Roadway Traffic Analysis Scheme using Unmanned Aerial Vehicle Based on Image Processing and Edge Computing

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Abstract: Traffic congestion is a major problem which is increasing day by day in developing countries. So, traffic analyzing has become a more important issue. For the development of smart cities, traffic management using UAV is one of the most important asset. UAV used for roadway traffic management are more efficient and easier to detect the traffic and send the required data to the receiver station and it performs continuous operations with no human intervention. There has been voluminous research which provided that unmanned aerial vehicles (UAV's) are a viable and less time-consuming alternative to real time disturbed traffic analysis and management, providing the eye-in the sky solution to the problem. UAVs use image processing algorithms for detecting the roadways and vehicles. We present a simple approach to road traffic analyzing using UAVs by combining the concepts of edge detection in image processing and edge computing representing the road network. The results reflect the value of flexibility and bird-eye view provided by UAV videos or images thereby depicting the overall applicability of the UAV-based traffic analysis system. The further Research On this application might be done in future.

Keywords : Edge computing, edge detection, image processing, traffic analysis, Unmanned Aerial Vehicle(UAV).

1. Introduction

An unmanned aerial vehicle is an aircraft that flies without a human crew on board of the aircraft. It uses state-of-the art microprocessors and microsensors to navigate and track targets. There are wide variety of UAVs and Micro UAV (MUAVs) in shapes, sizes, configurations, and characteristics. A pilot on the ground with remote control or an onboard computer can autonomously control the UAVs flight[1]. During the low-level flight, the UAV can interact with highway traffic via camera or wireless transmission. The primary objective of the autopilot flight system includes pitch attitude hold, altitude hold, air hold, automatic take-off and landing, roll-angle hold, turn coordination, and heading hold.

Unmanned vehicles have several advantages compared to manned vehicles because it can be implemented with less cost, safely and firstly for the operations and functions. UAVs can be deployed for many applications related to transportation management and road construction planning. UAV is furnished with a camera and measured to be a flexible and low-cost system that provides data attainment in an efficient and reliable manner.[2] In a traditional traffic monitoring system, continuous monitoring is required. Thus, the cost of maintaining static video and/or induction loops is higher than aerial sensor-based system. For urban areas, the UAV-based traffic monitoring system is competitive to cost, more accurate and highly flexible

The main emphasis of our work is to analyze the role of a UAV in a road traffic management system. The road way traffic monitoring using UAV's is an area of significant research these days. There has been voluminous research which provided that unmanned aerial vehicles (UAV's) are a viable and less time-consuming alternative to real time disturbed traffic monitoring and management, providing the eye-in the sky solution to the problem.[3] Our project consists of two scenarios: In first scenario we assemble the parts and solved technical related issues for stable flight and air path deviations. In second scenario we implemented camera for capturing the required traffic data and then the data is sent to the receiver using telemetry, where UAVs use image processing algorithms for detecting the roadways and vehicles. Image processing technique is used to count the number of vehicles on road and estimate the density. The main objective of detecting vehicle and counting in a video or image traffic is to develop a method for automatic detection of vehicles and count them on roadways.[4]

UAV'S are primarily used in military operations where UAVs avoid potential diplomatic embarrassment when a manned aircraft is shot down and the pilots captured. Automated drones can be used in oil & gas facilities for security, surveillance, emergency response and infrastructure inspection used for roadway traffic management are more efficient and easier to detect the traffic and send the required data to the receiver station and it performs continuous operations with no human intervention.

Image processing is processing of images using any form of signal processing for which the input is an image. The output of image processing may be either an image or a set of characteristics parameters related to the image. Image processing technique is used to count the number of vehicles on road and estimate the density. The number of vehicles found can be used for surveying or controlling the traffic signal. This is one of the best modern methods that countries are seeking to introduce into the traffic system. The main objective of detecting vehicle and counting in a video or image traffic is to develop a method for automatic detection of vehicles and count them on highways.

2. Problem Statement

In the context of Unmanned Aerial Vehicle for roadway Traffic Analysis System, we aim to detect the presence of traffic at a certain interjection. Each of our UAVs are assigned with different locations and outbound path and a return path according to the tasks assigned to them, by this we can ensure that the forces are put to the right use.

Our Contribution

Edge computing is going to make the process entirely seamless and will make it more resilient.

- Firstly, we provide a seamless experience with the combination of UAV and edge computing
- Secondly, we also provide the traffic density based on real time traffic conditions

Organization of the paper:

This paper contains the following sections: Section 1: Introduction, Section 2: Related Work, Section 3: Proposed road traffic analysis scheme, Section 4: Results and Discussion, Section 5: Conclusion, Section 6: References.

3. Related work

Already many research organizations have come up with various optimal solutions for UAV roadway Traffic Management. These methods being successfully tested and deployed for commercial applications still cannot ensure accuracy in its operations, efficient traffic control and its performance needs to be improved.

Mahmud Hossain, MD. Arafat Hossain, Farhana Akhter Sunny from Green University of Bangladesh, Dhaka, Bangladesh has published paper on [1] “A UAV-Based Traffic Monitoring System for Smart Cities” In this research paper, we have observed a general traffic monitoring system where a user can get an appropriate path information for going to a destination. In this system, we set UAV in all junction of road and the UAV collects data (no of a vehicle) from the junction and stored in cloud server. The cloud server sends data to the main server. And all users must register to the system with Web Application. When user wants to travel. They just set the destination and get the best path information from the main server. In this case, the traffic jam will decrease because every user chooses the path where the vehicle is minimum. So, Vehicles can be distributed efficiently in the roads.

Ismail Bayezid, go khan Inhalant, Ban§ Fid an and Jan P. Huissoon [2] has published paper on “Experimental Modeling and Adaptive Control of an Unmanned Aerial Vehicle as Roadside Assistance” In this paper we work for contributing traffic flow stability with providing external dynamic support among separate mini-platoons as described in Section V. We incorporate 10 identical vehicles in three separate platoons. The string stability condition is waypoint tracking for a small-scale UAV and interaction between separate highway platoons for increasing traffic flow stability. Finally, the separate platoons are unaware of each other, but these separate platoons can be converted to single CACC node with external support of our UAY. Future directions will be testing these results with employing real test-beds. Additionally, we derive real longitudinal model of different vehicles and improve our high-level platoon controllers considering heterogeneous vehicle dynamics. Then, we also analyze the stability effect of arranging vehicle orders in the vehicle formation.

Carlos Justo de Fr´ıas, Abdulla Al-Kaff, Francisco Miguel Moreno, Angel Madrid no,´and Jose Mar´´ıa Armingol [3] published paper on "Intelligent Cooperative System for Traffic Monitoring in Smart Cities" This paper presents a cooperative system of Un-manned Aerial Vehicles (UAVs); providing a helpful tool for traffic monitoring in smart cities. In this system, a Semantic Neural Network has been proposed; to obtain the relative positions of the vehicles from a monocular camera. This model transforms an RGB image (It) to a segmented image (St) of the vehicles, then, their positions from image coordinates are translated to 2D real-world coordinates. Afterward, the system sends this data to the vehicles providing meaningful information about the position of each other vehicle.

Konstantinos Kanistras Goncalo Martins, Matthew J. Rutherford and Kim on P. Valavanis.[4] has published paper on "A Survey of Unmanned Aerial Vehicles (UAVs) for Traffic Monitoring" This paper presents a survey of current research activities going on in universities and research centers around the globe in the area of UAVs used for traffic monitoring. As a conclusion, it may be stated that UAVs can be very useful for traffic monitoring. However, issues with UAV deployment for civil applications must be addressed. Due to the fact that the approval of FAA, FCC and other regulatory agencies for flying the UAVs in civil airspace is keep delaying, universities have not yet implemented a lot of real-life scenarios.

Maneuverability and wireless network communication are two of the key points that make unmanned air vehicles more useful than the other methods currently used. The first one makes them capable of tracking vehicles on the ground while the second one allows the transmission and reception of instructions and image and video information to a ground base. Research is focused not only on the types of the sensors that could be used on board (Radar, Vision, Hybrid), but also on the type of processing (on-board, off-board) of the data in vision sensors.

Nikolai Vladimirovich Kim1 & Mikhail Alekseevich Chervonenkis2 [5] has published paper on "Situation Control of Unmanned Aerial Vehicles for Road Traffic Monitoring" This paper aims to introduce an approach to the organization of road traffic monitoring by the means of unmanned aerial vehicles (UAVs), which is based on the automatic situation control of UAVs. The research includes analysis of existing methods of on-board automatic detection of emergency and abnormal traffic situations with UAV artificial vision systems (AVS), preliminary classification of these situations including the allocation of emergencies and disastrous situations.

The paper presents the choice of UAV controls in compliance with the recognized situation. The traffic situation identification method introduced in the paper is based on Bayes and Neyman-Pearson criterion. Furthermore, the research involves the analysis of the existing approaches to the detection of moving and stationary vehicles by the means of UAV AVS. The paper proposes vehicles detection method based on the image segmentation, along with the use of machine learning methods,particularly the artificial neural network method known as Deep Learning. The research provides solutions for vehicle tracking and velocity detection problems in order to describe traffic situations. The proposed approach contributes to the efficiency of UAV in road traffic monitoring by means of the management and detection processes automation.

Ezedin Barka, Chaker Abdelaziz Kerrache, Nasreddine Lagraa , Abderrahmane Lakas [6] has published paper on " Behviaor aware UAV-assisted Crowd Sensing Technique for Urban Vehicular Environments." :- This paper presents Crowd and traffic sensing are among the most important topics related to the smart city and intelligent traffic man- agement. Furthermore, with the emergence of the UAVs, this crowd sensing task can be achieved in a timely and less costly manner. However, in any distributed and mobile network, relaying on the assumption that all vehicles are honest and collaborative can lead to unwanted situations.we studied a new trust-aware UAV-assisted crowd sensing scheme. Our proposal offers a fully distributedand timely view about traffic conditions in a city scale.In addition, it also helps as a trust-based routing strategy offering reliable data delivery, thanks to our efficient inter-vehicle trust establishment. This hierarchical crowd sensing solution starting by vehicles level then UAVs until reaching the deployed RSUs is a software- based solution with no additional cost.The simulation results of our solution evidence our proposal's ability to ensure high detection ratios even for a high presence of attackers. The simulation also shows high packet delivery ratios even in the scenario of a higher vehicular density with low overhead. As future work, we plan to implement our proposal on android-based devices and extend it to be used for the intelligent and adaptive traffic lights. we also plan to investigate the energy-related problems and UAVs best path and communication strategy to consume the less possible energy

Anuj Puri [7] has published paper on ":- A Survey of Unmanned Aerial Vehicles (UAV) for Traffic Surveillance" :- This paper is a survey of the current research activities going on in several universities around the world in the area of application of UAVs in traffic surveillance. It has been generally accepted that UAVs can be very useful and successful for traffic surveillance.A UAV has a rapid launch as compared to a manned aircraft, while it has better maneuverability as compared to ground vehicles. UAVs can communicate through a wireless network with the base station to receive control instructions as well as to send images taken from the UAV. New methods are being developed for data collection and image processing of remotely sensed data. Several universities are using commercially available aircrafts or helicopters for their experiments, while some of the researchers are focusing on development of helicopters with customized capabilities required for traffic surveillance and other applications. The following table shows the various research works, the type of UAV used, and the fundamental goals and objectives desired.Most of the research work is still in the design phase. It has been noticed that not much has been done in terms of implementation and testing. Several issues must be resolved for the deployment of UAVs for civil applications. The industry and universities are still awaiting the approval of FAA, FCC and other regulatory agencies for flying the UAVs in civil airspace.

3. Proposed roadway traffic analysis (rta) sceheme

The proposed scheme has three phases namely; phase 1: system initialization, phase 2: Proposed algorithm-Image Processing and Edge Computing , phase 3: TD(Traffic Density) computation.

Network Architecture:

The architecture of our traffic analysis system presented in this paper is shown in fig 1. The main components of the architecture are: (i) ROI(region of interest), (ii) PiC(Pi Camera), (iii) RP(Raspberry Pi), (iv) IP(Image Processing), (v) GS(Ground Station), (vi) TD(Traffic Density). A thorough explanation of the components is given after the diagram.

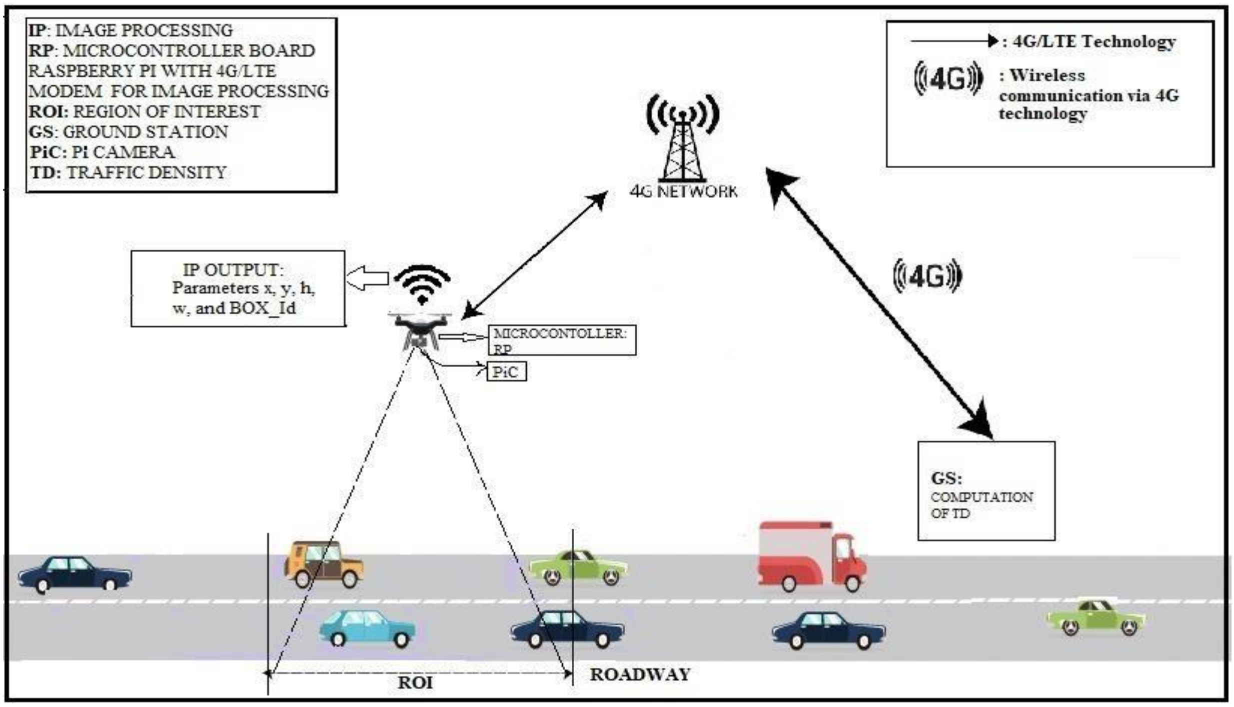

Fig1 : RTA Network Architecture

- ROI: otherwise called the region of interest. In this, we select a region in the frame where the entire image processing will happen.
- PiC: Pi Camera is a compatible camera used with the RP. It communicates with the RP via MIDI camera serial interface protocol. It is commonly used in surveillance UAVs since it weighs comparatively lesser.
- RP: RP is the Raspberry Pi microcontroller. This is where the video captured from PiC is received. The IP computation happens here.
- IP: Image Processing is a process of deducing data from digital images either by training the model with previous data sets or detection and tracking as we are doing here.
- GS: Ground Station has a server that can store the data and compute it accordingly.
- TD: TD is the measure of the number of vehicles at unit area.

Phase 1: System initialization

The following system initialization is carried out as follows:

- We are assuming that there is an existing publicly available network for output transmission.
- To calculate the TD, we need the area for the road which is going to assumed.
- We are setting a T for the TD, above which the traffic is considered to be jammed and below which it is considered that traffic is smooth. If it the TD is equal to T it is considered to be optimum.
- We are going to calculate the TD in percentage.
- We will not be calculating TD of each vehicle class but rather the entire traffic.

The list of notations used in this paper are listed in Table I.

TABLE 1

Notation	Description
UAV	Unmanned Aerial Vehicle
IP	Image Processing
ROI	Region Of Interest
TD	Traffic Density
RP	Microcontroller board Raspberry Pi
GS	Ground Station
PiC	Pi Camera
T	Threshold for TD status determination
H	Height of the Box in Pixels
W	Width of the Box in Pixels
A	Area of the ROI
x,y	x and y coordinates of the box in the ROI
I	Number of Vehicles

phase 2: Proposed algorithm-Image Processing and Edge Computing

The proposed algorithm can be used to detect and trace the vehicle. The output parameter we get out of this phase will be transferred to phase 3 for TD (traffic density) computation.

Input: video taken from the PI camera that is embedded on the drone

Output: Five parameters namely; (x,y,h,w,box_id)

1. **BEGIN**
2. Video capturing in MP4 format.
3. Masking, converts 8 bit color images to 1 bit black and white image.
4. Contouring, draws a rough outline at the detected vehicles.
5. Selecting region of interest (ROI), selects an area in the frame where the processing happens.
6. Apply step 2 and step 3
7. Subduction, removes the shadows formed by the vehicles.
8. Edge detection, draws confined edges to the detected objects.
9. Object tracing, assigns consecutive numbers to each detected box.
10. **END.**

To start off, it take the input for the processing via the PI camera that is installed on the drone, called as <u>Video Capturing</u>, the captured video is in mp4 format which is the most commonly used format to store video and audio. Using the captured video the frames are extracted, where each frame is used for further processing, this process is called as <u>Frame extraction</u>. Each captured frame goes through process called <u>Masking</u> where 8-bit color images is converted into a 1-bit black and white format, this is done to reduce the edge content in an image and to make transitions between different pixels as smooth as possible and also helps in noise reduction. Here the black part of the frame will be the background and the white colored parts is where the vehicle is detected (roughly). Further to this, a process called <u>Contouring</u>**,** it is done for detecting white spaces in an 8-bit image which helps in creating a boundary for the objects (vehicles) for vehicle detection purposes. On proceeding, we have to select a Region of Interest (ROI) here the selected frame there are a lot of negative spaces which makes the object detection process a tad bit complicated. So, selecting a particular region of the frame for processing where all the vehicles will pass through, makes the image processing process easier and much precise. As we go up in the process, we must use a concept called Edge detection it allows us to observe the features of an image for a significant change in grey level. Most of the shape information of an object is enclosed in edges which is necessary for our vehicle detection application. Subduction is a process where the shadows of the vehicles are eliminated to make the process of vehicle detection much precise. Object Tracing, After all the above processing for a frame, the vehicles are detected. The detection process includes x and y coordinates of the box (position of the box in the frame), height, and width of the box which is used for classifying the vehicle class.

Vehicle tracking**:** Each block identified by vehicle detection is embedded with box_id where each vehicle centroid is detected. Using the vehicle centroid, the number of vehicles passed through the ROI is tracked and the vehicle count is incremented. The data is transmitted further using 4G/LTE Modem The modem grants the Raspberry Pi or 40-pin Pi compatible single-board-computer. Remote management of your devices on the field, secure connection over the mobile network, reliable coverage across the globe with lots of carrier options is available with this stacked on the Raspberry Pi. Making a remote controllable LTE Wi-Fi Hotspot, high-speed GPS tracking, more and more use case is possible with his add-on board.

Phase 3- TD computation.

Servers installed at GS receive x, y, h, w, and BOX_Id parameters from the drone after all the on air computations in RP from the UAV. Here, after receiving the parameters of the vehicle count on the specific road, we can calculate the traffic density on the road using the value & area of the road.

Traffic density (TD) is the ratio of number of vehicles on the road to the area of the road. We can compute the TD on roadway using all the above parameters x, y, h, w and the BOX_Id in the GS server. Height of vehicle is represented by H (pixels), Width of vehicle is represented by W (pixels), A is the variable Area of road in a single frame of the video and n is the number of vehicles detected in the Region of Interest. The values of H and Waredescribed by the below equation:

n TD=

i=0$H\times W$

A

We can determine the condition of traffic density on the road namely: Smooth, Optimum, and Jammed. Using a pre-set threshold value T.

$$Condition = \begin{cases} If\ TD < T; Smooth \\ If\ TD = T; Optimum \\ If\ TD > T; Jammed \end{cases}$$

4. Result and discussion

This section presents, the performance evaluation of the proposed Road Traffic Analysis using UAV scheme. Performance evaluation depicts the efficiency of the scheme.

4.1. Simulation Environment

The proposed scheme is simulated in the computer system with Intel Core i7-8750H, CPU @ 2.20 GHz, and 8 GB RAM. We used the PyCharm community Edition 2021.1 open source software library with python 3.6. We used Mission Planner open source software suite and QGround control 3.5.6 . The fig.2 is showing the masking process of the frame, in fig.3 the frame is undergoing contouring process, fig.4 shows selecting the ROI region in the frame and both masking and contouring applied to ROI, fig.5 show both subduction and edge detection applied to the frame, Fig.6 shows the received parameters, Fig.7 shows the Box_IDs assigned to each confined box.

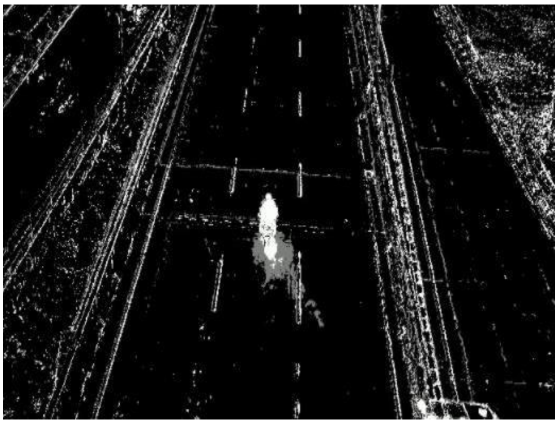

Fig.2 Masking

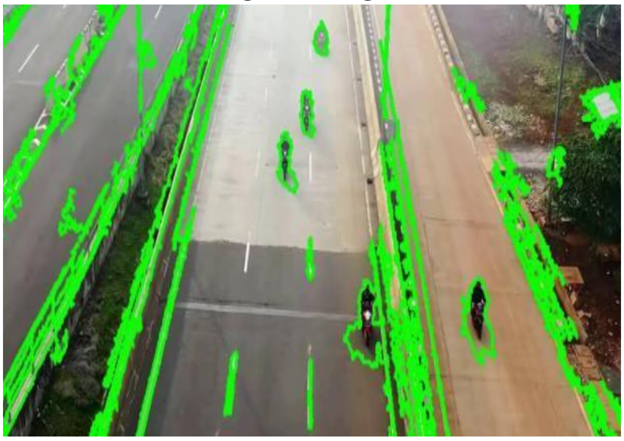

Fig.3 contouring

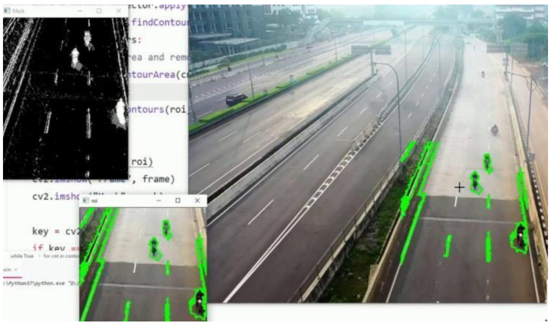

Fig.4 selecting ROI and repeating masking and contouring on selected ROI

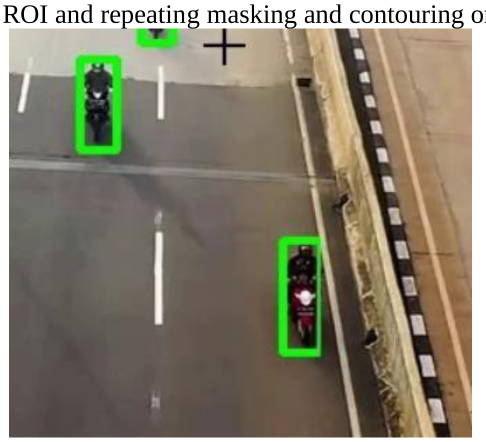

Fig.5 edge detection and subduction

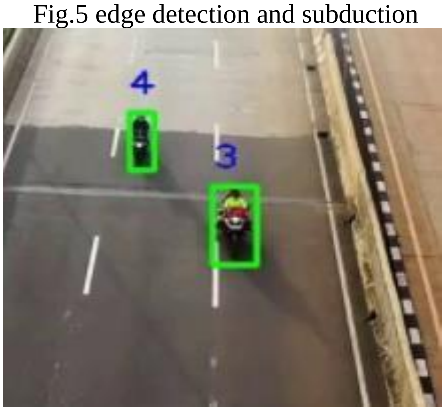

Fig.6 Output parameters

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[[200, 95, 28, 52], [150, 29, 15, 38]]
[[200, 100, 27, 52], [148, 35, 18, 37]]
[[200, 105, 28, 54], [147, 39, 19, 39]]
[[201, 109, 27, 56], [146, 45, 18, 38]]
[[200, 115, 28, 55], [146, 51, 18, 38]]
[[201, 120, 27, 57], [146, 56, 18, 39]]
[[201, 125, 29, 60], [144, 61, 16, 40]]
[[200, 131, 31, 62], [144, 65, 16, 42]]
[[200, 135, 33, 61], [143, 71, 17, 42]]
```

Fig.7 assigning consecutive Box_Ids to the detected boxes

4.2 Performance analysis

Consider a case where the captured video of a roadway from UAV is processed and the vehicle count is sent to the GS server from the UAV via 4G/LTE network + , the server at GS computes the TD and based on the T value, the condition of the TD is calculated. For 25% TD value, the condition is smooth, for 50% TD the condition is optimum, and for more than 50% TD the condition is congested.

5. Conclusion

In this paper, a Unmanned Aerial Vehicle for traffic monitoring on roadway scheme is proposed where we capture the video of the roadway using the camera mounted on the drone and process it in three phases. In phase-1 , we layout the assumptions for creating the environment. In phase 2 , we capture the image using the camera and process it frame by frame to get the vehicle count parameters using Edge computing. In phase 3, we calculate the traffic density using the vehicle count in the GS server and determine the traffic status on the particular Roadway. The proposed scheme's performance can be further improved by computing even the traffic density on air and sending only the status of traffic on the mentioned roadway to the Ground station.

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