Smart Headlights to Facilitate Driver Safety

Submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology

in

Information Technology

by

YASH BHAVIN JASANI

20BIT0053

Under the guidance of

Dr. PRASANNA M

School of Computer Science Engineering and Information Systems

(SCORE)

VIT, Vellore.

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<u>DECLARATION</u>

I hereby declare that the thesis entitled **“Smart Headlights to Facilitate Driver Safety**” submitted by me, for the award of the degree of *Bachelor of Technology in Information Technology* to VIT is a record of bonafide work carried out by me under the supervision of Prof. Dr. Prasanna M.

I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place: Vellore

Date : 25/04/24

Signature of the Candidate

CERTIFICATE

This is to certify that the thesis entitled **"Smart Headlights to Facilitate Driver Safety**" submitted by **Yash Bhavin Jasani (20BIT0053), SCORE**, VIT, for the award of the degree of Bachelor *of Technology in Information Technology*, is a record of bonafide work carried out by him under my supervision during the period, 08. 01. 2024 to 08.05.2024, as per the VIT code of academic and research ethics.

The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The thesis fulfils the requirements and regulations of the University and in my opinion, meets the necessary standards for submission.

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Internal Examiner **External Examiner**

Dr. Prabhavathy P

(Information Technology)

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Yash Jasani

Yash Bhavin Jasani
Student Name

Executive Summary

As the prevalence of night-time driving continues to rise, ensuring driver safety has become a critical concern. This research project delves into the escalating issue of intense low beam headlights, examining their potential impact on driving safety and the increasing frequency of car accidents. While high beams are subject to regulations and penalties, intense low beams, often as bright as their high-beam counterparts, remain legal. This project aims to shed light on the potential dangers associated with these headlights, which, although enhancing visibility for the driver employing them, may pose a significant risk to other road users. This project aims to focusing on the evolving technology of adaptive beam headlights. these cutting-edge systems employ sophisticated camera technology to assess the road environment and the positions of oncoming vehicles. Through real-time adjustments, these headlights modulate brightness and beam shape, including a customizable "cut-off," to prevent blinding oncoming drivers while effectively illuminating the remaining road space. The study explores the multifaceted capabilities of adaptive beam headlights, investigating their continuous adjustments in response to changing road conditions and the positions of other vehicles. Hopefully with the help of adaptive headlights, we can reduce the temporary blinding of drivers and reduce the number of road accidents.

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List of Abbreviations

IoT	Internet of Things
ML	Machine Learning
LDR	Light Dependent Resistor
LED	Light Emitting Diode
SHM	Smart Headlight Module
ROI	Region of Interest
OpenCV	Open Source Computer Vision
IDE	Integrated Development Environment

Appendix

Github Link	https://github.com/yash13902/smart-headlight-module

1. INTRODUCTION

1.1 Objective

Safety of people has always been an issue, whether it is indoors or outdoors. Driving safely is of utmost importance. There are several accidents that take place just because of careless driving or poor visibility on roads. Visibility during driving is very important, because if the driver cannot see what is in front of them, then how will they drive safely protecting their life as well as the life of the person in front of them.

Headlights are very important when a person is driving at night. It illuminates the road in front of them and they are able to see the road as well as any other vehicle in front of them as there is not sunlight to guide them. It is not feasible to attach street lights all over the country as the road network is very huge and dense. Most of the times the highways are far away from the towns and cities to effectively provide electricity for the street lights. Hence, headlights are very important.

As useful as headlights are, they pose a serious problem while driving. The intensity of the headlights is high enough to illuminate the road in front but it also can be a hindrance to the driver on the opposite side in front of the car. The bright light can cause irritation to the other person’s eye and can cause then to momentarily look away or be blinded because of it. These high beam headlights can cause temporary blindness where the driver is not able to look around at anything. It also takes a while for the driver to return to the normal state where they are able to see what is in front of them.

This problem causes so many tragedies around the world. To solve or to provide a solution to this problem can help to tackle the deaths and the fatalities that are caused by accidents due to high beam headlights. This can help reduce if not completely eliminate the accidents and help save the lives of people. With the help of smart headlights we can improve the visibility on the roads. This solution will allow the driver to see the road and not disturb the other driver at the same time. Smart headlights should be introduced and attached in all cars, so that we can create an ecosystem where the drivers are not blinded by the intense glare and are able to safely drive on the roads at night.

In this project, the study explores on how can smart headlights be developed in an economical way and how we can use technology to improve visibility for cars on roads at night. With the help of microcontrollers and sensors a device can be created which can provide a solution to the above problem and can give suggestions to help if not solve the larger problem at hand.

1.2 Motivation

The motivation behind this project is to create a solution that can tackle the problem of the huge number of accidents that are being caused due to intense glare from headlights. With the ever growing technology and new inventions it is crucial and important that we adapt and leverage it, to provide solutions that can have an impact on the world and the lives of the people.

The motivation lies in the noble act of saving the lives of people and making it safer to drive when there is low visibility. With this solution the blinding effects of headlights can be reduced while making sure that the headlights are used with the intention with which they were created. With the help of IoT and ML we can make a robust solution which can help create such a system..

1.3 Problem definition

In India, traffic accidents are a major cause of annual fatalities, injuries, and property damage. According to the National Crime Records Bureau (NCRB) 2021 report, 155,622 people lives have been claimed by road accidents. According to a study by IIT Delhi, although national highways make up only 2% of India's total road length, they are responsible for 36% of all fatalities and 30.3% of all traffic accidents. According to surveys, there is a higher percentage of accidents between the hours of 6 p.m. to 6 a.m. than there is during the day. The primary cause of these collisions is the use of high beam lights by cars on the opposite side which can bring momentary blindness to the drivers. Road traffic safety experts believe that because many crashes go unreported, the true death toll may be higher than that which is reported.

The drivers are blinded temporarily for a small amount of time by the light coming from the opposing direction's cars. It takes a few seconds for the person driving to see clearly once again when the regular light returns. In addition to having many blind spots, roads that are not straight and have a lot of curves can cause accidents in hilly or curved terrain.

Throughout the years, high beam headlight-related auto accidents have resulted in enormous losses in terms of both lives lost and money. Because health and safety are crucial metrics used by international safety and health organisations to preserve human life and lower financial losses, problems that are serious and more closely tied to people's health and safety cannot be handled lightly.

By using technology to the extent it was meant to and to capitalize on it benefits we can make driving safe by introducing smart headlights which can help save lives of people. This technology can be implemented in nearly every situation whether it is roads on the plains or roads on the mountains.

1.4 Theoretical Background

Troxler Effect –
Troxler's effect, sometimes referred to as Troxler fading or the Troxler phenomenon, is a perceptual phenomenon that happens when a person fixes their attention on a stationary stimulus for a prolonged amount of time, like a little dot or object. The brain progressively 'fades' or filters out the input from conscious experience when the surrounding visual field is monotonous, unchanging, or devoid of detail.

It is thought that the brain's mechanisms for adaptability and procedures for selective attention are what cause Troxler's effect. Peripheral visual information is gradually filtered out or muted from conscious awareness as the retina's photoreceptors are desensitised to static visual stimuli and attention is concentrated on the central fixation point.

Troxler's Effect is a visual phenomenon that arises when a bright light falls onto the eyes of an individual. The effect that creates temporary blindness in the driver is known as Troxler's effect or also known as 'fading effect'. A study shows that if our eyes are exposed to a very bright light source of around 10,000 lumens, we experience a glare [16] This glare is caused due to the over exposure inside the eye. Even after removing the source of the glare, an after-image remains in our eye that produces a blind spot. Troxler's effect poses a serious danger and safety hazard while driving. Driving requires the driver to constantly pay attention to the road and if the driver is blinded for even a small while they might overlook something.

Troxler's effect is the cause of many accidents. Troxler effect applies to all age groups. Anyone exposed to sudden bright light experiences it.

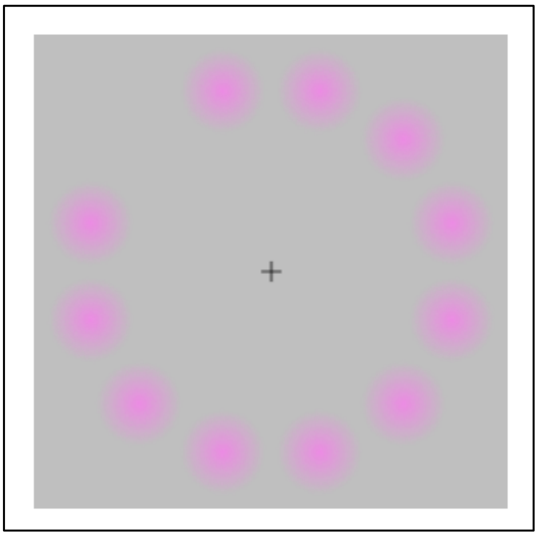

Figure 1.4.a: Example of an illusion caused due to Troxler effect

Light Dependent Resistor -

Light Dependent Resistor, or LDR for short, is a photoresistor. This particular kind of resistor changes resistance in response to the quantity of light that strikes its surface. As passive electronic components, light-dependent resistors (LDRs) react to external stimuli, such as light, rather than producing or generating electrical impulses.

An LDR's resistance increases as light intensity decreases and reduces as incident light intensity increases, respectively. Because of this feature, LDRs can be used in a wide range of applications where light detection or sensing is necessary.

Common uses for LDRs include the following:

- Automatic Street Lights: Automatic street lights turn on and off based on ambient light levels detected by LDRs, which are utilised in street lighting systems.
- Photography: To measure light levels and modify camera settings like ISO sensitivity, shutter speed, and aperture, LDRs are used in cameras and photography equipment.
- Security Systems: LDRs are used in security systems to sense changes in the surrounding light, setting off alerts or turning on security cameras.

- Solar Panels: LDRs are used in solar panels to detect the position of the sun and optimize solar panel orientation for optimal sunlight exposure.

Use of LDR in smart headlight System –

LDR will be used to sense the surrounding light conditions. If the lighting conditions are considered to be bright then the headlights will not be required and hence we can turn them OFF. If the lighting conditions are not enough, and it is dark outside then we can turn the headlights ON. This functionality will be facilitated with the help of the LDR.

All things considered, LDRs are adaptable parts that find use in many different sectors and domains where light sensing, detection, or control is necessary. They offer a dependable and reasonably priced way to monitor and react to variations in ambient light levels.

Object Detection Algorithms –

Algorithms for object detection in images or videos are computer vision techniques that help locate and identify objects. These algorithms are essential to many applications, such as robotics, autonomous vehicles, image analysis, and surveillance.

With the help of object detection algorithms we can detect the moving vehicles on the road and classify them as vehicles which is the basis for the project. Once they are classified and these vehicles are detected then we can find their position and control the LED Matrix to create a Smart Headlight System.

There are many different Object Detection Algorithms that we can use. One of the algorithms that has been used over here is the YOLOv8

YOLOv8 Model –

The most recent and advanced YOLO model, YOLOv8, is applicable to tasks like instance segmentation, object detection, and image classification. Ultralytics developed YOLOv8. In the field of computer vision, the YOLO (You Only Look Once) series of models has gained notoriety. The reason for YOLO's popularity is that it is remarkably accurate while keeping a small model size. Because YOLO models can be trained on a single GPU, a broad spectrum of developers can use it. It can be inexpensively deployed by machine learning practitioners on edge hardware or in the cloud.

Overview –

1. Single Shot Detection: Yolo is a single-shot detector, which means that it scans the network only once to detect and classify objects. This is not like previous detection systems, which usually have several steps, like region proposal networks and then classification.
2. Grid-Based Detection: YOLO predicts bounding boxes and class probabilities for objects inside each cell by dividing the input image into a grid of cells. YOLO can effectively identify objects in the image at various scales and locations thanks to this grid-based method.
3. Bounding Box Prediction: YOLO predicts bounding boxes that enclose the detected objects for each grid cell. These bounding boxes typically have four coordinates: x, y, width, and height. YOLO can forecast bounding boxes with different sizes and aspect ratios by using these bounding boxes, which are represented as offsets from the grid cell boundaries.
4. Object Classification: YOLO forecasts the probabilities of various classes for every bounding box in addition to the bounding boxes themselves. Because of this, YOLO is able to recognise objects and categorise them into predetermined groups, such as people, cars, and dogs.
5. Feature extraction: To extract features from the input image, YOLO usually uses a deep convolutional neural network (CNN) as its core architecture. We then use these features to predict class probabilities and bounding boxes.
6. Efficiency: YOLO's speed and efficiency are two of its primary benefits. YOLO achieves real-time performance on standard hardware by detecting objects in a single pass through the network, which makes it appropriate for applications like robotics, autonomous driving, and surveillance.

All things considered, YOLO has greatly advanced the field of object detection by offering a quick and precise method for identifying and categorising objects in pictures and videos. It is one of the most well-liked and frequently used object detection frameworks in both research and industry thanks to its simplicity, speed, and efficacy.

LED Matrix -

An LED matrix is a display that can show alphanumeric characters, symbols, images, or animations. It is made up of a grid of light-emitting diodes (LEDs) arranged in rows and columns. LED matrices are widely used in many different applications, such as clocks, scoreboards, digital signage, and artistic installations.

Individual LEDs are arranged in a rectangular grid, usually in rows and columns, to form LED matrices. Because of the multiplexed connection of the LEDs, individual LEDs can be controlled by addressing particular rows and columns.

We can use LED matrix for our headlights as each LED can be individually controlled hence allowing to control the direction of the beam, also LED are bright and can illuminate the road significantly.

2. PROJECT DESCRIPTION AND GOALS

In this project, the study explores on how can smart headlights be developed in an economical way and how we can use technology to improve visibility for cars on roads at night. With the help of microcontrollers and sensors a device can be created which can provide a solution to the above problem and can give suggestions to help if not solve the larger problem at hand.

By using technology to the extent it was meant to and to capitalize on it benefits we can make driving safe by introducing smart headlights which can help save lives of people. This technology can be implemented in nearly every situation whether it is roads on the plains or roads on the mountains. It can help improve visibility by controlling the blinding nature of the bright headlights meanwhile also allowing the headlights to do the work it was designed for which is illuminating the road in pitch darkness providing the driver with vision to drive safely on the roads.

2.1 Objectives of the Project:

The primary goal in creating a smart headlight system is to lower the number of accidents caused by momentary blindness from the strong glare of high-beam headlights. Those who depend on driving or who commute by road vehicles on a daily basis are aware of the major inconvenience and possible risk this presents. Presenting a remedy for this problem seeks to reduce the momentary interruption in their vision and hence save them from untimely tragedies.

By using smart headlight technology, we hope to make driving safer for everyone who uses the road. These technologies help to lower accident rates and increase road safety by efficiently controlling lamp intensity and minimising glare. Whether travelling on distant highways or through metropolitan streets, smart headlights provide a dependable approach to improve visibility and reduce the dangers of momentary blindness while driving.

Main objectives are:-

1. Using sensors to find whether the lighting conditions in the surroundings require the use of headlights – if it is day time then the headlights are not required, but it is required in the night time.
2. Detect fast moving vehicles and find their position – with the help of a camera for input and using machine learning models and fine-tuned models we can create a system that is able to detect the position of the vehicles on the road.
3. Control LED matrix according to the position of the fast moving vehicles – once we have the location of these cars, we can control the intensity and whether we need to turn the light off in that direction to prevent glare.

2.2 Scope of the Project:

The implementation of smart headlights, provide an approach which enhances the visibility meanwhile also addressing the blinding effect caused by it. By adjusting the intensity and direction and shape of the beam, the system will enable drivers to maintain clear vision on the road in pitch darkness and adapt if there are other cars around. They also make sure that the primary function of headlights which is to illuminate the road for safe navigation is not changed.

We can utilize technology to its fullest extent, with the different solutions and advancements that it provides. We can create smart headlights which present an opportunity to increase safety on the road by managing the intensity of the headlights effectively. We can capitalize the benefits of advanced system and enhance driving conditions to save lives.

In this project, the study explores on how can smart headlights be developed in an economical way and how we can use technology to improve visibility for cars on roads at night. With the help of microcontrollers and sensors a device can be created which can provide a solution to the above problem and can give suggestions to help if not completely solve the larger problem at hand.

3. LITERATURE SURVEY

Table 3.a : Literature review

Title of Paper	Author	Published in	Description	Advantages / Disadvantages	Future Scope
A Case study on Automatic Smart Headlight System for Accident Avoidance [1]	RD. Balaji.	International Journal of computer communication and informatics, 2(2), 70-77.	The research paper gives a proposal for developing an Automatic smart headlight system which is aimed at reducing the accidents on roads at night-time or during adverse weather like rain and fog. The system they have proposed incorporates microcontrollers and sensors that automatically adjust the brightness and the shape of the headlight beam based on the surroundings. the proposed components are cost-effective compared to the ones found in luxury cars, making them suitable for adoption in economy sector vehicles	The project suggests a design for the backside lighting systems and the blind spot vehicle detection system. The proposed system is cost effective. The proposed system uses only few lights as it has been designed keeping in mind 2 wheelers. More lights can be added for 4 wheelers.	The proposed system uses wired connection for communication between the sensors and the circuit board. It can be made wireless using different technologies.
Smart Vehicle Headlights Control System [2]	Basma Al Subhi, Feras N. Hasoon, Hilal A. Fadhil, Suresh Manic, Roshima Biju	AIP Conference Proceedings (Vol. 2137, No. 1). AIP Publishing.	This project shows the design of a smart vehicle headlight system. They have used Arduino to automatically control the headlight system of the car depending on the surroundings. They have made the use of LDR and ultrasonic sensors to sense the surrounding lighting conditions and if	It is able to control the intensity of the car headlights automatically. It helps in reducing the energy consumption of the cars by controlling the	Incorporating features to manage the shape of the headlight beam. Manage the time gap caused by the sensors and make them work more in

			a car is approaching from opposite direction. This system is able to detect the above conditions and control the intensity of the car headlights automatically.	intensity of the headlights. It only focusses on controlling the intensity rather than the shape of the beam. Each sensor is able to work within its limits causing a small time gap.	accordance to each other.
Automotive lighting: method of assessing the visibility of objects in the light of car headlights [4]	Andrii KASHKANOV, Volodymyr KUZHEL, Igor Piotr KURYTNIK, Volodymyr KUCHERUK	Przegląd Elektrotechniczny, 9, 90-94.	In this project they have explored the effect that 3 types of the headlights have on the human eyes and visibility - halogen, xenon and LED. They have explored the reaction that a person has to the photometric parameters like illumination, brightness and others. They have made the use of fuzzy logic and machine learning to assess the distance of visibility. They found that the dazzling intensity of the lights can reduce the visibility by up to 25%. Also they have proposed methods to find the optimal distance of visibility.	This study helps in understanding the effects that high intensity lights such as Halogen, Xenon and LED can have on the visibility. It shows that how dangerous these lights can be and confirms that it can cause accidents. They are limited by the effectiveness of the model that they have created and the errors that it comes with.	For the future they work on improving the model and providing more accurate decision on the optimal distance for visibility of drivers.

Vehicle Headlight Automation With Smart Energy Management System [5]	Poornima G R, Harish V, Karthik S, Nagesh Kumar B S, Varun Kumar S	2019 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT) (pp. 396-399). IEEE.	This project provides a solution for two problems. First being the issue of high intensity headlights. For this they have used a Light Dependent Resistor (LDR) sensory which senses the high beam of the opposite vehicle and with the help of Arduino UNO they are dimming the headlights to prevent blinding from the glare. Second they are trying to provide a solution for the high energy consumption of the street lights, when there are no cars around. It controls the power consumption and provides smart energy management.	They have provided a solution for the problem of high intensity headlights as well as addressed the problem of energy wastage of street lights. Make effective use of sensors for the application of smart headlights and smart street lights. Implementation has been done on small scale and requires more application on a large scale.	Create system for larger modules. Control the direction and shape of the beam rather than only focussing on intensity of the beam.
New scheme of LiDAR-embedded smart laser headlight for autonomous vehicles [7]	Yung-Peng Chang, Chun-Nien Liu, Zingway Pei, Shu-Ming Lee, Yeong-Kang Lai, Pin Han, Hsing-Kun Shih, and Wood-Hi Cheng	Optics express, 27(20), A1481-A1489.	In this project a unique solution for smart headlight system has been provided. They have employed the use of LiDAR embedded smart headlight module. They have been able to control laser headlights, by integrating signals from LiDAR and CCD image with the help of a smart algorithm. They	LiDAR-embedded headlight module provides a visibility range of over 600m. The headlights are able to detect the regions where there are cars	In the future they aim to improve the recognition algorithm from 86% to 95%. They will use a combination of multiple-sensors with AI algorithms to make improvements.

			were able to achieve 86% accuracy for recognition of objects. With the help of Hue Saturation Value (HSV), image processing, they have created regions of interest (ROI) where if cars or pedestrians enter, the light for that ROI is turned off. Once they have left the ROI the headlights are turned back on. With the help of smart algorithm and LiDAR and CCD image signals, they were able to propose a unique solution to reduce glaring effect and provide safety to drivers.	or pedestrians and turn off the lights in those areas, thus still providing illumination to the rest of the road with required intensity. Laser headlights can be harmful to the eyes of the drivers, so they had to use protective casings, which makes the unit heavy and complex.	Improve the quality of the hardware used like higher resolution camera, short distance radars and several other improvements.
Adaptive Headlight System for Accident Prevention [8]	Shreyas S, Kirthanaa Raghuraman, Padmavathy AP, S Arun Prasad, G. Devaradjane	In 2014 International Conference on Recent Trends in Information Technology (pp. 1-6). IEEE.	In this project a microcontroller based Adaptive Headlight System is proposed. They have provided a cost effective solution to illuminate blind spots that the driver faces while turning. The headlights can be automatically controlled, by turning it ON or OFF according to the light in the surroundings. With the help of DC generator and stepper motors and an algorithm, they are able to control the movement of headlights to illuminate blind spots generated while turnings.	This solution provides a solution for blind spots and poor visibility while turning and can turn the headlights to approximately 40% providing illumination while turning. Manual turning ON and OFF or headlights is not required. Intensity of the headlights	In the future, headlights system can be made more effective by controlling how the light beam spreads. With the help of an ‘automatic range extender’ the beam shape can be controlled. They can also incorporate intensity controller when objects

			The system can turn the headlight approximately 40 degrees on both sides. This solution address problems like blind spots, dazzling effect of high intensity headlights and low visibility due to darkness or weather conditions.	cannot be controlled, nor the shape if a driver or pedestrian comes in front.	are detected in front of the car.
Research on Intelligent LED Headlamp System Based on Multi-Sensor Fusion [9]	Youyu Wu, Longqin He	IOP Conference Series: Materials Science and Engineering (Vol. 677, No. 3, p. 032055). IOP Publishing.	the project contains a research on automobile headlamp system. They have made the use of multi-sensor fusion technology. Their proposal gives 3 solutions: first, the headlights can switch between high and low beam according to their surroundings and speed of vehicle; second, with the help of acquiring real-time angle of steering wheel, the illumination angle of headlamps are adjusted, providing visibility during turns; third, by fetching the inclination of the vehicle and the speed, headlights can be adjusted to provide better lighting of the roads on slopes.	It takes care of 3 functionalities – automatic lighting and control of illumination on bends, slopes and according to the surrounding lighting and speed of vehicles, thus providing a comprehensive solution. It can only switch between high beam and low beam and not control the intensity	In the future, they can control the intensity of the headlights to improve functionality as well control the shape of the beam, to provide selective lighting of the roads according to the requirement.
Optimizing Headlamp Focusing Through Intelligent System as	S. K. Rajesh Kanna, N. Lingaraj, P. Sivasankar, C. K. Raghul Khanna	Advances in Manufacturing Technology: Select Proceedings of ICAMT 2018 (pp. 533-545).	In the research they have made an attempt to optimally control the motion of the headlight system through sensors and Arduino board. They have made the use of	They are providing solutions to many different problems, covering many use cases,	Increase the accuracy of the ANN model. Test it with different types of headlights to find optimal

Safety Assistance in Automobiles [10]	and M. Mohanakrishnan	Springer Singapore.	ML model based on ANN to find the optimal movement of the headlights and data from the incoming cars. This intelligent lighting system is capable of shifting form low to high beam, light distribution at turnings, lighting the corners at junctions, lighting during high speeds and adaptive lighting. This has helped minimize the number of accidents at night time and in different conditions by increasing the visibility for the drivers.	which provides a comprehensive solution. They have made the use of ANN which can help finding optimal solutions for dynamic inputs. The cost of the solution is very less and can be implemented on a large scale. ANN comes with the cost of being accurate and can give wrong results if not trained properly.	headlight and colour of beam.
Programmable Automotive Headlights [11]	Robert Tamburo, Eriko Nurvitadhi, Abhishek Chugh, Mei Chen, Anthony Rowe, Takeo Kanade, and Srinivasa G. Narasimhan	Computer Vision–ECCV 2014: 13th European Conference, Zurich, Switzerland, September 6-12, 2014, Proceedings, Part IV 13 (pp. 750-765). Springer International Publishing.	They have created a single hardware system that can perform various tasks. The headlight system is a reactive visual system that has ultra-low latency. It can sense, react and adapt very quickly to the environment even while moving at high speeds. The different tasks that the system can perform include – anti-glare high beam, improved visibility for the driver during snow storm,	The system works at the high speed, which is the requirement considering it should be used in highways where most accidents happen. The latency between detection and reaction of the headlights is	For future systems they can incorporate ml models for more accurate detection while keeping the latency low. The device needs to be made smaller so that it can fit inside the vehicle and is not fit above the vehicle. Also make

			timely visual warnings of obstacles/obstructions and increased and higher contrast of lanes and sidewalks. They have used a high-resolution Spatial Light Modulator (SLM), for example a Digital Micro-Mirror Device. With the help of a camera they can process images to generate illumination patters. They have achieved high-accuracy by reducing the latency of reaction of the headlights	very less hence it is effective. The size of the device is very big and hence and be a hindrance.	some engineering changes to make the device handle vibrations and heat produced by the vehicle.
GaN-based mini-LED matrix applied to multi-functional forward lighting [12]	Quang-Khoi Nguyen, Yi-Jou Lin, Ching Sun, Xuan-Hao Lee, Shih-Kang Lin, Chi-Shou Wu, Tsung-Hsun Yang, Tian-Li Wu, Tsung-Xian Lee, Chao-Hsin Chien, Yeh-Wei Yu & Ching-Cherng Sun	Scientific reports, 12(1), 6444.	They have developed adaptive head lamps, where the illumination area can be optimized for the driver and the pedestrians which are in front of the vehicle. This can be achieved by switching the light sources on the LEDs. In the project they have presented a study of the headlamps which have a reflector and a mini LED-matrix. This can perform high-beam and low-beam for different illumination ranges. They also propose to use infrared light based on GaN die. Use of infrared light will not cause glare also the infrared light can be detected by a photo imager. With the	Use of LED matrix helps in controlling the shape of the beam and can be useful. Use of infrared light does not cause glare and reduced light pollution to the driving circumstance. Infrared lights also helps in photo detection by photo imager.	They would like to extend the led matrix horizontally to provide better results. The usage of mini-LED matrix can be extended by coating IR phosphor on the blue LED dies in the high-beam zone.

			help of this they can control the shape and intensity of the beam and provide relief to the drivers to reduce accidents.		
Optical and Thermal Designs of LED Matrix Module used in Automotive Headlamps [13]	Wei Chen, Jiajie Fan, Gaojin Qi, Chengzhong Sun, Weiqiao Yang, Suming Cao	2019 16th China International Forum on Solid State Lighting & 2019 International Forum on Wide Bandgap Semiconductors China (SSLChina: IFWS) (pp. 220-224). IEEE.	In this project is proposed a matrix automotive headlamp which has a rectangle lens array to help visibility during driving while also reducing glare. They have worked on two things, first do develop a LED configuration and a structure for an optical system, secondly the thermal management of the module for which they used fluid finite elements. They have produced simulations to test and conduct research. Their findings include – the LED matrix with a specific designed rectangle lens array which can contain different size of lenses can produce an independent non-overlapping light spots of rectangle shape which is what is required. The heatsink which is designed optimally with pin fins can provide very effective thermal dissipation.	The design and research has been done which is laid the foundation on which the use of LED matrix can be done. They have found optimal shapes and design of LED matrix and the heat sinks for best use. This is not tested on a real vehicle, hence its efficiency is not known. The research has just been done to produce different patterns, it does not detect and create patterns in real time.	Making a model which can be fitted on vehicles and tested on field. Using models to detect objects and controlling the LED matrix accordingly.

LED Modules for Matrix and Pixel Light Solutions - On the Way to New Features in Headlight Systems [14]	Thomas Liebetrau, Roland Fiederling and Maximilian Vogl, Dieter Stephan Parth	(No. 2014-01-0432). SAE Technical Paper.	The team has described a LED matrix system which can dynamically adjust and provide a glare-free and continuous high beam. They have focussed on modularity of the system and the optimization of the thermal properties of the LED matrix. This was done to make sure that the model is reliable under the harsh conditions of the environment inside the headlight. This electronic concept coordinated with LED technology, allows a highly dynamic and independent control of each of the LED component in the matrix. The system they have made is robust and reliable and reduces glare while providing a high beam.	The use of LED is used to dynamically adjust and provide continuous high beam. The beam provided is glare-free. The system is robust and reliable. The cost of manufacture is high. The shape and the intensity cannot be controlled dynamically.	Future works include improvement in design and optimization to actually fit and be appropriate to install in the car. Reduce the cost of the product. Couple it with cameras and sensors to improve the functionality.

Balaji [1] in this research paper presents a proposal for developing an Automatic Smart Headlight system which aims to reduce night-time and adverse weather-related accidents on roads. They have tried exploring economically viable designs to provide solutions. They have made the use of sensors and microcontrollers to achieve this. Additionally, they have outlined the design of backside lighting systems and blind-spot vehicle detection systems to enhance overall road safety.

With the use of sensors and Arduino Al-Subhi, et. al. [2] have designed a smart vehicle headlight control system. To detect the lighting conditions around them and the oncoming car from the other side of the roadway, they have employed light-dependent resistors (LDRs) and ultrasonic sensors. They have used these sensors with an Arduino board to control them. This project has helped them implement the system which receives data from the sensors and effectively controls the intensity of the headlights. This has helped them with energy conservation as well as protecting the eyes of the drivers.

In the paper Andrii [4] et. al. have explored how the 3 different types of headlights Halogen, Xenon and LED have on the visibility of the driver. They found that these lights can reduce the visibility of the driver by around 25%. This confirms that the high intensity of the headlights have a dazzling effect on the drivers and can cause temporary blindness. This can cause serious accidents. They have made the use of ML models to carry out the research.

Poornima and et. al. [5] have proposed a system for smart energy management. It takes care of 2 problems. The problem of high intensity of headlights and the wastage of energy of street lights in empty roads. They have made the use of sensors like LDR, PIR and Arduino UNO which is used to detect the light from opposite cars, movement of cars and whether there is sunlight or not. With the help of these sensors they are able to solve the problems and provide a comprehensive one stop solution to the problems at hand.

In this paper Chang et. al. [7] have explored a unique method of smart headlight system. They have employed the use of LiDAR (light imaging, detection and ranging) embedded smart headlight module (SHM). They have been able to control laser headlights, by integrating signals from LiDAR and CCD image with the help of a smart algorithm. They were able to achieve 86% accuracy for recognition of objects. Laser headlights can achieve range up to 600m which improves driver visibility. With the help of Hue Saturation Value (HSV), image processing, they have created regions of interest (ROI) where if cars or pedestrians enter, the light for that ROI is turned off. Once they have left the ROI the headlights are turned back on. With the help of smart algorithm and LiDAR and CCD image signals, they were able to propose a unique solution to reduce glaring effect and provide safety to drivers.

Shreyas et. al. [8] have created a microcontroller based Adaptive Headlight System. They have provided a cost effective solution to illuminate blind spots that the driver faces while turning. The headlights are automatically controlled, by turning it ON or OFF according to the light in the surroundings. This solution address problems like blind spots, dazzling effect of high intensity headlights and low visibility due to darkness or weather conditions. With the help of

DC generator and stepper motors and an algorithm, they are able to control the movement of headlights to illuminate blind spots generated while turnings. The system can turn the headlight approximately 40 degrees on both sides, thus providing a unique solution for smart adaptive headlights.

Youyu et. al. [9] in the paper have conducted a research on automobile headlamp system. They have made the use of multi-sensor fusion technology. This helps to acquire data for full automation of headlights. They carried out research on functions such as switching between high beam and low beam, adaptive lighting during bends, and adaptive lighting in ramps. Their proposal gives 3 solutions: first, the headlights can switch between high and low beam according to their surroundings and speed of vehicle; second, with the help of acquiring real-time angle of steering wheel, the illumination angle of headlamps are adjusted, providing visibility during turns; third, by fetching the inclination of the vehicle and the speed, headlights can be adjusted to provide better lighting of the roads on slopes.

Rajesh et. al. [10] in the research have made an attempt to optimally control the motion of the headlight system through sensors and Arduino board. They have tried making a system in which the features include shifting between main beam and low beam, diverging light projections while turning, beam projection according to weather, increase in divergence of beam at junctions. These features have been predicted and implemented with using data like speed, motion of other vehicles, movement etc. This helps the driver get a more clear view of the surroundings. They have made the use of ML model based on ANN to find the optimal movement of the headlights and data from the incoming cars. This intelligent lighting system is capable of shifting form low to high beam, light distribution at turnings, lighting the corners at junctions, lighting during high speeds and adaptive lighting. This has helped minimize the number of accidents at night time and in different conditions.

Tambur et. al. [11] have created a single hardware system that can perform various tasks. The headlight system is a reactive visual system that has ultra-low latency. It can sense, react and adapt very quickly to the environment even while moving at high speeds. The different tasks that the system can perform include – anti-glare high beam, improved visibility for the driver during snow storm, timely visual warnings of obstacles/obstructions and increased and higher contrast of lanes and sidewalks. They have used a high-resolution Spatial Light Modulator (SLM), for example a Digital Micro-Mirror Device. This can divide the light beam into smaller ones which can control the shape. With the help of a camera they can process images to generate illumination patters. They have achieved high-accuracy by reducing the latency of reaction of the headlights

Nguyen et. al. [12] have developed adaptive head lamps, where the illumination area can be optimized for the driver and the pedestrians which are in front of the vehicle. This can be achieved by switching the light sources on the LEDs. In the paper they have presented a study of the headlamps which have a reflector and a mini LED-matrix. This can perform high-beam and low-beam for different illumination ranges. They also propose to use infrared light based on GaN die. Use of infrared light will not cause glare also the infrared light can be detected by a photo imager. With the help of this they can control the shape and intensity of the beam and provide relief to the drivers to reduce accidents.

Chen et. al. [13] have proposed a matrix automotive headlamp which has a rectangle lens array to help visibility during driving while also reducing glare. They have worked on two things, first do develop a LED configuration and a structure for an optical system, secondly the thermal management of the module for which they used fluid finite elements. They have produced simulations to test and conduct research. Their findings include – the LED matrix with a specific designed rectangle lens array which can contain different size of lenses can produce an independent non-overlapping light spots of rectangle shape which is what is required. The heatsink which is designed optimally with pin fins can provide very effective thermal dissipation.

Liebetrau et. al. [14] have described a LED matrix system which can dynamically adjust and provide a glare-free and continuous high beam. They have focussed on modularity of the system and the optimization of the thermal properties of the LED matrix. This was done to make sure that the model is reliable under the harsh conditions of the environment inside the headlight. This electronic concept coordinated with LED technology, allows a highly dynamic and independent control of each of the LED component in the matrix. The system they have made is robust and reliable and reduces glare while providing a high beam.

4. TECHNOLOGICAL STACK

4.1 Machine Learning and Object Detection

- Python: Used as the primary programming language for training the model and object detection due to its versatility, extensive libraries. It is used to write logic to detect objects and their positions.
- OpenCV: OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. It is used to integrate camera and videos to test the project.
- ML model – YOLOv8

  The YOLOv8 is a machine learning model used for object detection tasks. It utilizes a deep convolutional neural network architecture for feature extraction. With an input image size of 640x640 pixels, this model is capable of detecting and localizing objects within images with high accuracy and efficiency.

  For this project we have used custom dataset to fine tune the model and use it to detect oncoming vehicles. The model is used to only detect the vehicles that are coming and it does not detect other objects. This model is used so that we can extract features and carry out object detection with respect to region.

4.2. Integrated Development Environments –

- Visual Studio Code – Used to implement object detection on a video, image or live feed. After detecting, finds the location of the vehicle and then sends the signal to the Arduino which controls the LED modules.
- Google Colab – Used to train the YOLOv8 machine learning model which helps in object detection.
- Arduino IDE – This IDE is used to code the Arduino. It gets the signal from the output of the object detection model and then controls the LED Modules. It is also used to program and take the input from the LDR and program accordingly. It is used to program the hardware used in the project.

4.3 Hardware Used -

Microcontroller Board – Arduino Uno R3

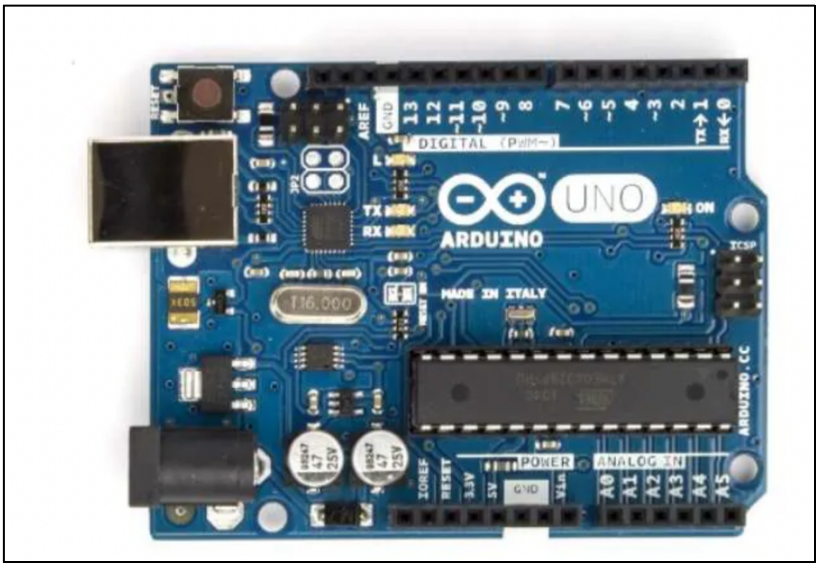

Figure 4.3.a: Arduino Uno R3

The Arduino Uno R3 is a compact and versatile microcontroller board featuring the ATmega328P chip, offering ample I/O pins for interfacing with sensors and actuators. This will be used to control the LED matrix and the LDR and is used to control the headlight module.

LED matrix – Max7219 matrix (4 components of 8x8 LED dot matrix)

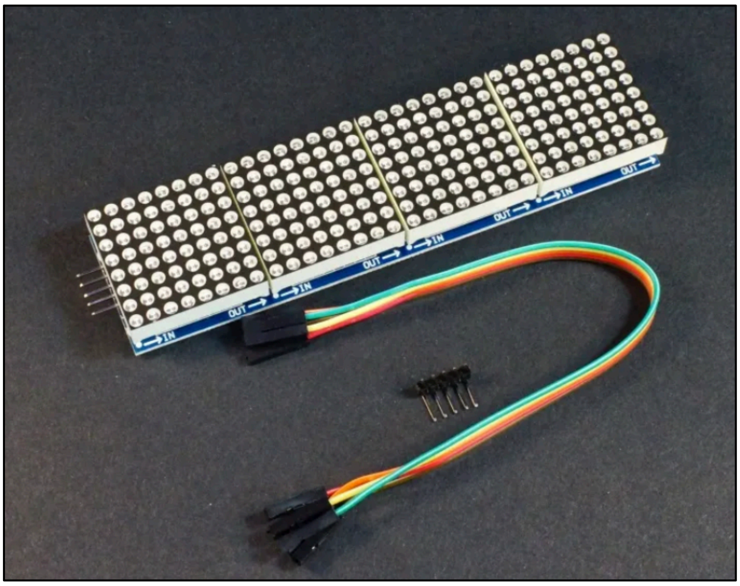

Figure 4.3.b: MAX7219 LED Dot Matrix

The MAX7219 LED matrix consists of four modules, each featuring an 8x8 array of LED dots. Controlled by the MAX7219 driver chip, it offers easy interfacing and efficient control of individual LEDs, making it ideal for displaying graphics, text, and patterns in various applications. This will be used to simulate the headlights of the cars and act as the headlights in the headlight module.

<u>Light dependent Resistor – LM393 Photosensitive Light-Dependent Control Sensor LDR Module</u>

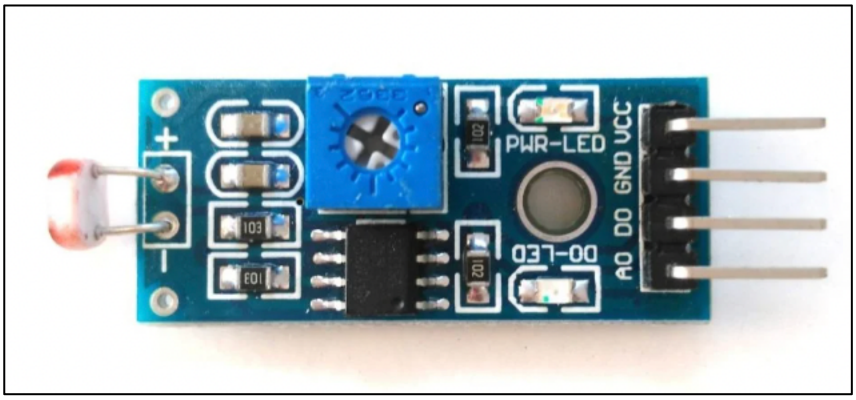

Figure 4.3.c: Light Dependent Resistor

The LM393 Photosensitive Light-Dependent Control Sensor LDR Module, commonly known as a Light Dependent Resistor (LDR), is a type of resistor whose resistance varies with the amount of light falling on it. This module utilizes the LM393 comparator chip to provide digital output based on the light intensity detected by the LDR. This will be used to sense the lighting conditions of the surroundings to decide whether the headlights are required or not.

Breadboard

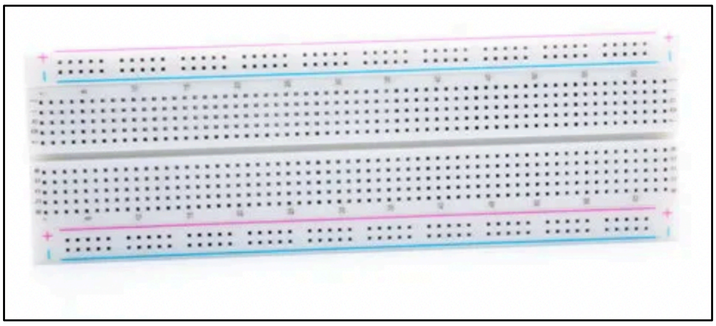

Figure 4.3.d: Breadboard

A breadboard is a versatile solderless prototyping tool used in electronics to create and test circuit designs. It consists of a grid of interconnected holes where electronic components and wires can be inserted and connected, allowing for quick and temporary circuit assembly and modification without the need for soldering. This will be used to provide voltage and power to the various component like LDR and LED matrix.

Jumper wires

Figure 4.3.e: Jumper Wires

These are wires which are used to connect the components and to make the circuit. For the project 2 types of wires are being used – male to male wires and male to female wires.

5. PROPOSED APPROACH AND DETAILS

5.1 Proposed Architecture

The architecture of the smart headlight system is very simple. It takes into account the models and the components present in the headlights.

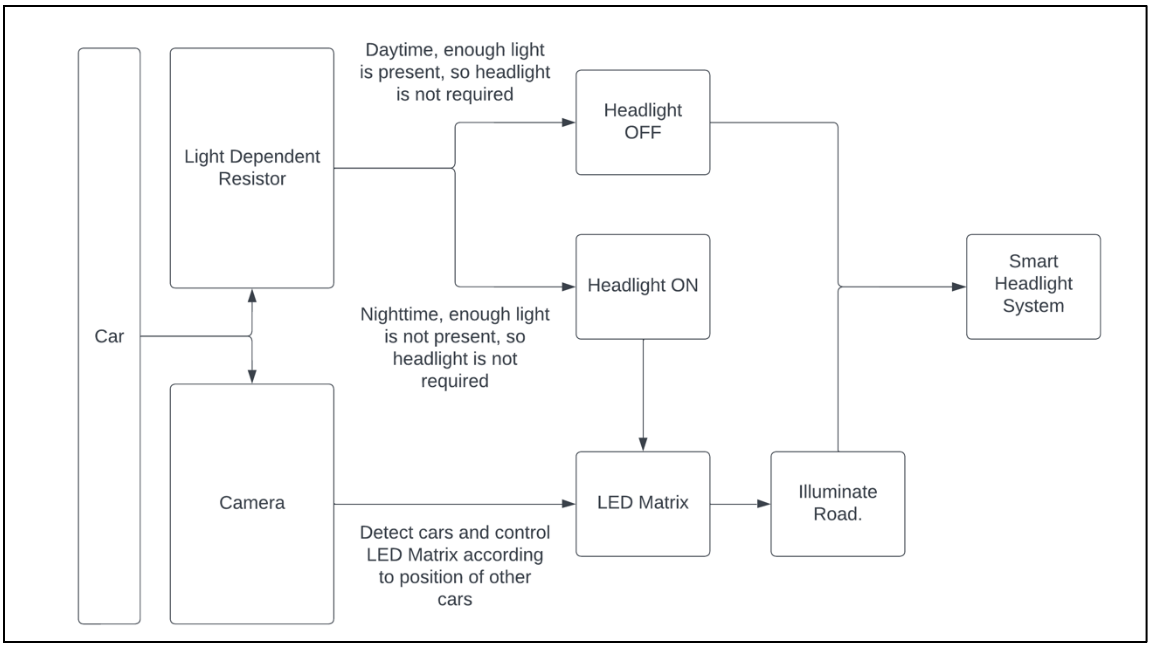

Figure 5.1.a: Architecture of the Proposed Headlight System

This figure explains the architecture of the proposed headlight system. There are 2 parts to the proposed system. The vehicle detection with the help of a camera and the surrounding lighting condition detection with the help of an Light Dependent Resistor.

1) The flow of the vehicle detection and controlling of the LED Matrix –

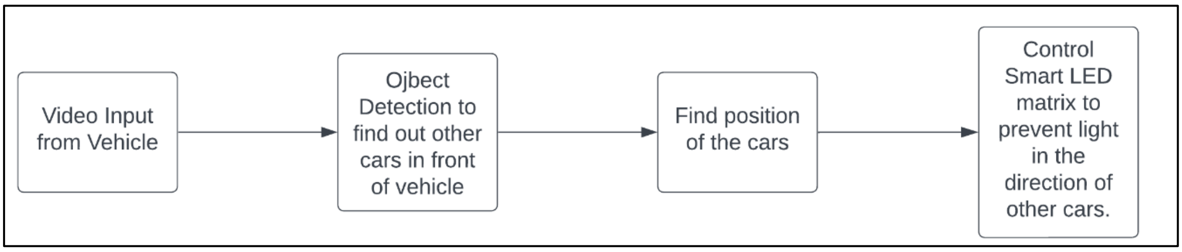

Figure 5.1.b: Flow of the Camera module for object detection and controlling LED Matrix

- With the help of a camera which will be attached on the car will take the real time input of the road and the vehicles that are on the road.
- Once the input is taken then with the help of Machine Learning algorithms we can detect the oncoming vehicles on the road on the opposite side.
- After that is detected and the position of these cars are located. We can get the coordinates of these cars.
- With the help of the coordinates of the oncoming cars and vehicles we can configure the LED matrix to control where the headlight shines and where it does not.
- This will help in reducing the glare that the drivers have to experience.

2) The flow of the Light Dependent Resistor and how it will control the headlights –

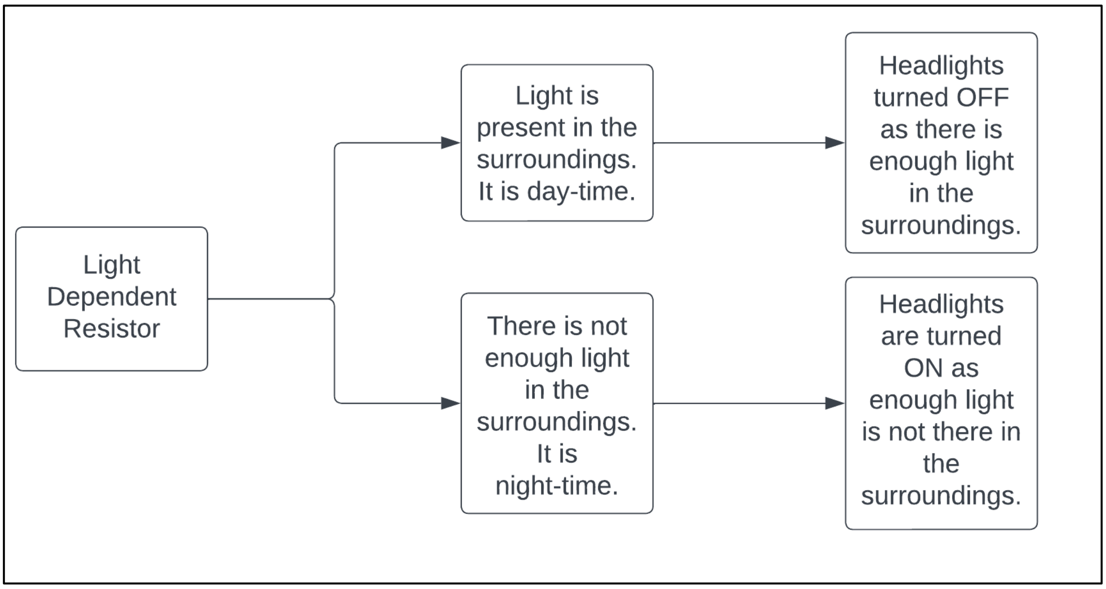

Figure 5.1.c: Working of the Light Dependent Resistor

- The Light Dependent Resistor can help us detect illumination.
- With the help of LDR we can gauge the lighting conditions of the surroundings and make a decision whether the headlights are required or not.
- If the lighting conditions are of a certain state, like if it is daytime and there is enough light in the surroundings then there is no need to the headlights and hence we can turn them off
- If the lighting conditions are not enough and it is dark, then the headlights can be turned on and then we can make the use of the smart headlight system.

This is the architecture of the proposed Headlight System. What we have focussed on is making the smart use of technology and making a device which can help reduce the glare that drivers receive while driving.

This smart system makes the use of LDR make a decision whether the headlights are required or not. This helps the user in some ways where the use of the headlights can become automatic. The user does not have to make the decision rather the car can switch the headlights on for the driver itself.

The camera and object detection will help detect cars on the road and modify and dynamically change the direction of the light from the headlights to prevent the other drivers from getting glare. this helps in reducing the accidents that are caused by the harsh glare that is seen in the cars currently in use.

5.2 Novelty of the proposed System

Drawing inspiration from the other works, the novel elements that the project provides are -

- Each frame from the received video is used to detect the oncoming cars. The algorithm used makes the use of the individual frames to detect the oncoming vehicles and controls the LED matrix in real-time.
- LED matrix system is used instead of using traditional headlamps.
- The main focus is to direct the LED light in different direction than the oncoming vehicle rather than only controlling the intensity.
- A combination of LDR and LED matrix is used to make the smart headlight system.

5.3 Proposed Methodology

<u>Software Side -</u>

- We utilize machine learning algorithms, particularly the model developed by Ultralytics - YOLOv8.
- The process involves training the model with labelled data, indicating the presence of vehicles, and testing it with various datasets to ensure accuracy.
- Once trained, the model can be invoked to detect vehicles in images or videos in real-time.

- Upon detecting vehicles, the model outputs their positions, which are then sent to an Arduino board.
- The Arduino board controls an LED matrix, visually indicating the positions of detected vehicles by illuminating corresponding LEDs.
- This setup enables us to visually perceive where the headlights of vehicles on the opposite side are providing light, aiding in decision-making and safety measures.

Hardware Side -

Hardware Components:

- Arduino Uno R3
- LED matrix (4 modules of 8x8 LED matrix MAX7219)
- Analog light-dependent resistor (LDR)
- Jumper wires
- Breadboard

Circuit Configuration:

- Connect the LED matrix modules to the Arduino Uno using jumper wires, ensuring proper data and power connections.
- Connect the LDR to the Arduino Uno to measure ambient light levels, allowing for automatic control of the headlights.

Functionality:

- The Arduino Uno receives input from the machine learning model regarding the position of detected vehicles.
- Based on the input, the Arduino Uno controls the LED matrix to create different shapes of beams, directing light away from the eyes of oncoming drivers.
- The LDR detects ambient light conditions and adjusts the headlights accordingly. If the light falls below a certain threshold, the headlights are automatically turned on; otherwise, they remain off.
- This setup ensures that headlights are utilized appropriately based on surrounding lighting conditions, enhancing safety for both the driver and other road users.

6. DESIGN APPROACH

Design of the Model

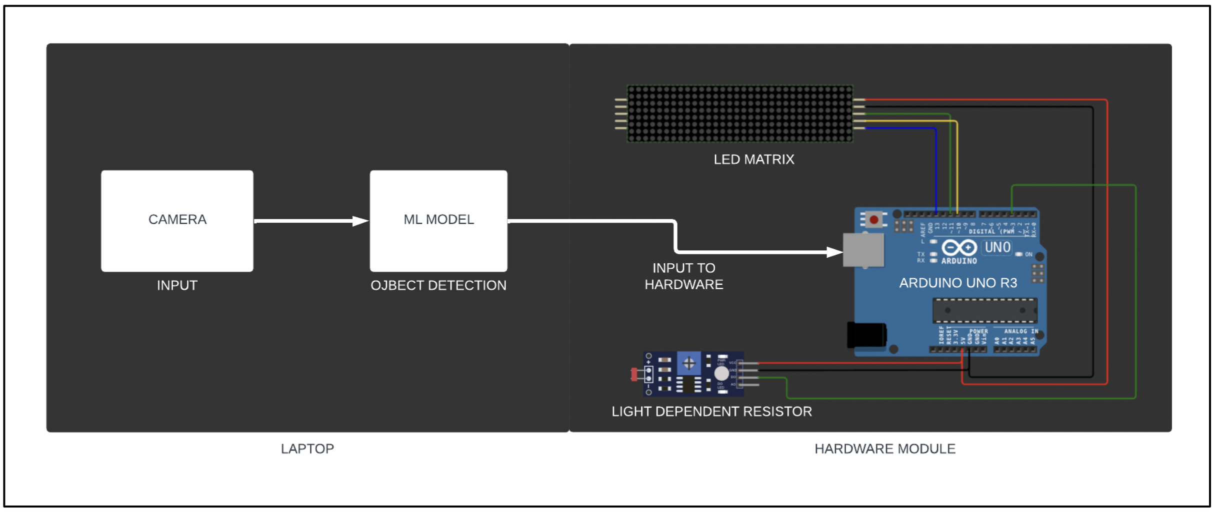

Figure 6.a: Design of the Model

Diagram Overview:

- Input Source: Camera attached to the system captures video feed of the surroundings.
- Machine Learning Model: Receives the video feed and performs object detection in real-time, identifying the position of vehicles.
- Data Transmission: Detected vehicle positions are transmitted to the Arduino for further processing.
- Arduino Processing:
    - Data Reception: Arduino receives coordinates of detected vehicles.
    - LED Matrix Control: Based on the received coordinates, Arduino controls the LED matrix to generate specific beam shapes, directing light away from oncoming drivers' eyes.
    - Light-Dependent Resistor (LDR):
        - Continuously monitors ambient lighting conditions.
        - Provides feedback to Arduino regarding surrounding light levels.
- Headlight Control:
    - Automatic Activation: If ambient light falls below a predefined threshold, indicating darkness, headlights are automatically turned on.

    - Automatic Deactivation: When ambient light is sufficient, headlights are automatically turned off.
- System Functionality:
    - Glare Reduction: By directing light away from oncoming drivers' eyes and automatically adjusting headlight direction also controlling the headlight based on ambient light, the system reduces glare, enhancing safety for all road users.
    - Integration: The integration of camera, ML model, Arduino, LED matrix, and LDR creates a smart headlight system that operates efficiently in various lighting and traffic conditions.

7. SCHEDULE, TASKS AND MILESTONES

Table 7.a: Project Schedule and Milestones

S. No	Reg. No	Student Name	Date, Time & Venue	Key Points Discussed	Remarks By Guide	Guide Name	Guide Sign with Date
1	20BIT0053	Yash Bhavin Jasani	08/01/24 12:00 PM Call Mode	Discussion about Capstone Project Topic and what is expected	Topic for Capstone Steps to approach the problem. Novelty Scope of the project	Prof. Dr. PRASANNA M	
2	20BIT0053	Yash Bhavin Jasani	02/02/24 4:00 PM Call Mode	Progress for Review 1	Format for Literature Review What to include in Architecture	Prof. Dr. PRASANNA M	
3	20BIT0053	Yash Bhavin Jasani	01/03/24 3:00 PM Teams Meeting	Progress for Review 2. How to work with LED matrix and LDR. How to handle cases when there are more than 2 vehicles on road	Different situations where LDR can be applied and how it can be applied. Different patterns to create for different situations. Property of intensity of light.	Prof. Dr. PRASANNA M	
4	20BIT0053	Yash Bhavin Jasani	27/03/24 4:15 PM Teams Meeting	Shown demonstration of project. Given presentation and update of work done. Shown different scenarios and how LED matrix works with different patterns.	Focus on hardware module and its working. Try using headlight module and LDR in real-time scenario with different lighting and see if it works. Try finding and creating a more robust dataset and train the model	Prof. Dr. PRASANNA M	

					and improve its accuracy.		

8. IMPLEMENTATION

Image of the Hardware Module –

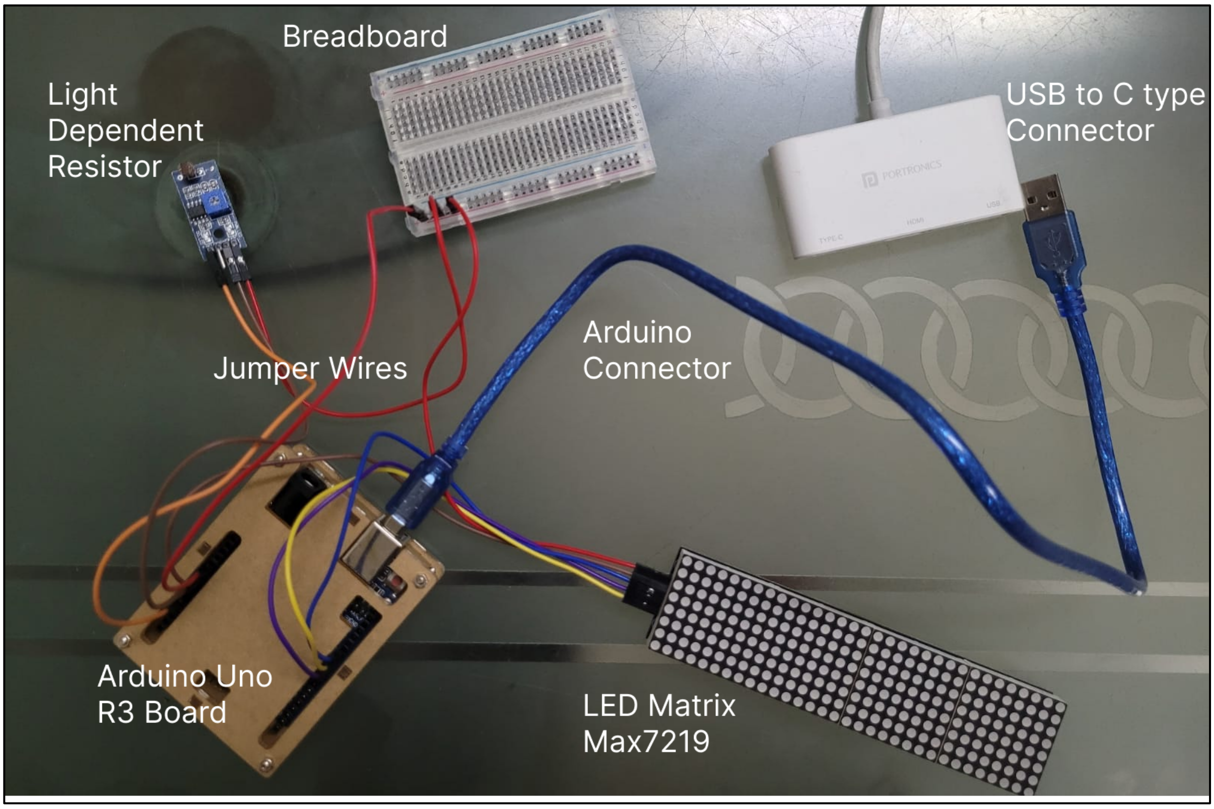

Figure 8.1: Image of the Hardware Module

Above attached is the hardware module. You can see the various components that are connected to each other to make the working model.

Components –

1. Arduino Uno R3
2. LED Matrix Max7219
3. Light Dependent Resistor
4. Breadboard

Overview –

- Arduino Uno R3 board serves as the central controller.
- USB to C-type converter links the Arduino to the computer for power and code loading.

Power Distribution –

- The Arduino receives the power from the laptop.
- The LDR receives an input of 5V from the Arduino
- The LED Matrix receives an input of 5V from the Arduino
- As there is only one 5V output pin in the Arduino Board, the breadboard is used. With the help of the breadboard we are able to supply 5V to both the LDR and the LED Matrix.

Light Dependent Resistor –

- The VCC pin is connected to the breadboard where 5V of power is being supplied from the Arduino.
- The ground pin is connected to the ground pin of the Arduino.
- The A0 pin which is the output of the LDR is connected to the A0 pin of the Arduino. The output of the LDR is given from the A0 pin of the LDR and it is given as input to the A0 pin of the Arduino.

LED Matrix –

- The VCC pin is connected to the breadboard where 5V of power is being supplied from the Arduino.
- The ground pin is connected to the ground pin of the Arduino.
- The Chip Select pin is connected to pin 10 of the Arduino.
- The Clock pin is connected to pin 11 of the Arduino.
- The Data In pin is connected to pin 12 of the Arduino.

This setup efficiently integrates the hardware components required for the smart headlight system, ensuring proper power distribution and communication between the Arduino and connected devices.

For Controlling the Arduino and the other Components we are going to use Development Environment – Arduino IDE. Here we can write the Code and upload it to our Arduino for it to be able to control the various components that are connected to it.

8.1 Working of the LED Matrix –

The LED matrix can be programmed to produce different patterns, which can effectively control the shape of the beam and prevent shining directly into the eyes of the driver.

For controlling the LED matrix we are going to use the Library that is provided in the ArduinoIDE - LedControl.h

Below is the Code attached to setup the LED Matrix to work with the Arduino.

```
#include <LedControl.h>

// Pin connections for MAX7219
const int MAX7219_DATA_PIN = 12;  // Data IN Pin
const int MAX7219_CLK_PIN = 11;   // Clock Pin
const int MAX7219_CS_PIN = 10;    // Chip Select Pin

// Number of MAX7219 ICs (4 - 8x8 LED modules)
const int NUM_MAX7219 = 4;

// Create an instance of the LedControl library
LedControl lc = LedControl(MAX7219_DATA_PIN, MAX7219_CLK_PIN, MAX7219_CS_PIN, NUM_MAX7219);

void setup() {
  Serial.begin(9600);  //Start serial connection
  // Initialize the MAX7219

  lc.shutdown(0, false);  // Wake up MAX7219 (0 = first IC)
  lc.shutdown(1, false);  // Wake up MAX7219 (1 = second IC)
  lc.shutdown(2, false);  // Wake up MAX7219 (2 = third IC)
  lc.shutdown(3, false);  // Wake up MAX7219 (3 = fourth IC)

  lc.setIntensity(0, 15); // Set the brightness (0-15)
  lc.setIntensity(1, 15); // Set the brightness (0-15)
  lc.setIntensity(2, 15); // Set the brightness (0-15)
  lc.setIntensity(3, 15); // Set the brightness (0-15)

  lc.clearDisplay(0);  // Clear the display (0 = first IC)
  lc.clearDisplay(1);  // Clear the display (1 = second IC)
  lc.clearDisplay(2);  // Clear the display (2 = third IC)
  lc.clearDisplay(3);  // Clear the display (3 = fourth IC)

}
```

Figure 8.1.1: Set up Code for the LED Matrix

```
LedControl lc = LedControl(MAX7219_DATA_PIN, MAX7219_CLK_PIN,
MAX7219_CS_PIN, NUM_MAX7219);
```

This line helps us create an instance of the LedControl and we are able to control the LED matrix with the help of this instance..

The different patterns of the LED Matrix –

1. All of the LEDs are turned on –

Code for turning all LED modules ON -

```
void turnOnAllModules() {
  // Turn on all LEDs in the four LED modules
  for (int module = 0; module < NUM_MAX7219; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
}
```

Display on LED Matrix –

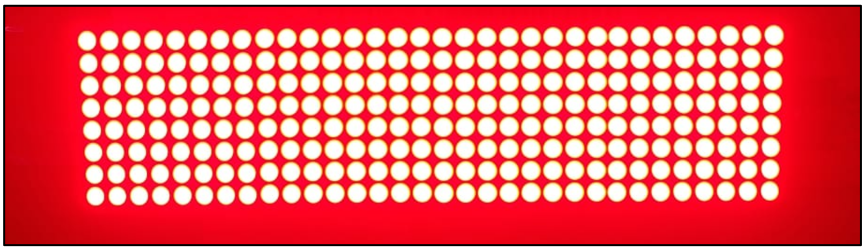

Figure 8.1.2: LED Matrix when all LEDs are ON

All the LEDs that are present in the matrix are on, this is when there are no cars that are oncoming and the roads are empty.

Intensity of the light produced by this –

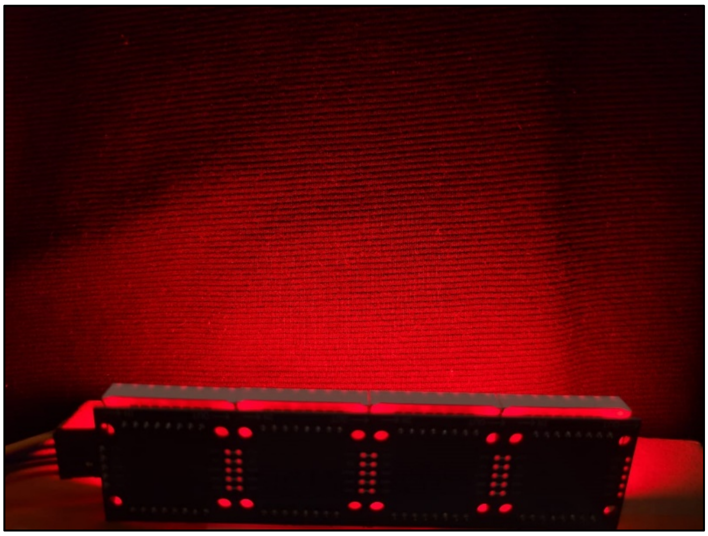

Figure 8.1.3: Intensity of the light produced by LED image above

Here you can see that the LED is shining in all directions and providing light.

2. All the LED Modules are on except the 1st one –

Code for turning on LED Modules 2,3 and 4 and turning off LED module 1 while keeping its last row turned ON.

```
void turnOffModule1() {
  // Turn off in module 1 and on all LEDs in the other three
LED modules
  lc.shutdown(0, false);
  lc.setRow(0, 7, B11111111);
  for (int module = 1; module < NUM_MAX7219; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
}
```

Display on LED Matrix –

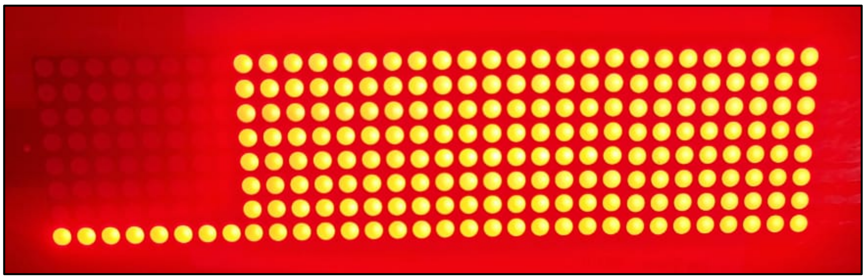

Figure 8.1.4: LED Matrix with modules 2, 3 and 4 are ON.

The LED modules 2, 3 and 4 are on and the last row of the 1st LED module is on. Rest all the rows in the 1st LED module are off. This pattern is used if there is a car that is oncoming from the extreme left. The last row of the 1st module is left on so that the road below is still illuminated even though the other lights are turned off in that direction.

Intensity of the light produced by this –

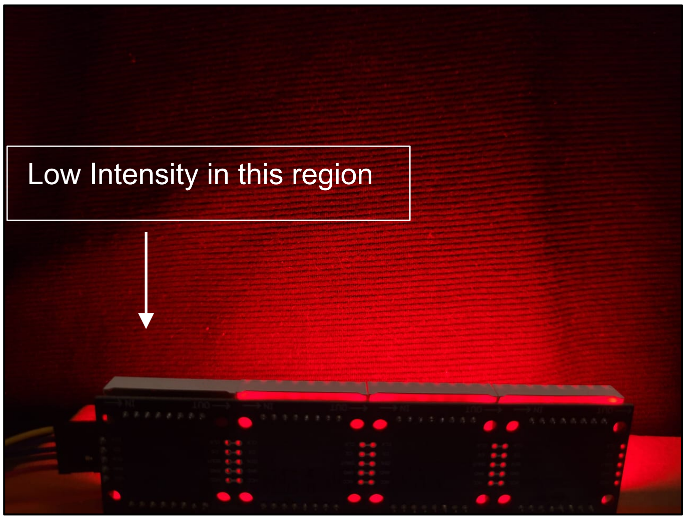

Figure 8.1.5: Intensity of the light produced by LED image above

Here we can see that the intensity in the extreme left is a little less than in the other areas. This shows that the lights are cut off in that direction.

3. <u>All the LED Modules are on except the 2nd one –</u>

Code for turning on LED Modules 1, 3 and 4 and turning off LED module 2 while keeping its last row turned ON.

```
void turnOffModule2() {
  // Turn off in module 2 and on all LEDs in the other three
LED modules
  lc.shutdown(1, false);
  lc.setRow(1, 7, B11111111);
  for (int module = 2; module < NUM_MAX7219; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
  for (int row = 0; row < 8; row++) {
    lc.setRow(0, row, B11111111);
  }
}
```

<u>Display on LED Matrix –</u>

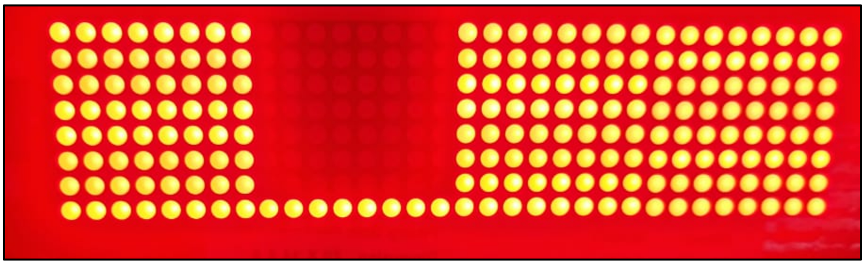

Figure 8.1.6: LED Matrix with modules 1, 3 and 4 are ON.

The LED modules 1, 3 and 4 are on and the last row of the 2nd LED module is on. Rest all the rows in the 2nd LED module are off. This pattern is used if there is a car that is oncoming from the extreme left. The last row of the 2nd module is left on so that the road below is still illuminated even though the other lights are turned off in that direction.

Intensity of the light produced by this –

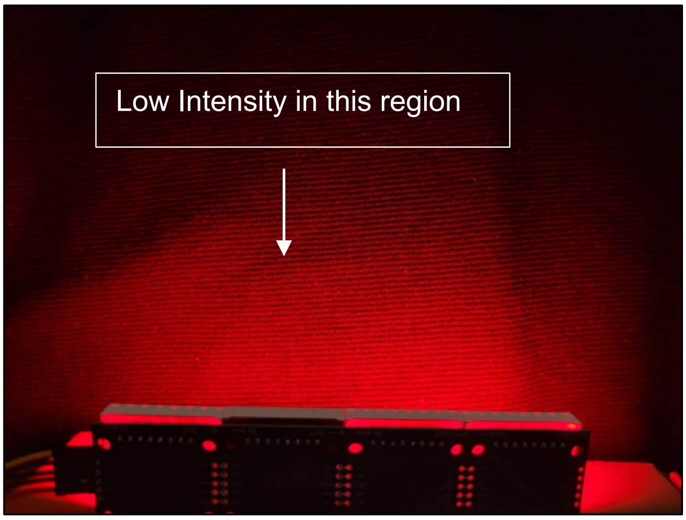

Figure 8.1.7: Intensity of the light produced by LED image above

Here we can see that the intensity in the middle left is a little less than in the other areas. This shows that the lights are cut off in that direction.

4. All the LED Modules are on except the 3rd one –

Code for turning on LED Modules 1, 2 and 4 and turning off LED module 3 while keeping its last row turned ON.

```
void turnOffModule3() {
  // Turn off in module 3 and on all LEDs in the other three LED modules
  lc.shutdown(2, false);
  lc.setRow(2, 7, B11111111);
  for (int module = 0; module < NUM_MAX7219 - 2; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
  for (int row = 0; row < 8; row++) {
    lc.setRow(3, row, B11111111);
  }
}
```

Display on LED Matrix –

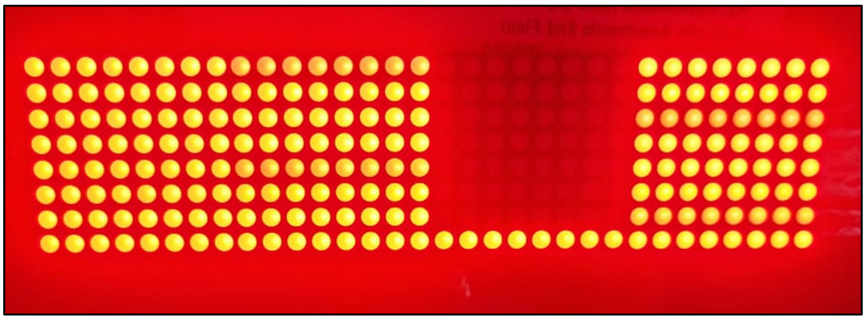

Figure 8.1.8: LED Matrix with modules 1, 2 and 4 are ON

Intensity of the light produced by this –

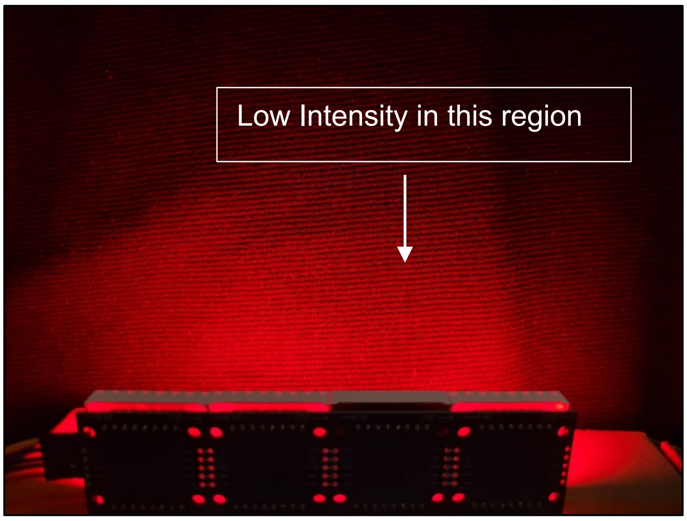

Figure 8.1.9: Intensity of the light produced by LED image above

Here we can see that the intensity in the middle right is a little less than in the other areas. This shows that the lights are cut off in that direction.

5. All the LED Modules are on except the 4th one –

Code for turning on LED Modules 1, 2 and 3 and turning off LED module 4 while keeping its last row turned ON.

```
void turnOffModule4() {
  // Turn off in module 4 and on all LEDs in the other three LED modules
  lc.shutdown(3, false);
  lc.setRow(3, 7, B11111111);
  for (int module = 0; module < NUM_MAX7219 - 1; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
}
```

<u>Display on LED Matrix –</u>

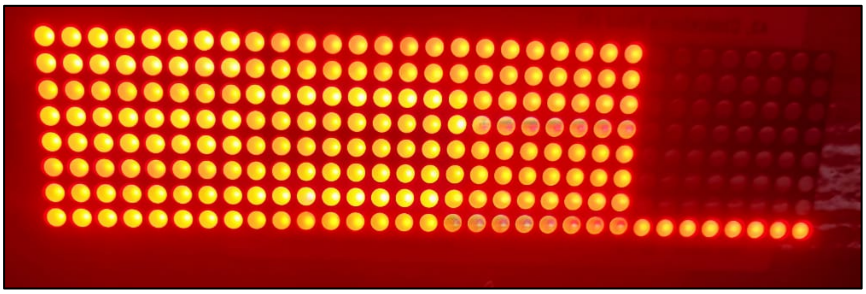

Figure 8.1.10: LED Matrix with modules 1, 2 and 3 ON

<u>Intensity of the light produced by this –</u>

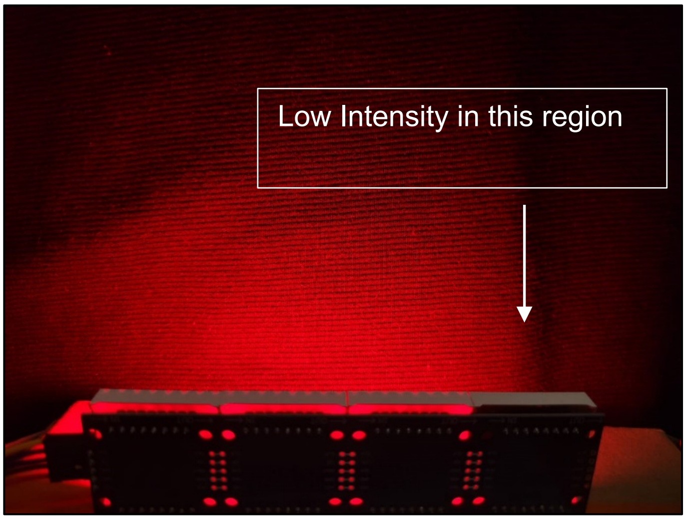

Figure 8.1.11: Intensity of the light produced by LED image above

Here we can see that the intensity in the extreme right is a little less than in the other areas. This shows that the lights are cut off in that direction.

6. 3rd and 4th LED Modules are on and the 1st and 2nd are off –

Code for turning on LED Modules 3 and 4 and turning off LED modules 1 and 2 while keeping its last row turned ON.

```
void turnOffModule1and2() {
  // Turn off in module 1 and 2 and on in 3 and 4
  lc.shutdown(0, false);
  lc.setRow(0, 7, B11111111);
  lc.shutdown(1, false);
  lc.setRow(1, 7, B11111111);
  for (int module = 2; module < NUM_MAX7219; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
}
```

Display on LED Matrix –

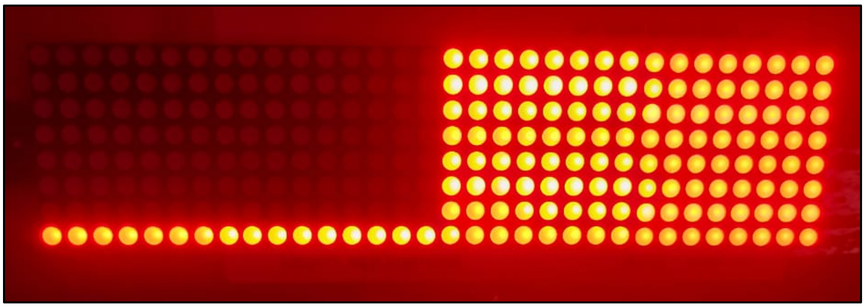

Figure 8.1.12: LED matrix with 3rd and 4th Modules ON and 1st and 2nd Modules OFF

Intensity of the light produced by this –

Figure 8.1.13: Intensity of the light produced by LED image above

Here we can see that the intensity in the right side is a little less than in the left side. This shows that the lights are cut off in that direction.

7. 1st and 2nd LED Modules are on and the 3rd and 4th are off –

Code for turning on LED Modules 1 and 2 and turning off LED modules 3 and 4 while keeping its last row turned ON.

```
void turnOffModule3and4() {
  // Turn off in module 3 and 4 and on in 1 and 2
  lc.shutdown(2, false);
  lc.setRow(2, 7, B11111111);
  lc.shutdown(3, false);
  lc.setRow(3, 7, B11111111);
  for (int module = 0; module < NUM_MAX7219 - 2; module++) {
    for (int row = 0; row < 8; row++) {
      lc.setRow(module, row, B11111111);
    }
  }
}
```

Display on LED Matrix –

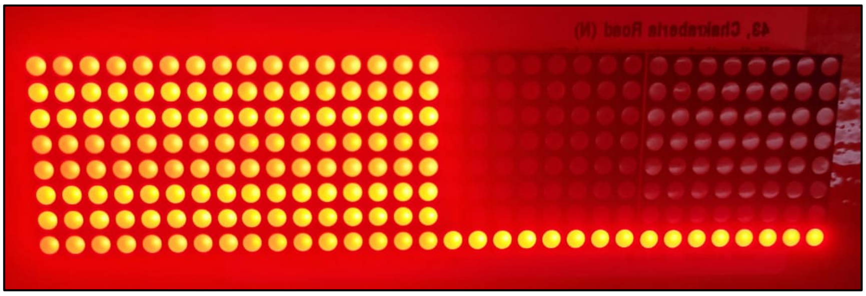

Figure 8.1.14: LED matrix with 3rd and 4th Modules OFF and 1st and 2nd Modules ON

Intensity of the light produced by this –

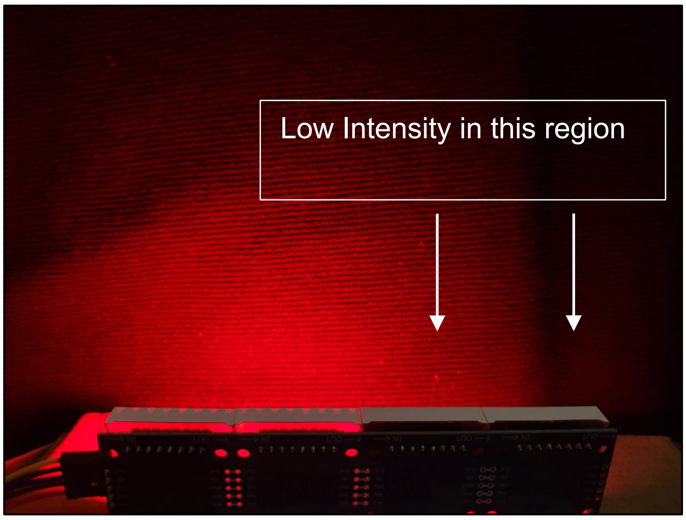

Figure 8.1.15: Intensity of the light produced by LED image above

Here we can see that the intensity in the left is a little less than in the right side. This shows that the lights are cut off in that direction.

8. 2nd and 3rd LED Modules are on and the 1st and 4th are off –

Code for turning on LED Modules 2 and 3 and turning off LED modules 1 and 4 while keeping its last row turned ON.

```
void turnOffModule1and4() {
  // Turn off in module 1 and 4 and on in 2 and 3
  lc.shutdown(0, false);
  lc.setRow(0, 7, B11111111);
  lc.shutdown(3, false);
  lc.setRow(3, 7, B11111111);
  for (int row = 0; row < 8; row++) {
    lc.setRow(1, row, B11111111);
  }
  for (int row = 0; row < 8; row++) {
    lc.setRow(2, row, B11111111);
  }
}
```

Display on LED Matrix –

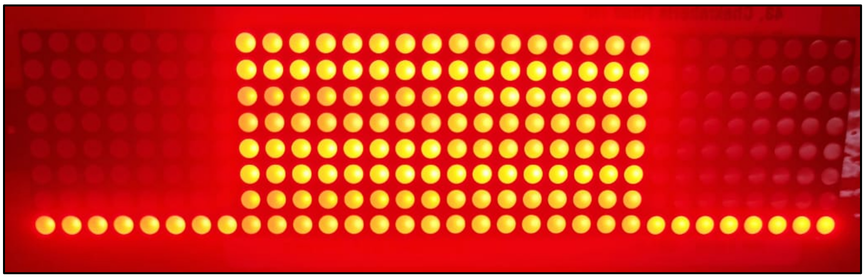

Figure 8.1.16: LED matrix with 1st and 4th Modules OFF and 2nd and 3rd Modules ON

Intensity of the light produced by this –

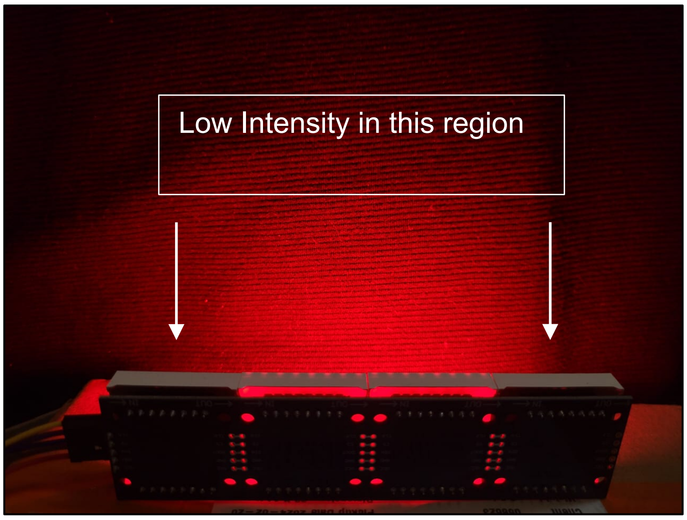

Figure 8.1.17: Intensity of the light produced by LED image above

Here we can see that the intensity in the extreme right and extreme left is a little less than in the middle area. This shows that the lights are cut off in those direction.

9. all LEDs are off, only the LEDs of the bottom 2 rows are on –

Code for turning off all the LEDs except for the bottom 2 rows.

```
void turnOffAllRowsExceptBottom2() {
  // Turn off all columns in the LED matrix
  turnOff();
  for (int module = 0; module < NUM_MAX7219; module++) {
    lc.setRow(module, 6, B11111111);
    lc.setRow(module, 7, B11111111);
  }
}
```

Display on LED Matrix –

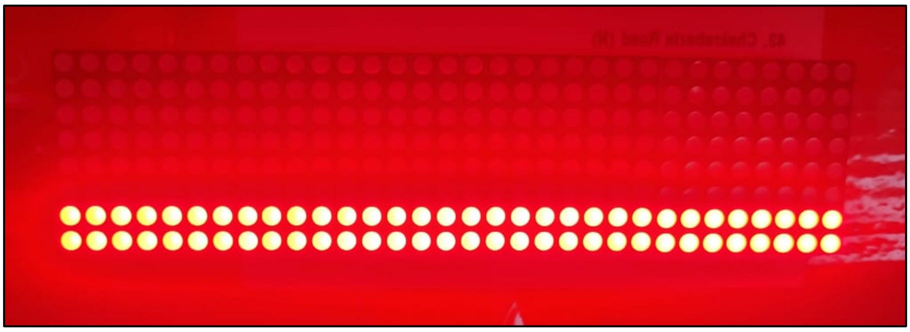

Figure 8.1.18: LED Matrix with only bottom 2 rows ON

Intensity of the light produced by this –

Figure 8.1.19: Intensity of the light produced by LED image above

Here we can see that the intensity of the LED module is reduced from when all the LEDs of all the modules were on rather than only the bottom 2 rows.

8.2 Working of the Light Dependent Resistor –

Light Dependent Resistor is used to detect the lighting in the surroundings. The LDR is sensitive to light and given analog readings according to the amount of light in the surrounding.

Image of the LDR circuit –

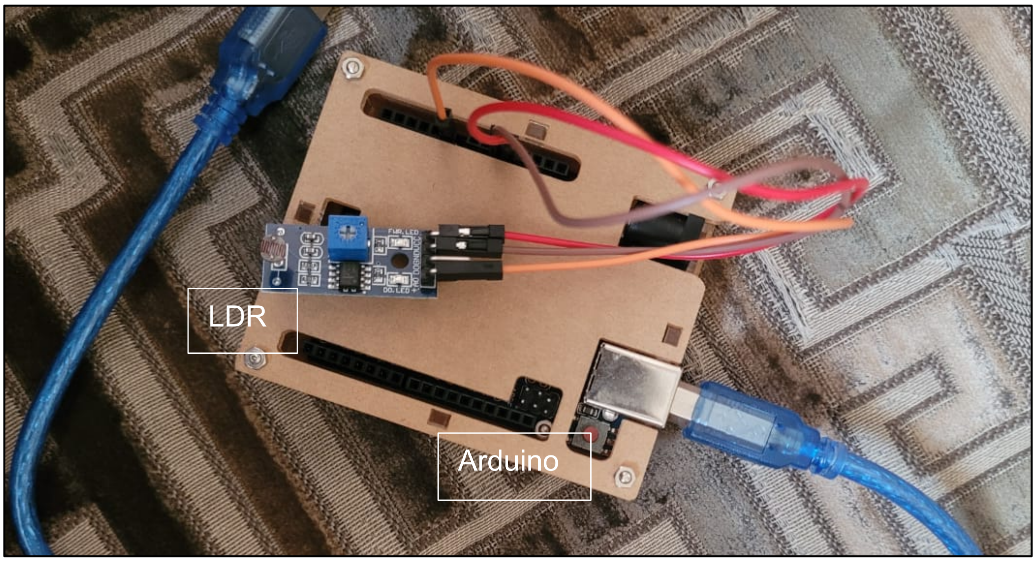

Figure 8.2.1: LDR Hardware Module

```
const int analogInPin = A0;  // Analog input pin that the LDR
is attached to

int sensorValue = 0;  // value read from the LDR
int outputValue = 0;  // value output to the LDR (analog out)

void setup() {
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
}

void loop() {
  // read the analog in value:
  sensorValue = analogRead(analogInPin);
  sensorValue = 1023 - sensorValue;
```

```
  // map it to the range of the analog out:
  outputValue = map(sensorValue, 0, 1023, 0, 255);
  // print the results to the Serial Monitor:
  Serial.print("sensor = ");
  Serial.print(sensorValue);
  Serial.print("\t output = ");
  Serial.println(outputValue);

  // wait 1 second before the next loop for the analog-to-
digital
  // converter to settle after the last reading:
  delay(1000);
}
```

This is the code for using the LDR module. The analog pin is connected to the A0 pin of the Arduino. And then we set the sensor value to 0. The output from the LDR is in the range 0-1023. Then we take the analog reading, to get the appropriate value, we subtract it from 1023. Then we map it to the get it in the range of 0-255. This is done to be able to use the values properly.

<u>LDR in day-time –</u>

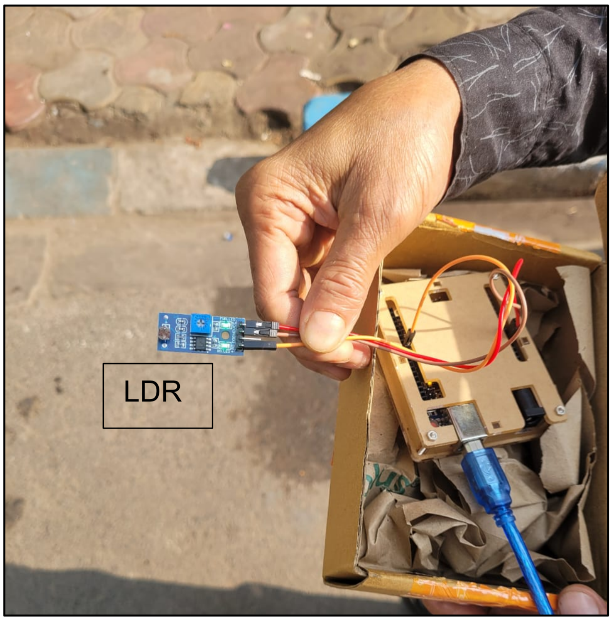

Figure 8.2.2: LDR in Day-Time

The time this reading was taken is 8:38AM in the morning when there is adequate sunlight and clear conditions.

The readings are given below -

```
08:38:52.792 -> sensor = 942     output = 234
08:38:53.819 -> sensor = 941     output = 234
08:38:54.807 -> sensor = 945     output = 235
08:38:55.796 -> sensor = 968     output = 241
08:38:56.817 -> sensor = 1007    output = 251
08:38:57.803 -> sensor = 1005    output = 250
08:38:58.824 -> sensor = 1007    output = 251
08:38:59.814 -> sensor = 1006    output = 250
08:39:00.803 -> sensor = 1000    output = 249
```

Figure 8.2.3: Values of the LDR in the morning.

The values range from 800-1023 including when there is a shade on the road or when there is only sunlight.

<u>LDR in night-time with no streetlights -</u>

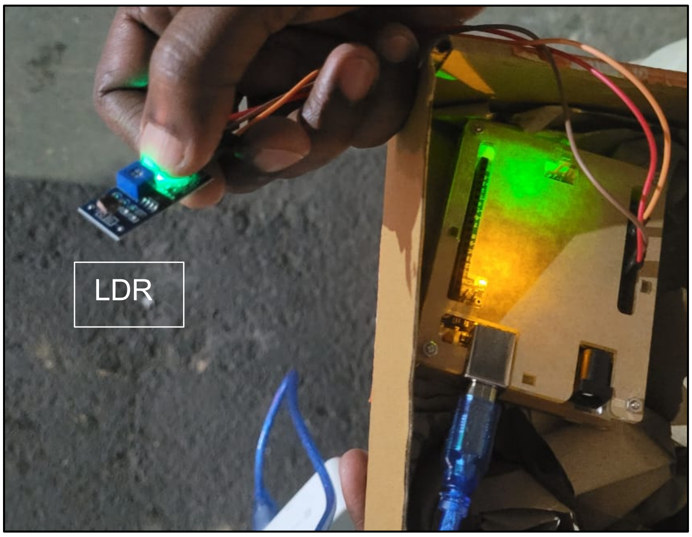

Figure 8.2.4: LDR in night-time with no streetlight.

The time this reading was taken is 9:45PM in the night with no streetlights and only little light from the surroundings and moonlight.

```
21:45:03.517 -> sensor = 102     output = 25
21:45:04.540 -> sensor = 97      output = 24
21:45:05.530 -> sensor = 77      output = 19
21:45:06.517 -> sensor = 81      output = 20
21:45:07.534 -> sensor = 87      output = 21
21:45:08.523 -> sensor = 87      output = 21
21:45:09.546 -> sensor = 91      output = 22
21:45:10.535 -> sensor = 91      output = 22
21:45:11.524 -> sensor = 86      output = 21
21:45:12.543 -> sensor = 88      output = 21
21:45:13.534 -> sensor = 141     output = 35
21:45:14.556 -> sensor = 148     output = 36
```

Figure 8.2.5: Values of the LDR in the night-time without streetlights.

The values range from 40-150 when it is night time with no street lights and little light in the surroundings.

<u>LDR in night-time under streetlights –</u>

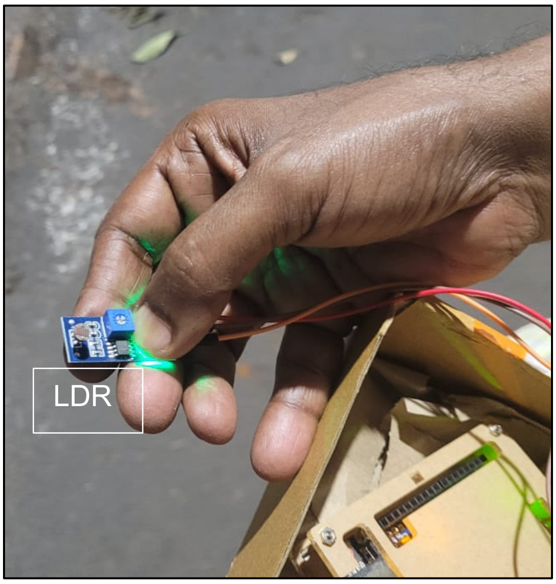

Figure 8.2.6: LDR in night-time under streetlight.

The time this reading was taken is 9:45PM in the night under streetlights and only little light from the surroundings and moonlight.

```
21:44:52.528 -> sensor = 556     output = 138
21:44:53.518 -> sensor = 579     output = 144
21:44:54.511 -> sensor = 141     output = 35
21:44:55.502 -> sensor = 570     output = 142
21:44:56.525 -> sensor = 618     output = 154
21:44:57.513 -> sensor = 614     output = 153
21:44:58.535 -> sensor = 611     output = 152
21:44:59.523 -> sensor = 593     output = 147
21:45:00.512 -> sensor = 578     output = 144
21:45:01.536 -> sensor = 564     output = 140
21:45:02.525 -> sensor = 512     output = 127
```

Figure 8.2.7: Values of the LDR in the night-time under streetlights.

The values range from 400-650 when it is night time under street lights and little light in the surroundings. this is still less than the value that the sensor shows during day-time, hence we can use this to control the headlight's functionality.

8.3 Working of Headlight Module –

8.3.1 Working of the Machine Learning Model –

The Model used is YOLOv8. It is the latest version of the object detection algorithm developed by Ultralytics. It is built on deep learning and computer and vision and it has high performance in terms of speed and accuracy.

The model was trained on Google Colab - https://colab.research.google.com/drive/1MO4WFtWVx0j50xnYuc_Yy4Bt-F7ITFkd?usp=sharing

The dataset included pictures of cars driving at night, each image was labelled and the position of the oncoming vehicle was defined with the class – "vehicle". This helps us create the dataset to train the model. The website Roboflow was used to upload the dataset, 614 labelled images were uploaded to the site, with the help of the site, the additional 337 images were created to increase the size of the test set for more accurate results.

A total of 951 images were used, off which –

- 765 images were used as training set,
- 119 images were used for valid set and

- 67 images were used as test set.

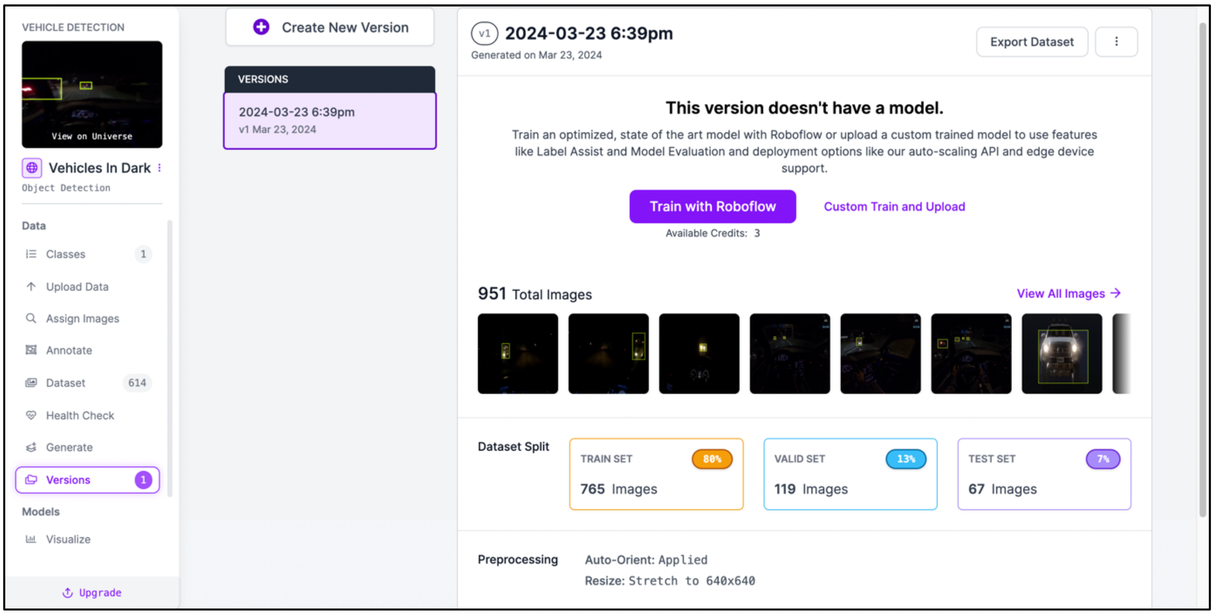

Figure 8.3.1.1: Screenshot of the Website where the Dataset is uploaded.

For pre-processing the images were auto-oriented and resized to 640x640 for better results. Augmentation was applied where the images were flipped horizontally to increase the dataset as well as the performance metrics of the model. Once the dataset was uploaded a link to the dataset was received which we can easily use with YOLOv8 model to train our model.

```
from roboflow import Roboflow
rf = Roboflow(api_key="api_key")
project = rf.workspace("vehicle-detection-
iiqof").project("vehicles-in-dark")
version = project.version(1)
dataset = version.download("yolov8")
```

This piece of code helps us download the dataset which we want to use to train our ML Model.

```
yolo task=detect mode=train model=yolov8m.pt
data={dataset.location}/data.yaml epochs=100 imgsz=800
plots=True
```

We have used a pre-trained model provided by YOLO and fine-tuned it to suit our purpose. The model used is YOLOv8M this is the medium sized model which is not very heavy but produces better accuracy and speed for object detection. The number of epochs used are 100. The total time taken to train the model is 1.17 hours which is close to 70 minutes. This model is then saved so that we can use it as we like. We can even deploy our trained model to Roboflow where with the help of a single API call we can use our model for object detection.

A file called best.pt is created after we finish training our model. This file is our trained model which we can use for our object detection.

<u>To detect vehicles in images we can do the following –</u>

```
model = YOLO("best.pt")
results =
model.predict('/Users/yashjasani/Desktop/car_pic_1_left.png',
conf=0.5, imgsz=640)
```

This loads the YOLOv8 model and then detects it in images. Below is the output of the following code. We can even the get the x and y coordinates as well as the width and the height of the box where the vehicle has been detected. With the help of that we can figure out which headlight to turn on and which to not, to prevent dazzling effect as well as illuminating the road.

Figure 8.3.1.2: Example of the model detecting vehicle.

We can even do object detection on videos, the code below shows the piece of code that is used for detection of vehicles in videos.

```
model = YOLO('best.pt')
# Open the video file
video_path =
"/Users/yashjasani/trynthtime/data/test_video2.mp4"
cap = cv2.VideoCapture(video_path)
# Loop through the video frames
while cap.isOpened():
    # Read a frame from the video
    success, frame = cap.read()
    if success:
        # Run YOLOv8 inference on the frame
        results = model.predict(frame, imgsz=640)
        # Visualize the results on the frame
        annotated_frame = results[0].plot()
        # Display the annotated frame
        cv2.imshow("YOLOv8 Inference", annotated_frame)
        # Break the loop if 'q' is pressed
        if cv2.waitKey(1) & 0xFF == ord("q"):
            break
    else:
        # Break the loop if the end of the video is reached
        break
cap.release()
cv2.destroyAllWindows()
```

8.3.2 Working of Object Detection and the Hardware Module –

There are 4 different cases of detection of vehicles that has been handled in the project –

<u>No vehicles detected</u>

This is the case when there are no cars detected in the video or the image. At this time all the lights in the headlights module should be turned on –

```
results = model.predict(frame, imgsz=640)
for r in results:
    if r.boxes.shape[0] == 0:
        ledOnOff(1, ser)
        print("no cars")
```

This detects that there are no vehicles on the road and hence we call the function ledOnOff() with state = ‘1’ and the instance of the Arduino so that we can control it.

The function ledOnOff() –

```
def ledOnOff(state, ser):
    # If state is 1, switch all the LEDs ON
    # Since there is no cars detected
    posX = ""
    if state == 1:
        posX = "0"
    posX1 = "x" + "y" + posX
    print(posX1)
    # Write the final data to the serial port
    ser.write(posX1.encode())
```

this send the data “xy0” to the Arduino where it reads this data and turns on all the LEDs in the matrix.

Example of image -

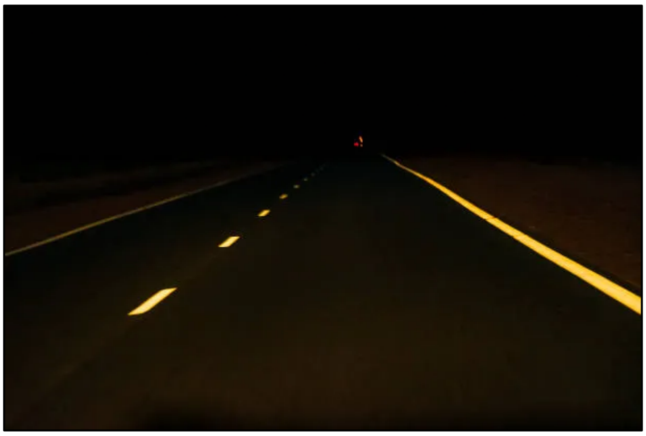

Figure 8.3.2.1: Example of empty street

output –

```
image 1/1 /Users/yashjasani/Desktop/empty_road.png: 448x640
(no detections), 281.2ms
Speed: 5.4ms preprocess, 281.2ms inference, 6.2ms postprocess
per image at shape (1, 3, 448, 640)
408 612
torch.Size([0, 4])
xy0
no cars
Arduino received:  b'1'
```

Pattern of the headlight –

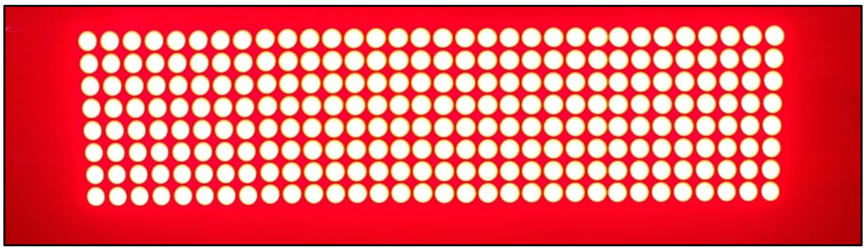

Figure 8.3.2.2: Pattern of headlight.

More than 2 vehicles detected

This is the case when there are more than 2 cars detected in the video or the image. At this time all the lights in the headlights module should be turned off except the last 2 rows –

```
results = model.predict(frame, imgsz=640)
for r in results:
    if r.boxes.shape[0] > 2:
        ledOnOff(0, ser)
        print("more than 2 cars")
```

this detects that there are more than 2 vehicles on the road and hence we call the function ledOnOff() with state = ‘0’ and the instance of the Arduino so that we can control it.

The function ledOnOff() –

```
def ledOnOff(state, ser):
    # If state is 0, switch off all the LEDs except bottom 2
rows
    # Since there are more than 2 cars detected
    posX = ""
    if state == 0:
        posX = "9"
    posX1 = "x" + "y" + posX
    print(posX1)
    # Write the final data to the serial port
    ser.write(posX1.encode())
```

this send the data “xy9” to the Arduino where it reads this data and turns off all the LEDs in the matrix except the bottom 2 rows.

Example of image –

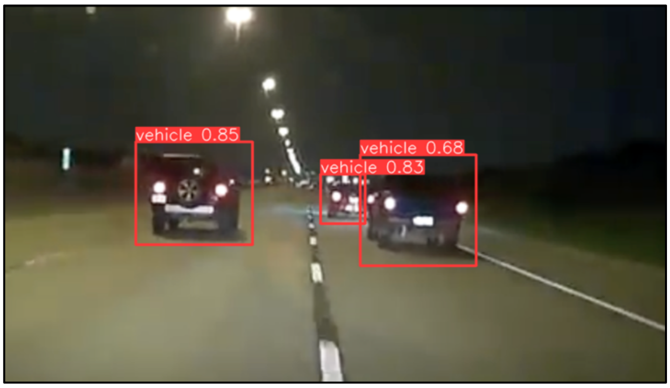

Figure 8.3.2.3: Example of street with more than 2 cars.

output –

```
image 1/1 /Users/yashjasani/Desktop/many_vehicle.png: 384x640
3 vehicles, 220.4ms
Speed: 3.4ms preprocess, 220.4ms inference, 6.6ms postprocess
per image at shape (1, 3, 384, 640)
486 882
torch.Size([3, 4])
xy9
more than 2 cars
Arduino received:  b'0'
```

Pattern of Headlight –

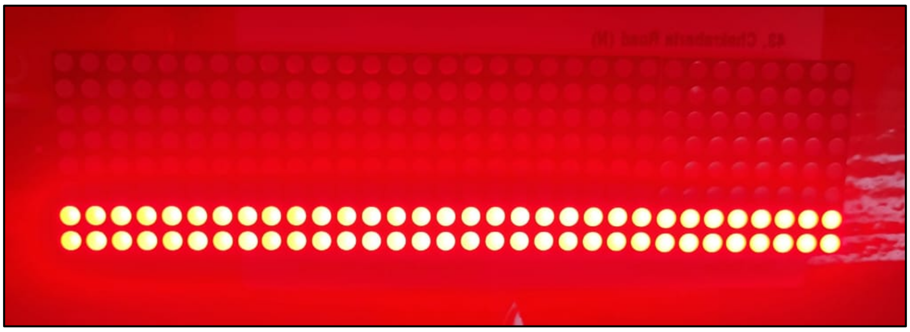

Figure 8.3.2.4: Pattern of headlight.

<u>1 vehicle detected</u>

When there is one vehicle detected, the car can be at different positions. I have divided the frame into 4 vertical columns and the car can be placed in 8 different positions.
There are 6 different patterns that can I have created for these 8 different positions.

<u>Code when 1 vehicle is detected -</u>

```
if(r.boxes.shape[0] == 1):
     for cor in r.boxes.xywhn:
     x = cor[0].item()
     y = cor[1].item()
     w = cor[2].item()
     h = cor[3].item()
     if(y<0.65):
     singleCar(x,w,ser)
     print("1 car")
```

In this code we get the number of vehicles with the help of the results. We find the x and y coordinates along with the width and the height. We make sure that if the y coordinate is below 65% of the image, only then we will consider making a pattern then to make sure that if there is a wrong classification we don't make patterns for light sources above.

<u>The function singleCar(x,w,ser) –</u>

```
def singleCar(x, w, ser):
    car = x+w
    posCar = ""
    if(x <= 0.25 and car <= 0.25):
        posCar = "a" #module 4 is turned off
    elif(x > 0.25 and x <= 0.50 and car > 0.25 and car <=
0.50):
        posCar = "e" #modules 3 and 4 are turned off
    elif(x > 0.50 and x <= 0.75 and car > 0.50 and car <=
0.75):
        posCar = "f" #moduels 1 and 2 are turned off
    elif(x > 0.75 and car > 0.75):
        posCar = "d" #module 1 is turned off
    elif(x <= 0.25 and car <= 0.50):
        posCar = "e" #modules 3 and 4 are turned off
    elif(x > 0.50 and car >= 0.75):
        posCar = "f" #moduels 1 and 2 are turned off
    elif(x < 0.50 and car <= 1):
        posCar = "g" #modules 1, 2 and 3 are turned off
```

```
    elif(car >= 0.75 and x > 0):
        posCar = "h" #modules 2, 3 and 4 are turned off
    else:
        posCar = "0" # all modules except last row is turned
off
    print(posCar)
    ser.write(posCar.encode())
```

there are 9 cases here which will tell us which pattern to call according to which position of the car. This will print the position and then send the position to the Arduino where it is coded to produce a particular pattern according to the input it has received.

<u>Below I will show examples for few of the cases –</u>

<u>When the Car is on the extreme left –</u>

Figure 8.3.2.5: Example of street with car on extreme left

<u>Output –</u>

```
image 1/1 /Users/yashjasani/Desktop/test/car_left.png: 448x640
1 vehicle, 285.2ms
Speed: 12.3ms preprocess, 285.2ms inference, 7.0ms postprocess
per image at shape (1, 3, 448, 640)
474 708
torch.Size([1, 4])
e
1 car
Arduino received:  b'a'
```

Pattern of headlight –

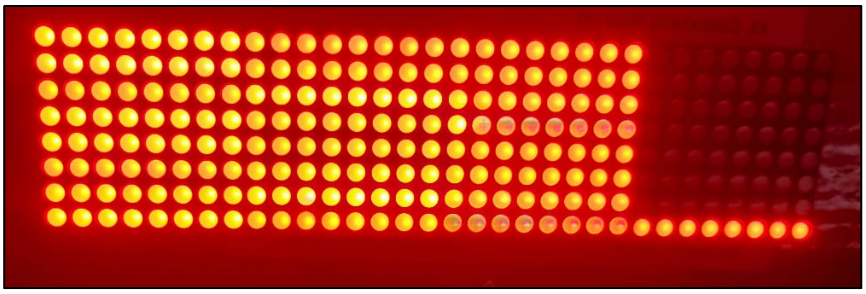

Figure 8.3.2.6: Pattern of headlight.

The 4th module is turned off as the car is in the extreme left hand side.

When car is on the right side, but not extreme right, it is in close to the middle and right –

Figure 8.3.2.7: Example of street with car on right hand side.

Output –

```
0: 448x640 1 vehicle, 239.3ms
Speed: 1.8ms preprocess, 239.3ms inference, 0.5ms postprocess
per image at shape (1, 3, 448, 640)
1060 1592
torch.Size([1, 4])
f
1 car
Arduino received:  b'f'
```

Pattern of headlight –

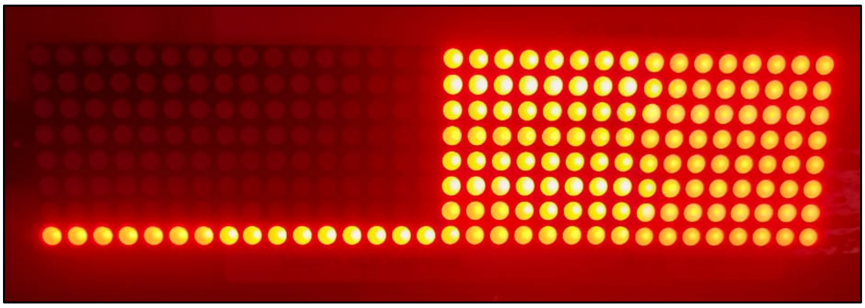

Figure 8.3.2.8: Pattern of headlight.

The 1st and 2nd modules are turned as the car is not on the extreme right. So the right side of the headlight is turned off.

2 vehicles detected –

When there is one vehicle detected, the car can be at different positions. I have divided the frame into 4 vertical columns and the car can be placed in 27 different positions.
There are 8 different patterns that can I have created for these 27 different positions.

Code when 2 vehicle are detected -

```
if r.boxes.shape[0] == 2:
        print(r.boxes.xywhn)
        numbers_list = r.boxes.xywhn.tolist()
        x1 = numbers_list[0][0]
        y1 = numbers_list[0][1]
        w1 = numbers_list[0][2]
        h1 = numbers_list[0][3]
        x2 = numbers_list[1][0]
        y2 = numbers_list[1][1]
        w2 = numbers_list[1][2]
        h2 = numbers_list[1][3]
        if(y1<0.65 and y2<0.65):
            doubleCar(x1,w1,x2,w2,ser)
        print("2 cars")
```

In this code we get the number of vehicles with the help of the results. We find the x and y coordinates along with the width and the height. We make sure that if the y coordinate is below 65% of the image, only then we will consider making a pattern then to make sure that if there is a wrong classification we don’t make patterns for light sources above.

The function doubleCar(x1,w1,x2,w2,ser) –

```
def doubleCar(x1, w1, x2, w2, ser):
    if(x1 > x2):
        doubleCar(x2,w2,x1,w1,ser)
    car1 = x1+w1
    car2 = x2+w2
    posCar = ""
    if(x1 < 0.25 and car1 <= 0.25 and x2 >= 0.75 and car2 >
0.75):
        posCar = "a" # module 4 is turned off
    elif((x1<0.25 and car1<=0.25 and x2>=0.25 and x2<0.5 and
car2>0.25 and car2<=0.5) or (x1<0.25 and car1<=0.25 and
x2<0.25 and car2<=0.5) or (x1>=0.25 and x1<0.5 and car1>0.25
and car1<=0.5 and x2>=0.25 and x2<0.5 and car2>0.25 and
car2<=0.5) or (x1<0.25 and car1<=0.50 and x2>=0.25 and x2<0.5
and car2>0.25 and car2<=0.5)):
        posCar = "e" #module 3 and 4 turned off
    elif((x1>=0.5 and car1<=0.75 and x2>=0.5 and car2<=0.75)
or (x1>=0.5 and x1<0.75 and car1>0.5 and car1<=0.75 and
x2>=0.5 and x2<0.75 and car2<0.5 and car2<=0.75) or (x1>=0.5
and x1<0.75 and car1>0.5 and car1<=0.75 and x2>=0.5 and
car2>=0.75) or (x1>=0.5 and car1>=0.75 and x2>=0.75 and x2<1
and car2>0.75 and car2<=1)):
        posCar = "f" # modules 1 and 2 turned off
    elif(x1>=0.75 and car1<=1 and x2>=0.75 and car2<=1):
        posCar = "d" # module 1 turned off
    elif((x1<0.25 and car1<=0.25 and x2>=0.25 and x2<0.5 and
car2<0.75) or (x1<0.25 and car1<=0.5 and x2>=0.25 and x2<0.5
and car2<=0.75) or (x1>=0.25 and x1<0.5 and car1>0.25 and
car1<0.5 and x2>=0.25 and x2<0.5 and car2<=0.75)):
        posCar = "h" # modules 2, 3 and 4 turned off
    elif(x1<0.25 and car1<=0.25 and x2>=0.5 and car2>=0.75):
        posCar = "b" # modules 1, 2 and 4 turned off
    elif(x1<0.25 and car1<=0.5 and x2>=0.75 and car2>=0.75):
        posCar = "c" # modules 1, 3 and 4 turned off
    elif((x1>=0.25 and x1<0.5 and car1>=0.5 and car1<0.75 and
x2>=0.5 and x2<0.75 and car2>=0.5 and car2<0.75) or (x1>=0.25
and x1<0.5 and car1>=0.5 and car1<0.75 and x2>=0.5 and x2<0.75
and car2>=0.75) or (x1>=0.25 and x1<0.5 and car1>=0.5 and
car1<0.75 and x2>=0.75 and x2<1 and car2>=0.75 and car2<1)):
        posCar = "g" # modules 1, 2 and 3 turned off
    else:
        posCar = "0" # all turned off except bottom 2 rows
    print(posCar)
    ser.write(posCar.encode())
```

This code contains all the 27 different cases where the car position can be found. The 27 different cases are handled with 8 different patterns.

<u>Below I will show examples –</u>

<u>When there are 2 cars on the right hand side –</u>

Figure 8.3.2.9: Example of street with 2 car on right hand side.

Output –

```
image 1/1 /Users/yashjasani/Desktop/test/2_car_right.png:
384x640 2 vehicles, 291.6ms
Speed: 3.8ms preprocess, 291.6ms inference, 9.1ms postprocess
per image at shape (1, 3, 384, 640)
910 1562
torch.Size([2, 4])
tensor([[0.6064, 0.3753, 0.0795, 0.1465],
        [0.7143, 0.4237, 0.0545, 0.1295]])
f
2 cars
```

Pattern of headlight –

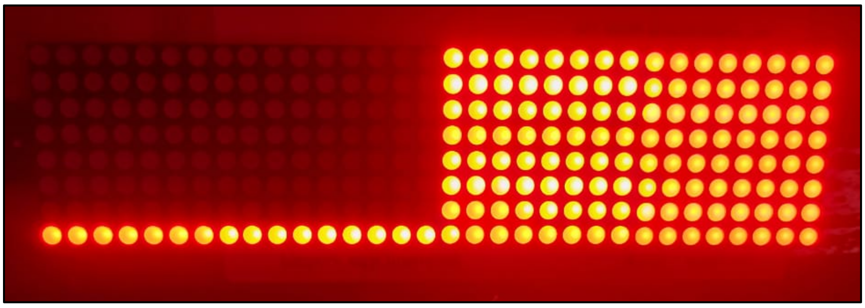

Figure 8.3.2.10: Pattern of headlight.

The 1st and 2nd modules are turned as the cars are on the right. So the right side of the headlight is turned off.

9. TESTING AND PERFORMANCE METRICS

The machine learning model used is YOLOv8. It is an object detection model and it is known for speed and accuracy.

The precision for the trained model is – **76.4%**

The recall for the trained model is – **86.6%**

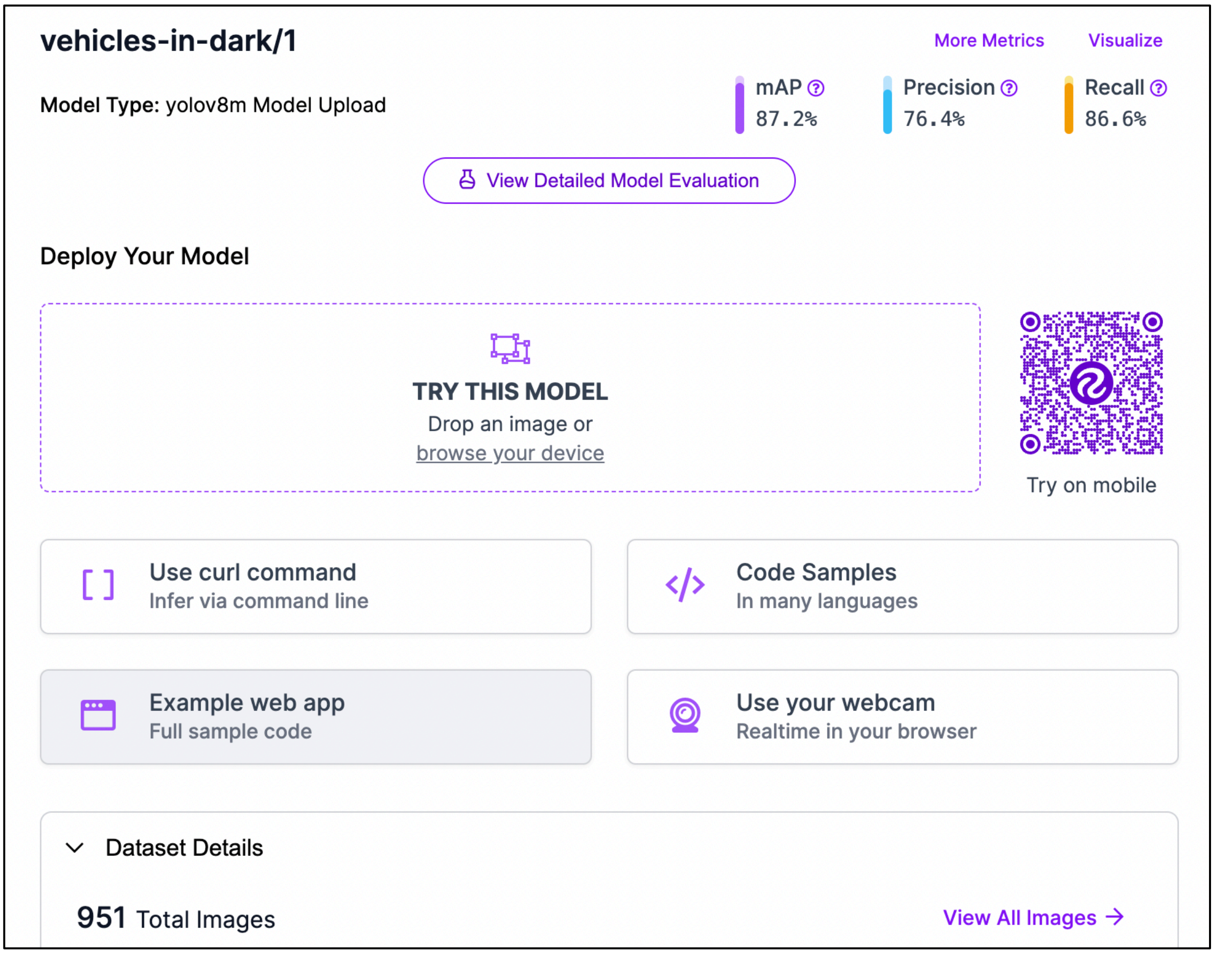

Figure 9.1: Image of model metrics

Training performance metrics –

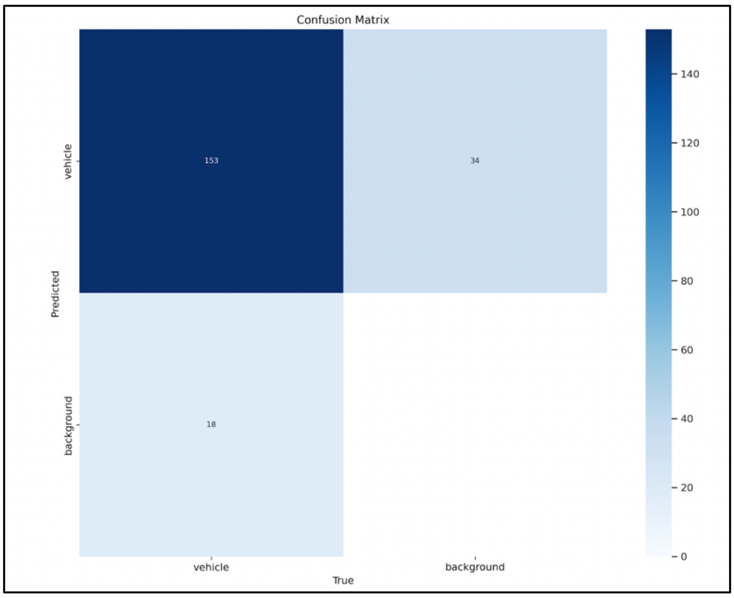

Figure 9.2: Confusion Matrix

Above attached is the Confusion Matrix, which shows how well the model is able to detect vehicles.

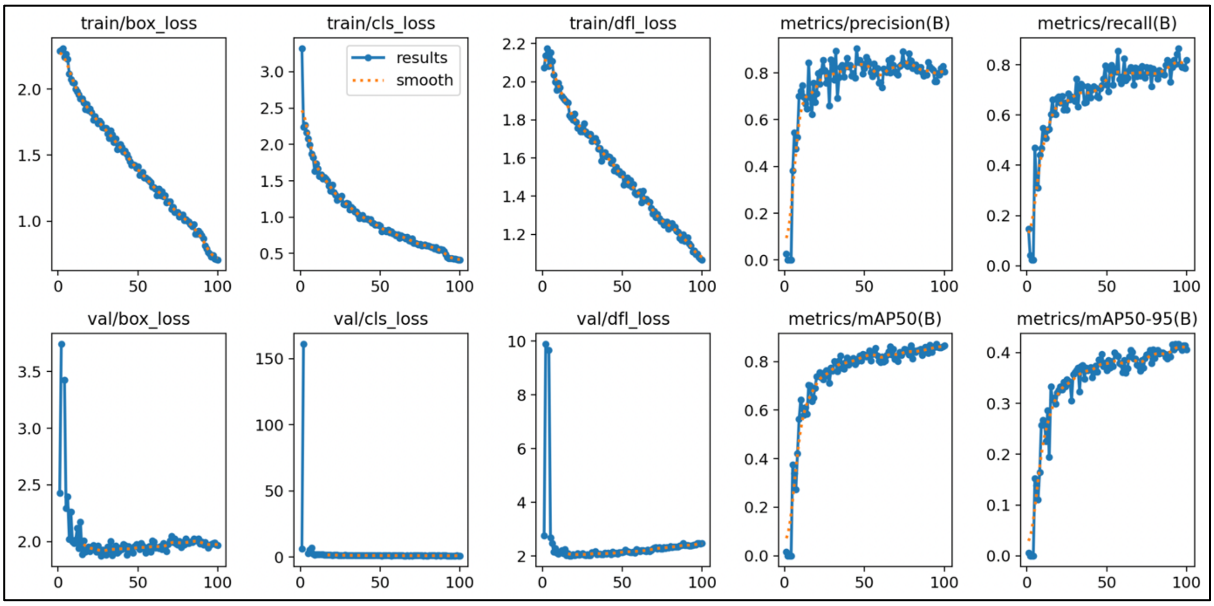

Figure 9.3: Training graphs

Above attached are the graphs which shows the training and testing metrics. The different graphs like box_loss, precision and recall are shown

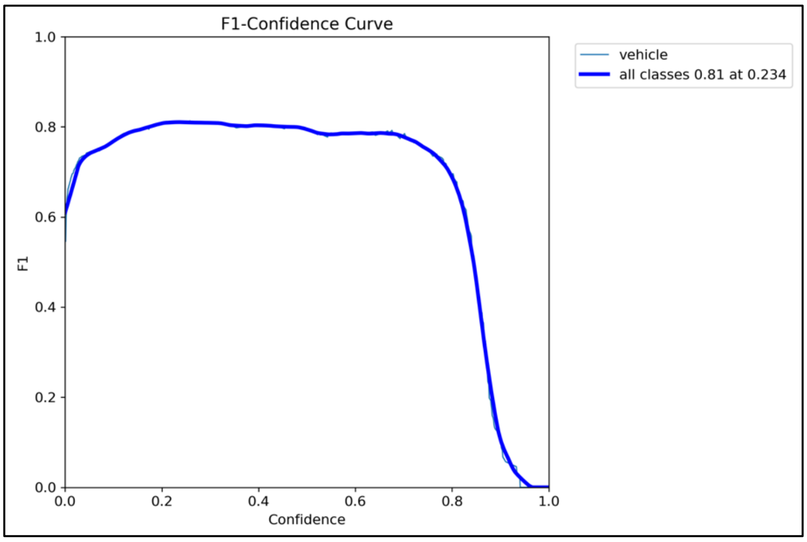

Figure 9.4: Confidence Curve

Above is the graph for the confidence of the model.

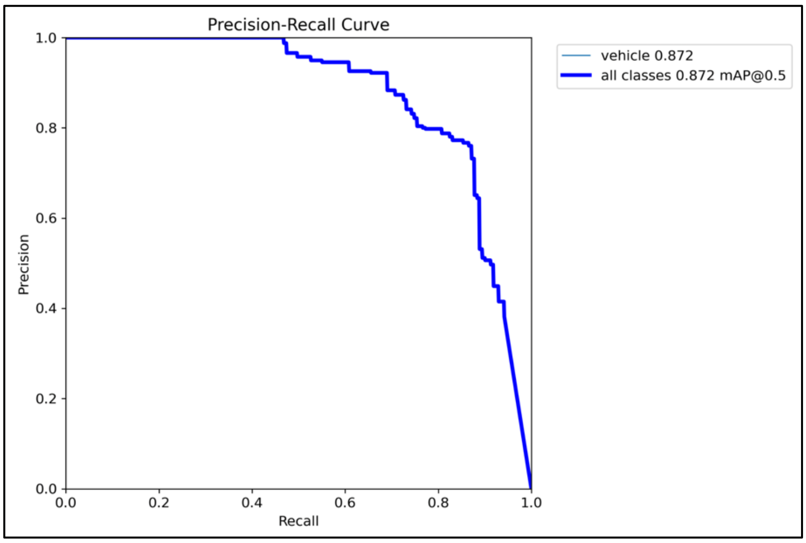

Figure 9.5: Precision Recall Curve

Above is the graph for the precision-recall of the model.

10. SUMMARY

In conclusion, this research project addresses the critical issue of intense high beam headlights and their potential impact on driving safety. The project explores the use of adaptive beam headlights, which employ advanced camera technology to adjust beam shape in real-time, aiming to prevent blinding oncoming drivers while illuminating the road effectively.

By introducing smart headlights that adjust their direction based on position of oncoming vehicles, we aim to improve visibility without disturbing other drivers. Leveraging IoT and machine learning technologies, we propose a robust solution to address this safety concern.
By implementing smart headlights, we aim to enhance visibility and reduce the risk of accidents caused by momentary blindness.

In summary, the implementation of smart headlights presents an opportunity to enhance road safety by effectively managing headlight intensity and direction. By leveraging technology, we can create a solution that improves visibility while minimizing the risk of accidents caused by glare, ultimately saving lives and making driving safer for everyone.

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