Enhancing car plate recognition with convolutional neural network and regular expressions correction

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ABSTRACT

This research paper presents the development and evaluation of an automatic number plate recognition (ANPR) system using convolutional neural networks (CNN) with regular expressions (RegEx) correction. The aim is to enhance the accuracy and effectiveness of car verification and security processes at First Technical University, Ibadan. The ANPR system was implemented both without RegEx correction and with RegEx correction. The evaluation results demonstrate significant improvements in the system's performance when CNN with RegEx correction is employed. The CNN-based ANPR system achieves a precision of 1.00, recall of 0.90, and F1-score of 0.95 in accurately identifying number plates. These scores indicate increased accuracy and reduce false positives compared to the system without RegEx correction. The integration of CNN and RegEx correction effectively handles variations and errors in the number plate data, leading to a reliable and efficient car verification process. Future work can focus on further refining the CNN model and optimizing the RegEx correction algorithms to enhance the system's accuracy and robustness. The developed ANPR system, utilizing CNN with RegEx correction, shows great potential for enhancing car verification and security in various domains, including law enforcement, parking management, and traffic monitoring.

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1. INTRODUCTION

Car license plate recognition (CLPR) is a widely studied and actively researched area in the field of image processing [1]. These systems play a crucial role in various applications, such as traffic and security management, parking systems, access control, and tracking of stolen vehicles. By utilizing intelligent algorithms, CLPR systems can recognize and read license plates on cars in real-world scenarios. The license plate serves as an official identification code permanently affixed to a vehicle and contains valuable information associated with the car or its owner [2]. One of the key components of automatic number plate recognition (ANPR) systems is optical character recognition (OCR) algorithms, which have undergone significant advancements [3]. ANPR systems employ artificial intelligence, computer vision, and pattern recognition techniques to extract text information from license plates. The ANPR process involves three main steps: number plate localization (NPL), character segmentation (CS), and OCR matching. NPL focuses on identifying and localizing number plates within images, CS involves segmenting individual characters from the detected number plate, and OCR converts the characters into encoded text information [4].

In various institutions, including First Technical University, auto-theft and vehicle insecurity present significant challenge [3]. The existing manual systems for car verification and security are often inefficient and prone to errors. Furthermore, the tally system used for car verification involves direct hand contact between security personnel and car owners, raising concerns about the spread of germs. This study aims to develop an optimized ANPR system using convolutional neural network (CNN) algorithm for CS with regular expressions (RegEx) correction. Implemented in Python and Jupyter, the system improves car security at First Technical University. Thereby eliminating the tally system, reducing germ spread, providing efficient car verification, and enhance record and management performance.

The remaining parts of this paper are organized in the following ways section 2 is the literature review. In section 3, the methodology for the study is explained, and in section 4 the experimental results are presented and the discussion are compiled. In section 5, the authors wrap up the study.

2. LITERATURE REVIEW

2.1. Nigerian number plate and properties

Cars in Nigeria require number plates for identification purposes due to the similarities in models, external features, and colors. These number plates are created using various methods, with each character holding significance based on country preferences. Nigeria's current generation of car registration was established in 1992 and upgraded in 2011, Nigeria and Liberia are the only African countries that have adopted the North American standard. Number plate identification involves considering factors such as material, size, and color [5]. In Nigeria, number plates are commonly made of aluminium, specifically retro-reflective sheeting combined with standard aluminium, which possesses infrared reflector qualities. The standard size for number plates in Nigeria is 6×12 inches (305×152.5 mm). Typically, Nigeria's number plates have a white color background with blue numbers and an embossed font of the Nigerian flag on a one-layer aluminum plate with a reflective film background in its original red color [6]. The unique format of Nigeria's number plates, such as "KJA-193AA" for new plates, indicates the local government area of car registration, followed by three figures and two letters for numbering purposes. The colors used on the plates, including red and green, hold specific meanings: red plates for commercial cars, green plates for government vehicles, and purple plates for diplomatic vehicles, with white writing. However, it should be noted that our study does not consider number plate color identification. Figure 1 shows the pictures of old and new Nigerian car number plate.

New number plate **Old number plate**

Figure 1. Nigeria car number plates, new car number plate (left) and old car number plate (right)

2.2. Object detection

Object detection is a computer software technique used in computer vision to visualize digital images and videos, including applications such as face detection, face identification, and video object detection. Its importance lies in locating objects in real-time scenarios, such as the identification and tracking of number plates on cars. To facilitate object detection, characteristic features are selected to enhance the computer's accessibility. Color attributes, represented by histograms, depict the appearance of objects, while edge-based features focus on image intensity borders [2]. Optical flow, based on motion segmentation and tracking, captures pixel motion through displacement vectors, enabling motion-based segmentation and tracking. However, object detection encounters challenges that require attention. Accurate object positioning is challenging due to potential location changes during the detection process. Lighting variations affect object appearance, demanding robustness in detection algorithms. This study only considered the new number plates. Rotation, occlusion, and changes in object size further complicate the detection task. Addressing these challenges and leveraging characteristic features enables object detection algorithms to deliver precise results in real-world applications, including the identification and tracking of car number plates.

2.3. Automatic number plate recognition

ANPR is a system composed of three main stages: NPL, CS, and OCR [3]. NPL involves image preprocessing and a computer vision algorithm to detect and localize the license plate. CS focuses on separating characters within the detected plate. OCR employs a deep learning method to identify the plate number. The NPL process includes image prepossessing by blurring the image using a bilateral filter, followed by plate localization and dataset division into training and testing stages [7]. OpenCV, an open-source computer vision library, is used for image processing and testing due to its wide range of applications [8].

CS algorithm applies to the localized plate, converting the license plate images to grayscale. It detects characters and numbers and adjusts the size based on the reserved space for English words. The algorithm normalizes sizes and selects contours based on area criteria, ensuring uniform character size. Edge detection in CS involves steps like Gaussian filtering, intensity gradient location, non-maximum suppression, and hysteresis-based edge suppression. Finally, contours are traced, and character recognition is applied [9]. OCR converts images of text into machine-readable text and plays a crucial role in ANPR. It recognizes characters on the license plate and extracts the data for further processing. Various OCR engines are available, and Tesseract, an OCR engine with extensive language support, is commonly used in ANPR systems. Tesseract can be trained to understand different languages and offers different output formats. In ANPR projects, Tesseract is typically used as the final step after sufficient image processing to achieve optimal results [10], [11]. In summary, ANPR relies on NPL, CS, and OCR stages for efficient license plate recognition. These stages involve image preprocessing, computer vision algorithms, CS, and deep learning methods. OpenCV serves as a useful platform for image processing, while Tesseract is commonly employed for OCR as shown in Figure 2. These technologies enable accurate and reliable automatic license plate recognition [3], [10], [12].

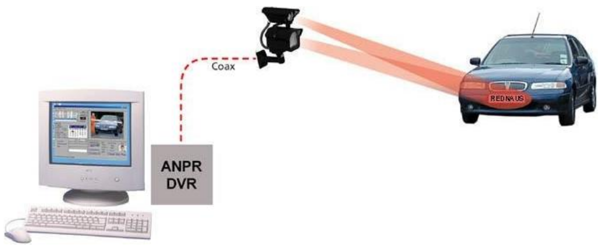


Figure 2. Overview of ANPR system

2.4. Machine learning and deep learning

Deep learning is a subset of machine learning that utilizes algorithms to process data and replicate the thinking process. It involves multiple layers of algorithms that learn and adapt over time, similar to human learning [13], [14]. Deep learning algorithms have various applications in real-world domains, including medical image analysis, image captioning, speech recognition, image recognition, and natural language processing [15]. One prominent classification of deep learning algorithms is SL, which includes CNN, deep belief networks (DBN), and recurrent neural network (RNN). CNN is widely used for image recognition tasks due to its ability to automatically learn hierarchical representations from input images. CNN has demonstrated remarkable success in various image-related applications, making it a valuable tool in the field of deep learning [16]. Here are a few foundational mathematical theorems related to CNN, as shown in theorems and (1).

2.4.1. Convolutional layer theorem

Let $f(x)$ and $g(x)$ be two functions with Fourier transforms $F(k)$ and $G(k)$ respectively. The convolution theorem states that the Fourier transform of the convolution of $f(x)$ and $g(x)$ is given by the product of their Fourier transforms:

$$\mathrm{F}\{f * g\}(k) = F(k) * G(k) \quad (1)$$

where (F) denotes the Fourier transform operator and ($*$) represents the convolution operation.

2.4.2. Pooling theorem

A fundamental concept in CNN is the pooling theorem. Aplying pooling operations to the feature maps in a CNN architecture, effectively decreases spatial dimensions while retaining crucial features. This theorem is applicable and useful in this study as it helped to optimize the performance of CNN by reducing spatial dimensionality and preserving crucial features. The pooling theorem is frequently used in the context of max-pooling or average-pooling operations in signal processing, particularly in the context of digital signal processing and CNNs. In this context, the theoretical foundations and characteristics of these pooling operations—such as their capacity to maintain significant features while lowering computational complexity and spatial dimensionality—may be referred to as the pooling theorem.

2.5. RegEx

RegEx are essential for text processing and pattern matching, providing a flexible way to search, match, and manipulate strings based on specified patterns [17]–[25]. In natural language processing, RegEx is used for tasks like text cleaning, tokenization, and information extraction. Researchers rely on RegEx to identify specific patterns in textual data, enabling the extraction of relevant information for analysis. In our study, we applied RegEx for error correction in our ANPR system.

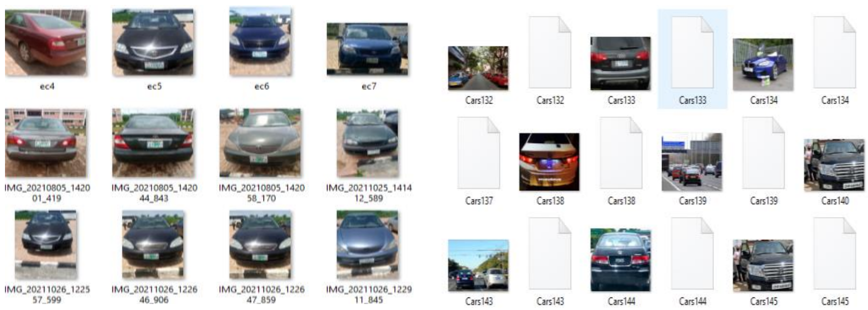
3. METHOD

3.1. Consent form

At the beginning of the study, a consent form was provided to staff members who voluntarily agreed to participate. The consent form outlined the purpose of the study, the procedures involved, and the use of their car images and personal pictures for conducting a survey test for the security personnel. It emphasized the protection of their privacy and ensured that their participation was voluntary.

3.2. Study area and dataset

The study was conducted at the First Technical University, Ibadan, which served as the study area. This location was chosen due to its relevance to the research objectives and the availability of necessary resources and participants. This section discusses the data collected for the study and the conducted memory test. The study uses both primary and secondary data sources Figure 3.



(a) (b)

Figure 3. Data from (a) car owners at First Tecnical University Ibadan and (b) kaggle

3.2.1. Primary data

A comprehensive dataset is essential when performing a car number plate recognition task. The primary data source for this study was collected by engaging the staff members of First Technical University, Ibadan. This included obtaining consent and gathering relevant data such as car images, number plates, and personal pictures to facilitate the mapping of cars with their owners.

3.2.3. Secondary data

In addition to the use of primary dataset obtained from staff members of First Technical University, a secondary data was sourced from Kaggle. This online platform is renowned for its extensive collection of datasets and served as a valuable resource for supplementing the primary data for this study. This data included a diverse range of car number plates, which provided a broader perspective for analysis and comparison. The link to this particular Kaggle car number plate dataset in [26].

3.3. Memory test

A car/car owner matchup test was conducted to assess the accuracy of matching cars with their respective owners. The test evaluated the ability of current security personnel or relevant individuals to correctly identify car owners based on their memory. Data collected, including car images, number plates, and personal pictures of the owners, was used for the test. Participants were shown car images and asked to identify the corresponding owner, providing insights into their proficiency in recognizing and recalling car owners Figure 3. The study includes a memory test conducted among seven security personnel to evaluate their proficiency in matching cars with their owners based on memory. The test scores ranged from 7 to 2, highlighting the need for an efficient number plate recognition car owner mapping system to support their tasks.

3.4. Machine learning

The machine learning algorithm used to develop our model is the CNN. CNN is known for its ability to effectively extract intricate patterns and features from complex data such as car images and number plates. The machine learning section of the study encompasses the essential steps of data preparation, model training, and testing and validation. In CNN architectures, these operations are frequently used to downsample feature maps, lowering their spatial dimensions while keeping the most pertinent data.

3.4.1. Data preparation

During the data preparation stage, we process and organize the collected data, which includes car images, number plates, and personal pictures of car owners. This data is carefully divided into two subsets, with 80% of the data allocated for training the CNN model, while the remaining 20% is used for testing the model. We apply data preprocessing techniques, such as image preprocessing and feature extraction, to enhance the quality and relevance of the data for effective model training.

3.4.2. Model training

The model training phase involves the application of deep learning algorithms, specifically CNNs, to construct models capable of accurately identifying and classifying car images and their corresponding number plates. We train the CNN models using the training subset of the dataset, and their performance is evaluated using various metrics to assess their accuracy and effectiveness. Through iterative training, we optimize the performance of the models and enhance their ability to recognize and extract meaningful features from the input images.

3.4.3. Testing and validation

The testing and validation phase involves evaluating the trained models using separate datasets to measure their ability to correctly recognize and match car number plates with their respective owners. The trained models were tested using a separate dataset, different from the one used for training. This helps ensure the models' generalisation and their ability to accurately identify car owners based on their number plates. Various performance metrics can be used to evaluate the models, such as accuracy, precision, recall, and F1 score.

3.5. Implementation tool

This study was conducted using a personal computer equipped with an Intel(R) Core (TM) i5-2410M CPU @ 2.30 GHz, comprising 2 cores and 4 logical processors. Additionally, the system featured a RAM size of 6 GB. These hardware configurations provided the necessary computational power and memory capacity to execute the machine learning model utilized for the study effectively.

4. RESULTS AND DISCUSSION

The memory test results for car mapping showed that seven participating security personnel were assessed based on their ability to match cars with their respective owners using their memory. The test consisted of ten car mapping questions, and the scores obtained ranged from 7 to 2. The highest score of 7 indicated a strong proficiency in accurately identifying car owners based on memory. However, the remaining scores varied between 6 and 2, suggesting varying levels of effectiveness in the car mapping task among the security personnel. These findings underscore the importance of developing an efficient number plate recognition car owner mapping system to support the security personnel in their role. Performance metrics used to evaluate models developed with classification algorithms are precision, recall, F1-score and confusion matrix. Figure 4 illustrates the result obtained from the system when used with RegEX and without RegEX correction. The classification reports provide valuable insights into the performance of the CNN in the ANPR system, both without and with RegEx correction. Without RegEx correction, the CNN-based ANPR system achieved a precision of 1.00, indicating that all identified number plates were classified correctly. However, the recall for correct number plates was only 0.30, suggesting that the system accurately identified only 30% of the actual correct plates. The F1-score, which represents the overall accuracy, was 0.46 for correct number plates. The system's accuracy without RegEx correction was 30%, indicating a relatively low performance. Table 1 is the finding highlight.

On the other hand, with RegEx correction, the CNN-based ANPR system demonstrated a precision of 1.00, indicating that all identified number plates were classified correctly. The recall for correct number plates significantly improved to 0.90, indicating that the system accurately identified 90% of the actual correct plates. The F1-score for correct number plates reached 0.95, reflecting a substantial improvement in the overall accuracy of the system. The system's accuracy with RegEx correction was 90%, demonstrating a significant enhancement compared to the performance without RegEx correction. The weighted average F1-score was 0.95, reaffirming the CNN-based ANPR system's improved performance in accurately identifying and classifying number plates when RegEx correction was applied.

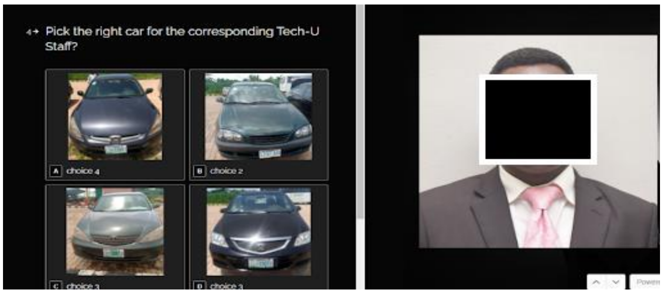


Figure 4. Memory test application

Table 1. These findings highlight the limitations of the CNN-based ANPR system in accurately identifying and classifying number plates without the application of RegEx correction

Plate number	CNN with RegEx	CNN without RegEx	Plate number	CNN with RegEx	CNN without RegEx
	EKY396GB	EKY396GB		KJA193AA	KJA19344
	FKJ254XA	FKJ254XA		GWA294NV	GHAZ94NV
	GGE123ZY	GGE1Z3ZY		KSF622AE	KSFGZZAE
	APP456CV	APPA56CV		BEN319HH	BEN319H4
	KET748AA	KET748AA		WRN479AA	WRN479AA

5. CONCLUSION

In conclusion, this research paper presented an ANPR system using CNN with RegEx correction. The study aimed to enhance car verification and security by improving the accuracy of character recognition. The results demonstrated that the integration of RegEx correction significantly improved the system's performance. The CNN-based ANPR system effectively segmented and recognized characters, and the RegEx correction further enhanced the recognition of characters, resulting in improved accuracy. This system has the potential to revolutionized car verification and security, providing a reliable and efficient solution. Future work can focus on further refining the CNN model and optimizing the RegEx correction algorithms to achieve even higher recognition accuracy.

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