Fuzzy logic-based Control for Intelligent Traffic Systems

Fuzzy logikán alapuló vezérlés intelligens közlekedési rendszerekhez

Ahmed Alareqi*, Ahmed Douzi*, Judit Lukacs**
*Óbuda University, Doctoral School on Safety and Security, Budapest, Hungary
** Óbuda University, Donát Bánki Faculty of Mechanical and Safety Engineering, Budapest, Hungary
ahmedalareqi@outlook.com; ahmeddouzi1993@gmail.com; lukacs.judit@bgk.uni-obuda.hu

Abstract — **In the realm of traffic management, conventional systems often rely on manual intervention at junctions, leading to inefficiencies and stress for commuters. This manual approach causes mental strain for passengers and results in significant fuel wastage due to delays at traffic junctions. Intelligent Traffic Systems (ITS) have long been recognized as effective tools for mitigating traffic congestion and improving traffic flow. By combining hardware and software techniques, ITS can monitor traffic movements and optimize signal timings to alleviate congestion. The cost-effectiveness of ITS is significantly influenced by the method used for traffic data collection. Utilizing ultrasonic and IR sensors for traffic flow measurement has been proposed as a means to reduce installation and maintenance expenses while enhancing system efficiency. This paper presents the design and implementation of an intelligent traffic lights controller utilizing fuzzy logic. By integrating roadside sensors and an Arduino Mega interface with ultrasonic sensors, the system dynamically adjusts traffic signals to manage congestion effectively. Implementing this system at intersections not only eliminates the need for manual traffic control but also reduces overall wait times compared to traditional traffic control systems.**

Keywords: Fuzzy logic, Intelligent Traffic Systems, Arduino, smart traffic lights controller, ultrasonic sensors.

Összefoglalás — **A forgalomirányítás területén a hagyományos rendszerek gyakran a csomópontokban történő manuális beavatkozásra támaszkodnak, ami hatékonyságvesztéshez és a ingázók számára stresszhez vezet. Ez a manuális megközelítés mentális terhelést okoz az utasoknak, és jelentős üzemanyag-pazarlást eredményez a forgalmi csomópontokban tapasztalható késések miatt. Az Intelligens Közlekedési Rendszerek (ITS) régóta elismert hatékony eszközök a forgalmi torlódások enyhítésére és a forgalom javítására. Hardveres és szoftveres technikák kombinálásával az ITS képes figyelemmel kísérni a forgalom mozgását és optimalizálni a jelzések időzítését a torlódások enyhítése érdekében. Az ITS költséghatékonyságát jelentősen befolyásolja a forgalmi adatok gyűjtésére használt módszer. Az ultrahangos és infravörös (IR) érzékelők alkalmazása a forgalom mérésére javasolt, mint az telepítési és karbantartási költségek csökkentésének, valamint a rendszer hatékonyságának növelésének eszköze. Ez a tanulmány egy intelligens közlekedési lámpa vezérlő tervezését és megvalósítását mutatja be, amely fuzzy logikát alkalmaz. Az út menti érzékelők és egy Arduino Mega interfész ultrahangos érzékelőkkel történő integrálásával a rendszer dinamikusan állítja be a forgalmi jelzéseket a torlódások hatékony kezelésére. Ennek a rendszernek a kereszteződésekben történő bevezetése nemcsak megszünteti a manuális forgalomirányítás szükségességét, hanem a hagyományos forgalomirányítási rendszerekhez képest csökkenti az általános várakozási időket is.**

Kulcsszavak: Fuzzy logika, Intelligens közlekedési rendszerek, Arduino, intelligens közlekedési lámpavezérlő, ultrahangos szenzorok

1 INTRODUCTION

Traffic lights are mainly utilized to regulate and coordinate movement among vehicles. Every day, traffic congestion issues increase as a result of the increasing number of fixed-frame vehicles on the road. The existing clock-based traffic light systems are categorically ineffective for controlling traffic in this circumstance. The traffic lights guarantee that vehicles can pass through the intersection in a systematic way from all directions. The traffic signal lights are typically set to turn on and off at specific times. But in daily life, we see that traffic on a two-way road is typically heavier on one side than the other. In this case, scheduling equal amounts of time for both types of traffic leads to congestion during peak traffic hours and causes traffic delays.

There are many ways to reduce traffic congestion; one of them is to inform the driver about the actual cause of the traffic [1], this is not the best solution, so a framework for continual traffic control that adjusts the traffic signal based on traffic density is needed to address this problem.

The current traffic signal control system uses postponements, where the sign change timings are predetermined and independent of the flow of traffic. In order to resolve the major traffic jam difficulties, the current traffic density should be increased. So, to address several problems and enhance the trafficking framework, An intelligent traffic signal framework is presented.

Using ultrasonic sensors and IR sensors located on each side of the road, and an Arduino MEGA 2560 Microcontroller, which is a key component of the framework, helps to control the traffic automatically.

There is excessive and unnecessary waiting time on the roads, and vehicles use more fuel, because of the predetermined time gaps between green and red lights. This ultimately contributes to environmental degradation and causes several health problems for those living nearby and traveling nearby. Additionally, these traditional traffic light control systems lack any options for providing data on traffic volumes on different roadways, which causes traffic jams.[2]

The transportation industry has just recently begun to conceptualize congestion in this way. However, this is essential because different methods must be developed to deal with each congestion source, and these techniques can differ greatly from one highway to another. Fig.1 shows a graphic representation of the estimated national contribution of each of these sources to overall congestion. These figures are approximations based on a variety of previous and continuing research investigations.

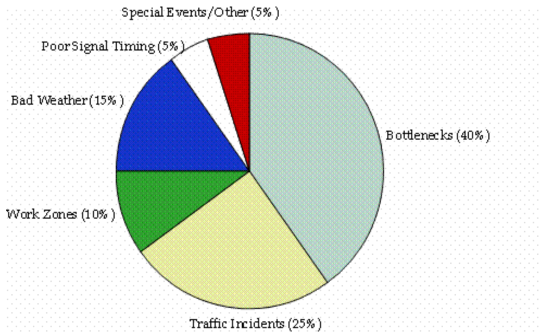

Fig. 1: The sources of congestion national summary [3]

The reliability of travel times is another growing issue. One important factor in the congestion issue is the daily change in travel times. Travel delays do not always result in the same amount of additional travel time or disruption to the day or system. It affects not only commute travel but also every trip made during peak travel times, and it is a major worry for both big and small businesses across the board. Agencies can determine the additional travel time that must be allocated—or buffer time—above the normal travel time using extremely comprehensive data from some urban freeways. Congestion has a direct impact on the amount of time that shippers, carriers, business travelers, commuters, and homeowners must budget for.

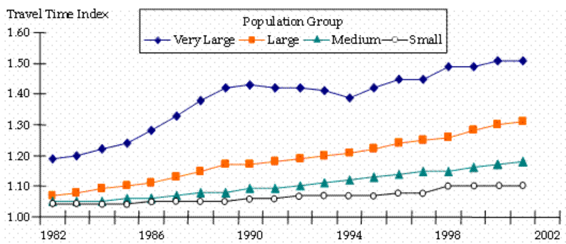

Fig. 2: Peak-Period Congestion (Travel Time Index) Trends by U.S. Population Group [3]

In this paper, the implementation of an intelligent traffic lights control system using fuzzy logic technology, capable of mimicking human intelligence in controlling traffic lights, is discussed. A hardware model has been developed to simulate an isolated traffic junction. Analyses such as waiting time, density, cost, etc., can be performed using the hardware. Additionally, the hardware model can serve as an educational tool for undergraduate and graduate students to grasp the concept of fuzzy logic and its real-world applications.

This paper has been organized as follows. First, a brief overview on traffic lights control system is presented. Then, the Literature review and already existed solutions. After that, development of the hardware model and its usage is next discussed. A comparison between the performance of the fuzzy traffic lights controller and the conventional fixed-time controller is analyzed and discussed in the section that follows. Slower speeds, longer travel times, and higher vehicular queuing are the hallmarks of the transport condition known as traffic congestion. Congestion occurs when transportation demand is high enough that interactions between cars slow down the flow of traffic

2 Literature review

Accuracy in the collection of traffic data, such as traffic flow, speed, and density, is one of ITS's most important features. The system uses the data as input to make the appropriate judgments. In order to assess traffic conditions like congestion and backups, the number of vehicles and their rate of movement during a given time period in the road networks is typically utilized as a technique. This has given rise to a wide variety of techniques for recording vital information about traffic flow on a road network. In a document titled "Vehicle Sensing: Ten Technologies to Measure Traffic," ten (10) vehicle sensing technologies were covered. Manual counts, video vehicle detection, pneumatic road tube counting, piezoelectric sensors, inductive loops, magnetic sensors, and other methods were covered. The manual and automatic vehicle detection approaches can be classified into two major categories at once. Zheng and Mike[4], who conducted a thorough investigation of the manual counting of vehicles, came to the conclusion that the method can be successful with the exception of the classification of vehicles, which is susceptible to error.

Automatic vehicle counting counts the number of moving cars along a road using a variety of hardware and software technologies. The hardware used for data acquisition and the algorithm used to process the data once it has been acquired in order to extract the required information from it generally make up the system's strength. This field is active because of problems with sensing device accuracy, installation methods, energy consumption, installation maintenance costs, and the impact of the environment on performance[5].

The Peripheral Interface Controller (PIC) Microcontroller was introduced by R. Weil, J. Wootton, and A. Garcia Ortiz in 1998[6]. As an intelligent traffic signaling system based on traffic density. The total number of cars in the memory is saved by this system in real time. The microcontroller transmits the collected data in its entirety to a computer. To reduce traffic jams, the person who has full access to the computer at the main station will be aware of all the traffic conditions pertaining to any active traffic light on the nearby street. Future versions of this system will be able to inform drivers about the flow of traffic in various locations, but it will also require human input to determine which road should be opened, which will be determined by human assessment.

Research on traffic systems based on traffic density is presented in "K. Thatsanavipas, N. Ponganunchoke, et al.," 2010 [7]. It is based on image processing methods such as edge detection to identify the density of traffic that emerges from the current traffic signaling system, as shown in fig.2.

The key benefits of developing a smart system for traffic control include the decrease of congestion, lower operating costs, providing drivers with alternate routes, and finally, the development of high-capacity infrastructure. Generally, it's a complicated system and also too expensive due to the use of a high-quality camera and the operation of installing it on roads, besides the need for a high computing machine if compared with the proposed sensors' prices and installation method.

The traffic control system based on traffic density will be constructed using an infrared [IR] sensor that will determine the green light time interval using a microcontroller, according to Wanjing Ma and Xiaoguang Yang, 2008,[8].

The sensor will be placed on the sides of the road, where it will look for cars before sending the information to the microcontroller. The microcontroller will choose the duration of the red and green light cycles based on the fuzzy controller. So, the timing of the traffic light delay here will be determined based on the number of cars and the queue.

Roswan Latuconsina, Tito Waluyo Purboyo, and Moch Agung Prasetyo (2018)[9] introduced another system that was similar to ours but quite different in terms of cost. The proposed system consists of three ultrasonic sensors placed along each road to measure the level of traffic congestion and report the situation to the microcontroller as follows: the first sensor indicates light traffic, and the second indicates a normal traffic jam. The third indicates heavy traffic, which prompts a change of the traffic light to decrease traffic congestion.

According to the previously examined literature, the current systems have used an infrared (IR) sensor or several ultrasonic sensors for the traffic control system, which has a disadvantage or a challenge. The difficulty in using numerous ultrasonic sensors to measure the amount of traffic on the road and send the situation to the microcontroller consequently The first sensor indicates light traffic. The Second Senator stands for a typical traffic jam. The third position denotes heavy traffic, which prompts a change in the traffic lights to ease the gridlock Another issue with using three ultrasonic sensors for each road is their price.

3 METHODOLOGY

This section, the main components, which were used in this paper, are going to be explained. Also, the fuzzy controller will be briefly explained. The main components are Arduino Mega microcontroller,Ultrasonic sensor,Traffic LEDs, infrared (IR) sensor, and Fuzzy controller

3.1 Arduino Mega

Arduino Mega was used to provide sufficient digital I/O; using an Arduino UNO with extra extensions was a possible solution, but the Arduino Mega was chosen to simplify the wiring and assembly process in Fig.[3].

The Atmega 2560 microprocessor is the foundation of the open-source Arduino board, a microcontroller board. The processing or wiring language is executed by this board's growing environment. With a user-friendly platform that allows anyone with little to no technical background to start by learning some necessary skills to program and run the Arduino board, these boards have revitalized the automation sector. These boards can be connected to PC programs like MaxMSP, Processing, and Flash, or they can be utilized to extend distinct interactive items. The ATmega2560 microcontroller is essential for microcontroller boards like the "Arduino Mega." It has 54 digital input/output pins, of which 16 are used as analog inputs and 14 as PWM outputs. There are also four hardware serial ports (UARTs), a 16 MHz crystal oscillator, an ICSP header, a power jack, a USB port, and an RST button. This board primarily contains all of the components required to support the microcontroller. Therefore, this board's power supply can be accomplished by using a USB cable to link it to a PC, a battery, or an AC-DC adapter. A base plate can be used to shield this board from an unexpected electrical discharge.[10]

Fig. 3: Arduino Mega Microcontroller[11]

3.2 Ultrasonic sensor

The HC-SR04 Ultrasonic Sensor is a very reasonably priced proximity/distance sensor that has primarily been utilized in robotics applications for obstacle avoidance in .Additionally, it has been utilized as a parking sensor, a water level sensor, and in turret applications. The popular HC-SR04 Low-Cost Ultrasonic Sensor has been updated with this module.

This new version of the HC-SR04 has a wider input voltage range, allowing it to work with controllers that operate on 3.3V, in contrast to the first-generation model, which could only operate between 4.8V and 5V DC. The HC-SR04 ultrasonic sensor offers a very simple and inexpensive way to measure distance.

Sonar is used to measure distance; the device emits an ultrasonic pulse (about 40 kHz) that is much above human hearing, and the target's distance is calculated by timing how long it takes for the echo to return. This sensor comes in easy-to-use packaging and provides excellent range accuracy and reliable readings. The sensor may be easily prototyped by connecting it to a solderless breadboard using an onboard 2.54 mm pitch pin header.

The Trig pin must be set to a High State for 10 s in order to produce the ultrasonography, resulting in an emitted ultrasonic burst of 8 cycles that will move at the speed of sound. Once that 8-cycle ultrasonic burst is emitted, the Echo pins will immediately go high and begin to listen for, or wait for, the wave to be reflected from something.

If there is no object or reflected pulse, the echo pin times out after 38 milliseconds and returns to the low state. Conversely, if a reflected pulse is received, the echo pin will close earlier than those 38 milliseconds. The duration for which the echo pin remained HIGH, as depicted in Fig.[4], allows for the calculation of the travel distance of the sound wave and, consequently, the distance between the sensor and the object.

To calculate this distance, the following basic distance calculation formula is utilized:

$$\text{Speed } x \text{ Time } = \text{ Distance} \quad (1)$$

Fig. 4: ultrasonic sensor [11]

In this project, the function of the ultrasonic sensor is to detect the cars and give us information on the existing cars waiting for traffic.

3.3 Traffic LEDs

An LED (light-emitting diode) traffic light may alter and encode information in its visible light. It can therefore be used to transmit audio messages or other traffic or road-related information. To a large extent, all LED traffic lights can function as communication tools.

This mini traffic light display module shown in Fig.[5] has high brightness and is perfect for making models of traffic light systems.

It is distinguished by its compact size, straightforward wiring, and targeted and personalized installation. A PWM connection can be made to adjust the LED's brightness.

Fig. 5: Mini traffic light

Insert the figures and tables into the text, right after the sentence which first mention these.

3.4 IR sensor

An infrared (IR) sensor operates by emitting and detecting infrared radiation, primarily for obstacle detection. The main components of an IR sensor include an IR transmitter, a receiver, an operational amplifier (Opamp), a variable resistor, and a light-emitting diode (LED). The IR transmitter, which is an IR LED, emits light within the infrared frequency range. IR light is invisible to the human eye as its wavelength (700 nm – 1mm) is much longer than that of visible light, and it typically emits at an angle between 20-60 degrees, covering a distance from a few centimeters up to several feet in Fig.[6].

The receiver portion of the sensor is a photodiode that acts as the IR receiver, detecting the IR light that is reflected back. This photodiode is distinctively coated black on its outer side. Within the sensor, the Opamp functions as a voltage comparator. The variable resistor plays a role in calibration, allowing adjustment of the distance at which objects are detected by the sensor. [12]

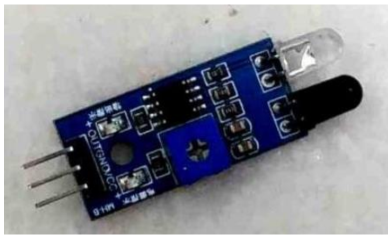

Fig. 6: infrared (IR) sensor [12]

3.5 Power supply

The Mean Well RS-15-5 enclosed power supply 5V / 3A, a 15W single output switching power supply, was used in my project. This power supply features an all-purpose AC input and a full range of safety measures including overload protection, overvoltage protection, and over-temperature protection. It employs free air convection cooling and underwent a 100% full load burn-in test. Features also include an LED indicator as seen in Fig.7 and the use of long-life 105°C capacitors that can withstand a 300-volt surge for five seconds. It has a high operating temperature, reaching 70°C, resists 5G vibration at all times, and offers great reliability, longevity, and efficiency.

Fig. 7: Mean Well RS-15-5 power supply

4 DESIGN CRITERIA AND CONSTRAINTS

After some research was conducted and existing solutions were reviewed, the conclusion was reached that the best approach for a traffic control system is to utilize roadside sensors with fuzzy logic controller. These sensors monitor traffic flow and determine whether it is normal or congested, with traffic light timings adjusted accordingly based on the road conditions. This field is active as a result of various cases, inaccurate sensor measurements, and increasing traffic congestion in expanding and large cities.

4.1 Fuzzy logic controller

Fuzzy Controller is a mathematical controller that deals with dynamic systems. It contains three parts: the input part, the process part, and the output part. Input parts, called fuzzification, read analog signals that transform from sensors such as pressure, sound, temperature, … etc., or digital signals like ON, OFF switches and convert it to membership function. The process part is the most important part which can be designed by experiment. In this part, the rules of the controller are generated, and they will be translated to the output port of the fuzzy controller. The final part is the output which consists of the defuzzification that converts the analyzed result into the specific output value [13]. A fuzzy logic system is shown in Fig. 8.

The controller utilizes two fuzzy input variables: the volume of traffic approaching the intersection (Arrival) and the volume of traffic waiting (Queue). When the north and south sides are green, they represent the arrival side, whereas the west and east sides function as the queuing side, and the roles reverse accordingly. The output variable from the fuzzy logic controller is the additional time required for the green light on the arrival side (Extension time) as seen in Fig.12 . Therefore, based on the prevailing traffic conditions, fuzzy rules are established, directing whether the controller should extend the current green light duration. If there is no extension, the traffic light state will promptly transition, allowing traffic from the alternate direction to proceed.

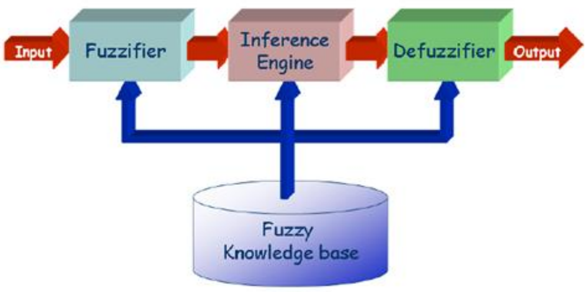

Fig. 8. Overview diagram of a fuzzy system [13]

4.1.1 Input and Output Membership Functions

For controlling the traffic lights, the system employs four membership functions for each input and output fuzzy variable. Table 1 displays the fuzzy variables for Arrival, Queue, and Extension. Abbreviations on the right-hand side are used to succinctly represent these variables.

Table 1: Fuzzy variables of arrival, queue and extension of the traffic light control.

Input				output	
Arrival		Queue		Extension	
Almost	AN	Very Small	VS	Zero	Z
Few	F	Small	S	Short	S
Many	MY	Medium	M	Medium	M
Too Many	TMY	Large	L	Longer	L

Fig.9,10,11 displays the graphical representation of the membership functions for the linguistic variables used. The y-axis measures the membership degree of each fuzzy variable. On the x-axis, the universe of discourse for input fuzzy variables is represented by quantized sensor signals that measure the quantity of cars. For the output fuzzy variable, the universe of discourse denotes the duration to be added in seconds. According to Fig.9,10,11, 10 cars linked for the "Too Many" or "Large" fuzzy subsets in this simulation and receive full membership. For the "Many" or "Medium" fuzzy subsets, full membership consists of 7 cars. Regarding the output fuzzy variable, a full membership in the "Long" category corresponds to approximately 10 seconds, while a "Medium" category correlates with about 7 seconds. The setup of these membership functions is tailored based on expert analysis of the system and its environment. However, the width and center points of the membership functions for these fuzzy subsets are adjustable and can be customized to match varying traffic conditions. For instance, in cases where a junction is overly congested, the count for cars within the "Too Many" or "Large" fuzzy subset should be increased. Conversely, the width of the membership functions should be narrowed in scenarios with less congestion.

Fuzzy logic control facilitates a seamless transition from one fuzzy subset to another, smoothing out changes between control actions, thereby necessitating overlapping of these subsets. Without some degree of overlap, the control actions may become too binary or step-like in nature. However, excessive overlap can introduce unnecessary fuzziness, obscuring clear distinctions between control actions. A pragmatic approach typically involves overlapping the fuzzy subsets by approximately 25%.

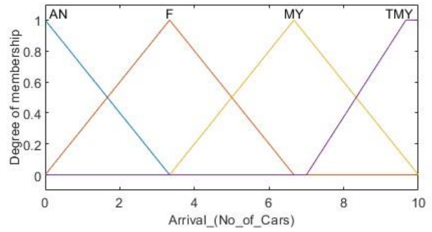

Fig. 9: Graphical representation of membership functions of the Input-1 of fuzzy logic controller.

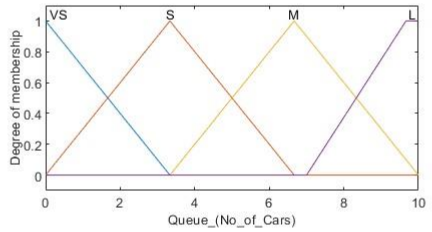

Fig. 10: Graphical representation of membership functions of the Input-2 of fuzzy logic controller.

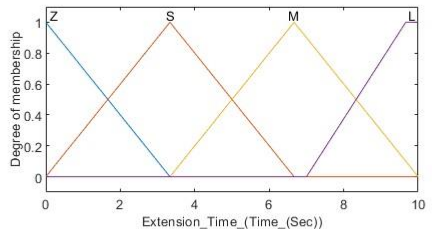

Fig. 11: Graphical representation of membership functions of the Output of fuzzy logic controller.

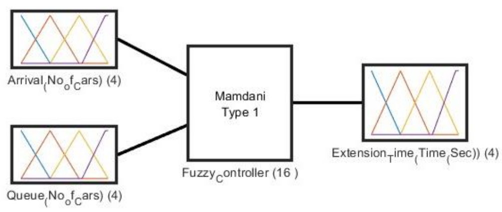

Fig. 12: Design of fuzzy controller

4.1.2 Fuzzy Rule Base

The inference mechanism in the fuzzy logic controller mirrors the human reasoning process, linking fuzzy logic technology with artificial intelligence. Humans naturally apply rules when executing actions, much like a traffic policeman managing a junction, for instance, from the north and west directions. He would rely on his expert judgment to control the traffic, generally in the following manner:

IF traffic from the north of the city is HEAVY

AND traffic from the west is LESS

THEN allow movement of traffic from the north LONGER

IF traffic from the north of the city is AVERAGE

AND traffic from the west is AVERAGE

THEN allow NORMAL movement of traffic for both sides

The advantage of fuzzy logic lies in its ability to employ approximate reasoning with terms like HEAVY, LESS, AVERAGE, NORMAL, LONGER, and so on. Thanks to the techniques for assigning membership, as previously discussed, these linguistic variables, despite their fuzzy characteristics, can be effectively managed within a computer using fuzzy logic technology.

In the development of the fuzzy logic controller, we use almost similar rules and below are some examples: If there are too many cars (TMY) at the arrival side and very small number of cars (VS) queueing then extend the green light longer (L). If there are almost no cars (AN) at the arrival side and very small number of cars (VS) queuing then do not extend the green light at all (Z).

These rules can be shorten as follows:

- IF Arrival is TMY AND Queue is VS THEN Extension is L
- IF Arrival is F AND Queue is VS THEN Extension is S
- IF Arrival is AN AND Queue is VS THEN Extension is Z

In this context, "Arrival" and "Queue" serve as the antecedents, while the "Extension" of the green light acts as the consequent. Such rules can be formulated based on the traffic conditions at the junction, and a matrix can be used to succinctly display these rules. The matrix's size, or the total number of rules, corresponds to the possible input combinations, which are calculated from the number of membership functions per input. For instance, in the traffic control system, with two inputs each possessing four membership functions, the total number of rules would be sixteen. While it might not be necessary to utilize all rules in the matrix bank for many applications, for this specific application, filling up all the rules is essential.

4.1.3 Inference Engine and Defuzzification

In the fuzzy logic controller, once the relevant rules are activated, the membership degree of the output fuzzy variable, namely the Extension time, is established by encoding the antecedent fuzzy subsets, specifically Arrival and Queue, in this instance. The traffic lights fuzzy control system employs the max-min implication technique [14]. This technique determines the final output membership function for each rule by clipping the true value degrees of the membership functions linked to the antecedents. After the membership degree for each output fuzzy variable is ascertained, all activated rules are aggregated, and the precise, crisp output is derived through the process of defuzzification. There are various methods of defuzzification, and for this development, the center of gravity defuzzification technique is utilized.

4.2 Flowchart

A flowchart is a diagram that shows how a system, computer algorithm, or process works. They are frequently used in many different fields to examine, organize, enhance, and convey frequently complex processes in simple, understandable diagrams. As shown in Fig.13:

- The system will operate and read data from IR sensors and ultrasonic sensors by Arduino Mega.
- Data for the four directions will be sent to the fuzzy controller in MATLAB using serial data connection.
- Based on fuzzy controller rules, the output of the controller will be sent back to Arduino.
- Arduino Mage will change the timing of the traffic lights according to data which been sent from the fuzzy controller.

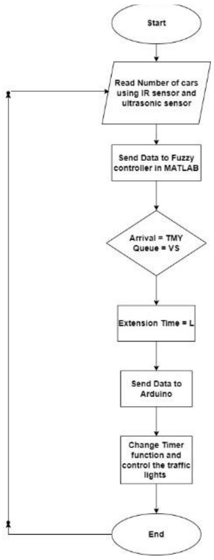

Fig. 13: Flowchart of the system

4.3 Hardware

The concept for this project came from an existing system that consists of sensors for object detection and a microprocessor that system has software installed to enable it to function.

A 50 x 30 cm table divided into two sections is utilized. Drilling could have been done to conceal the wires beneath the table, but it was decided against. Instead, the wires were placed along the table's edges, as shown in Fig. 14.

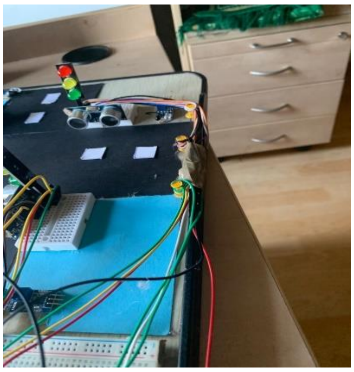

Fig. 14: wiring connection

Five volts and ground are connected to the Arduino Mega to establish the system's power supply. This power supply facilitates easy access to power wherever electricity is available and simplifies the wire connections. To ensure short wiring, two whiteboards were placed beside the Arduino Mega.

Fig. 15: 3D model of the system

Each ultrasonic sensor and IR sensor is placed beside its corresponding traffic LEDs on a small whiteboard, allowing for the observation of object detection and the corresponding changes in the lights, as illustrated in Fig. 15 and in Fig.16.

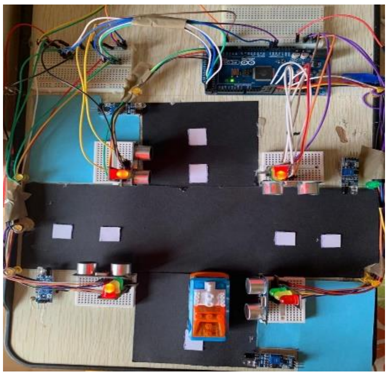

Fig. 16: Constructed system in prototype

5 DISCUSSION AND RESULTS

The working of the project is described in two tests:

5.1 *Test 1: Fixed-Time Model*

It is a description of the current normal state of the roads that expresses the constant duration of the signal for the regular opening of each traffic light in order with a pre-established time limit 20 second for the opening of each signal.

5.2 *Test 2: Smart-Time-Fuzzy-Logic Model*

This system chosen will route depend on the highest number of vehicles in any route, as seen in Fig.17. The route has highest number of vehicles their route will be open first and so on. If there are two routes have the same number of cars the light open for the route that have less than time. The same route can't be open twice in the same turn even if it has the highest number of vehicles. If there is no vehicle in all routes the light is become red. Counter time is flexibility change depend on the volume of traffic approaching the intersection (Arrival) and the volume of traffic waiting (Queue).

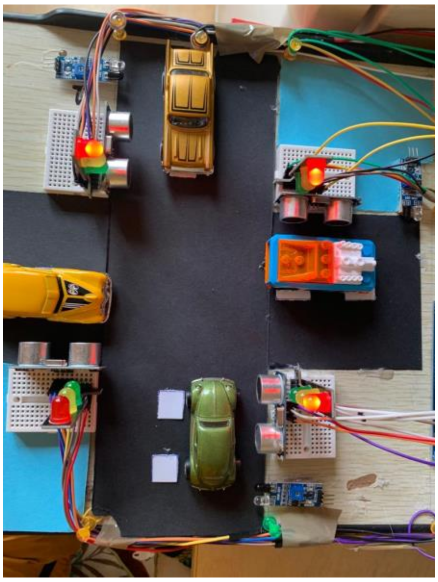

Fig. 17: Smart-Time-Fuzzy-Logic Model

6 CONCLUSION AND FUTURE WORK

Classical traffic signal systems rely heavily on a traffic police officer to regulate and control traffic in accordance with traffic density. There have been numerous studies done to estimate or calculate traffic density and then use a sensor to adjust traffic signals depending on that information. In addition, some traffic management systems use image processing to estimate traffic density.

The fuzzy logic traffic lights controller outperforms both the fixed-time controller and vehicle-actuated controllers due to its greater flexibility. This flexibility pertains to the number of vehicles detected at the approach to the junction and the subsequent extension of green time. In the case of a fixed-time controller, an open-loop system, the green time does not extend regardless of the density of cars at the junction. Vehicle-actuated traffic light controllers, which are advanced versions of fixed-time controllers, do allow for the extension of green time whenever a vehicle is detected; however, these extensions are preset to certain limits, like an additional 5 or 10 seconds, up to a maximum time.

In contrast, the fuzzy logic controller does not use fixed extension times. Instead, it operates with fuzzy variables for extension times, such as long, medium, or short. Furthermore, the number of cars detected by the controllers are also translated into fuzzy values like very small, small, medium, or too many. Additionally, the fuzzy controller benefits from using linguistic rules that mimic human decision-making, akin to how a traffic policeman would manage the flow at a typical junction. The reasoning method in the fuzzy controller similarly reflects the intuitive tactics employed by humans in controlling traffic.

Future work for the fuzzy logic-based traffic control system could explore integrating machine learning for predictive traffic optimization and adapting fuzzy rules dynamically. Real-time data from GPS, social media, and crowdsourced apps could enhance decision-making, while Vehicle-to-Infrastructure (V2I) communication could further optimize signal timings. Testing the system in diverse, real-world environments and integrating public transport data would improve robustness. Additionally, future studies could focus on scalability for smart cities, energy efficiency, and reducing environmental impact, making the system more adaptable and efficient in managing urban traffic.

REFERENCES

[1] A. P. R. L. Richard Arnott, „Transportation Research," pp. 309-318, September 1991.

[2] S. M. Shinde, „Adaptive traffic light control system," in International Conference on Intelligent Systems and Information Management (ICISIM), Aurangabad, India, 2017.

[3] U. d. o. transportation, „Traffic Congestion and Reliability: Linking Solutions to Problems," Federal highway adminstration , United States, 2017.

[4] M. PengjunZhenga, „An investigation on the manual traffic count accuracy„" in International conference on traffic and transportation studies, 2012.

[5] U. D. o. transportation, „A Summary of Vehicle Detection and Surveillance Technologies use in Intelligent Transportation Systems," https://www.fhwa.dot.gov/policyinformation/pubs/vdstits2007/05pt2.cfm.

[6] J. A.-O. R.Weil, „mathmetical and comuputer modeling," Traffic incident detection: Sensors and algorithms, pp. 257-291, may-june 1998.

[7] N. P. e. a. K. Thatsanavipas, „Wireless Traffic Light Controller," in International Science, Social Science, Engineering and Energy Conference„ Nakhonphanom, Thailand., 2010.

[8] S. V. M. Ashok. P.V, „International Journal of Applied Engineering Research," %1. kötet12, 2017.

[9] Hamara Chaudhuri, Nishanth P Raikar, „Traffic Control Management with help of State of Control Algorithm using Ultrasonic Sensors & GSM Technology," International Research Journal of Engineering and Technology, %1. kötet05, %1. szám04, 2018.

[10] *The Arduino Mega 2560*. (2024, March 11). https://docs.arduino.cc/hardware/mega-2560/.

[11] Ultrasonic Sensor HC-SR04 and Arduino – Complete Guide. (2017, April 11). https://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/.

[12] Mullapudi, Chaitanya. (2020). Implementation of Arduino-Based Counter System. International Journal of Engineering and Technical Research. 9. 10.17577/IJERTV9IS090456.

[13] Nour, Morsy & Said, Sayed M. & Ramadan, Hassanien & Ali, Abdelfatah & Farkas, Csaba. (2018). Control of Electric Vehicles Charging Without Communication Infrastructure. 10.1109/MEPCON.2018.8635277.

[14] Khiang, Kok & Khalid, Marzuki & Yusof, Rubiyah. (1997). Intelligent Traffic Lights Control By Fuzzy Logic. Malaysian Journal of Computer Science. 9. 29-35.