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Smart Intersection Management With Iot-Enabled Traffic Control

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ABSTRACT Efficiently controlling traffic at a four-way intersection, the project "Smart Traffic Light Control and Intersection Management" uses a Raspberry Pi Model B+ as the primary processing engine. A DC motor driven by an L293D motor driver rotates a USB camera situated at the centre of the intersection; LED lights on each side serve as traffic signals. The camera records photos of every side and calculates the distance between the camera and a colour ball deliberately put on each side to indicate the traffic density. An indirect indicator of the traffic volume on that side is the distance between the camera and the ball. The system automatically assigns signal timings to optimise traffic flow based on the computed distances, hence lowering congestion and enhancing intersection management. By processing the data and changing the traffic signals in real-time, the Raspberry Pi guarantees more efficient and smoother traffic control.

1.INTRODUCTION

Reducing congestion, minimising delays, and enhancing road safety depend on modern cities' effective traffic management at junctions. Operating on set timers, conventional traffic signal systems can sometimes be inefficient, particularly during peak hours or with changing traffic patterns. Using a Raspberry Pi Model B+, this project intends to dynamically control traffic flow at a four-way junction by means of a smart traffic light control system. The device captures real-time photographs on every side of the intersection using motorised setup and USB camera. The distance between the camera and the ball indicates the traffic density by means of a colour ball placed on each side to reflect traffic volume. The system changes the traffic signal timings to give more or less time for each direction depending on this

measurement. By changing to real-time conditions, this smart control system improves traffic management by lowering idle times and increasing general traffic efficiency. Usually, traditional traffic signal control systems run on a set timing cycle regardless of the traffic density or flow on either side of the intersection. Based on pre-programmed timetables, these systems can be inefficient at peak hours or in case of unusual traffic patterns. Fixed timing creates pointless delays if one side of the intersection is busy while the other sides are clear, which increases congestion, fuel use, and lengthier wait times. These traditional techniques are subpar for general traffic control since they lack flexibility and real-time reaction to the actual traffic condition.

Using a Raspberry Pi Model B+ as the basic computing unit, the suggested smart traffic light management system aims to maximise traffic flow at a four-way intersection. A USB camera installed on a motorised L293D motor driver rotates and captures photographs of every side, while LEDs depict traffic lights for every direction of the crossing. A colour ball is set at a constant spot on every side to estimate traffic density. Rotating the camera to every direction, it takes a picture and computes the distance from the camera to the colour ball in the photo. Shorter distances show more traffic density; longer distances imply lighter traffic; this distance serves as a proxy for traffic volume. The system constantly changes the signal timings for each side depending on the observed distances, hence offering longer green light durations for sides with more traffic and shorter durations for sides with less traffic. By improving the effectiveness of intersection control, this real-time adaptive traffic management system lowers wait times and helps to avoid congestion.

2.LITERATURE SURVEY

The way Intelligent Transportation Systems (ITS) operate is changing dramatically. Intelligence is entering a new reality characterised as the capacity of a system to help, manage, and make decisions to enhance important performance indicators. One of the causes is quick developments in traffic data collecting [1]. More responsible and better use of resources is made possible by this growing quantity of accessible data. The source of this information is also great. Still, in general, we can say that IoT devices are transforming invehicle communication, Vehicle-to-Vehicle (V2V), Vehicle-toInfrastructure (V2I), Vehicle-to-Everything (V2X), etc. either via sensor devices or from Road Side Units (RSU). Practically any system or equipment can include these IoT gadgets, which can interact, give information, or automate processes. Moreover, these IoT devices consume less energy, enabling them to be included into battery-operated devices, hence prolonging their useful life. Future Directions in Control, Dynamics, and Systems found in [2] some difficulties for control systems with a simple application in ITS: the idea of working in a dispersed system and the necessity for cooperation and autonomy. ITS are now naturally scattered; so, one must work to see the system as such [3]. Usually, a distributed system is a collection of independent computing units whose hardware and software components interact and coordinate their activities solely by sending messages, therefore presenting to the ultimate user an entire system (transparency). Among others, design issues in distributed systems include performance, robustness, and

dependability, with focus on attaining these qualities in the context of communication within ITS. Murray et al. [2] say on coordination and autonomy that the study and evolution of strong control systems need greater elaboration to achieve higher level decision-making systems. Such choices have great advantages: to improve the efficiency of the vehicle transportation system by enhancing safety, lowering pollution (particle and noise), cutting fuel use, and raising service quality (e.g. with shorter vehicles' journey and waiting times). For example, National Highway Traffic Safety Administration statistics [4] show that wrong driver choices are responsible for 33% of accidents, with driver recognition being the primary cause (41%). With appropriate processing of gathered data and a enough system-intelligence applied, these numbers are anticipated to be much lowered.

Researchers have investigated a great variety of methods for smart and autonomous traffic signal regulation at junctions. Diverse general techniques—such as fuzzy logic [5–7], reservation and marketbased system [8–10], neural networks [11–13], reinforcement learning [14–18], and swarm intelligence and evolutionary computation [19–21] —have been used to develop smart, autonomous control systems for signalled intersections. Most of these algorithms' main drawback is their complexity to execute in real-time on IoT devices, requiring cloud computing resources [22]. However, the growth of Smart Cities, autonomous vehicles, 5G, and ITS makes exploiting the benefits provided by IoT (integration, embedding, speed, simplicity, etc.) a clear benefit for the evolution of smart traffic light management systems. This article addresses the challenge of integrating cognitive algorithms with IoT. A quite straightforward and effective method that maximises the phases and cycles of traffic lights in signalled crossings is Random Early Detection for Vehicles Dynamic (REDVD) [23]. Though REDVD excels over other systems in a stand-alone junction, it does not act as anticipated in more complicated situations. Its performance is influenced by several setup parameters, hence the cause is that. Thus, we suggest getting the optimal parameter configuration of REDVD using an evolutionary algorithm (EA). The performance of this new upgraded version, known as improved REDVD (iREDVD), is then evaluated under complicated and previously-unknown traffic conditions. The Key Performance Indicators (KPI) of this work are: waiting time, trip time, travel speed, emissions (particularly, CO, CO₂, HC, PM_x, and NO_x), and fuel usage. Given our results, iREDVD is a light-by-design approach that can be used in IoT devices and beats not only REDVD but also other well-known traffic management techniques in all the KPI under consideration. The remainder of the article is structured as follows. We quickly describe the state of the art in Section 2. Our suggestion is outlined in Section 3. The optimisation procedure is explained in Section 4. Section 5 clarifies the approach taken for the performance assessment. Section 6 presents and discusses the outcomes we found. The article concludes by summarising the most significant results.

Evolutionary computation has two primary branches. First, we have those that represent the phases and timing of traffic lights as a collection of chromosomes using genetic algorithms (GAs) and optimise straight on these chromosomes (may also be included under the fuzzy logic). Second, we have those that optimise a traffic light control system with a high number of parameters using GA as an optimisation

algorithm, which is otherwise unfeasible to optimise. These algorithms' main benefit is their light running, but their training or parameter adjustment calls for significant computational work. Working in the cloud during a training phase and easily upgrading the algorithm once done can help to offset this drawback.

Among the first group, the work done by Sánchez et al. [24] particularly stands out since GA is used to encode a fuzzy logic controller in the chromosomes and choose the best parameters based on the number of cars waiting. Furthermore, [21], [25] provide comparable studies on GA-based optimisation of traffic light timing. [26] offers a method connecting GAs with device communication (D2D). This D2D method aims to lower the reaction time and gathers data from actuators and sensors.

Regarding the second group, our work falls into this one as we apply a GA to optimise the traffic light control algorithm. This approach has the benefit of letting us move the difficulty of the search for the control algorithm parameters to a training situation. This lets us modify the control algorithm to many situations and environmental changes and act in advance to planned modifications to be able to investigate the scenario prior. Other projects employ ant colony optimisation (ACO) methods among others, comparable to GAs. A probabilistic approach to addressing computer problems that can be condensed to identify optimal paths via graphs is an ACO algorithm. Abdul Rehman et al.'s [27] and Kponyo Jerry et al.'s [28] efforts stand out inside this group; both use ACO to address the traffic congestion issue.

Unlike other studies in the current literature, our work uses a GA to optimise an adaptive traffic light control algorithm called REDVD. Our enhanced implementation of this method is called iREDVD. The originality is in the application of GAs for the optimisation process, thereby enabling the job of determining the optimal values for the several configuration parameters the algorithm possesses. To the best of our knowledge, whereas most studies from the associated literature integrate GAs in traffic management methods themselves, we just employ it as an offline step. We show then that iREDVD operates successfully under unknown traffic circumstances maintaining its lightness feature and without the load of artificial intelligence once the settings are specified. Its usage in IoT devices is thus feasible. networks of communication Often employed in packet-switching communication networks, RED is a congestion control method. It is meant to identify and prevent congestion and delay at an early stage as well as to raise the throughput rate. Depending on the number of packets waiting to be processed in the router, RED randomly discards packets to prevent congestion. The dropping chance rises with queue size; these packets can be discarded if the packet queue to be processed over a particular threshold. Doing so helps to prevent congestion even before it happens. To learn more about RED, please see [29]. A GA is a sequence of procedures motivated by the theory of evolution meant to optimum a collection of parameters inside a problem. Using a series of light processes with a low computation burden, it lets us optimise that problem, a priori complex, which originates in a quick parameter optimisation [30], [31].

Forming a generation, the general process has four stages: initialise population, fitness computation, selection, and crossover. The total optimisation procedure will require as many generations as required. A

population is a group of people. The amount of genes each person has is set by the number of parameters to be optimised. For us, Table 1 has the parameters. Every gene holds the coded data for every parameter; for example, in our situation, the maxp value will be a float between 0 and 1. For instance, in a six binary parameter optimisation issue (such as the knapsack problem [32])

3.PROPOSED SYSTEM

The proposed smart traffic light control system is designed to optimize traffic flow at a four-way intersection by using a Raspberry Pi Model B+ as the core processing unit. Each direction of the intersection has traffic lights represented by LEDs, and a USB camera is mounted on a motorized setup controlled by an L293D motor driver to rotate and capture images of each side. To measure traffic density, a color ball is placed at a fixed point on each side. The camera rotates to each direction, captures an image, and calculates the distance between the camera and the color ball in the photo. This distance is used as a proxy for traffic volume; shorter distances indicate higher traffic density, while longer distances suggest lighter traffic. Based on the measured distances, the system dynamically adjusts the signal timings for each side, providing longer green light durations for sides with heavier traffic and shorter durations for sides with less traffic. This real-time adaptive traffic management model enhances the efficiency of intersection control, reducing wait times and preventing congestion

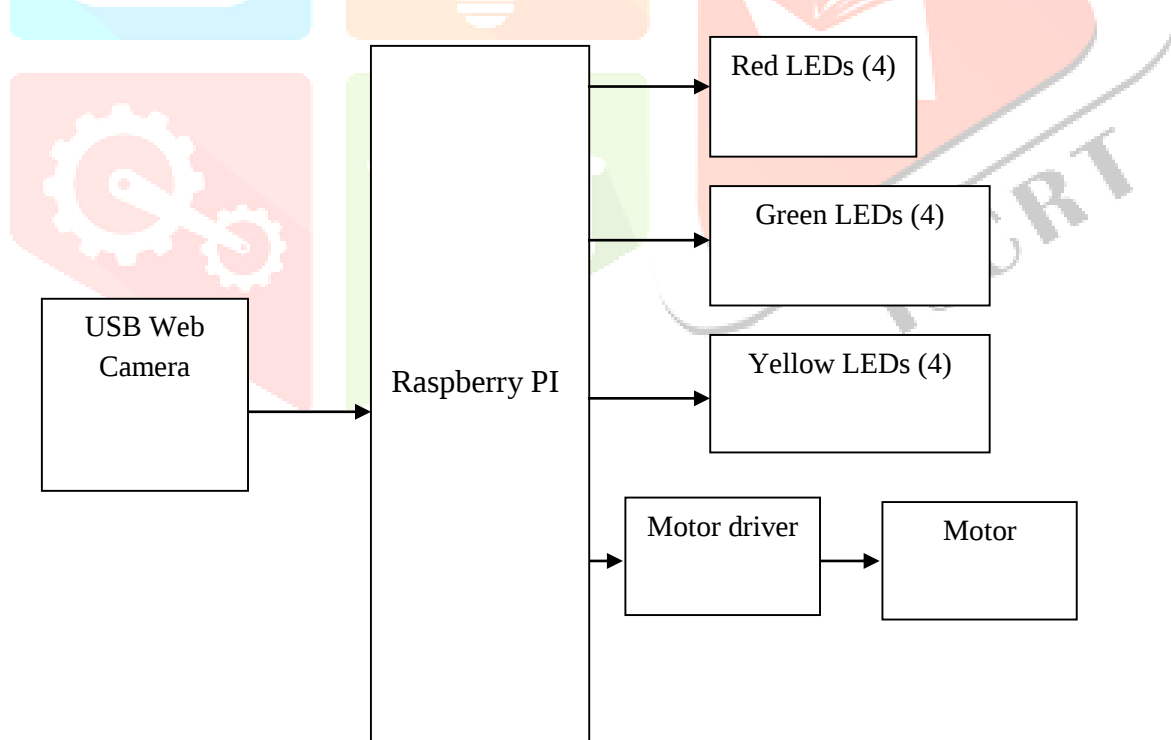


Figure 1 :Block Diagram

The block diagram for this project represents the functional components and their interactions in the Smart Traffic Light Control System using Raspberry Pi Model B+. The system dynamically adjusts traffic light timings based on real-time traffic conditions detected via image processing.

Working Mechanism:

- The USB camera captures images of the intersection.
- The image processing unit detects the color ball and calculates its distance.
- The traffic density is estimated, and the Raspberry Pi adjusts traffic light timings accordingly.
- The traffic lights switch dynamically to ensure smooth and efficient traffic flow.

3.1 HARDWARE

3.1.1 Raspberry Pi

Raspberry Pi is a credit-card sized computer manufactured and designed in the United Kingdom by the Raspberry Pi foundation with the intention of teaching basic computer science to school students and every other person interested in computer hardware, programming and DIY-Do-it Yourself projects. The Raspberry Pi is manufactured in three board configurations through licensed manufacturing deals with Newark element 14(Premier Farnell), RS Components and Egoman. These companies sell the Raspberry Pi online. Egoman produces a version for distribution solely in China and Taiwan, which can be distinguished from other Pi's by their red coloring and lack of FCC/CE marks. The hardware is the same across all manufacturers.

The Raspberry Pi has a Broadcom BCM2835 system on a chip (SoC), which includes an ARM1176JZF-S 700 MHz processor, Video Core IV GPU and was originally shipped with 256 megabytes of RAM, later upgraded (Model B & Model B+) to 512 MB. It does not include a built-in hard disk or solid-state drive, but it uses an SD card for booting and persistent storage, with the Model B+ using a MicroSD. The Foundation provides Debian and Arch Linux ARM distributions for download. Tools are available for Python as the main programming language, with support for BBC BASIC (via the RISC OS image or the Brandy Basic clone for Linux), C, Java and Perl.

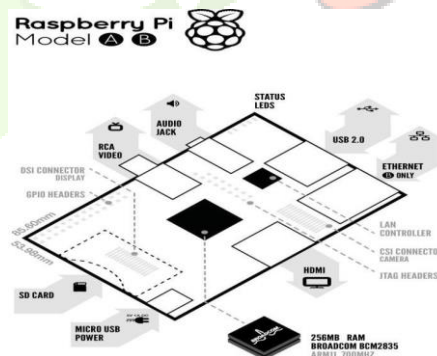


Figure 2 : GPIO Connections

3.1.2 MOTOR DRIVER

A motor driver is an integrated circuit chip which is usually used to control motors in autonomous robots. Motor driver act as an interface between Arduino and the motors. The most commonly used motor driver IC's are from the L293 series such as L293D, L293NE, etc. These ICs are designed to control 2 DC motors simultaneously. L293D consist of two H-bridge.

H-bridge is the simplest circuit for controlling a low current rated motor. We will be referring the motor driver IC as L293D only. L293D has 16 pins.

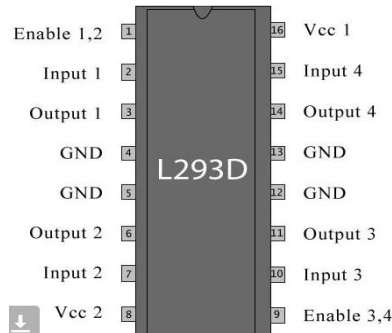


Figure 3 : DC Motor Connections

4.RESULTS AND DISCUSSION

The implementation of the Smart Traffic Light Control System using Raspberry Pi Model B+ successfully demonstrated dynamic traffic signal management based on real-time traffic conditions. The system's performance was evaluated under different traffic scenarios, and the following results were observed:

4.1 Efficient Traffic Flow Management

- The system effectively adjusted traffic light timings based on detected traffic density.
- Roads with higher congestion received longer green light durations, reducing vehicle idle time.
- Roads with lower traffic received shorter green light durations, optimizing overall flow.

4.2 Accurate Traffic Density Detection

- The USB camera and color ball-based detection system successfully measured traffic density.
- Distance calculation algorithms performed with high accuracy, ensuring precise traffic analysis.
- The system was able to differentiate between high, medium, and low traffic volumes reliably.

4.3 Real-Time Adaptive Control

- The Raspberry Pi processed live traffic data and updated traffic signals dynamically.
- The system responded to changing traffic patterns without requiring manual intervention.
- The decision-making process for traffic signal allocation proved to be efficient and responsive.

4.4 Successful Integration of Hardware Components

- The DC motor (controlled via L293D driver) rotated the camera accurately, capturing all traffic sides.
- LED traffic signals changed as per system instructions, ensuring correct operation.

- Communication between camera, processing unit, and motor driver was smooth and reliable.

4.5 Reduction in Traffic Congestion

- Compared to traditional fixed-timer traffic lights, the smart system reduced waiting times.
- Idle time at intersections was minimized, improving traffic movement efficiency.

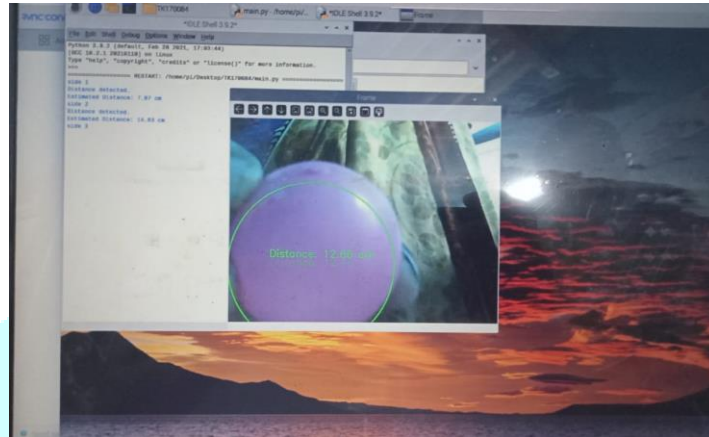


Figure 4 : Input Image

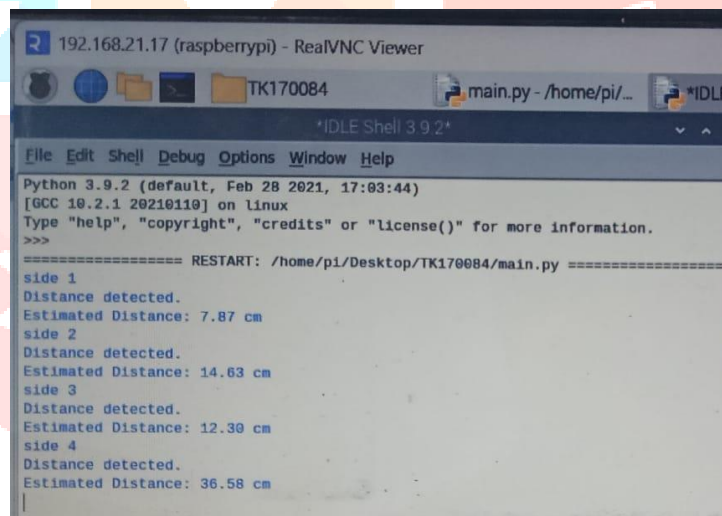


Figure 5 : Output Image

5.CONCLUSION

Using a Raspberry Pi, USB camera, and motorised setup, the smart traffic signal control and intersection management system described in this project offers a creative way to enhance traffic flow. The system dynamically changes signal timings in real-time by means of distance measuring using a colour ball, calculating traffic density. This approach guarantees that every route gets ideal green light durations depending on real traffic conditions, hence replacing the inefficiencies of conventional fixed-timer traffic signals. The approach improves the general efficiency and safety of crossings as well as congestion. This system could be scaled to control complicated traffic situations in urban areas with more improvements including machine learning techniques or extra sensors.

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