Automatic detection of number-plate and traffic infractions of motorcyclists by Intelligent Transportation Systems

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Abstract. Public Transportation Strategic Systems are a digital transformation for the urban transportation service in the Colombian medium-size cities, from 200,000 to 600,000 inhabitants. The implementation of the urban public transportation services has not started in many cities; as a result, this cities in Colombia have an increase of illegal motorcycle taxis, which cause a high number of road accidents. The main method for controlling illegal motorcycle taxis is by giving the drivers transit fines. In order to give such transit fines, transit police have several control points in medium-size cities. In this article, we developed a mobile application to detect three types of transit infractions usually committed by motorcycle taxi drivers. The purpose of this application is to be a tool for the transit police agents to disincentivize the use of motorcycle taxis. The mobile application detects a possible transit infraction, saves the photo, motorcycle plate number, date, and time. Afterwards, the application generates a support for the transit infractions that will be issued by the transit police officer. We performed an experiment using this mobile application in the city of Valledupar, Colombia. The mobile application captured 40 possible transit infractions.

1. Introduction
The lack of a public transport system that meets quality requirements –such as, efficiency, coverage, accessibility, and sustainability– is one of the main reasons for the rise of illegal transport providers in medium-size cities in Colombia [1]. Gwilliam defines illegal transportation (also known as paratransit) as a transportation service for passengers that is not part of the public transportation [2]. The most common types of paratransit are: buses, collective taxis, particular cars and motorcycle taxis. Motorcycle has become the principal transport medium in Thailand, India, and Colombia, where most of the population use this medium for daily travels. In India, 11.7 million motorcycles were sold in 2016 [3]. Motorcycle Accident in Depth Study (MAIDS), made by France, Italy, Netherlands, Spain, and Germany, mentions that in 68.7% of the motorcycle reported accidents, the helmet could have prevented or reduced the amount of accidents [4]. For this reason, in many countries the use of helmet is mandatory by law.
In Colombia, paratransit has caused the elimination of bus routes in medium-size cities. This has caused a decrease of coverage of the bus routes, and paratransit providers took this opportunity to provide substitute alternatives for public transportation [5]. The use of paratransit alternatives, motorcycle taxis in particular, has caused a reduction of road traffic safety. In 2018, more than 3,000 people died in traffic accidents in Colombia, according to the Colombian National Road Safety Agency (ANSV, in Spanish). The Colombian Ministry of Transportation confirmed that there is a correlation between paratransit and deadly road accidents [6]. The main control that transit officers do to reduce paratransit is giving transit fines to motorcycle drivers that are not wearing helmets, driving in prohibited places in the city (for instance, downtown), or are driving with a passenger when it is prohibited (depending on the city, this could be fixed days or permanently). This kind of motorcycle monitoring is inefficient because transit police officers are limited, and human senses are limited to tracking every motorcycle driving in the area along their number-plates.

The control measurements performed by transit police officers are previously established by the local authorities previously. Valledupar city, in Colombia, is an example of these measurements. The city mayor created the following policies by law. (1) Do not allow the driving of motorcycles, during weekdays, with passengers, inside the city center area. (2) Do not allow the driving of motorcycles on Wednesdays from 8:00am to 6:00pm. (3) Do not allow to transport passengers in a motorcycle during Saturdays. (4) Both passenger and motorcycle driver must wear a helmet. The infringement of these policies can be punished with a transit ticket by the transit police officers [7].

The hypothesis of this article is: using a mobile phone application, is it possible to detect plate number and transit infractions caused by motorcycle drivers? We developed a mobile application that could serve as a tool for transit police officers to automatically detect, using their cellphones, the motorcycles driving in a certain area and the transit infractions that their drivers perform. The mobile application uses machine learning and artificial intelligence to recognize 3 types of infractions: not wearing a helmet, driving in prohibited places, and transporting a passenger.

In what follows, we present Intelligent Transportation Systems in Section 2. After, in Section 3, we describe automatic number-plate recognition. In Section 4, we explain object detection using computer vision. In Section 5, we explain materials and methods. In Section 6, we show the obtained results. Finally, in Section 7 we give some conclusions and future work.

2. Intelligent Transportation Systems

An Intelligent Transportation Systems (ITS) refers to the use of Information Communication Technologies (ITCs) to solve problems in conventional public transportation systems using technology to increase safety, effectiveness, efficiency, accessibility, and sustainability of the transportation network without increasing the capacity of the network [8]. The Colombian Ministry of Transportation defined an intelligent transportation system as the combination of several engineering areas (transportation, telecommunications, environmental, financial, among others) to increase the efficiency of public transportation, reduce the environmental impact, and safe human lives (road safety) [9].

The incorporation of edge technology in transportation systems is one of the strategies used in the main cities of the world to improve mobility and road safety. Singapore, London, New York, Barcelona, among others have implemented this kind of systems, which are physically and operationally integrated, using traffic management centers. In doing so, they have paid less attention to big road construction projects proposed in the second half of the twentieth century. The benefits of the operation of an ITS are traffic reduction, travel time, cost, emissions, noise, and accidents [10].

2.1. Technologies in Intelligent Transportation Systems

ITS include a wide range of functions. These functions range from a simple mobile phone alert to sophisticated traffic control systems. It uses several technologies available such as those shown in Table 1 [11].
### Table 1. Technologies, implementation and examples of ITS [11,12].

| Technology                                      | Implementation and Examples                                      |
|------------------------------------------------|----------------------------------------------------------------|
| Data processing and management                 | Archived Data Management Systems (ADMSs)                        |
| Detection technologies                         | Traffic detector, automated vehicle detection, speed detection, environmental sensors |
| Communication technologies                     | Communication architecture                                       |
| Information transmission technologies          | Dynamic Message Sign (DMS)                                      |
| Positioning and location technologies          | Global Navigation Satellite System (GNSS)                       |
| Vehicle and Transit Control Technologies       | Motorway Control Center                                         |
| Electronic Payment Technologies                | Front-end, Back-end                                            |

To control and manage incidents, one solution is to use a television closed circuit. These systems are composed of digital cameras. Control and management incident systems are composed by intelligent digital cameras placed in strategic places to monitor traffic, speed, and other characteristics of traffic. As an example, autoscope cameras and cetrac system [13].

3. **Automatic number-plate recognition**

   In the first years of the twenty-first century, there has been an increased interest to develop safety mechanisms. Technologies such as biometric identification (for instance, voice, face, and signature) appear as new options replacing fingerprints. Automatic Number-Plate Recognition (ANPR) has been studied since 1976 by the UK police [14]. In all the cities of the world, there has been vehicle traffic problems, accidents, and drivers that break the law. This kind of problems led to the creation of identification and following of vehicles and has been extended to the identification of stolen vehicles [15].

   The vehicle control systems using number-plate recognition is among the new technologies that stands out. Nonetheless, its efficiency was not good at the beginning, and only recently, it has improved with the use of infrared systems and refined algorithms. In London, since 2003, there is a governmental program to reduce traffic during peak hours in downtown. To achieve this, cameras were installed in downtown, and using an ANPR software, it was possible to know which vehicle entered downtown, compared the number against a databased of prepaid vehicles, and in case that the vehicle was not registered in the database, issued a payment form. Although this system was originally planned to be a temporal measurement, the British authorities claimed to have made it permanent and extent it through out all the United Kingdom because they say that it helps to reduce crime [16]. As another example, in Italy, the company Advanced Technologies implemented an ANPR system to control access to restricted places in the city [17].

4. **Person and object detection using artificial vision**

   Automatic object detection starts with the acquisition of an image in a three-dimensional scene. Afterwards, the image is processed to improve quality and remove imperfections. The next step consists to separate the object from the background and obtain characteristics from the object such as color, texture and geometry. Finally, the characteristics of the object are compared with other objects in a knowledge database to determine the kind of object [18].

   The characteristics used in artificial vision are Hough transform, local binary patterns (LBP), histogram of oriented gradients (HOG) and Scale Invariant Form Transformation (SIFT) [19].
Chiverton developed a system to detect helmet on motorcycle drivers [20]. Chiverton’s system used a Support Vector Machine (SVM) model trained with characteristics obtained from data of the images in the region where the motorcycle drivers appear.

The selected characteristics capture the form and reflecting properties of the helmets, as the first half of the helmet is brighter than the second half. This system also considers the circular shape of the helmet. The system uses a circular shape detection using Hough transformation [21]. The main inconvenient with Chiverton’s approach was the high classification error because other objects in the scene are classified as helmets and some helmets are not detected. Another limitation is that the system does not detect first the motorcycle and its driver before detecting the helmet; therefore, the system may detect other helmets in the scene that are not related to motorcycle drivers.

To improve the classification problems of Chiverton’s system, Silva [22] developed a system that first identify the motorcycle divers in the scene using an SVM classifier that uses characteristics extracted from the LBP descriptor. After that, the helmet classification is made using another SVM model on the characteristics obtained from combining three descriptors: Circular Hough, HOG, and LBP.

5. Methods and Materials
In this article we use an incremental version of the design science research methodology [23]. The methodology has 5 steps: awareness of problem, suggestion, development, evaluation, conclusion.

**Awareness of the problem:** We made a literature review to understand the problem that motorcycle taxis are causing in Colombia. We also found out that the medium-size cities have not had enough budget to implement strategic transport systems, even though a law requiring this was passed 10 years ago.

**Suggestions:** We studied three designed alternatives to solve the problem of automatic plate number and transit infraction detection by considering the constraint that the solution needs to be low cost and respect the Colombian law. The first idea was to use a mobile application in a moving vehicle to detect the plate numbers and detect the transit infractions. We discarded this solution because the Colombian law does not allow automatic detection systems in moving vehicles [24]. The next solution was a fixed-place automatic detection system. This was discarded because the Colombian law requires that such a device comply with the following criteria: high accident rate, history of transit infractions, calibration mechanisms, and announce the detection system 500 meters before its location. These requirements will increase significantly the cost of the solution, Table 2 shows compliance with the requirements by type of tool. Finally, we designed a system that uses a mobile phone over a camera tripod and a mobile application as a tool for transit police officers to monitor motorcycle infractions. According to the Colombian law, transit police officers can use this kind of technological tools to detect transit infractions, in the same way they can use a speed detector or alcohol meter.

**Table 2.** Compliance of the requirements of the designed solutions according the Colombian law for automatic detection tools.

| Type of tool        | Technical criteria | Calibration mechanisms | Software tests | Authorization from the Colombian Ministry of Transportation | Signalization 500 meters before |
|---------------------|--------------------|------------------------|----------------|-------------------------------------------------------------|-------------------------------|
| Fixed-place device  | ✘                  | ✘                      | ✘              | ✘                                                           | ✘                             |
| Mobile device       | ✓                  | ✓                      | ✓              | ✓                                                           | ✓                             |
Development: The mobile application was developed using open source tools, in Figure 1 shows the design of our system. We used OpenCV, a computer-vision library, to process the images and locate the plate number area. We also used Tesseract, an Optical Character Recognition (OCR) library to recognize the characters of plate numbers.

![Diagram of the automatic detection system](image)

**Figure 1.** Design of the automatic detection system composed of a mobile phone, mobile application, portable cell phone power bank and camera tripod.

For helmet detection, we used MATLAB 2018 function `imfindcircles` that uses Hough circular transformation to detect circles in the analyzed images. We calibrated the parameters for sensibility and luminosity to detect the motorcycle helmets.

The experiment was performed for an hour, on a Sunday, in Valledupar City, placing the designed system at a traffic light with high vehicular traffic. For the tests, we used a Motorola Moto G4 mobile device that has a 13Mp camera. The mobile phone was installed on a tripod that reaches 70 cm in
height as shown in Figure 2. The system allows to have a good visibility of the number-plates and people on motorcycles using the camera. Figure 3 shows the detection and recognition of a number-plate by the mobile application. In this case, the characters of the number-plate are correctly recognized.

![Figure 3](image1.png)

**Figure 3.** License Plate Recognition by the App.

**Evaluation:** The metric to assess this experiment were the accuracy and precision [25]. The metrics were calculated using the Equation (1) and (2), respectively

\[
\text{Accuracy} = \frac{p}{N} \quad \text{(1)}
\]

\[
\text{Precision} = \frac{p}{N+q} \quad \text{(2)}
\]

where \(p\) is the number of samples correctly classified, \(q\) is the number of samples incorrectly classified, and \(N\) is the total number of samples.

**Conclusions:** To conclude this research we considered the problem in the context of Colombian sociocultural aspects, Colombian law, and the hypothesis of the research.

**6. Results**

During the experiment, 40 number-plates were detected. The accuracy was 85.5% and the precision was 77.7%. Figure 4 shows a case in which the number-plates could not be detected, analyzing the image shows that the angle of number-plate is not ideal for detection.

The system could not recognize 5 of the 40 number-plates captured by the camera during the experiment. This error was caused by environmental factors such as overexposure of the license plate or the angle of the camera with respect to the motorcycle. Figure 4 and Figure 5 shows an example of this problem.
The tests done in MATLAB for the detection of helmet and passenger showed us a precision of 53% and an accuracy of 67%, respectively. An example of the tests can be seen in Figure 6 and Figure 7.

**Figure 4.** Number-plate with an angle that does not allow recognition.

**Figure 5.** Detection of number-plate and helmet with overexposure.

**Figure 6.** Helmets detection using MATLAB. Left side shows a case in which detection was not correct. Right side shows a case in which the detection was correct.

**Figure 7.** Passengers detection using MATLAB. Left side shows a case in which detection was not correct. Right side shows a case in which the detection was correct.

In what follows, in Table 3 and Table 4, we show the confusion matrices of the helmet detection problem and the passenger detection problem, respectively. In the case of the helmet detection, the
main error arises when detecting people without a helmet as if they had a helmet and in the case of passenger detection it happens that in many cases it does not detect the passenger.

| Predicted value | With helmet | Without helmet |
|-----------------|-------------|----------------|
| Real value       |             |                |
| With helmet      | 32          | 7              |
| Without helmet   | 15          | 10             |

Table 3. Confusion matrix of the helmet detection.

| Predicted value | With Passenger | Without passenger |
|-----------------|----------------|-------------------|
| Real value       |                |                   |
| With passenger   | 9              | 11                |
| Without passenger| 1              | 19                |

Table 4. Confusion matrix of the passenger detection.

7. Conclusions
The local authorities of medium-size cities in Colombia have a huge interest in increasing road security. In particular, they want to reduce traffic accidents caused by motorcycles because it has been proven that they play a big role in this problem. In this article, we propose a new system to monitor and control motorcycle illegal transportation which is highly correlated with road accidents. Through our experiment, we confirmed the initial hypothesis: Using a mobile phone application, is it possible to detect number-plates and traffic infractions caused by motorcycle drivers? Using our mobile application, we were able to recognize the number-plates of the motorcycles and using MATLAB we were able to detect the motorcyclists who were not wearing a helmet. The precision was of 77.7% and the accuracy was of 85.5% for the case of number-plate recognition. The limitations of our system as in the case of excessive sunlight, in which the number-plates are overexposed. Another limitation is that the system is not designed to work 24 hours, 7 days a week. In order to do it, a different hardware is needed. The accuracy for helmet and passenger detection were 53% and 67%, respectively. These results can be improved because other circles were detected in the images that do not correspond to a helmet and or passenger. A solution to these problems in the detection of the helmet, is to first detect the motorcycle, and only after analyzing the area of interest of the image to detect the circles. For future work, we recommend improving the training of the algorithms for Automatic Number-Plate Recognition to increase its accuracy. We also recommend implementing algorithms in the mobile application for object detection in order to detect driver or passengers not wearing a helmet and when the motorcycle has a passenger in addition to the driver. In this way, MATLAB will not be required and the mobile application will work stand alone.
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