IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 1, April 2024

Dynamic Traffic Light Control System Based on Real-Time Traffic Density using IR Sensors

Bhavadharini M[1] and Dr. S. Rathinavel[2]
Student, Department of Electronics and Instrumentation[1]
Assistant Professor, Department of Electronics and Instrumentation[2]
Bharathiar University, Coimbatore, Tamilnadu, India

Abstract*: As the world population continues to grow, the number of vehicles in daily use is increasing dramatically. Due to this, traffic congestion is becoming a major problem. Traffic congestion cause delays and stress among motorists and passenger. Various natural resources are not only depleting but also increasing air pollution. Although it seems ubiquitous, megacities are the most affected. At intersections, traffic light control systems are frequently utilized to regulate traffic flow. Currently, most traffic light systems use pre-time and countdown timers to control traffic flow. This paper proposes a novel approach for dynamic traffic light control based on real-time traffic density using readily available infrared (IR) sensors. The system strategically positions IR sensors at four-way intersections to detect the presence of vehicles, cyclists, or pedestrians approaching from each direction. Upon detection, a timer is initiated. If the IR sensor continuously detects activity for a predefined duration, the system prioritizes that direction by extending its green light phase. Conversely, if no activity is detected within a set timeframe, indicating low traffic density, the system immediately switches to the next signal sequence, optimizing signal timing for changing traffic patterns. This adaptive behaviour based on IR sensor data and intelligent algorithms aims to reduce congestion, improve traffic flow efficiency, and enhance overall urban mobility.*

Keywords: Traffic light system, Traffic density, PIC16F877A microcontroller, IR sensor, Lcd display.

I. INTRODUCTION

Efficient traffic management is critical in urban areas to mitigate congestion and accidents. Traditional fixed traffic light timings often fail to adapt to varying traffic volumes, leading to inefficiencies. By employing an automatic algorithm based on artificial intelligence and real-time car detection, traffic light timings can be dynamically adjusted, optimizing traffic flow and minimizing delays. Validation against manual control methods confirms the algorithm's efficacy, promising significant improvements in transportation system performance [1].a smart cities is a critical challenge due to congestion, especially during emergency missions. While existing methods prioritize minimizing delays for emergency vehicles, ordinary commuters face significant trip disruptions. This paper introduces STC, a Fuzzy rule-based system for traffic signal-timing, aimed at reducing trip delays for emergency vehicles by leveraging expert knowledge and fuzzy sets for linguistic parameters [2]. Urban traffic congestion demands advanced technology for effective control. This paper proposes a system utilizing real-time vehicle density measurement through canny edge detection with digital image processing, promising substantial improvements in traffic management efficiency over existing methods [4,5,6].The efficient of traffic management in India, given its burgeoning population. It proposes a comprehensive traffic control system focusing on managing congestion, prioritizing clearance for emergency vehicles, and detecting stolen vehicles using RFID tags. By emphasizing these key aspects, the system aims to enhance traffic flow and safety on busy roads during peak hours [8]. The challenges of urban traffic congestion by proposing a centralized traffic light control system. It utilizes wireless communication networks to enhance traffic signal coordination and contribute to the advancement of smart city initiatives [9]. The Adaptive Traffic Control System (ATCS) that adjusts signal timings based on real-time traffic demand. It presents a camera-based monitoring system to reduce cycle time and cater to emergency vehicles. This approach combines hardware sensors for traffic density estimation with software analysis for efficient traffic flow management [10]. The traffic congestion with a real-time

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monitoring system that adjusts timings based on traffic density. It integrates camera technology and sensor networks for higher accuracy and efficiency. Additional features include RFID prioritization for emergency vehicles, stolen car tracking, and a user-friendly GUI for ease of control room operations [11]. The describe a MIMO Volterra series technique for characterizing transmitters, focusing on nonlinear cross-kernels and self-kernels. By analyzing sample averages of outputs with varying sample periodicity, it offers insights into RF MIMO transmitter hardware effects and aids in creating behavioural models and compensation strategies [12]. The Traffic Lights Expert System (TLES) utilizing Expert System (ES) or Rule-Based System (RBS) to dynamically allocate cycle times at intersections. It integrates rule-based knowledge representation and hardware like Arduino and IR sensors for effective traffic light control and congestion monitoring [13]. The s focuses on autonomous traffic lights with traffic timing to enhance urban highway flow efficiency. It proposes a smart system that dynamically adjusts light timings based on vehicle volume, utilizing an expandable Internet of Things setup with PIR sensors and Raspberry Pi, alongside plans for camera integration [14]. The traffic lights across intersections due to various factors and proposes a PIC microcontroller-based solution. It includes a portable controller for emergency vehicle management and infrared sensors to dynamically adjust timing slots based on traffic congestion [15]. The urban traffic control approach, improving traffic flow in small urban areas. Traffic congestion, especially in mega cities, demands real-time traffic density monitoring for signal control optimization. Video monitoring enables dynamic adjustments, easing congestion and enhancing road safety while providing data for future planning and synchronization of traffic lights [18]. The traffic congestion, an Arduino Uno ATMega 328-based system automatically adjusts signal time in traffic density using IR sensors. LED traffic signals enable effective management without human intervention, while solar power sustains a smart prototype, reducing congestion and enhancing efficiency at intersections.

II. METHODOLOGY

PIC16F877A microcontroller as the core processing unit. Install IR sensors at strategic positions for each direction (North, South, East, and West) at intersections. Connect LED lights for each direction to indicate the corresponding traffic signal state. Incorporate an LCD display for real-time feedback and status updates. Configure the microcontroller to continuously monitor the output of IR sensors. Implement input-driven routines to capture sensor data changes instantaneously. Develop algorithms to analyse IR sensor data in real-time to determine traffic density. Utilize data from all four IR sensors to calculate overall traffic density at the intersection. Design algorithms to dynamically adjust signal timings based on detected traffic density. Set predefined thresholds for each traffic density level to trigger signal timing adjustments. Implement a timer mechanism to measure the duration of detected activity Develop logic to promptly transition to the following signal pattern when continuous activity is detected for a predefined duration. Ensure smooth transitions between signal patterns to maintain traffic flow efficiency. Integrate an LCD display to provide real-time feedback on the current traffic signal state and system operation. Display relevant information, such as traffic signal timings.

2.1 BLOCK DIAGRAM

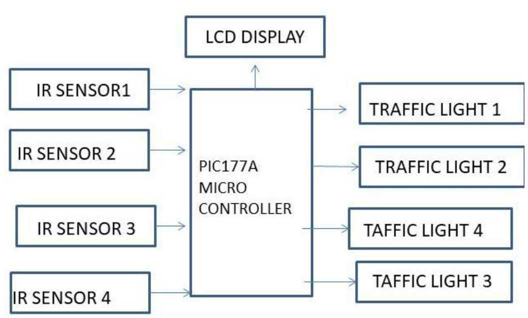

Figure.1. Overview of hardware setup

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2.2 HARDWARE COMPONENTS

2.2.1 PIC16F877A Microcontroller:

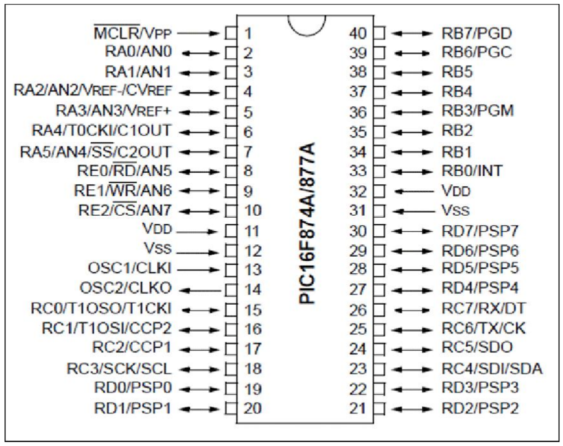

Figure 2: Pic microcontroller

Microchip manufactures the PIC 16F877A family of Harvard architecture microcontrollers, which are integrated circuits (ICs) made up of an EEPROM memory, RAM, ROM, and a basic CPU. In addition, it has five input/output ports, a clock, timers, and A/D converters. However, programming is made easy and simple by its 35 instructions. Additionally, it offers a operating voltage range of 2 V to 5.5 V, low power consumption, and an input clock that operates at up to 20 MHz

The PIC16F877A pin configuration five bi-directional input/output ports on a microcontroller are categorized as follows: A is a general-purpose 6-bit port that can be Also set up as an analog to digital converter (A/D); port E is a 3-bit port, whereas ports B, C, and D are 8-bit general purpose ports. These ports are used to send command signals or data to output devices, such as LCD, 7-segment, LED, motor driver, relay, etc., or to receive data generated by keypads, sensors that are push buttons, switches, etc.

2.2.2 LCD display

Figure.3. LCD display

The Liquid Crystal Display (LCD) is a versatile, power-efficient flat-panel display that may be a wide range of digital and electronic circuits for simple programmability. It uses a matrix construction where the intersection of two electrode buses is where the active element, which creates the pixel cell, lies. The constructed prototype's 16x2 LCD, in particular, can show data across two lines with 16 characters each. In reality, there are two types of registers that are used to setup an LCD the command register is suggested for control instructions such initializing the LCD, clearing the screen, adjusting the cursor location, and managing the display. The ASCII code of the characters that instantly appear on the display data register is stored data register, though. Adding information to this register.

2.2.3 IR SENSOR:

An infrared sensor is an electronic device utilized for detecting objects by measuring either their heat or motion. It operates by emitting or receiving infrared radiation, which is invisible to the human eye. The mechanism is straightforward: when the IR radiation emitted by the LED reaches the photodiode, the output voltages change based on the magnitude of the IR light, typically toggling between 5V and 0V.

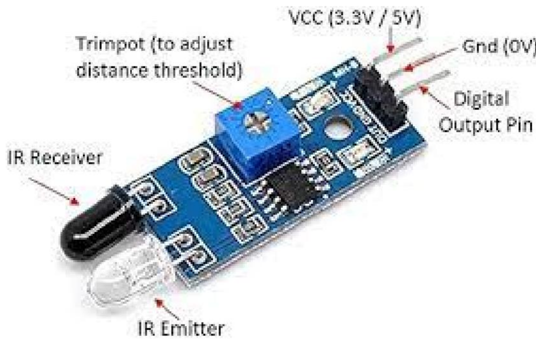

Figure.4. IR SENSOR

A fundamental principle is that black absorbs most incident radiation, while white reflects it entirely. The components of an IR sensor typically include an IR LED, a photodiode, a potentiometer for sensitivity adjustment, an operational amplifier (Op-Amp) for signal amplification, and an LED for indication. In the context of traffic lights, there are three universally recognized colours: The green light permits traffic to proceed in the designated direction. The yellow light serves as a warning for vehicles to prepare for a brief stop. The red signal prohibits any traffic from advancing This setup ensures regulated traffic flow and safety at intersections**.**

FiGURE 5: traffic light

When an flow of electric current occur a light-emitting diode (LED), a semiconductor device, it creates visible light. The LED system in this setup is a smaller version of an actual traffic signal system. Electronic componentas LEDs, or light-emitting diodes, release light when an electrical current flows through them. They can emit light in a range of hues, including red, green, yellow, and white, and are widely used in displays, lighting, and other applications. Indicators also come in a number of sizes and shapes. Brighter LEDs produce higher lumen values, which are commonly measured in lumens. Direct current (DC) is normally used to power LEDs, and a resistor is needed to limit the amount of current that may pass through them. The operating voltage of the LED and the desired current are used to calculate the resistor value. The energy efficiency of LEDs is one of their key benefits. They can function for thousands of hours with relatively little electricity. They may be utilized in a range of applications, such as displays, signage, automotive lighting, and lighting, and they are also incredibly resilient, vibration-free, and shock-resistant. Additionally, they are frequently utilized as indications on electronic gadgets including laptops, cell phones, and household appliances

III. RESULT & DISCUSSION

Before hardware, we can simulate and view the output with the help of the software called Proteus Design ISIS Professional, as shown in below.

The system controls the LEDs to the sequence of a typical traffic light, including red, yellow, and green phases for each direction. Then, it utilizes IR sensors to detect the presence or absence of objects, simulating traffic approaching from different directions. Next, the duration of the green light for a specific direction adjusts based on continuous activity detected by the corresponding sensor. If there's no continuous activity for a predefined time, the system switches to the next phase to simulate low traffic density. Finally, an LCD display provides essential information, such as the current status of the traffic lights for the running direction, enhancing user understanding and facilitating monitoring of the system's operation.

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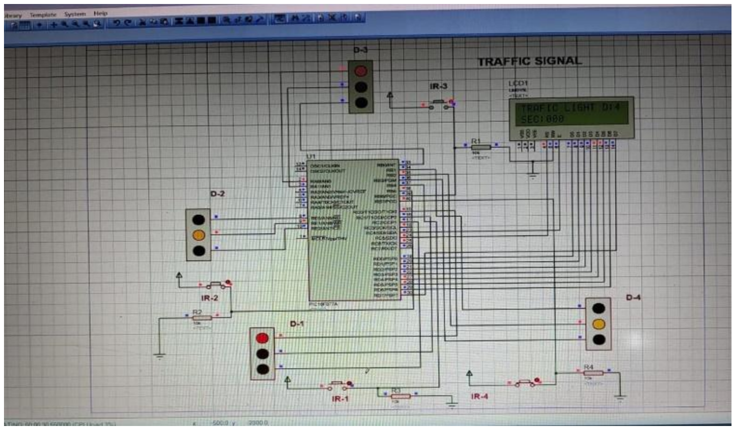

Figure.6. Simulated Output

IV. CONCLUSION

The proposed system represents a holistic approach to managing traffic flow in urban settings, combining real-time data collection, intelligent algorithms, and dynamic adjustment mechanisms. At the heart of this system are infrared (IR) sensors installed at each intersection, continuously monitoring traffic by detecting vehicles and gauging traffic density. These data streams are then processed by sophisticated algorithms, meticulously analyzing traffic conditions to determine optimal traffic light timings for each intersection.

The system's adaptability shines through its dynamic adjustment mechanism, which prioritizes directions with lighter traffic density to ensure smoother flow. It promptly responds to changing traffic conditions, seamlessly transitioning to the next signal sequence. Through this agile approach, traffic light timings are optimized in real-time, with longer green light durations allocated to less congested directions and shorter durations for busier routes. This proactive management aims to significantly enhance traffic flow efficiency, minimizing delays and improving overall urban mobility.

By mitigating congestion, the system addresses a key urban challenge, leading to reduced travel times, decreased fuel consumption, and lower emissions. Moreover, its impact extends beyond mere traffic management, with potential benefits in streamlining commuting, encouraging public transportation usage, and fostering a more sustainable urban environment.

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