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IOT based Smart Traffic Signal Violation Monitoring System using Edge Computing

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***Abstract* —Monitoring the traffic signal surveillance camera by a group of police administrators can be a daunting task due to the sheer volume of data(videos) that must be collected and analyzed. In developing countries such as India, traffic police department need a easy way to catch the vehicle owners who have violated the traffic signal rules. Currently, they are collecting the video near the traffic signal for 24*7 and the administrators are manually analyzing to find if anyone has violated the traffic signal rules. They need to capture the license plate and then send a report. The proposed system addresses this problem. IOT based Smart traffic signal violation system make use of the features provided by edge computing. It shall surveil the signal only when it turns red and captures the video. Later it analyses the video using suitable image processing algorithm and captures the traffic rule's violator's license plate and send it to the administrators. In this way it reduces the manual work done by the police administrators and analyzes the video at the edge device itself.**

Keywords—Edge Computing, internet of things, real-time, monitoring, edge device, image processing, smart traffic signal violation, Django web application.

I. INTRODUCTION

The modern data center with its climate-controlled aisles, gleaming racks of equipment and armies of admins excels at handling data. Data that's all in one place and comes in during predictable time periods can be leveraged, stored, protected and governed in a civilized manner. But data is no longer created, consumed and stored in the traditional data center or even in the cloud. Today's data isn't centered around any one point-on the map. It is streaming in constantly from a variety of sources and locations many of them wireless and unanchored. Some data has a useful shelf life of just a few seconds. Other data is most valuable when combined with historical data and analyzed for deeper insights. The unbounded and ephemeral place where the digital and physical worlds intersect and data is securely collected, generated and processed to make new value is called "the edge". Customers are demanding immersive, real-time digital experiences and interactions. And businesses are responding by rethinking their applications and placement of infrastructure, moving them as close to the point of data creation and consumption as possible. This enables the real-time insights that inform competitive decision making.

Some of the challenges that are faced at the edge are:

- Locational: Bandwidth and network connectivity is limited
- Environmental: Housed in dusty environments
- Spatial: Needs to fit in tight spaces
- Power: Subject to less-than-ideal power and cooling conditions
- Operational: Far away from skilled IT staff
- Bandwidth: Constrained, unpredictable or sporadic
- Security: IT needs to control and monitor security outside the confines of the data center

Edge computing is all about how businesses can overcome these constraints, with products that are engineered for the edge. The proposed design has been modelled keeping all the above-mentioned challenges in mind.

Video surveillance includes monitoring an event or set of events and finding actions that are unacceptable or may suggest the appearance or presence of improper behavior. In many developing countries, the lack of smart video surveillance system is causing a lot of manual work. This problem is mainly faced by the traffic police department. There are thousands of administrators who are monitoring each camera present in their area, to find out if anyone has violated the traffic rules. In addition to this, they must manually note down the vehicle number which has violated the traffic rules and file a report. This is a huge burden to the traffic police department as it requires 24*7 monitoring and huge amount of man power.

The proposed model provides a solution to the problem discussed above. It describes a framework to build a smart video surveillance system which will monitor the zebra-crossings and will capture the vehicle number which will violate the Red-signal.

The main cause for traffic signal violation is lack of strict rules. The violators are aware that they can fool the human eye and need not have to pay huge fines. The proposed system will ensure to catch most of the traffic signal violators, which will enforce strict traffic rules. Also, it consumes lot of resources to stream the video 24*7. The proposed system will capture the video/series of pictures only when the signal turns red. This will add the first layer of filtering. In addition to that, it will analyze the video captured to see if anyone has violated the traffic signal. If so, it will capture the violator's license plate rather than sending it to the central server for manual analysis. If there are no violators at a given interval, then those videos can be discarded after few days.

II. LITERATURE SURVEY

Qingyang Zhang et. Al.,[1] reviewed the existing video analytics and stated the following. Video analytics have become an integral part of public safety. Video analytics is usually intended to jointly use advanced computer vision (CV) and artificial intelligence (AI) to solve the FOUR-W problem. That is to describe Who did something (What) at some point (When) at a specific location (WHERE). Edge video analytics is inspired by the growing popularity of edge computing and can be widely implemented for static and mobile purposes in various video surveillance to improve the public security of our everyday lives.

Bilal Ghazal et. Al.,[2] presents a system which is based on PIC microcontroller that estimates the traffic density with the help of IR sensors and achieves a dynamic timing slots with different levels as the current traffic control systems do not account for the difference in cars flow with time, the movement of emergency vehicles, and the pedestrian crossings, resulting in traffic jams. However, the proposed system consumes huge amount of power, so it is advised to use low power consuming system.

Chaitra B et. Al.,[3] proposed an Automatic Number Plate Recognition (ANPR) device to identify vehicles that breach traffic signals by obtaining number plate from their digital images. The obtained data is then compared with that of existing in the database and then a violation SMS is sent to the violator within a minute of the violation. The above device was proposed to replace the existing device that was ineffective in detecting various traffic signal violations due to the need of manual intervention in finding the violators. The suggested approach has the downside of being unable to identify number plates in a variety of fonts, types, languages, and shapes. As a result, before the proposed approach is applied in practice, number plate standardization is recommended.

Ashok Kumar P.M. et. Al.,[4] proposed an Optical Flow based Transfer Learning method which is not present in the existing system, is used to detect the Traffic rule violation by identifying the irregularities present in source and target picture without labelling manually. This method stresses on detection of accident.

Anuran Chattaraji. et. Al.,[5] proposed a system for building intelligent devices to control the traffic, based on a simple technique of RFID tracking of vehicles, which can operate in real-time, improve flow of traffic and saving expensive human interaction. However, it is arguable whether vehicle monitoring is fair enough acceptable and whether it is a basic civil rights violation—privacy.

Hasan Omar Al-Sakran et. Al.,[6] proposed an architecture that combines the Internet of Things with an agent platform, in which agent technology manages efficient communication and interfaces among a largely distributed, heterogeneous and IoT-decentralized set of devices. It can also provide a new method of monitoring the traffic flows thus improving the traffic conditions and the usage of resources. However, the suggested architecture involves IoT-based traffic network that is made up of vast number of RFIDs and sensors that wirelessly transmit the data, necessitating improved security to protect these huge amounts of user data and privacy. Future research will focus on ensuring the safety of smart objects in the traffic control management network in the event of a cyber-attack.

Jubair Mohammed Bilal et. Al.,[7] presented a new, digital-logic-based system that outperforms the current traffic system. Traffic can be made very effectively by installing sensors at each entry and exit of a junction and measuring the number of cars at the junction, which is a good application of Digital Signal Processing. However, the maximum advantage can only be realized if this method, which is very costly, is implemented at any intersection in a region.

Syed Hassan Ahmed et. Al.,[8] presented a design for a smart and safe traffic violation ticketing system using future Internet technologies such as NDN. Officials in charge of traffic law will be able to identify drivers who break the law without chasing them down and endangering lives. It also outlines potential work directions for designing and implementing the proposed Smart-Cop program in real-world test beds and simulations. However, simulations show that the time it takes to issue a ticket and how much it costs depends on the number of violators and the speed of the vehicles.

Nourdine Alian et. Al.,[9] provided an experimental forum for an advanced driver assistance system (ADAS) which records the traffic violations. Its aim is to guide drivers and to inform them of the existence of certain traffic signs. The warnings are delivered through the vehicle's loudspeakers and are given enough time for the driver to respond to the oncoming traffic situation. If a traffic violation is eventually committed, the warning and allowed reaction time are registered. The violation record consists of displaying the traffic sign, a picture of the surroundings, and the vehicle's speed. However, this is very costly, as it necessitates the installation of sensors in the region. It also applies only to vehicles with loudspeakers.

Allan M de Souza et. Al.,[10] presented a classification, review and qualitative analysis of Traffic Management System present in the literature which focuses on improving the traffic efficiency, fuel consumption. To achieve these goals, they must track traffic by recognizing traffic congestion and accident hotspots, suggesting alternative routes for vehicles, and adjusting vehicle speeds. Despite the TMS's ability to integrate data from multiple sources to improve overall efficiency, it remains an open issue. The biggest problem is figuring out how to do this integration when we have a lot of different systems and sources that don't talk to each other and have a lot of data that isn't standardized.

III. System Architecture

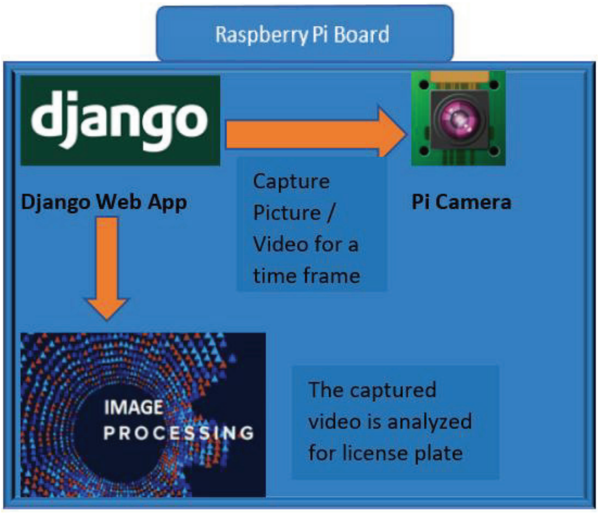

Fig. 1. System Architecture of the Edge device

The architecture of the edge device is as shown in fig 1. The methodology followed to design the proposed system is explained in this section. The proposed system follows the IOT design methodology as shown in fig 2.

IOT based Smart Traffic Signal Violation Monitoring System aims to utilize the features of edge computing to make the life of the traffic police administrators easier. The application is built using Django Web Framework. It is scheduled with respect to time cycle of the traffic signal. Only during the interval when the signal turns red, the pi camera is switched on and it starts to take video or pictures based on the image processing algorithm requirement. The camera is turned off when there is green signal. During this time, image processing algorithm can be used to analyze the video or series of pictures captured and check if vehicles are beyond the zebra crossing line. Then, process the license plate and mail it to the administrators. The same procedure is followed whenever the signal turns red.

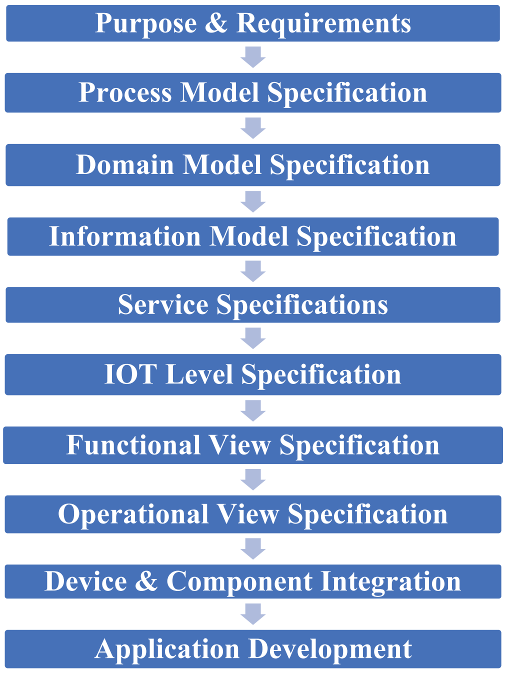

Fig. 2. IOT Design Methodology

The system strictly follows the steps mentioned in the IOT design methodology. The information model specification is as shown in fig 3. There are two virtual entities. Some of the image processing algorithms prefer pictures rather than videos as videos have to converted into series of frames. Instead they can use a series of pictures for analysis. However, the framework support's both the entities. It has two states: On and Off. The camera will be turned on only when the signal turns red. It will be turned off otherwise.

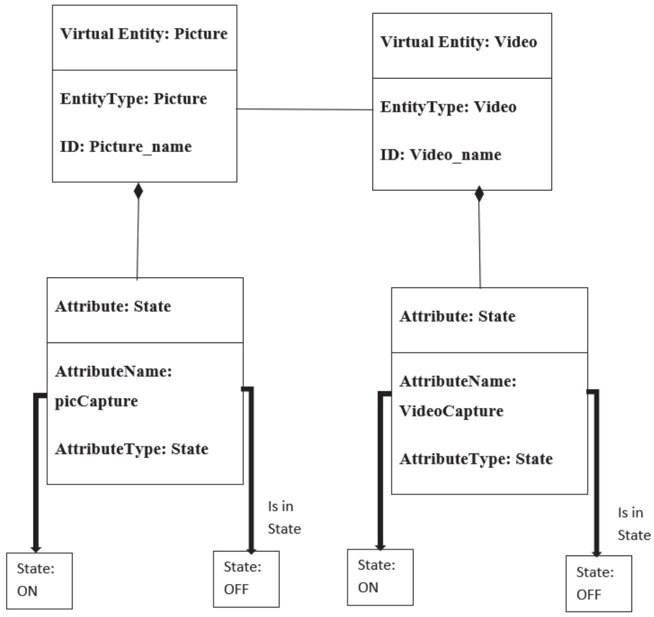

Fig. 3. Information Model Specification

The service specification model is shown in fig 4. The Django application acts as the controller service. For a scheduled interval, it will provide two kind of service. One is to capture picture and other is to capture video.

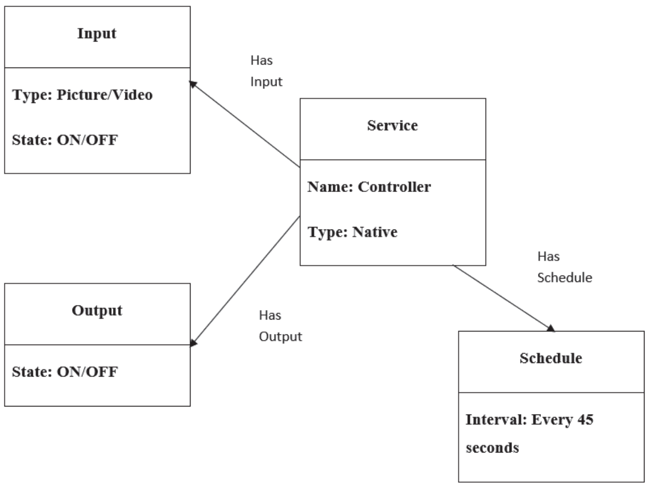

Fig. 4. Service Specifications

The proposed system follows IOT level 1 specification.

A. Django Application

The application is built utilizing the features present in Django Web Framework. It follows model-view-template architecture model. Pi Camera module is incorporated within the views. Views acts as the controller service to capture the video/picture. Templates are used to render a webpage. The police officers can use the URLs configured, to capture video or picture dynamically. They can also use it to view the existing captured videos/ pictures present in the edge device from anywhere. They just need to have the right URL.

B. Raspberry Pi 3

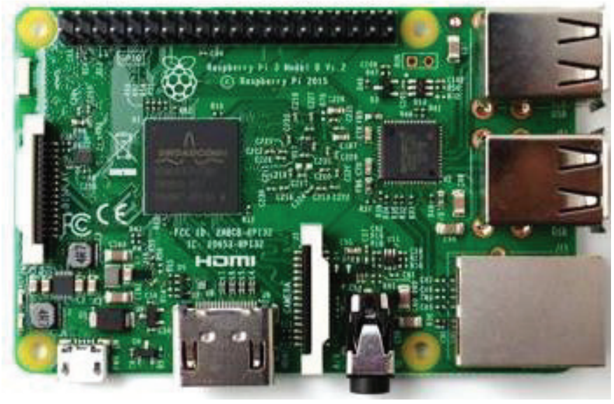

Fig. 5.

Raspberry Pi is a low-cost minicomputer. It is of a size of credit-card and hence can be connected to TV, mouse or keyboard. Basically, it was developed in UK by Raspberry Pi Foundation to encourage school's in developing countries to cultivate interest in Computer Science and advance the education. Raspberry Pi 3 is faster and cheaper. It can play 1080p MP4 video at 60 frames per second. It has built-in Wi-Fi 802.11 and Bluetooth 4.1 apart from the ethernet slot. The main advantage is it can boot directly from USB attached. It has a camera interface, to which pi camera is connected. 16GB memory card can be inserted in the memory card slot. It supports various family of OS. The proposed model uses Raspbian OS. Raspberry Pi has a major role to play in the proposed model. It acts as an edge device which provides all the necessary interfaces to perform video surveillance. It will help in capturing the video and analyzing them.

C. Raspberry PI Infrared IR Night Vision Surveillance Camera Module 500W Webcam

Fig. 6.

It is a 5MP camera module with a fixed focused mode having Omni-Vision 5647 sensor. This camera can be used in both daylight and in darkness. It can capture both photos and videos. It can be connected to Raspberry Pi using a host bus adapter. It has a dedicated Camera Serial Interface. CSI bus can carry pixel data. It supports 1080p @ 30fps, 720p @ 60fps and 640x480p 60/90 video formats. It has a focal length of 3.6mm. It has an upper-hand over other raspberry pi camera as it is capable of night surveillance. In the proposed model, the camera is used for surveillance. PiCamera package in python helps in managing and interfacing the webcam. The method capture() present in the PiCamera package is used to capture images. The methods start_recording() and stop_recording() are used to capture video for a specific time.

D. Image Processing

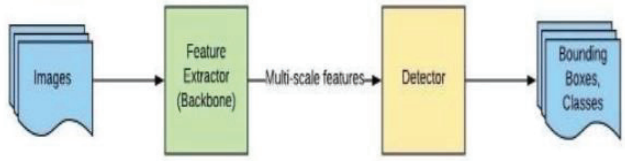

Fig. 7. Four blocks of YOLOv3 architecture [8]

Dr S Raj Anand et. Al., [11], discusses a way to process the surveillance video using an object detection algorithm called YOLOv3. This algorithm is constructed based on connected convolution neural network. The architecture of YOLOv3 is as shown in fig 5. First, the input key parameters are analyzed, frame by frame, from the video sequence. The input video is divided into two parts: foreground and background. Background is the environment which does not change and remains stable and foreground consists of the moving objects. From this step, feature representation is obtained. With the help of YOLOv3, 3 features are obtained as shown in fig 5. They are bounding boxes, classes of the objects and semantic segmentation which is used to determine the traffic violation. The paper provides a detailed description of the usage of the algorithm which can be used to process the video captured using the pi camera.

IV. CONCLUSION

The IOT based smart traffic signal violation monitoring system, monitors the zebra crossing only when the signal turns red and captures the video for that time frame. This will act as the first level of filtering. It later analyses the video using suitable image processing algorithm to detect if any vehicle is violating the traffic rules. It will capture the violator's license plate number and send it to the administrators for further processing. If there are no violations at that particular time frame, the video is just kept for few days and then it is discarded. This process is repeated whenever the signal turns red. In this way, the manual work done by the police administrators can be lessened. Since the system uses edge computing, the analysis part is done at the edge device rather than sending it to the central server. Also, the video is captured only for a specific time frames, which saves a lot of resources. Using the proposed model, a strict traffic regulation can be implemented in the country and help the police department.

V. FUTURE ENHANCEMENTS

1) Motion sensors can be attached to the zebra-crossing. Combining this with the video's captured can give more accurate results.

2) Dockers and containers could be used to deploy and manage all the edge surveillance devices.

3) After capturing the license plate, a mail could be sent directly to the owner of that vehicle, provided that the model has access to the database mapping each vehicle number to the owner.

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