, Digital World*

1. INTRODUCTION

Automated toll stations are next generation toll collection and management system which exploits state-of-art technologies to automate the two major processes involved:

i. Vehicle Detection
ii. Toll Collection

Though there have been several attempts to replace the conventional toll collection systems, most of them require the vehicle owner to attach some additional piece of equipment to the vehicle. Here, the conventional toll collections systems refer to the completely manual or sub-automatic functioning of barricades that open or close based on the toll paid by commuters. In such systems, manual labor needs to be deployed at each station lane to collect

toll and give out corresponding receipts. Modern systems make use of auxiliary technologies like RFID to detect the identity incoming vehicles. Though, RFID based systems have seen their fair bit of success, theoretically, an ideal system should remove any and all external dependencies (in this case, the RFID tag) while essentially identifying vehicles using its own innate components. This is where the proposed system steps in. It discerns vehicles based on their license plates to determine necessary action plan which in this case is opening or closing of the toll gate. Since, there is no other entry point in the system except the vehicle itself, the probability of an unlawful penetration or system rupture is much lesser than the alternatives. Increased robustness guarantees that the system cannot be bypassed by any other course of action than what it is designed for. This also enables the diversion of resources to other tasks like toll collection and management. Although, having a minuscule effect in terms of magnitude, the proposed system will also eliminate a few potential health and environmental hazards like air pollution caused by running engines and threats posed by RFID waves.

2. HISTORY

2.1 Why is toll tax collected?

To reduce travel time between long distances, cities or interstate travels, the governing bodies of a country sanctions the construction of highways. These roads have certain predefined stops where a passing vehicle has to pay a fee to travel that road. This fee is known as toll tax or simply toll. Most of these roads are built by local, state or national governments or in some cases by private builders. The cost of construction and maintenance of these roads are reimbursed using the toll taxes paid by people using them. These toll taxes also allow new roads to be built without increasing burden on public that doesn't use them. A toll road doesn't always keep charging toll tax. Sometimes, the toll is removed once the cost of construction of that road has been recovered. Also, toll taxes can be collected on roads not classified as *'highways'* owing to some other political, social or strategic purpose. Based on the degree of automation toll collection systems can be broadly classified into two types:

i. Traditional Toll Collection Systems
ii. Modern Toll Collection Systems

2.2 Traditional Toll Collection Systems

This was the first model of toll collection and is currently prevalent in most parts of the world especially third world and developing countries. In this model, an installation known as a toll station branches the toll road across multiple lanes depending on its breadth. Each of these lanes has a small toll booth, which generally accommodates a single person whose job is to collect the tax and give corresponding receipts. The problem here is, high dependency of the system on manual labour which is prone to commitment of mistakes and errors. Multiple employees also increase the maintenance cost for the toll station.

Figure 1. Traditional Toll Collection System

2.3 Modern Toll Collection Systems

Rapid evolution in technology gave birth to modern toll collection systems. These systems basically fill the loopholes of traditional toll collection systems. The key improvement here is, that along with multiple normal lanes, a couple of express lanes were introduced on the toll station. These lanes drastically reduce the management hassle and overall workload on the employees. To use an express lane, a vehicle must be equipped with some form of an electronic pass. This electronic pass is usually RFID based. The approaching vehicle's electronic pass is detected by an electronic pass detector placed on the express lane booth and the toll tax is levied on the registered owner's bank account or debit/credit card. These lanes allow the vehicles to simply zip through without creating laborious traffic. One major issue here is that an additional electronic pass has to be obtained by vehicles to use the express lanes. Notably, most modern toll stations are equipped with CCTVs for security purposes but have to install an additional electronic pass reader.

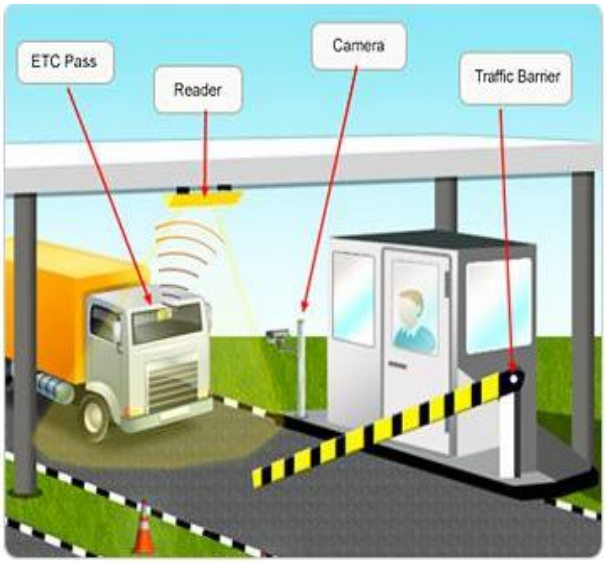

Figure 2. Efcon India's Automated Toll Collection System

3. METHODOLOGY AND PROTOTYPE

The core modules and data flow identified for the proposed system is as follows:

User Registration: Each user registers in the system with his/her basic details like Name, Email, Contact Number, Address and lists the license plate/plates registered with his/her identity. This information must be cross-checked and verified with the government body responsible for maintenance of vehicle records and registrations in the given geographical area.

The AVLR is made up of three components:

i. Proximity Sensor
ii. High quality camera
iii. Image Processing Algorithm

Proximity Sensor: A sensor is placed at a threshold distance from the toll gate, say 100 feet. This sensor would activate the subsequently placed high-quality camera and prepare it for image capture.

Camera: The camera must be placed at a height of about 2 feet above the ground, angling towards the tentative region where a vehicle's license plate will lie. The camera upon being activated by the proximity sensor captures a few clear images of the incoming vehicle's license plate and sends it to the image processing algorithm.

Image Processing Algorithm: The image processing algorithm receives multiple images from the camera and extracts the alpha numeric license plate number by isolating it. This process goes hand in hand with a background thread which simultaneously runs the extracted string against all the registered license plates in the system.

Digital Board: A small digital board is placed on each lane and at a conspicuous location so that any driver regardless of the dimensions of the vehicle can see the information being displayed on the board.

Open/Close toll gate: Upon finding a match and sufficient available funds to the linked account of the identified license plate, a green signal and the account holder's name is displayed on the digital board. The toll gate opens and the vehicle can pass through the same lane without stopping. If either of the above conditions are not met, the digital board displays a red signal coupled with the reason for failure. At this point, the driver has to shift to a manual lane.

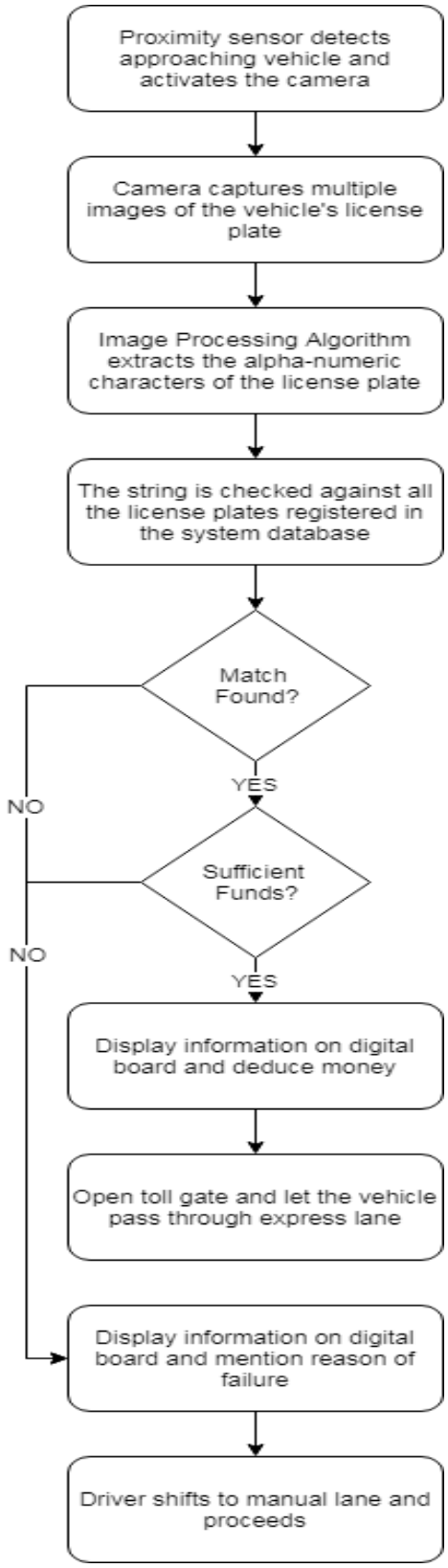

Figure 3. System Flow Chart

Based on the above research we designed a working model of the system using basic available technologies. We used a 10-megapixel smartphone's camera to capture the license plate of a few vehicles. These images were passed to Google's image processing Cloud Vision API. The response to open or close the toll gate was sent in the form of a Boolean value using ESP8266 Wi-Fi module.

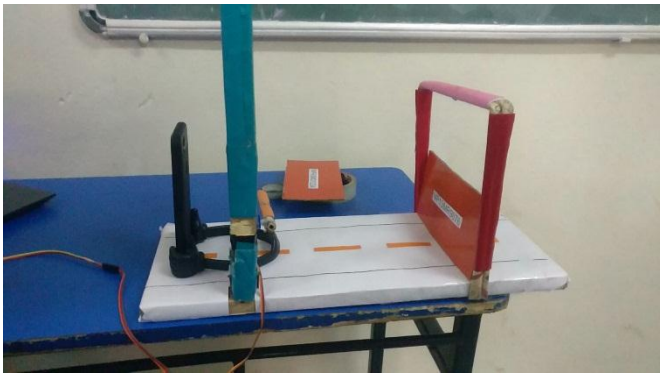

Figure 4. Snapshot of the prototype

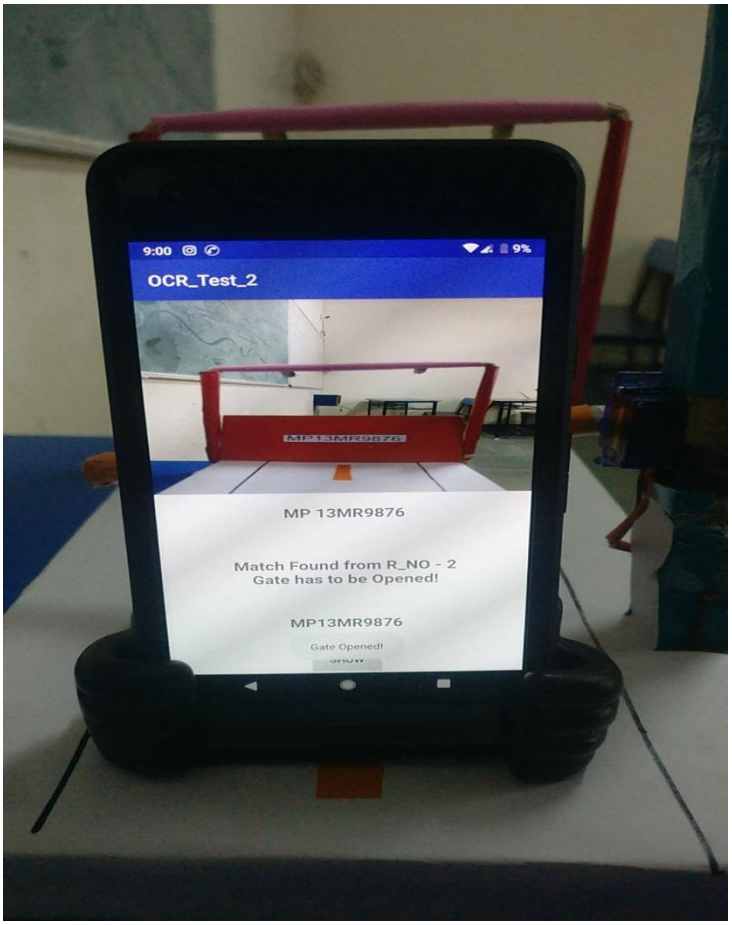

Figure 5. Snapshot of a sample test case

4. OBSERVATIONS

Out of 30 vehicle images captured, 29 were an absolute match while only 1 had a single misread character. This hit ratio of 96.6% can be further increased by a better-quality camera. The system's is quick enough to complete each cycle of toll collection and reset itself for the next vehicle. The key observation here is that the system is extremely precise and reliable but only when a few norms are stringently followed during deployment and all through the system's period of use. The following attributes reflect the important aspects with regard to which standards must be set. It is important to note that the specific values or magnitude of each attribute given below must be decided by the concerned parties upon rigorous field analysis. Failure to comply with laid norms could lead to system turbulence or failure in the worst case.

i. Position of placement for the proximity sensor, camera and digital information board must be defined precisely on the basis of system load, internet speed, volume of traffic and equipment quality.

ii. Speed limit at the toll station must be high enough to eliminate the possibility of a traffic jam and low enough for the driver to switch to normal lanes.

iii. Lane diversification points must be provided at locations where it's easy for the driver to switch to normal lanes.

iv. All the license plate characters must be clearly visible.

v. License plate characters should have a standard font type and size.

vi. The station must be equipped with a good internet connection to allow cloud requests.

vii. Grievance redressal point must be set up in case, a driver faces any difficulty like incorrect information on digital board.

5. ENHANCEMENTS

Although, the system ticks all the basic boxes but a few enhancements can make it even more enticing:

Vehicle Dimension Detector: Using a combination of vertical and horizontal array of sensors, the dimensions of a vehicle can be determined at run-time. This can be used to dynamically adjust camera position which can increase efficiency in correctly detecting license plates.

Preprocessing Booth: In case of a traffic jam at the station, a preprocessing booth can be activated which processes toll payments even before the vehicle reaches the toll gate.

Local Database: A local replica of master database could be maintained at the toll station with predefined refresh times to increase the overall response time of the system. This will keep the system going in case of a lengthy internet downtime.

Data Analytics: In-depth analysis can be performed on the collected data like vehicle passing frequency or busiest time of the day. This can help in dynamic allocation of resources at the existing toll station and reveal economically profitable or geographically feasible locations of new toll stations.

6. CONCLUSION

The final outcome of this paper leads to the development of a highly efficient modern toll collection and management system. A working prototype was implemented using an ESP8266 Wi-Fi Module, a smartphone, a user accessible website and Google Cloud Vision API's image processing algorithm. The result obtained is remarkable and exceeds expectations. It is safe to say that the system is feasible to implement in all respects. A full-fledged deployment of the proposed system has the capability to replace all current toll collection systems and that too at a comparatively cheap cost since most of the stations have already installed CCTV cameras. In a nutshell, smoother traffic flow and better capital management can be achieved all while simplifying the process.

The system helps in mitigating air pollution and harmful effects of electromagnetic waves used in RFIDs. The system could be handy in theft detection or fugitive tracking as it logs the precise time and identity of every passing vehicle using a camera as a primary and only source of information. With a few tweaks, this system could also be deployed in restaurants, shopping malls or any other points of interest to keep detailed information about parked vehicles and their parking fee collection.

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