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A Convolutional Neural Network-Based Vehicle Theft Detection, Location, and Reporting System

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***Abstract*—**One of the principal challenges that the world is confronted with is insecurity. The crime rate is increasing exponentially, and protecting our physical assets, especially in the motorist sector, is becoming impossible when applying our own strength. The need to develop technological solutions that detect and report theft without any human interference is inevitable. This is critical, especially for vehicle owners, to ensure theft detection and speedy identification towards recovery efforts in cases where a vehicle is missing or attempted theft is taking place. The vehicle theft detection system uses Convolutional Neural Network (CNN) to recognize the driver's face captured using an installed mobile phone device. The location identification function uses a Global Positioning System (GPS) to determine the real-time location of the vehicle. Upon identification of the location, Global System for Mobile Communications (GSM) technology is used to report or notify the vehicle owner about the whereabouts of the vehicle. The installed mobile app was implemented by making use of Python as it is undoubtedly the best choice in machine learning. It allows easy access to machine learning algorithms through its widely developed library ecosystem. The graphical user interface was developed by making use of JAVA as it is better suited for mobile development. Google's online database (Firebase) was used as a means of storage for the application. The system integration test was performed using a simple percentage analysis. 60 vehicle owners participated in this study as a sample, and questionnaires were used in order to establish the acceptability of the system developed. The result indicates the efficiency of the proposed system, and consequently, the paper proposes that the use of the system can effectively monitor the vehicle at any given place, even if it is driven outside its normal jurisdiction. More so, the system can be used as a database to detect, locate and report missing vehicles to different security agencies.

***Keywords*—**Convolutional Neural Network, CNN, location identification, tracking, GPS, GSM.

I. Introduction

SECURITY in general plays a major role in our day-to-day lives, and is a biggest contributor to our economy at large. The crime rate is very exponentially increasing, and so far citizens still need to protect our assets at all times. The issue of vehicle theft is increasing day by day in our society and regardless of the endeavors of the security agencies, it is not always the case that stolen vehicles are pinpointed, discovered or recovered.

Motor-vehicle industries have a challenge of making sure that the security measures that are in place keep up with the ever-changing world. Security models need to be developed to effectively help in dealing with the whole issue on how to better protect motor vehicles from theft [1]. The problem of vehicle theft is growing every day in our communities, regardless of all the security measures that are put in place by security agencies, not all the vehicles that are stolen are able to be detected, located and reported. Furthermore, most of these stolen vehicles are always detected, located and recovered in a different location that is different from where the vehicle was stolen either by security agencies or police due to lack of a real-time system that provides up-to-date information of the vehicle [2].

Some of the vehicles stolen are being cloned and sold back to consumers [3]. Cloning a vehicle refers to making an exact duplication or copy of a car, which was legally bought and registered. The South African Police Services (SAPS) reported 18,162 cases over the 2019/20 period; that equates to 50 cars being stolen in South Africa every day [4].

In view of vehicle theft challenges, this paper proposes an application that detects a stolen vehicle and reports the location of the vehicle. The application will use an installed mobile phone camera in the vehicle to capture the images of the potential drivers and attempt to recognize their faces compared against the faces stored in the database, this will be achieved through CNN.

II. Related Work

Reference [5] proposed a vehicle theft detection framework that used decentralized and secure platform to increase the security level of vehicles. They used 2-step Authentication (2SA) and Unauthorized access detection algorithms. The 2SA was used to secure the accessibility by providing random tokens chosen by the user.

Reference [6] proposed a Vehicle Alert and Location Identification Model that uses a combination of cellular network (GSM), GPS, and Web Technologies to create a system that will locate and alert the vehicle owner about the location of the vehicle. The system is triggered immediately when the ignition is switched ON, and an SMS is then sent from the vehicle (using the phone which is installed on the vehicle) to the owner's mobile phone, who then decides if the car should be reported as stolen or not.

Reference [7] proposed a Real Time Vehicle Theft Detection and Prevention system using Image Processing. The system collects photographs of the motorist and compares them to a database to determine whether or not he is an authenticated driver. The driver can only use the vehicle if he has been authenticated to do so. If he is not a verified driver, an alarm sounds and the electrical connections are turned off.

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Reference [8] proposed a Support Vector Machine (SVM) that could detect drowsiness during driving. The study used the SVM in identifying and differentiating changes that occur between alert and drowsy.

III. The Proposed System

A. CNN Function

CNN is one of the most popular deep learning neural networks. It has multiple layers; including convolutional layer, non-linearity layer, pooling layer and fully-connected layer. CNN has an excellent performance in machine learning problems, especially in applications that deal with image data, such as largest image classification data set (Image Net - A large visual database designed for use in visual object recognition), computer vision, and in Natural Language Processing (NLP) [9].

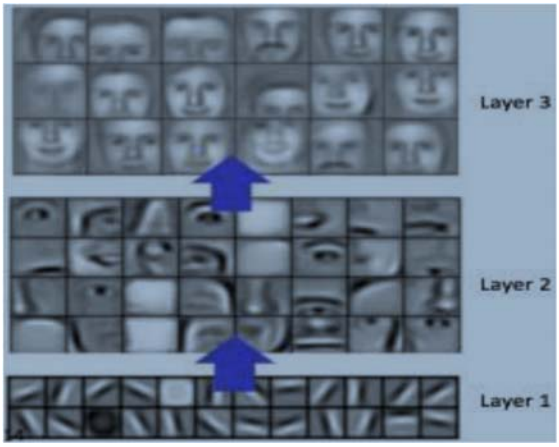

Fig. 1 CNN function

B. GSM Function

GSM is a standard that is used to describe the protocols for second generation (2G) digital cellular networks used by mobile devices such as mobile phones. The GSM cell tower enables the Short Message Service (SMS) to be sent from one mobile phone to another [10].

In this study, GSM will be used to send messages about the whereabouts of the vehicle from the vehicle to the vehicle owner.

Fig. 2 GSM function

C. GPS Function

The GPS is a satellite-based radio navigation system. It is one the Global Navigation Satellite Systems (GNSS) that transmits geological and time data to a GPS receiver from anyplace on or near the Earth with an unimpeded line of sight to four or more GPS satellites [11].

In this study, GPS will be used to identify the location of the vehicle.

Fig. 3 GPS function

Fig. 4 depicts the flow of data for the vehicle theft detection application. The vehicle driver will normally open the vehicle using his mobilizer/key then get inside. The driver will then attempt to turn on the ignition; immediately a picture of his face will be captured and compared with the existing ones in the database. If it is a match, the vehicle's ignition will successfully be turned on and a notification with the vehicle's location will automatically be sent to the vehicle owner's mobile phone. Similarly, if it is not a match, a notification with the vehicle's location will be sent to the vehicle owner's mobile phone, however, the vehicle's ignition will not be turned on.

Fig. 5 depicts a block diagram consisting of all the components of the developed application.

a. Vehicle Owner's Mobile Phone

It is mandatory that the vehicle owner should have a smart phone in order to be able to monitor the location of the vehicle through GPS and Google Maps.

b. Installed Mobile Phone

A built-in application on the installed mobile phone will allow the use of a SIM card in order to be able to send an SMS immediately when the vehicle ignition is turned ON. The installed mobile phone should support face recognition.

To gain access to the installed mobile phone, a profile per driver needs to be created which consists of their full name, a picture of their face, VIN number, and the vehicle owner's ID number (this will allow the owner to add family members as drivers of the vehicle).

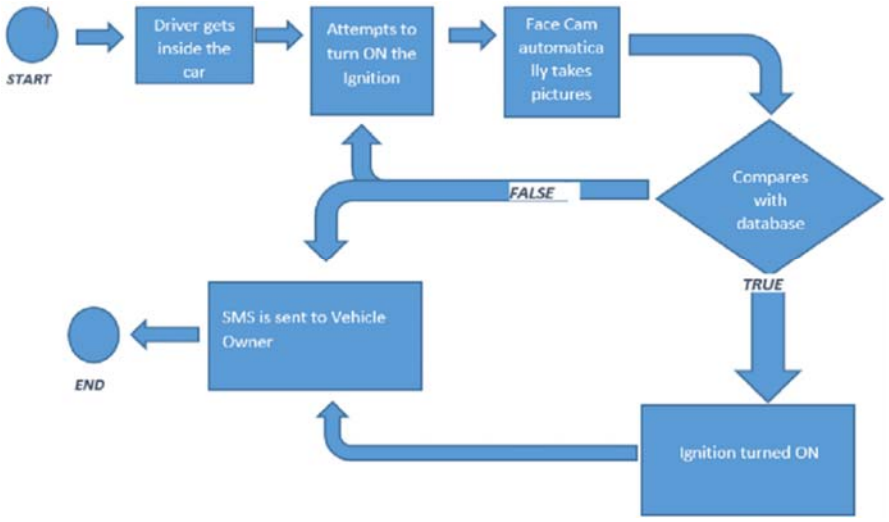

Fig. 4 UML representation of the vehicle theft detection application

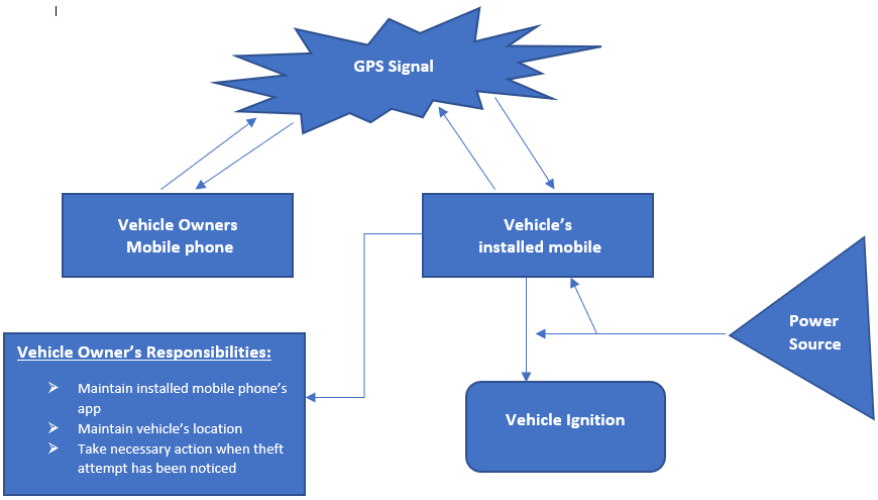

Fig. 5 Block diagram for the developed application

c. GPS

GPS will make it possible for the live location of the vehicle to be identified.

d. Power Source

The installed mobile phone's battery will act as the primary source of power for the installed mobile phone. The vehicle battery will act as an additional source of power for the installed mobile phone.

IV. Methods

The proposed vehicle theft detection method presents the researcher's technique for achieving a more affordable vehicle theft detection, locating and reporting application. The technique proposes the use of CNN, GPS and GSM technologies.

Fig. 1 represents the learned features from a CNN. CNN is incorporated in this study for the purpose of facial recognition.

Fig. 2 represents a physical working scenario depicting the communication established in symbolizing the theft reporting functionality.

Fig. 3 represents a physical working scenario depicting the communication established in symbolizing the location identification functionality.

V. System Integration Testing

To make sure the system's functionalities perform as intended, System Integration testing was performed on the vehicle theft detection, locating, and reporting application. The test indicates the way in which each component responded to an event. The results recorded are depicted in Table I. Table I depicts the inspection of the integration test performed on the vehicle theft detection, locating, and reporting application, this was performed as a means to determine how the application responds to instructions. Test case A indicates that 98.3% were able to capture their face and successfully be authenticated, however, 1.7% failed. Test case B indicates that 84.7% were able to send and receive an SMS from their mobile phone, however, 15.3% could not. Test case C indicates that 100% of the installed mobile phones were able to successfully send an

SMS. Test case D indicates that 73.8% of the vehicle's locations were identified immediately when the ignition switched ON, however, 26.2% failed to be identified. Test case E indicates that 73.8% of reports were sent, however 26.2% were not sent due to the location not being identified.

TABLE I
SYSTEM INTEGRATION TEST RESULTS

Test Case	Test event	Description of test	Expected Results	Results in %
A	Capture faces using installed cam	Capture and recognize faces of the driver	Identify authenticated driver	Successfully recognized faces 98.3% of the time. Failed 1.7% of the time.
B	Send and receive SMS from owner's mobile phone	Send an SMS to report and receive vehicle location	Ability to send and receive SMS messages	84.7 % Delivered, 15.3% Not delivered
C	Installed mobile phone send SMS	The installed mobile phone should be able to send an SMS automatically when the ignition is switched ON	When the ignition is switched ON the installed mobile phone should send an SMS to the vehicle owner to inform him about the event	100% Sent, 0% Not sent
D	Vehicle location detection	Identify the location of the vehicle	The location detection feature should pin point the exact location of the vehicle	73.8% Located successfully, 26.2% Failed to locate.
E	Report location	Send a notification containing the real time location of the vehicle	The owner should be able to see the live location of the vehicle	73.8% Sent, 26.2% Failed to send due to location not being identified

VI. Evaluation and Acceptance Analysis of the Developed System

The developed system was evaluated in order to accomplish the main objectives of this paper and also to acquire a full understanding of how the system works in a real environment. In order to determine the efficiency of the proposed developed system, end user data were collected (i.e., the owners of vehicles) that were used in the development of the system.

The mobile application that was developed was installed in 75 vehicles selected as a sample within three provinces in South Africa: Limpopo, Mpumalanga and Gauteng, in order to determine how effective the system was, and determine its ability to detect, locate and report a missing vehicle. In view of this, a questionnaire was used to ask the questions to understand the views of vehicle owners. The responses of the participants were collected immediately, and some questionnaires were sent via email, especially to those participants who are not near to where the study was carried out.

TABLE II
SYSTEMS EVALUATION ANALYSIS RESULTS

Questions	Reply (in % and number) Yes/Pleased	Reply (in % and number) No/Not Pleased
1) Are you familiar with vehicle theft detection application?	82% (49)	18% (11)
2) What is your opinion about vehicle theft detection application in detecting vehicle theft?	52% (31)	48% (29)
3) Does your vehicle have this application installed?	13% (8)	87% (52)
4) Would you recommend that every vehicle be fitted with this application?	72% (43)	28% (17)
5) Do you have another method to keep your vehicle secure?	8% (5)	92% (55)
6) Is your method effective?	0% (0)	100% (60)

Calculations of the evaluation analysis for the theft detection application were done by using simple percentage method as indicated in Table II. 60 out of 75 questionnaires were completed and sent back. The following are the questions that were asked:

a. Are you familiar with vehicle theft detection application?
b. What is your opinion about vehicle theft detection application in detecting vehicle theft?
c. Does your vehicle have this application installed?
d. Would you recommend that every vehicle be fitted with this application?
e. Do you have another method to keep your vehicle secure?
f. Is your method effective?

Feedback collected from the evaluation of the utilization of the developed application indicate that: 82% (49) of the selected vehicle owners are familiar with the vehicle theft detection application, however, 18% (11) had no idea what it was; 52% (31) are pleased with the vehicle theft detection application, however, 48% (29) are not pleased with it; 13% (8) confirmed that they have this application installed in their vehicles, however, 87% (52) do not have the application installed; 72% (43) recommend that every vehicle should have the vehicle theft detection application fitted, however, 28% (17) do not think it is necessary; 8% (5) have other means to secure their vehicle, however, 92% (55) only depend on the default security that comes with the vehicle. Of the 8% (5) who have other means to secure their vehicles, none (0%) of them believe their methods are effective.

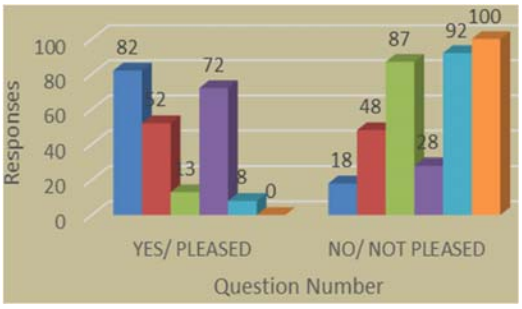

Fig. 6 Respondent analysis

VII. Conclusion

This paper focuses on vehicle theft prevention by means of face recognition, location identification and reporting as efforts towards recovering missing, stolen or unauthorized use of

vehicles. Several of the literature reviewed show how various technologies (e.g., Sensors, GPRS, GPS, GSM, RFID, etc.) have been used in this area over the past years.

The literature shows that even though most of these technologies have been helpful, they fail at times due to signal distortion and lack of network coverage. This paper proposed the use of CNN, GSM and GPS technologies to achieve the implemented system. To make sure the system's functionalities performed as intended, System Integration testing was performed on the vehicle theft detection, locating, and reporting application.

The developed application was evaluated in order to acquire a full understanding of how the application works in a real environment. In order to determine the efficiency of the application developed, end user data was collected.

Feedback acquired from the system integration and system evaluation indicates that the implemented application can be deployed and used as an affordable method for vehicle theft detection, locating, and reporting.

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