Journal of Computing & Biomedical Informatics
ISSN: 2710 - 1606
Volume 07 Issue 02
2024

Research Article
https://doi.org/10.56979/702/2024

IoT Based Smart Vehicular Identification using Machine Learning Techniques

Abdul Aziz[1], Uzair Ahmad[1], Shoaib Saleem[1], Munahil Khursheed[2], Arslan Munir[3], Manal Ahmad[2], and Muhammad Ahsan Jamil[2*]

[1]School of Computer Science, Minhaj University Lahore, Pakistan.
[2]Institute of Computing, MNS University of Agriculture Multan, Pakistan.
[3]Department of IT, Govt. Gradute College Muzaffar Garh, Pakistan.
[*]Corresponding Author: Muhammad Ahsan Jamil. Email: ahsan.jamil@mnsuam.edu.pk

Received: January 11, 2024 **Accepted:** July 21, 2024 **Published:** September 01, 2024

Abstract: Technology is growing fast, so a secure way of life and travel are in high demand among the community. A massive growth in traffic is caused by an excessively growing world population on hi-tech modern roads. There are more and more vehicles and trucks on the road. It is demand of time to identify vehicles and compute traffic jam on roads. For the control in addition monitoring systems, the identifying of vehicles is crucial. Number plates, which are a specific pairing of numbers and letters are used to identifying vehicles. However, physically identifying every single parked or moving car's license plate is a difficult and time-consuming task for anyone. Due to the daily tremendous growth of the vehicle industry, tracking individual vehicles has become a difficult undertaking. In the majority of applications involving the movement of vehicles, the identification and detection of a vehicle Number Plate (NP) are crucial techniques. In the field of image processing, it is also a hotly debated as well as ongoing research topic. For the purpose of discovering and identifying vehicle NPs, numerous techniques, methods, and algorithms have been created. You Only Look Once (YOLO) Algorithm is applied to detect as well as classify the vehicle NP. This proposed model shows more accuracy than the previous models.

Keywords: Internet of Things; Machine Learning; Vehicles; Number Plates; YOLO.

1. Introduction

Nowadays Life is busy and moving fast, everything which is related to or helps in serving life also growing fast. Technologies today play a significant role in all aspects of life to make things simpler by saving time and manpower. In Technology Machine learning is one of which is play a role as a backbone in modern-day life. One of the demanded artificial intelligence methods to handle the huge amount of data is Machine Learning (ML). The algorithm is self-learning. Improvised analysis and patterns are used to finish it [1]. In addition, deep learning, a subclass of ML, performs the ML process using a higher ranking level of neural networks [2, 3]. The neuron nodes that are joined serve as the links in artificial neural networks, which simulate human brain function [4]. Deep learning is usually known as deep neural networking or learning [2]. Deep Learning is a subclass of ML techniques that were inspired by artificial neural networks, which contain structural and functional components [31, 32]. Artificial neural networks are used by the majority of deep learning models. The word deep in deep learning indicates how many layers are used to modify the data [5].

Internet of Things (IoT) is the network of physical objects that are integrated with hardware, programs, sensors, in addition networking capabilities, as shown in Figure 1. This system allowed these devices to collect data, collect information as well as exchange data.

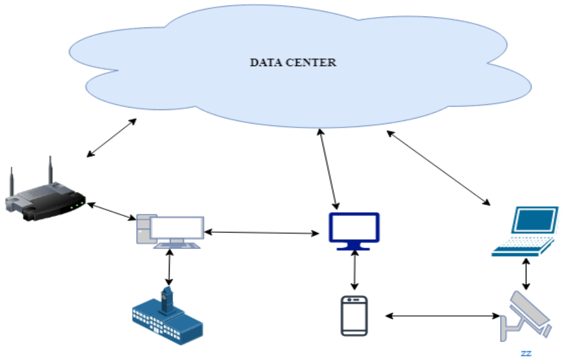

Figure 1. Structure of IoT

Detection of vehicles is a relatively new method of gathering transportation data and might serve as the backbone of an intelligent transportation system [35]. It is currently being implemented in parts in the Europe, United States and some Arab nations, including the UAE, with Qatar and Saudi Arabia as future possible aims. The Global Positioning System (GPS tool) is helpful for tracking business trucks and for navigation. While technology like License Plate detection (LPD) and RFID labels are more commonly employed for detecting traffic infractions, congestion pricing, and road tolls.

The US road transportation authorities have conducted numerous studies evaluating various vehicle identification techniques. Most of that research came to the conclusion that RFID tag systems were significant due to their high reliability and favorable cost/benefit ratio. These studies have also addressed the several significant public and national welfares that can be obtained from using RFID label frameworks and have outlined the privacy concerns that prevent such widespread use [6, 7].

The use of engine-powered vehicles as an alternative method of moving people and products contributed to the development of motorized transportation systems at the beginning of the 19th century. To manage and regulate traffic flows, transportation planning and traffic engineering have become essential. Planning became important as time went on in order to predict the quality and variety of transport frameworks that would be capable to meet the travel petition of the expanding population besides their escalating lifestyle activities. The excellence of the various transport researchers, their references, in addition plans will indisputably be squeezed by the accuracy of the data together, as social economic data, origin-destination surveys, traffic amounts, as well as other statistical data are the important and primary input for all transportation preparation and evaluation studies. A review of the evolution of transportation systems and data collection techniques during the following stages is therefore worthwhile [8].

The term ML pronounces a system's volume to gather and synthesis knowledge through extensive observation, as well as to progress in addition encompass itself by selection up new information rather than having it preprogrammed into it [29]. Artificial intelligence is used in machine learning, which gives computers the capacity to learn and memorized automatically and get better over time without explicit programming [33].

ML is a specialization of AI that enables computers to learn independently over time from training data and develop without explicit programming. Machine learning algorithms can create their own predictions by identifying patterns in the data and learning from them [30, 34].

YOLO is a deep learning algorithm that works on real-time image classification with the help of neural networks, by which each object in an image is detected. This algorithm's popularity is a result of its accuracy and speed. It has been used in many different situations to distinguish between animals, people, car parks, and traffic signals. The major used of this algorithm is for detecting and identifying the different vehicles at same time. YOLO algorithm works by means of the following three procedures; Residual blocks, Bounding box regression, Intersection over Union (IOU).

In figure. 2 the following graphic shows many grid blocks of uniform thickness. Vehicles that enter any grid block will be able to be detected. For examples, if an object's middle occurs inside a grid block, that block will be responsible for identifying the objects. To detect the vehicles in an image, residual blocks were used, by which each vehicle was detected and identified separately in a single image.

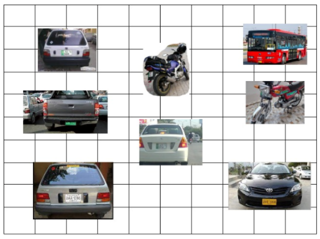

Figure 2. Residual Blocks

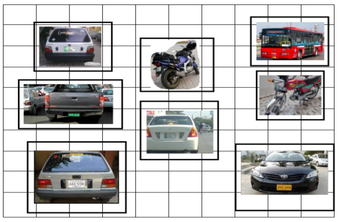

Figure 3. Highlight the object with bounding box in image

The following figure. 3 shows an example of a bounding box. Each bounding box indicated the objects separately within a single image, and they have been represented by a black outline. To determine an object's width, center, height and class, YOLO utilize a single bounding box regression. The probability of an identification phase in the bounding box is indicated in the fig. 3.

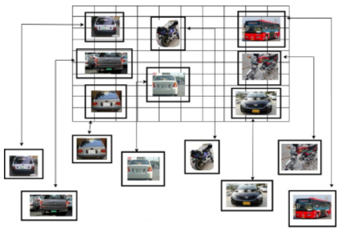

Figure 4. Intersection over union

In figure 4, we see that all vehicles that are in a single image are how marked or bordered after the residual blocks all at once and this procedure is known as IOU. In this way all the vehicles which are present in an image are detected and separated from each other.

The three procedures of YOLO algorithm is working combine for final detection of the vehicles. By which all the vehicles in a single image is detected and identified. So here we discuss the combination of these procedures.

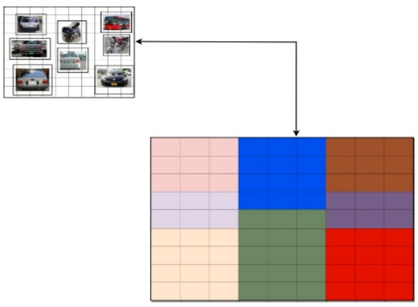

Figure 5. Class probability objects

These three procedures are applied to create the final detection of vehicle, as seen in the accompanying figure.

In figure. 6 grid blocks are initially used to partition up the image. So every grid block predicts bounding boxes and provides reliability values. The blocks apply the class probability to identify each object's class. The bus is bordered by the brown bounding box, but the heavy bike is bordered by the blue bounding box. The vehicle has been marked using the red bounded box.

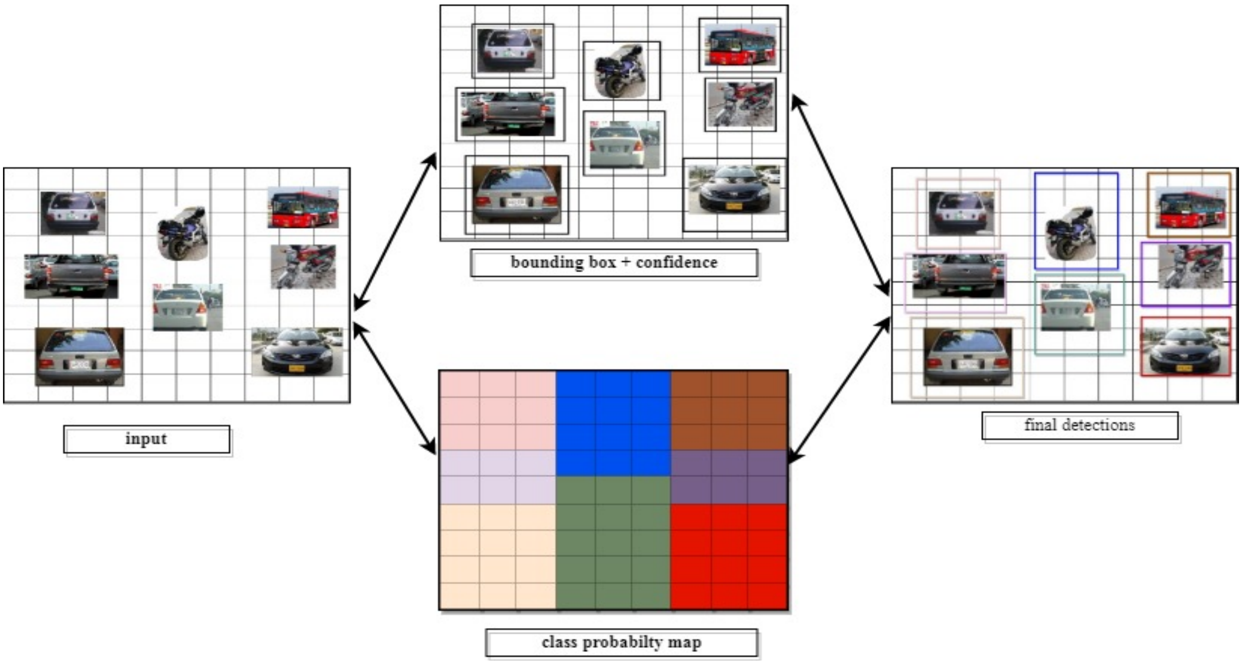

Figure 6. Techniques combinations

2. Literature Review

An extensive overview of earlier studies on vehicle number plate detection is provided in this section. There have been numerous investigations and research projects conducted in the past. In the Research area most researchers are used machine learning algorithms are included in which are given here: en et al. [2011] investigated a solution for picture disturbance caused by uneven lighting and several environmental factors such as shade and exposure, which are typically difficult to analyze well utilizing classic binary methods and use support vector machines (SVM), by which they get 93.54% accuracy for license plate recognition [9, 26-28].

Anagnostopoulos et al. [2006] proposed an algorithm for number plate position and character segmentation, based on a novel adaptive image segmentation technique (SCWs), in addition connected component analysis is used. Probabilistic neural networks (PNNs) are used to identify alphanumeric characters which have recently been segregated from the candidate's domain [10].

Punyavathi et al. [2021] discussed the modern techniques that are used for vehicle detecting and tracking for different scenarios by using IoT to reduce road accidents. They used two methods for this purpose. One is traditional and the second is the modern method. In traditional methods, they work on statistic method for vehicle detection. Then they used development of algorithm techniques which use blob detection, its outcome efficient then statistics methods. But they work on another method which is based on deep learning is YOLOv3, which gives more accurate and fastest results in a minimum duration [11].

Avatefipour, & Sadry, [2018] covered several IoT-related intelligent traffic management systems, as well as the many ways to collect raw information, including triangulation, automobile re-identification, GPS-based approaches, and smartphone-based tracking. The "vehicle re-identification" technique proved to be quite effective at gathering relevant data. Traffic monitoring systems, green wave systems, RFID tags, wireless technology, worldwide structure for smartphones, and infrared sensors are among the efficiency methods for managing traffic signals that are being compared. When comparing several approaches, "dynamic cycle TLS" comes out on top as having the maximum performance ratings. [12].

The suggested passive technique of verification discussed by Riener and Ferscha [13] [36] Biometrics-based methods have been used in early investigations on driver verification. The information gathered from heaviness patterns on the seats of a vehicle in overall and from the seated positions of drivers in particular [37] [38].

The driver recognition method is suggested based on pressure mapping systems by Chen et al. [14]. In their investigations, they used the arrangements of hand grips on the navigation wheel to identify drivers. These biometrics technique likewise others such as voice identification [15], face detection [16], or finger-vein pattern investigation [17] suffer from a number of disadvantages, such as being customized for particular activities to take place and being inappropriate for ongoing accurate situations.

3. Limitations

It is represented in Table 1 that a number of researchers have worked on the vehicular identification with multiple approaches but still there were few limitations that are being overcome in this proposed research work.

Table 1. Limitations of the previous published approaches

Sr.#	Authors	Title Paper	NP Detection	Vehicle Status	Method	YOLO Algorithm
1	Giannoukos et al. [2010] [21]	Operator background scanning to support high division rates for real time license plate recognition	NO	NO	novel scanning method	NO
2	Gong et al. [2019] [22]	By means of multi-label classification to recover object detection	NO	NO	multi-label classification	NO
3	Shindeet al. [2018] [23]	YOLO based human action acknowledgement and localization	NO	NO	YOLO	YES
4	Riener et al. [24]	Supporting implicit human-to-vehicle interaction: Driver identification from sitting postures	NO	NO	Feature classification	NO
5	Chen et al. [25]	Driver recognition based on dynamic handgrip pattern on steeling wheel	NO	NO	handgrip pattern on steeling wheel	NO
6	Proposed	IoT Based Vehicle Identification System Using Machine Learning Techniques.	YES	YES	YOLO	yes

4. Proposed Methodology

Technology is growing fast, there is a tremendous desire among people for safe living and travel. The number of vehicles on the road has increased due to the excessively increasing worldwide population, which has resulted in an upsurge in traffic on hi-tech current roadways. Vehicle monitoring is an significant topic in smart transportation network.

The initial stage in locating and identifying the vehicle NP is to locate and collect data for each road bound. To detect and recognize vehicle NPs, numerous strategies, methodologies, and algorithms develop. To accomplish this objective, we can successfully assist using the YOLO method. A database can be used to record all the information on the cars that are capture by security cameras, in addition to their categories and priority. The first step is successfully complete following the transfer of these data, which were gathered from security cameras position along the road. In the following steps, this technique offers a situation where this current information can be used for traffic monitoring. This model can be a big assistance to us in figuring out how to handle the issue of the direction of stolen vehicles. They can be put in place ahead of every intersection with a traffic signal so that the course of a stolen car can be quickly identify.

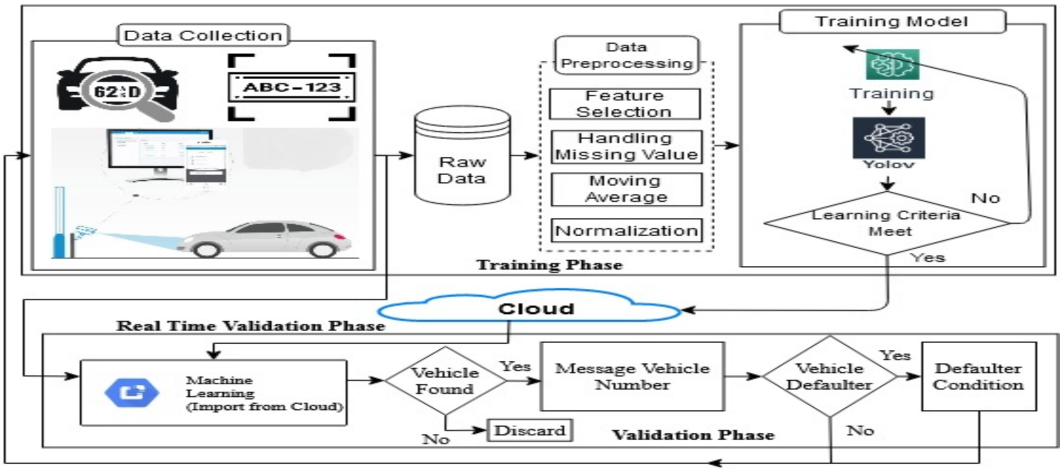

Figure 7. IoT Based Vehicle Identification System Using Machine Learning Techniques

Figure 7 is showing that the proposed system is dependent on the training as well as validation phase. First Training phase is divided into three processes. In the training phase firstly, data is composed with the help of different sensors from input parameters will be stored in a database known as raw data. The next process is to preprocess the data to minimize the noisy data. After preparing the preprocessed data will be forwarded for training the data while using Yolo Algorithm.

The target detection task's loss function is divided into two parts: classification loss as well as bounding box regression loss. IoU and its enhanced algorithm are the furthermost frequently utilised bounding box regression losses.

In the validation phase the real time data will be collected from input in addition trained values will be imported from the cloud for prediction purposes. Then it will be checked the condition of after predicting it will check the condition that learning criteria will be met or not. If the criteria will be met, the output move to the cloud if, the will not be meet the training process will be again updated with the data. Criteria the required condition fulfill and vehicle number plate detected then display the vehicle number on screen if not found the vehicle number then the system discard. After detect the vehicle number the proposed model check the condition of defaulter vehicle, if model detect defaulter condition indicate the vehicle and return to system and if model not detect any default in vehicle then proposed model direct return at the start point of the system.

5. Simulation Results

In this proposed IoT based Vehicle identification by using Machine Learning techniques (YOLO) are employed on a dataset. The total data is 433 samples which is separated commonly into 70% training (303 samples) in addition 30% validation (130 samples). The proposed model intentional the output by means of manifold statistical measures. Tables 2-3 depict the training in addition validation of ML approaches (YOLO). In addition to contrasts, the numerous statistical measures utilized for performance are measured from various metrics.

Table 2. Training of proposed IoT based Vehicle identification by using Machine Learning techniques (YOLO)

	Proposed Model Training		
	Total samples (303)	Output	
Input	Expected output	Predicted Positive	Predicted Negative
	160 Positive	True Positive (TP)	False-Negative (FN)
		153	7
		False Positive (FP)	True Negative (TN)
	143 Negative	11	132

Table 2 is showing the proposed IoT based Vehicle identification by using Machine Learning techniques inside the training phase w.r.t YOLO. A total of 303 samples are applied inside the training phase alienated into 160 and 143 positives as well as negative samples, correspondingly. It is determined that 153 samples are properly forecast as positive, showing there is traffic routing, but 7 samples are incorrectly predicted as negative, that means there is no traffic routing. Correspondingly, a total of 143 samples are composed, where negative specifies no traffic routing, in which 132 samples are properly forecast as negative, means there is no traffic routing, and 11 records are imprecisely predicted as positive, showing traffic routing.

Table 3. Validation of proposed IoT based Vehicle identification by using Machine Learning techniques (YOLO)

Proposed Model Validation			
	Total samples (130)	Output	
Input	Expected output	Predicted Positive	Predicted Negative
	79 Positive	True Positive (TP) 76	False-Negative (FN) 3
	51 Negative	False Positive (FP) 7	True Negative (TN) 44

Table 2 is showing the proposed IoT based Vehicle identification by using Machine Learning techniques within the validation phase w.r.t SVM. A total of 130 samples are applied within the training phase divided into 79 and 51 positive as well as negative samples, correspondingly. It is determined that 76 samples are properly forecast as positive, showing there is traffic routing, but 3 samples are imperfectly forecast as negative, that means no traffic routing. Correspondingly, a total of 51 samples are composed, where negative showing no traffic routing, in which 44 samples are correctly predicted as negative, means there is no traffic routing, and 7 records are imprecisely predicted as positive, which means traffic routing.

Table 4. Performance evaluation of proposed IoT based Vehicle identification by using Machine Learning techniques (YOLO) in training and validation using assorted statistical measures

	Accuracy (%)	**Sensitivity TPR (%)**	**Specificity TNR (%)**	**Miss-Rate FNR (%)**	**Fall-out FPR**	**LR +ve**	**LR -ve**	**PPV (Precision) (%)**	**NPV (%)**
Training	94.05	95.6	92.3	4.37	0.076	12.43	0.047	93.2	94.9
Validation	92.30	96.2	86.2	3.79	0.13	7.01	0.043	91.5	93.6

Table 3 is showing the performance of the IoT based Vehicle identification by using Machine Learning techniques in the training in addition validation phase's w.r.t. YOLO correspondingly. This specifies that the proposed model using the YOLO approach delivers 94.05%, 95.6%, 92.3%, 4.37%, and 93.2% within the training, and provides 92.30%, 96.2%, 86.2%, 3.79%, and 91.5% within the validation, in terms of accuracy, True Positive Rate (TPR) expressed as sensitivity, True Negative Rate (TNR) expressed as specificity, False Negative Rate (FNR) expressed as miss rate, and Positive Predictive Value (PPV) expressed as precision, respectively. In addition, more statistical actions of the proposed model are providing 0.076, 12.43, 0.047, and 94.9% within the training, and 0.13, 7.01, 0.043, and 93.6% within the validation in terms of False Positive Rate (FPR) expressed as fall-out, Likelihood Positive Ratio (LR+ve), Likelihood Negative Ratio (LR-ve), and Negative Predictive Value (NPV), respectively.

Table 5. Comparison

Sr.#	**Authors**	**Title Paper**	**NP Detection**	**Vehicle Status**	**Method**	**Accuracy**
1	Yuan Yuan, et al. 2017 [18]	An Incremental Framework for Video-Based Traffic Sign Detection, Tracking, and Recognition.	YES	NO	CNN	94%

2	Naren Babu R., et al. 2019 [19]	Indian Car Number Plate Recognition using Deep Learning.	YES	NO	YOLO V3	91%
3	Tayara, H., et al. 2017 [3]	Vehicle Detection and Counting in High-Resolution Aerial Images Using Convolutional Regression Neural Network.	YES	NO	CNN	93.2%
4	Chen, R. C. (2019) [4]	Automatic License Plate Recognition via sliding-window darknet-YOLO deep learning.	YES	NO	Darknet - Yolo	78%
5	Masood, S. et al. (2017) [20]	License plate detection and recognition using deeply learned convolutional neural networks.	YES	NO	CNNs	90%
6	Proposed	IoT Based Vehicle Identification System Using Machine Learning Techniques.	YES	NO	YOLO	< 94%

6. Conclusion

Due to the daily tremendous growth of the vehicle industry, tracking individual vehicles has become a difficult undertaking. In the majority of applications involving the movement of vehicles, the identification and detection of a vehicle Number Plate (NP) are crucial techniques. In the field of image processing, it is also a hotly debated as well as ongoing research topic. For the purpose of discovering and identifying vehicle NPs, numerous techniques, methods, and algorithms have been created. In this research, we present an IoT based vehicle identification with the help of YOLO algorithm is proposed. The proposed model use YOLO algorithm for vehicle identification.

Firstly, the vehicle is detecting and then verified by vehicle registration number with the help of YOLO algorithm after that we identified the vehicle and achieved the 94.05 % accuracy in training phase and 92.30 % accuracy in validation phase.

In the future, we will upgraded the proposed model for get more accurate results, minimize the drawbacks and merged with multiple departments database for track the specific vehicle in a real time for control the crime rate and rapid action against the complains.

References

1. Gong, T., Liu, B., Chu, Q, and Yu, N. "Using multi-label classification to improve object detection". Neurocomputing, Vol. 370, Issue C, pp. 174-185(2019).
2. Shinde, S., Kothari, A, and Gupta, V. "YOLO based Human Action Recognition and Localization". Procedia Computer Science, Vol. 133, pp. 831-838(2018).
3. Tayara, H., Soo, K. G., & Chong, K. T. "Vehicle detection and counting in high-resolution aerial images using convolutional regression neural network". IEEE Access, 6, pp. 2220-2230(2017).
4. Chen, R. C. "Automatic license plate recognition via sliding-window darknet-YOLO deep learning". Image and Vision Computing, Vol. 87, pp. 47-56(2019).
5. Lu, S., Wang, B., Wang, H., Chen, L., Linjian, M., and Zhang, X. "A real-time object detection algorithm for video". Computers & Electrical Engineering, Vol. 77, pp. 398-408(2019).
6. Persad, K., Walton, C. M., &Hussain, S. (2007). Electronic vehicle identification: Industry standards, performance, and privacy issues (No. Product 0-5217-P2).
7. Maccubbin, R. P., Staples, B. L., & Mercer, M. R. (2003). Intelligent transportation systems benefits and costs: 2003 update (No. FHWA-OP-03-075).
8. El Hamra, W., & Attallah, Y. (2011). The role of vehicles' identification techniques in transportation planning–Modeling concept. Alexandria Engineering Journal, 50(4), 391-398.
9. Wen, Y., Lu, J., Yan, Z., Zhou, K.M. Deneen, V, and Shi, P. An algorithm for license plate recognition applied to intelligent transportation system," IEEE Transactions on Intelligent Transportation Systems, Vol.12, Issue 3, pp.830-845(2011).
10. Anagnostopoulos, C. N. E., Anagnostopoulos, I. E., Loumos, V., andKayafas, E. "A license plate-recognition algorithm for intelligent transportation system applications". IEEE Transactions on Intelligent Transportation Systems, Vol.7, Issue3, pp. 377-392(2006).
11. Punyavathi, G., Neeladri, M., & Singh, M. K. (2022). Vehicle tracking and detection techniques using IoT. Materials Today: Proceedings, 51, 909-913.
12. Avatefipour, O., & Sadry, F. (2018, May). Traffic management system using IoT technology-A comparative review. In 2018 IEEE International Conference on Electro/Information Technology (EIT) (pp. 1041-1047). IEEE.
13. A. Riener and A. Ferscha, "Supporting implicit human-to-vehicle interaction: Driver identification from sitting postures," in International symposium on Veh. Comput. Systs., 2008, p. 10.
14. R. Chen, M. F. She, X. Sun, L. Kong, and Y. Wu, "Driver recognition based on dynamic handgrip pattern on steeling wheel," in ACIS SNPD, 2011, pp. 107–112.
15. J.-D. Wu and S.-H. Ye, "Driver identification based on voice signal using continuous wavelet transform and artificial neural network techniques," Expert Syst. Appl., vol. 36, no. 2, pp. 1061–1069, 2009.
16. Z. Mahmood, T. Ali, S. Khattak, S. U. Khan, and L. T. Yang, "Automatic vehicle detection and driver identification framework for secure vehicle parking," in Conf. FIT, 2015, pp. 6–11.
17. J.-D. Wu and S.-H. Ye, "Driver identification using finger-vein patterns with radon transform and neural network," Expert Syst. Appl., vol. 36, no. 3, pp. 5793–5799, 2009.
18. Yuan, Y., Xiong, Z., & Wang, Q. "An incremental framework for video-based traffic sign detection, tracking, and recognition". IEEE Transactions on Intelligent Transportation Systems, Vol. 18, Issue7, pp. 1918-1929(2016).
19. Babu, R. N., Sowmya, V., &Soman, K. P. "Indian car number plate recognition using deep learning". In 20192nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT) Vol. 1, pp. 1269-1272. IEEE (2019).
20. Masood, S. Z., Shu, G., Dehghan, A., and Ortiz, E. G. "License plate detection and recognition using deeply learned convolutional neural networks". ArXiv Preprint ArXiv: 1703.07330(2017).
21. Giannoukos, I., Anagnostopoulos, C. N., Loumos, V., andKayafas, E. "Operator context scanning to support high segmentation rates for real time license plate recognition". Pattern Recognition, Vol. 43, Issue 11, pp. 3866-3878(2010).
22. Gong, T., Liu, B., Chu, Q., & Yu, N. "Using multi-label classification to improve object detection". neurocomputing, Vol. 370, pp. 174-185(2019).
23. Shinde, S., Kothari, A., & Gupta, V. "YOLO based human action recognition and localization". Procedia computer science, Vol. 133, pp. 831-838(2018).
24. A. Riener and A. Ferscha, "Supporting implicit human-to-vehicle interaction: Driver identification from sitting postures," in International symposium on Veh. Comput. Systs., 2008, p. 10.

25. R. Chen, M. F. She, X. Sun, L. Kong, and Y. Wu, "Driver recognition based on dynamic handgrip pattern on steeling wheel," in ACIS SNPD, 2011, pp. 107–112.
26. Ghazal, T.M., Janjua, J.I., Abbas, S., Fatima, A., Saleem, M., Khan, M.A. and Alqarafi, A., 2024, May. Fuzzy-Based Weighted Federated Machine Learning Approach for Sustainable Energy Management with IoE Integration. In 2024 Systems and Information Engineering Design Symposium (SIEDS) (pp. 112-117). IEEE.
27. Waqas, M., Kamran, M., Saleem, M. and Ilyas, A., 2024. Traffic Congestion Monitoring Improvement Through Federated Learning Technique. International Journal of Computational and Innovative Sciences, 3(1), pp.13-19.
28. Ahmad, G., Saleem, M., Malik, J.A., Shehzad, M., Sarfraz, Z., Ahmad, R. and Hasham, A., 2024. Analysis of Convolutional Neural Network for Image Classification. Journal of Computing & Biomedical Informatics.
29. N. I. Kajla, M. M. S. Missen, M. M. Luqman and M. Coustaty, "Graph Neural Networks Using Local Descriptions in Attributed Graphs: An Application to Symbol Recognition and Hand Written Character Recognition," in IEEE Access, vol. 9, pp. 99103-99111, 2021, doi: 10.1109/ACCESS.2021.3096845.
30. Sikandar Ahmad Khan, Muhammad Asad, Haroon Asif, Amjad Ali, and Muhammad Ahsan Jamil, "Author Identification Using Machine Learning", *JCBI*, Feb. 2024.
31. N. I. Kajla, M. M. S. Missen, M. M. Luqman, M. Coustaty, A. Mehmood and G. S. Choi, "Additive Angular Margin Loss in Deep Graph Neural Network Classifier for Learning Graph Edit Distance," in IEEE Access, vol. 8, pp. 201752-201761, 2020, doi: 10.1109/ACCESS.2020.3035886.
32. Gulfraz Naqvi, Zunaira Anwar, Aiza Asim Khan, Aqsa Ahmad, Hafiz Muhammad Sanaullah Badar, and Nadeem Iqbal Kajla, " Advancements in Facial Expression-Based Automatic Emotion Identification Using Deep Learning", *JCBI*, vol. 5, no. 01, pp. 165–173, Jun. 2023.
33. Mehnaz Mustafa, Mirza Farrukh Baig, Hafiz Muhammad Sanaullah Badar, Malik Muhammad Saad Missen, and Nadeem Iqbal Kajla, "An Artificial Intelligence and IoT Based Approach for the Pink Bollworm detection in Cotton Crop", *JCBI*, Feb. 2024.
34. Hafiz Muhammad Sanaullah Badar, Nadeem Iqbal Kajla, Jehangir Arshad, Najia Saher, Manal Ahmad, and Muhammad Ahsan Jamil, "Lightweight Intrusion Detection for IoD Infrastructure using Deep Learning", *JCBI*, Apr. 2024.
35. Muhammad Rehan Mehmood, Nadeem Iqbal Kajla, Malik Daler Ali Awan, Malik Muhammad Saad Missen, Muhammad Umar Chaudhry, and Amnah Firdous, "Accident Alert System of Vehicle and Life Security using IoT Devices and Image Processing", *JCBI*, vol. 4, no. 01, pp. 197–206, Dec. 2022.
36. Shaker, B., Ullah, K., Ullah, Z., Ahsan, M., Ibrar, M., & Javed, M. A. (2023, November). Enhancing grid resilience: Leveraging power from flexible load in modern power systems. In 2023 18th International Conference on Emerging Technologies (ICET) (pp. 246-251). IEEE.
37. Munir, A., Sumra, I. A., Naveed, R., & Javed, M. A. (2024). Techniques for Authentication and Defense Strategies to Mitigate IoT Security Risks. Journal of Computing & Biomedical Informatics, 7(01).
38. Ali, H., Iqbal, M., Javed, M. A., Naqvi, S. F. M., Aziz, M. M., & Ahmad, M. (2023, October). Poker Face Defense: Countering Passive Circuit Fingerprinting Adversaries in Tor Hidden Services. In 2023 International Conference on IT and Industrial Technologies (ICIT) (pp. 1-7). IEEE.