Intelligent Traffic Light Control Using IoT

SANTOSH SINGH[1], MITHILESH VISHVAKARMA[2], RAHUL YADAV[3], HARSH ANAVKAR[4]
[1] *Head of Department, Department of IT, Thakur College of Science and Commerce, Thakur Village, Kandivali (East), Mumbai, Maharashtra, India*
[2] *Assistant Professor, Department of IT, Thakur College of Science and Commerce, Thakur Village, Kandivali (East), Mumbai, Maharashtra, India*
[3, 4] *PG Student, Department of IT, Thakur College of Science and Commerce, Thakur Village, Kandivali (East), Mumbai, Maharashtra, India*

Abstract— Urban population expansion has resulted in an unparalleled need for effective traffic control solutions. Even while they can be somewhat successful, traditional traffic signal management systems frequently fall short of dynamically adapting to the constantly shifting traffic circumstances, which leads to ongoing congestion, longer travel times, and environmental damage. In order to usher in an era of Intelligent Traffic Light Control, this study analyzes a revolutionary method that involves integrating the Internet of Things (IoT) with traffic light control systems. The management of traffic flow in cities and regions can undergo a paradigm change thanks to the Internet of Things' pervasive connection and data-driven insights.

Indexed Terms— IoT, Traffic Management, Safety, City Planning, Transportation

I. INTRODUCTION

Our cities' busy streets serve as both symbols of contemporary issues and emblems of human development. The complicated interaction between cars and pedestrians on our streets is made more difficult by the growing urban population. This calls for creative approaches to ease traffic, shorten commutes, improve safety, and lessen the negative environmental effects of transportation. The Internet of Things (IoT) integration into traffic signal management systems is one of these innovative ideas that promises to completely change how urban traffic is managed. The Challenge of Modern Traffic Management: Urbanization is a continuing trend of our time. According to the United Nations, approximately 68% of the global population is projected to live in urban areas by 2050. This urban influx brings with it a host of transportation-related challenges. Congestion in urban centers not only results in exasperating delays for commuters but also leads to increased fuel consumption, higher greenhouse gas emissions, and detrimental effects on air quality. Furthermore, congested traffic exacerbates road safety concerns and poses formidable economic implications, including lost productivity and increased infrastructure costs. The Promise of IoT in Traffic Management: In this context, the Internet of Things emerges as a beacon of hope for traffic management. IoT, the interconnection of physical devices and sensors through the internet, provides the infrastructure necessary for creating Intelligent Traffic Light Control systems. These systems leverage IoT's pervasive connectivity, real-time data collection, and data analytics capabilities to bring a new level of intelligence to traffic management. The essence of IoT-based traffic management lies in its ability to transform traffic lights from mere time-based controllers into dynamic, context-aware decision-makers. These intelligent traffic lights can respond in real-time to traffic patterns, emergencies, and environmental conditions, optimizing traffic flow and reducing congestion. By harnessing IoT technologies, traffic management can become more proactive, predictive, and efficient.

II. LITERATURE REVIEW

N. Dinesh Kumar, G. Bharagava Sai, K. Shiva Kumar proposed the LabVIEW Simulation model for controlling the traffic lights based on time interval [1]. The drawback of Traffic Light Controllers (TLC) based on microcontrollers and microprocessors is that it uses the pre-defined hardware that is it does not have the flexibility of modification on real time basis. LabVIEW based Traffic control system is relatively easier approach because it is very easier to design, redesign, and debug in graphical programming language like LabVIEW. Another research on Density Based Traffic Signal System [2] is based on image processing technique like edge detection to find the traffic density that regulates the traffic signals. The advantage of building Intelligent Traffic Control System is that it reduces congestion; operational costs, provide alternate routes to travelers and increases capacity of infrastructure. Intelligent Traffic Signal Control system [4] been developed using AVR 32 bit microcontroller with programmable flash memory, built-in 8 channels Analog to Digital Converter and IR Sensor. These sensors detect the presence of emergency vehicle and accordingly microcontroller give red signal to all sides of road except for one with emergency vehicle. Research been carried out employing PIC Microcontroller [5] towards density based Intelligent Traffic Signaling System. This system records total number of vehicles in the memory on real time basis based on user predefined interval. These data captured are sent to computer from the microcontroller. The administrator at the central station computer can access traffic conditions pertaining to any approachable traffic lights and nearby roads reducing traffic congestion. This system in future can inform the people about different place traffic conditions.

III. YOLO

A ground-breaking computer vision model that has transformed the field of object recognition is the YOLO (You Only Look Once) technique. YOLO, which was created in 2016 by Santosh Divvala and Joseph Redmon, is a notable breakthrough in real-time object detection. Its distinct approach to object detection distinguishes it from conventional techniques and has led to its widespread use in applications like as image recognition, surveillance systems, and self-driving cars. The core idea behind YOLO is to treat object detection as a regression problem. Rather than dividing an image into a grid and evaluating potential object candidates in each grid cell, YOLO divides the image into a grid but predicts bounding boxes, class probabilities, and objectness scores directly. This means that YOLO is incredibly fast, capable of processing images in real-time with high accuracy.

YOLO algorithm works using the following three techniques:

1) Residual blocks
2) Bounding box regression
3) Intersection over Union (IOU)

1) Residual Blocks:

First, the image is divided into various grids. Each grid has a dimension of S x S. The following image shows how an input image is divided into grids.

Fig. 1.0 Illustration of YOLO

In the image above, there are many grid cells of equal dimension. Every grid cell will detect objects that appear within them. For example, if an object center appears within a certain grid cell, then this cell will be responsible for detecting it.

2) Bounding box regression:

A bounding box is an outline that highlights an object in an image. Every bounding box in the image consists of the following attributes:

Width (bw)
Height (bh)

Class (for example, person, car, traffic light, etc.) - This is represented by the letter c.

Bounding box center (bx, by)

The following image shows an example of a bounding box. The bounding box has been represented by a yellow outline.

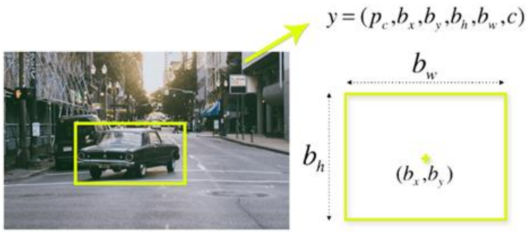


Fig.1.1 bounding box example

YOLO uses a single bounding box regression to predict the height, width, center, and class of objects. In the image above, represents the probability of an object appearing in the bounding box.

3) Intersection over union (IOU):

Intersection over union (IOU) is a phenomenon in object detection that describes how boxes overlap. YOLO uses IOU to provide an output box that surrounds the objects perfectly. Each grid cell is responsible for predicting the bounding boxes and their confidence scores. The IOU is equal to 1 if the predicted bounding box is the same as the real box. This mechanism eliminates bounding boxes that are not equal to the real box.

The following image provides a simple example of how IOU works.

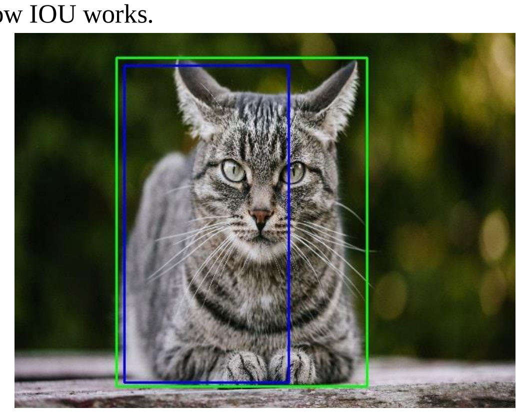


Fig 1.2 Intersection over Union example

In the image above, there are two bounding boxes, one in green and the other one in blue. The blue box is the predicted box while the green box is the real box. YOLO ensures that the two bounding boxes are equal.

Combination of the three techniques:

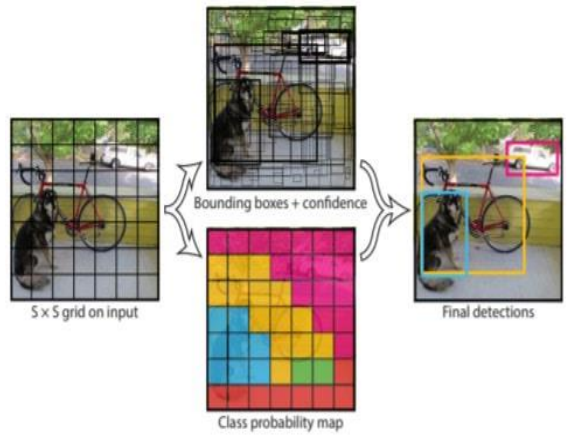
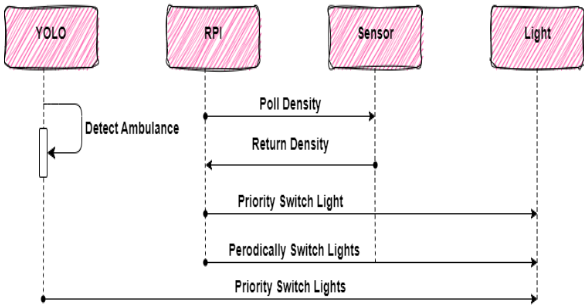


Fig. 1.3 Combination of all three techniques

The following image shows how the three techniques are applied to produce the final detection results.

IV. METHODOLOGY

In order to build intelligent traffic light control system that works on their own without human intervention as compared to modern traffic system that works on based on some specific time where there is no detection of traffic congestion, how much traffic is there, how the traffic is flowing which signal should be green or red or yellow which lane requires priority, priority vehicles like “Ambulance”, “Fire brigade vehicles”, “Police vehicles” because this vehicles should be priority on lanes first so that whenever there is an ambulance the system will detect and give lane towards the particular emergency vehicle so in this scenario it is not possible for today’s modern traffic signal to detect traffic because they work on timers so to avoid this we have developed a model which is an intelligent traffic light control system which is same as a modern traffic signal it also works on fixed time slots but its advantage over the other one is that it can hold the traffic lights based on priority for emergency vehicles but also use sensors on roads to monitor the traffic density i.e. congestion on roads, so whenever sensor detects any congestion it will check the other lanes and give green signal for that particular lane and it will also monitor emergency vehicles with the help of camera module that will be operated with servo motor and raspberry pi.



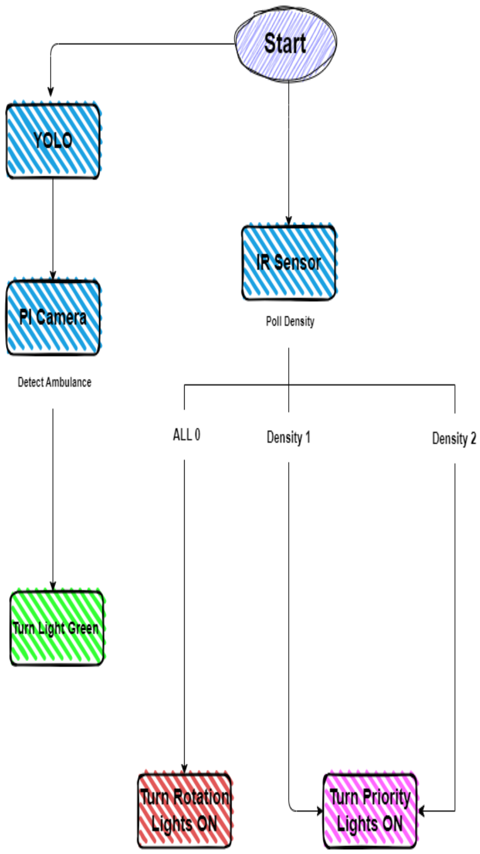


Fig. 1.4 Working of Model

V. RESULTS

In the realm of traffic management and safety, the advent of the Internet of Things (IoT) has heralded a new era of intelligent traffic light control. The system we propose employs cutting-edge technology to enhance the efficiency of traffic signal management in urban areas with four lanes. By continuously monitoring the traffic flow in each lane, our system can dynamically adjust the signal timings to optimize the traffic flow and minimize congestion.

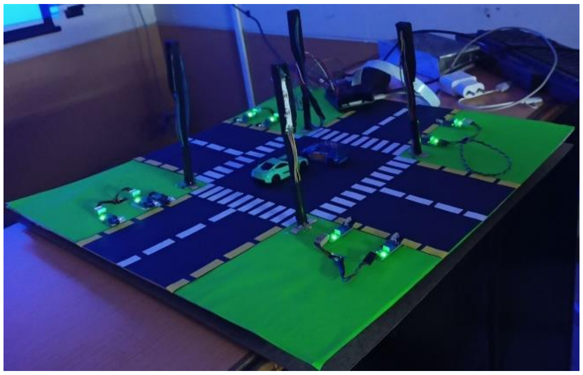


Fig. 1.5 rotation of traffic light according to density

One of the key features of this intelligent traffic light control system is its adaptability to real-time traffic conditions. When high traffic volumes are detected in any of the four lanes, the system promptly switches the traffic signal to green for that lane, facilitating a smoother flow of vehicles and reducing wait times for commuters.

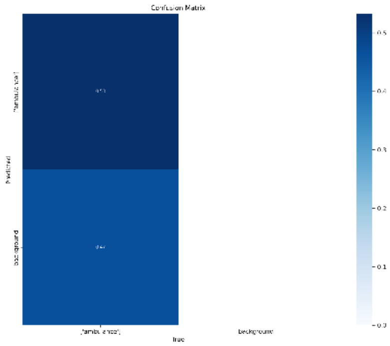


Fig. 1.6 Confusion matrix

Moreover, our system is equipped with a YOLO (You Only Look Once) model, which has the ability to detect emergency vehicles like ambulances. When an emergency vehicle is identified, the system will interrupt the regular signal cycle, immediately granting the right of way to the emergency vehicle to ensure swift and unhindered access to its destination.

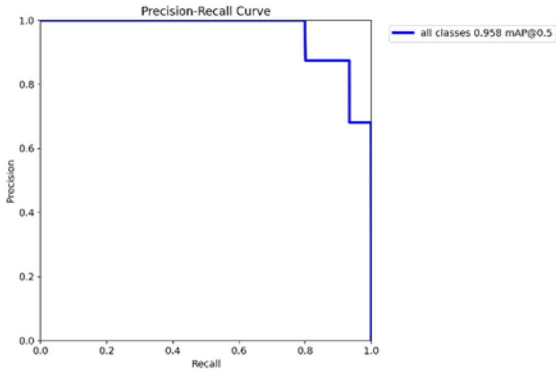


Fig. 1.7 Precision Recall Curve

This crucial feature significantly reduces response times during life-threatening situations, potentially saving lives. In summary, our IOT-based Intelligent Traffic Light Control System combines adaptive traffic signal management with advanced object detection technology to enhance traffic flow and prioritize the safety of citizens by giving priority to emergency vehicles.

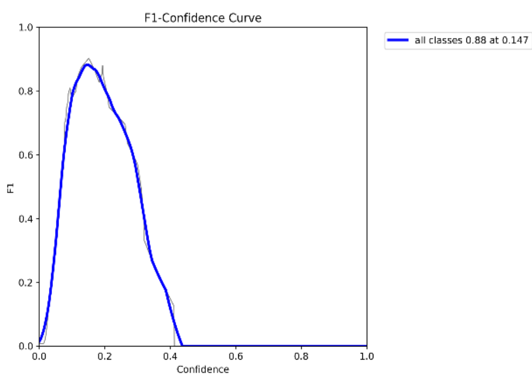


Fig 1.8 F1 score

This innovation represents a significant step towards more efficient, safer, and smarter traffic management in urban areas.

Fig. 1.9 Detection accuracy

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