Automatic street light control of urban streets

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Chapter 1: Introduction

A city's infrastructure is incomplete without a proper lighting system for streets and roads. Street lighting is considered vital for the development of countries worldwide. It is a particularly critical concern for public authorities in developing countries because of its strategic importance for economic and social stability. Inefficient lighting wastes significant financial resources every year, and poor lighting creates unsafe conditions. Energy efficient technologies and design mechanism can reduce cost of the street lighting drastically. Lighting can account for 10-38% total energy bill in typical cities[1]. Due to this reason, it has a huge financial impact on the electricity generation of the city. Furthermore, the continuous luminosity of the streetlights contributes to environmental pollution as well. However, conservation of electrical energy is a major concern of the 21st century, given the rapid speed in
burning of fossil fuels. If fossils are burned at the present rate, it is predictedthat fossil fuels would be exhausted by the year 2060[2]. Though, street lights are considered essential, it is highly expensive,energy consuming and poses as high priority loads due to safety concerns. The estimated number of streetlights in GPs of India is 3.08 crores[3].Hence, a big portion of the electricity produced is consumed by street lights.
It will be better to have a system in which only the street light needed is working on full power and rest are dimmed. This will save a lot of sustainable resources.
There have been previous works in this direction. Some of them are IOT based. But, here the idea is to develop a system using machine learning algorithms that focuses on efficient utilization of the street lights.

Machine learning is one of the most expanding fields in today's world. Novelty solutions to numerous problems are being proposed day in and day out. Taking the example of a Tesla, an automated driving vehicle. Though right now with limited functionalities, Tesla has opened doors for a lot of possibilities. Self-driving cars are a feat that has been accomplished using the capabilities of Machine Learning and Deep Learning.

Solutions involving the use of Modern Technology can be applied to our day to day lives. One such area that we can utilize Machine Learning practises is in Controlling Street Lights on Highways.

One of the greatest sources of pain to mankind currently is the limited availability of sustainable energy. In this project, we propose a solution that can be applied in one of the most common areas in day-to-day lives. A huge number of streetlights are used across the globe every day. Most of the time these lights are left turned on for an extended period of time even though there is no traffic on the streets.

At first glance, this may not seem like a big problem, but imagine millions of street lights being left turned on for this reason across the globe. This would utilize a lot of energy which is essentially wasted on illuminating a street that is not being used.

During the course of this project, we aim to create a solution for this problem.

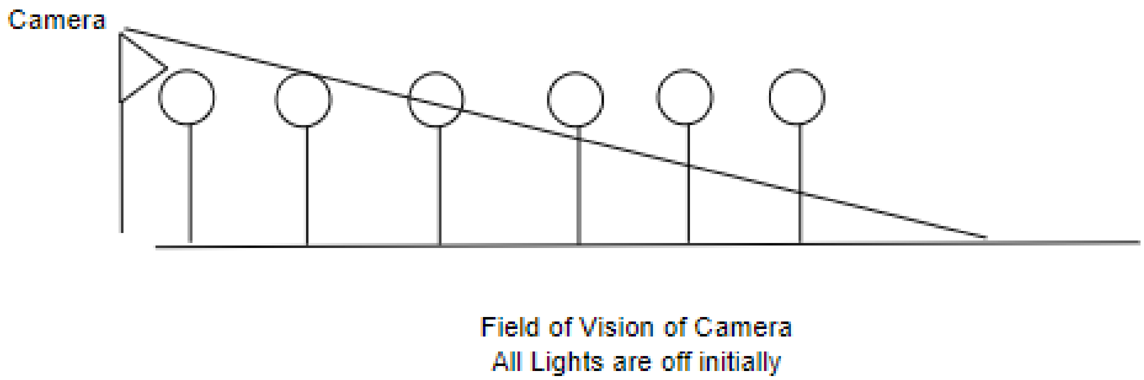

Figure 1.1 Field of Vision of Camera

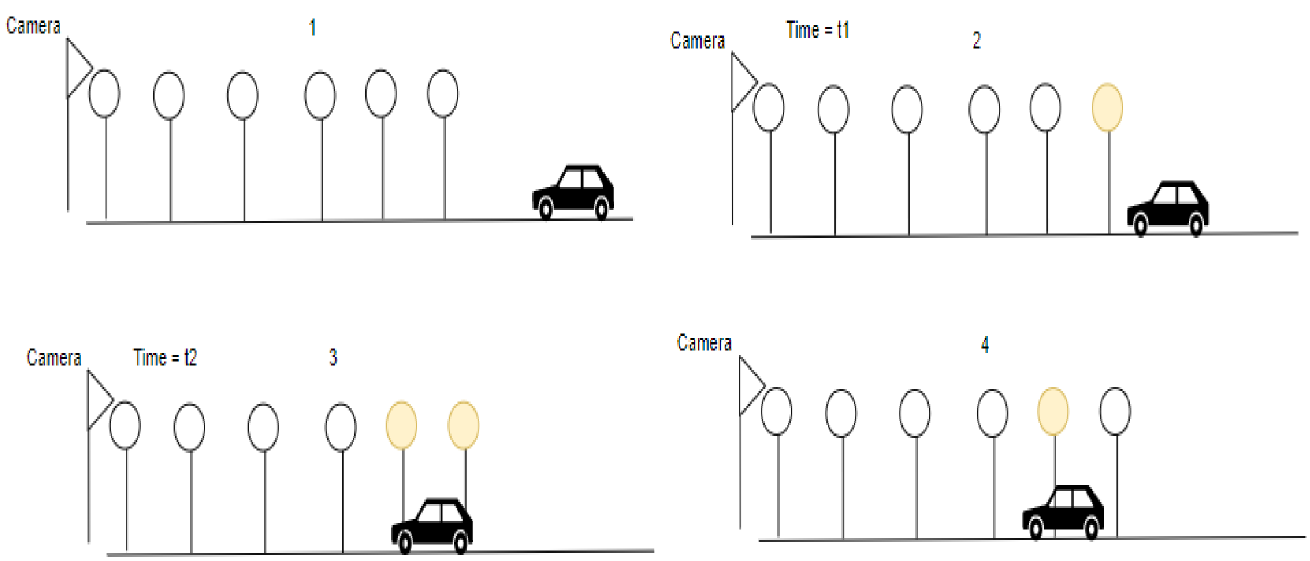

Figure 1.2: Triggering of Lights

Speed = distance / time taken

$$V = L / (t2-t1)$$

Chapter 2: Literature Survey

For any type of research that we want to do which is not a pioneer in the field, we need to find the existing solutions that are present for the problem at hand. This helps in a much better understanding of the problem we are trying to solve. It also helps to gain insights from existing solutions, address possible problems, and improve upon them.
For this, a Literature survey is an important part of working on any problem. It can be thought of as an entry point to any sort of research that has to be performed.

The predominant solutions that are currently available involve the use of various sensory devices.

During the course of this project, we have looked through various existing solutions that are present for the problem.

In a paper titled **Automatic Street Light Control System using Microcontrollers[4]**, authored by **Mustafa Saad, Abdalhalim Farij, Ahamed Salah,** and **Abdalroof Abdaljalil**, a solution involving the use of LDR (Light Dependent Resistor, Microcontrollers, and Photoelectric Sensors. This paper attempts to detect the light available in the surroundings with the help of an LDR and switch the street lights on and off accordingly using Photoelectric Sensors.
LDR is a resistor whose resistive nature varies based on the amount of light falling on its surface. Using LDR in the circuit where the LED Transmitters are connected to the Photoelectric sensor, the intensity of the light varies depending upon the resistance of the circuit.
The Photoelectric Sensors alter the state of the circuit depending upon the amount of light they receive. If there is a change in the intensity of the lights falling on the sensors, the state of the circuit is switched on or off depending upon the configuration of the circuit.

Whenever a vehicle passes through a street and obstructs the reception of light by the Photoelectric Sensors, the switch in the circuit is triggered and the lights are turned on. This works efficiently enough in various conditions. However, the cost for installation of such a system is rather high.

This type of system would require high maintenance costs along with efficient a high cost of equipment. The LDRs and Photoelectric Sensors are rather expensive when it comes to implementing this solution on a large scale. The lifecycle of these sensors has to be also taken into consideration for the implementation of this system, The sensors would need periodic maintenance as well as replacement at times.

The microcontroller chips also would require maintenance. These have to be cost efficient as well as have to have a long life. The overall feasibility of this solution with taking existing facilities into account is rather low. This solution is also not very cost efficient and would involve a lot of investment and maintenance.

Another paper titled **Adaptive Control of Streetlights using Deep Learning for the Optimization of Energy Consumption during Late Hours[5]** discusses a more data driven approach. In this paper the authors have installed cameras at high locations on streets. These are used to analyze traffic patterns for that street at various points during the day. A database is created using the data obtained from the video feeds and then used on a prediction model to analyze traffic patterns and volume at various points during the day.

This predictive model helps predict the amount of traffic any particular road would get at the time of the day and depending upon that either dim the lights or brighten them. The lights are turned on throughout the night with their varying intensity. The energy consumption is decreased and only a camera has to be installed on the streets for this solution to work which is installed on most of the streets these days. However, there is no real time factor involved in this solution. There may always be outliers in practical scenarios. The lights are turned on continuously which means that energy will still be expended if there are no vehicles on the street even if according to the model the current time is predicted to be a time of high traffic density and the lights are glowing at their brightest. Thus there is no real time element to this solution which proves it to be rather inefficient for the ongoing day to day scenario.

In another paper titled **Automation of Street Light For Smart City[5]**, a similar LDR technique as [3] is proposed. It also, however, has a fault detection mechanism inbuilt for identifying potential faults with the installed LED lights. It alerts the control center if the lights are not behaving in the certain predefined manner. The lights are illuminated only when a passing vehicle is detected and dimmed otherwise.The power source of the lights is switched to different Volts for different intensities.
In [6], an efficient street light control system was developed using Zig-Bee technology. Movement of human beings and objects are sensed with the help of IR sensor. Based on the output of the IR sensor a dimming control circuit was designed. Data from the base station are sent constantly to 0918 International Conference on Communication and Signal Processing, April 6-8, 2017, India 978-1-5090-3800-8/17/$31.00 ©2017 IEEE the Zig-Bee devices. The Zig-Bee communication is implemented using Digi-Max stream radio frequency modules whose transmission range is only few hundreds of meters. The system sends data from a particular street lamp to the central Zig-Bee node in case of failure and then measures are taken accordingly. The installation cost are comparatively high than the conventional model. Also, the system is observed to be technically complex

Chapter 3: Problem Statement

The power consumption of street lights accounts for about 10-38% of the total power consumption of cities, costing them millions of dollars every year, along with a waste of energy. If an automated mechanism is developed for the lights so that they turn on only when necessary, it will save a lot of energy and resources.

From the literature survey, we have seen various solutions proposed by scientists from across the world for solving this problem. However, all of these solutions mentioned above need to be improved in some way or another.

These solutions either require pricey equipment or high maintenance costs. High end microcontroller devices and sensors are not feasible to be spread out on streets across some of the less developed nations. The totally urbanized or first world countries can support such systems involving use of intricate networks and various sensors. However, in the developing world this is not possible.

The technique mentioned in [4] is more data driven in nature and much more feasible than other approaches that have been discussed throughout the course of the literature survey. However, the techniques used in [5] are not without their limitations. Here the only setup equipment required for the street is a camera which is nowadays installed in most of the developing nations for security purposes. The video surveillance feed obtained can be used to train models that are developed to predict traffic patterns. Spending upon the analysis of traffic patterns at different times of the day, the lights can be chosen to be dimmed or glowed brighter.

This approach is most cost efficient in nature. It would require setting up proper server architectures for the training and analysis of the models used but the only onsite expense would be that of a camera. Still, despite its cost efficient nature, the solution is still lacking. This solution has no real time element to it. If there are any outliers for a situation, this model won’t be able to perform as efficiently.

We can determine a solution to this problem using the principles of Machine Learning and its numerous applications which is real time and cost efficient in nature.

Since there are cameras installed on the streets for surveillance purposes in most of the cities across the world these days, we can use these cameras to check the flow of the traffic. If we are able to determine the speed of the vehicle in the camera's vision and are aware of the locations of street lights on the stretch of the road that the camera is covering, we can determine when the vehicle will reach in the region of interest of one particular street light.

Depending on the speed of the vehicle and the distance between the vehicles and the streetlights, we can compute the time for when the vehicle would be required which region to be illuminated by a street light.

If we do that, we can turn off the lights that are not in use and are turned on unnecessarily and only trigger the switches of the lights that light up the current path of the vehicle.

Objectives

1. Detects Vehicles on the street using the video feed provided by the camera.
2. Determine the average speed of the vehicle that is present in the current frame.
3. Compute an approximate time when the vehicle would be reaching the region that is covered by a particular street light and trigger the lights accordingly.

Chapter 4: Proposed Approach

We will consider a Machine Learning approach for the problem discussed in the Problem Statement.
Having determined the primary objectives that need to be accomplished in this project, we proceed to tackle them one at a time. In this report, we have successfully determined the vehicle detection method and its subsequent speed calculation.

Object Detection

When Humans look at images or videos, they can determine the objects of interest for them in any particular frame. Using Machine Learning techniques, we hope to replicate this ability in a computer system.
An image classification or image detection system simply checks if the targeted attributes are present in the given image. However, in object detection, the probability of an object lying in an image is determined based on the factors involved.

Image classification involves assigning a class label to an image, whereas object localization involves drawing a bounding box around one or more objects present in the image. Object detection is more challenging and combines these two tasks and draws a bounding box around each object of interest in the image and assigns them a class label. This problem together is referred to as object recognition.

Object recognition is a general term to describe a collection of related computer vision tasks that involve identifying objects in digital photographs. Image classification involves predicting the class of one object in an image. Object localization refers to identifying the location of one or more objects in an image and drawing a bounding box around their extent. Object detection combines these two tasks and localizes and classifies one or more objects in an image.

We explored two different mechanisms to approach the given problem. Determining the speed of the vehicles on the road can help determine when they will reach the region of interest at a particular street light.

Depending upon the camera's field of vision, we can determine the vehicles on the street and their speed with the distance they cover. After determining the time at which the vehicle might reach the region of interest of light, we can determine the time to trigger the lights illuminating the region covered by that light.

To execute this solution, we considered two techniques:

1. Background Subtraction
2. Haar Cascade

Background Subtraction

Background Subtraction is one of the most popular object detection methods. This method compares moving parts of the video to a background and a foreground image.

This method is used to find the foreground objects by isolating them and comparing frame by frame to a frame where no object is present. It finds differences between them and then creates a distance matrix. Basically, it compares the difference in the value of two frames, one frame without an object and the other with objects to count, with the threshold value. The threshold value is predefined by using the first few frames of the video. Hence if the difference in the value of two frames is greater than the preset threshold value, the result is marked as a moving object detected.

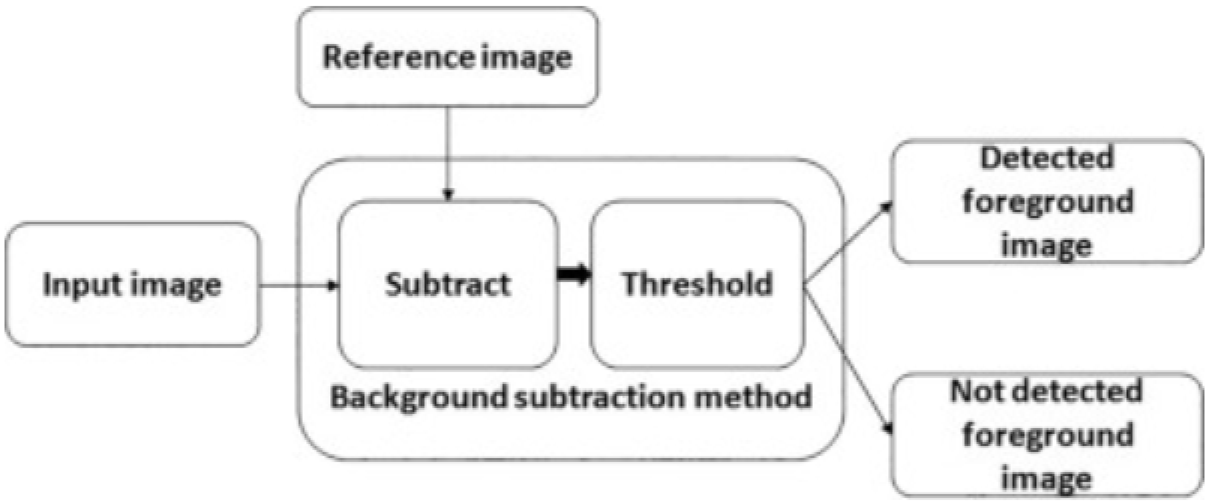

Figure 4.1: Working of Background Subtraction

We determine a region of interest for where the object detection has to be carried out. The algorithm compares the movements of the objects in that region to the threshold value and determines if any moving objects are present in that frame.

By establishing a scale for the distance in the video and the actual distance on the ground, we could determine the speed of the vehicles using the timestamps of the video. However, for background subtraction to work best, the region of interest must be reasonably sized. A massive region of interest would also give rise to additional noise due to detecting unwanted objects.

The larger the region of interest, the lesser the threshold value to be set. If we set the threshold value too low, excessive noise would be detected along with the required objects. The objects at the far end of the frame have smaller pixels and hence a lower resolution. Thus, the movements detected from them are quite low, so the threshold value has to be set lower. This creates a paradox of sorts and limits the accuracy of the results we can obtain.

Haar Cascading

Haar Cascade Classifiers are an effective way of performing object detection. This method was proposed in a paper by Paul Viola and Micheal Jones titled **Rapid Object Detection using a Boosted Cascade of Simple Features**. It is a machine learning based approach where a cascade function is trained from a lot of positive and negative images and then it is used to detect objects in other images.

- Positive Images: The images in which the object we want to be detected by the algorithm is present.
- Negative Images: The images in which the object we want to be detected by the algorithm is absent.

This algorithm is not so complex and can run in real time. Haar Cascade algorithms can be trained to detect various objects like cars, trains, bikes, faces, etc. Haar Cascade uses a cascading window, and it tries to compute features in every window and classify whether it could be the object we are looking for.

The algorithm can be explained in four stages:

- Calculating Haar Features
- Creating Integral Images
- Using Adaboost
- Implementing Cascading Classifiers

This model requires a huge dataset of positive and negative images for it to work efficiently.

Calculating Haar Feature

The first step is to collect the Haar features. A **Haar feature** is essentially calculations that are performed on adjacent rectangular regions at a specific location in a detection window. The calculation involves summing the pixel intensities in each region and calculating the differences between the sums. Here are some examples of Haar features below.

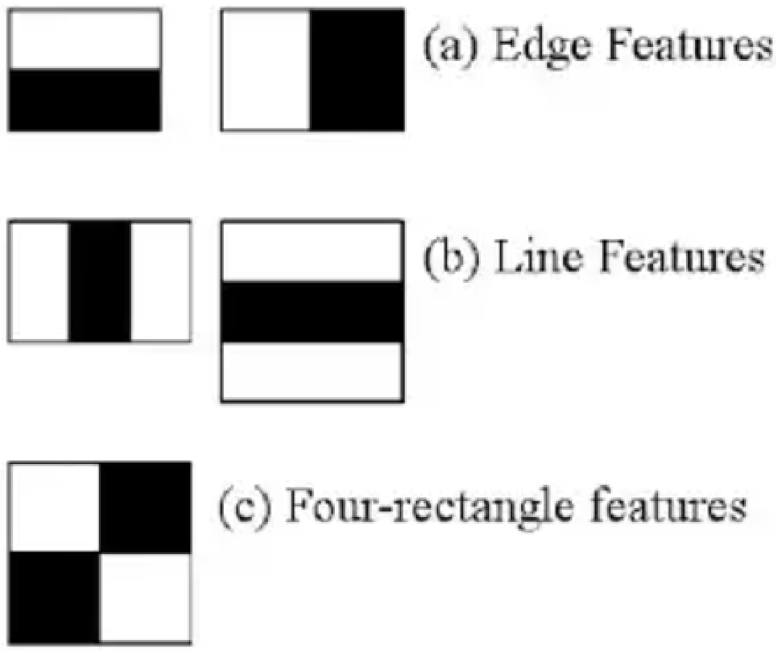

Figure 4.2: Haar Features

These features can be difficult to determine for a large image. This is where **integral images** come into play because the number of operations is reduced using the integral image.

Creating Integral Images

Without going into too much of the mathematics behind it, integral images essentially speed up the calculation of these Haar features. Instead of computing at every pixel, it creates sub-rectangles and array references for each sub-rectangles. These are then used to compute the Haar features.

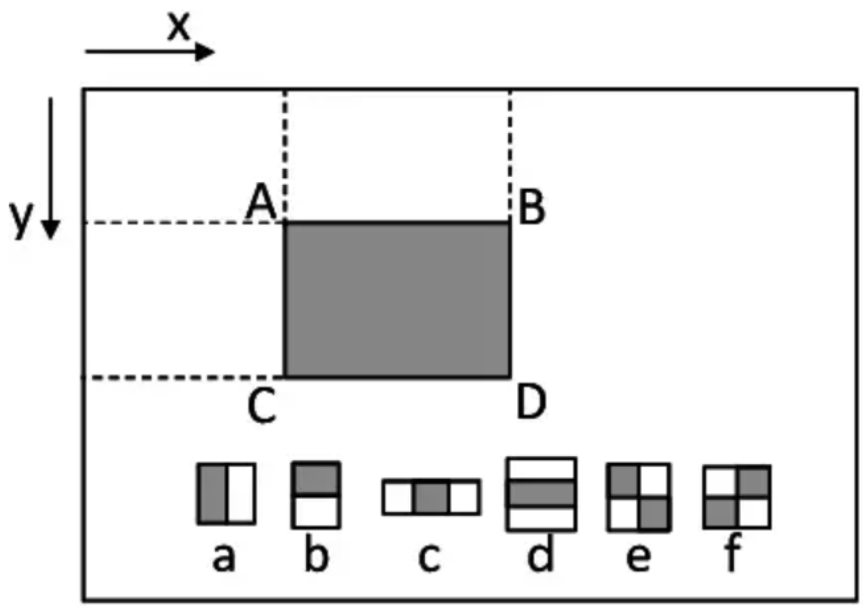

Figure 4.3: Individual Haar Features

It’s important to note that nearly all of the Haar features will be **irrelevant** when doing object detection, because the only features that are important are those of the object. However, it is difficult to determine the best features that represent an object from the hundreds of thousands of Haar features. This is where **Adaboost** comes into play.

Adaboost Training

Adaboost essentially chooses the best features and trains the classifiers to use them. It uses a combination of **“weak classifiers”** to create a **“strong classifier”** that the algorithm can use to detect objects.

Weak learners are created by moving a window over the input image, and computing Haar features for each subsection of the image. This difference is compared to a learned threshold that separates non-objects from objects. Because these are “weak classifiers,” a large number of Haar features is needed for accuracy to form a strong classifier.

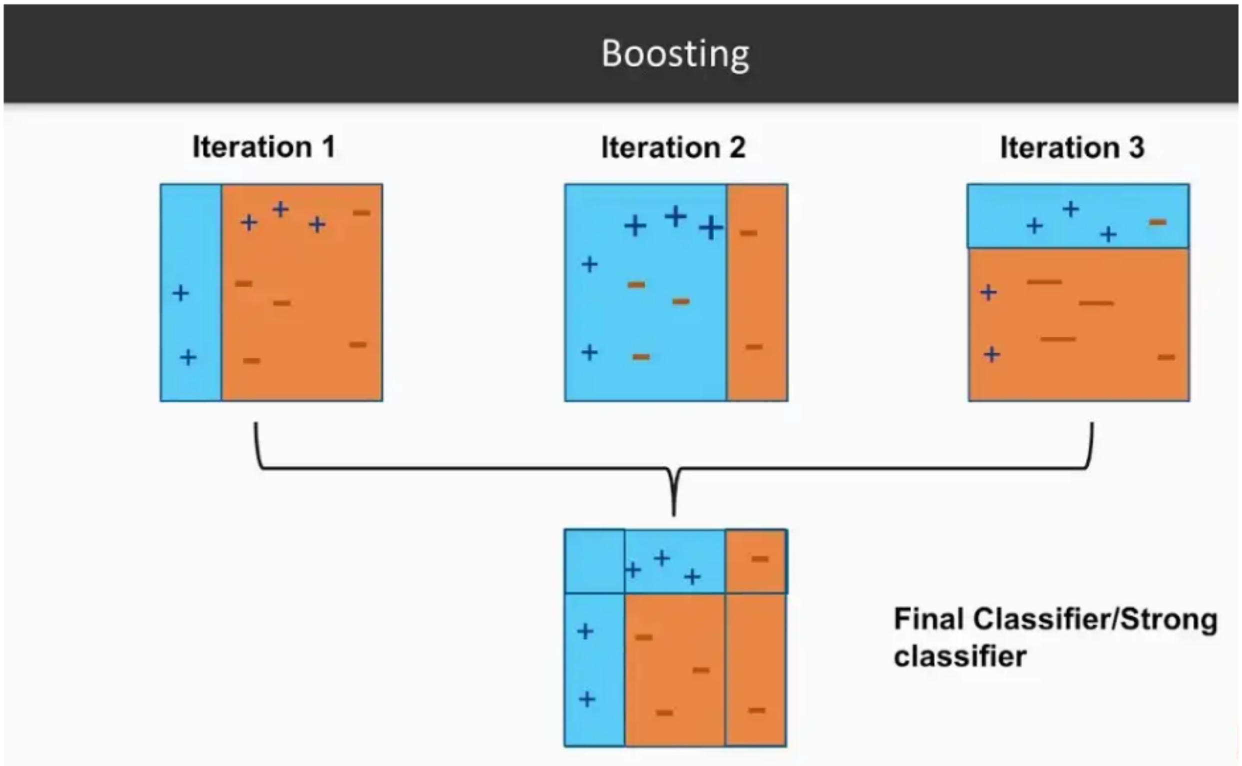

Figure 4.4: Adaboost Training

The last step combines these weak learners into a strong learner using **cascading classifiers**.

Implementing Cascade Classifiers

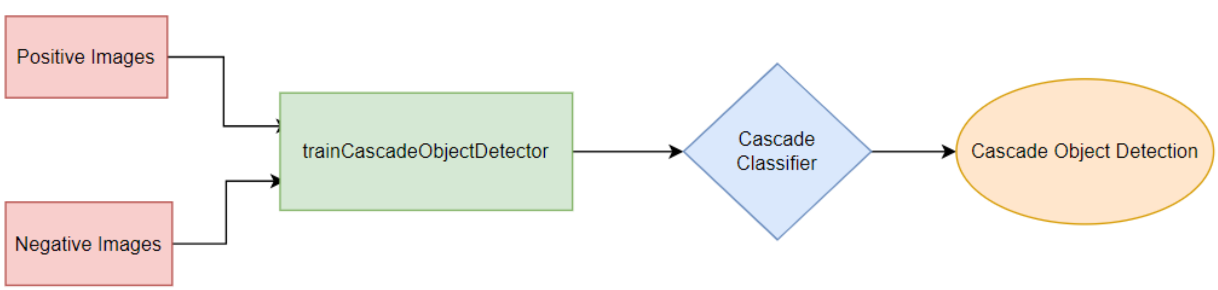

Figure 4.5: Implementing Cascade Classifier

The cascade classifier is made up of a series of stages, where each stage is a collection of weak learners. Weak learners are trained using boosting, which allows for a highly accurate classifier from the mean prediction of all weak learners.

Based on this prediction, the classifier either indicates an object was found (positive) or moves on to the next region (negative). Stages are designed to reject negative samples as fast as possible because a majority of the windows do not contain anything of interest.

The object detection data is stored in the program's XML files. Using Haar Cascading, we can continuously track specific objects without excessive background noise. This method proves to be accurate to a great extent, even for objects at the far end in the video.

After establishing proper object detection parameters, we can determine a pixel-per-meter ratio(ppm). This ratio would help us determine the actual distance on the ground that the vehicle has covered, and with the help of the video timestamps, we can determine the vehicle's speed.

With the determination of speed, it becomes now possible to determine when the vehicle will reach the region of interest of a particular street light, and depending upon the computations, the lights can be triggered just a little before the vehicle arrives in its region of interest.

Speed Calculation

In this project, we have used an existing trained model for vehicle detection using Haar Cascades. The accuracy of the model is fairly high.
We use a correlation tracker implemented in the dlib library for python for tracking objects[7]. By doing this we are assigning IDs to the vehicles when they are in the field of vision of the camera andd then determining the distance they cover in a short span of time to calculate the speed and by making the calculations for several short intervals, we take their average to determine the speed of the vehicle.
We are determining the distance traveled by the vehicle in terms of pixels. We need a pixel-per-meter ratio that can be easily calculated on the basis

of the actual distance on the ground and the video feed. Using this ratio, we can determine the actual distance covered by a vehicle.
After determining the distance covered, we divided it by the time required to travel that distance.
Thus we can obtain the speed of the vehicle.

Triggering of Lights

After calculating the speed, we determine the distance between the area covered by the light and the entry point of the vehicle in the frame of the camera. Using the speed and distance we can calculate the time required for the vehicle to enter the area covered by the street light.
The results obtained are supplied to the arduino and the lights are triggered for the supplied period of time at any time. As the vehicles keep coming in, the time for which the lights have to be turned on is updated and thus the operation is carried out.

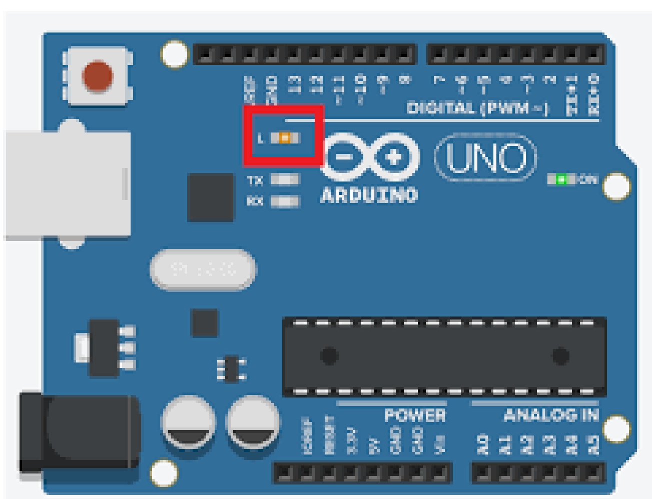

Figure 4.6 Output Image on Arduino

Chapter 5: Conclusion

The paper elaborates the vehicle detection and speed determination on a highway using two approaches, Background Subtraction and Haar Cascading. The first approach used was background subtraction. The results obtained needed to be more precise. Since it requires a reasonably sized region of interest to produce acceptable results. But, using a massive region of interest can introduce additional noise due to detection of unwanted objects. The objects at the far end of the frame have lower resolution because of having smaller pixels. Thus, the movements detected from them are quite low. This asks for a lower threshold value, which can increase our region of interest. Hence a paradox occurs which limits the accuracy of results obtained by this method.

Therefore Haar Cascading is used as an alternative. Haar Cascading provided accurate object detection and speed determination. It works well in real time as well. Haar Cascading has various advantages over background subtraction as we can tune the algorithm to detect specific types of objects only and ignore the others. Using this with correlation tracking, we can track the vehicle thoroughly throughout the video feed and assign them IDs to keep track of them.

After determining the distance traveled by any vehicle in a span of time, we can easily calculate their speed. After determining the speed, the time required by the vehicle to reach the area covered by the light is determined and henceforth the lights are triggered when the vehicle is almost on the verge of the area and the lights are then turned off as the vehicle pass the area of the light.

Chapter 6: Future Scope

After the successful vehicle and precise speed detection and light controls the project still has scope for improvement. Haar Cascading despite producing optimal results better machine learning algorithms can be developed.

The use of Neural networks and deep learning can help this project further. The video feed obtained can be analyzed to gain further data. This data can be used to implement features of smart cities and predict traffic congestion in certain areas. This can also help in better incident management.

This project can be further improved and integrated with Intelligent Transportation Systems.

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