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ADVANCED WIRELESS VEHICLE USING INFRARED REMOTE TECHNOLOGY

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Abstract
The Wireless Remote-Controlled Vehicle is planned to be controlled with the help of an infrared (IR) remote and infrared receiver module which offers an effective and cost-effective robotic means of control. This system is composed of the Arduino Uno microcontroller that receives an IR signal sent by a conventional IR remote. When sent these signals, the encoded messages are decoded through the Arduino and cause the L298N motor driver module to turn on and off the speed and direction of the vehicle DC motors. The car is made up of two motors and wheels on a bare chassis to ensure easy forward, retrogression, left, and right movement. The IR control technique provides a reliable and short wireless communication over the distance and without interference. In this project, the practical use of embedded systems, wireless communication and control over motor movement in robotics is realized. It is user friendly and can be extended to more sensors to obtain further automation and avoidance of obstacles.

Keywords: Wireless IR control, Arduino Uno, IR receiver, L298N motor driver, DC motors, robot chassis, embedded systems, short-range communication, motor control, robotics automation.

1. Introduction

The recent years observed the evolution of robotics and embedded systems and hence design of low-cost and efficient systems of wireless control. The Wireless Remote-Controlled Vehicle with IR sensor is only one such application that offers a fast and dependable source of controlling the robots movement. The system consists of an infrared (IR) remote and receiver unit to transmit and receive the signals, and the received signals are processed using a microcontroller such as the Arduino Uno, which also coordinates the motion of the motors with the help of a motor driver. This approach is widely used in educational and beginner-level robotics due to its simplicity, affordability, and ease of implementation. In the contemporary automation systems, wireless technologies of communication play a very important role. IR communication has provided an effective solution at short range (compared to other wireless approaches) at low costs, and without interference. Embedded system and wireless housing provide real-time response and effective operation of robotic cars. They can also be extended to obstacle detection sensors and automation to make such systems applicable in many real-life scenarios. Recent studies indicate that there is increasing significance of intelligent and automated systems. As an example, IoT-based monitoring solutions have been applied in the real-time data collection and the public health tracking in smart cities [1]. Likewise, self-charging autonomous robotic systems enhance efficiency in operation and decrease human intervention [2]. Monitoring systems with UAVs also reveal that there is the prospect of sophisticated technologies in the context of infrastructure checks and safety uses [3]. Also, wireless power transfer systems of electric cars demonstrate the growing tendency to automate and smart energy [4]. Moreover, the IoV-based vehicle control technology based on image-processing and speech-recognition can contribute to the vehicles being safer and more automated in the transportation [5]. In this way, the IR-based wireless vehicle system is a paradigm on which people can learn about current robotics and automation tools and how they can be improved and smartly used in the future.

1.1 Objectives

- To make a wireless remote controlled car using IR communication.
- To connect Arduino Uno to an IR receiver and motor driver.
- To regulate the velocity and motion of DC motors with the L298N motor driver unit.
- To have a moving vehicle (forward, reverse, left, right) using remote commands.
- To develop an affordable, easy-to-use robotic system, which can be enhanced to include sensors to automate and have obstacle avoidance.

1.2 Contributions of the work

- Developed a IR-controlled lowcost wireless robotic vehicle with a simple and reliable control method.
- Real-time signal decoding on Arduino Uno was used to ensure correct operation of the motors.
- Integrated L298N motor driver module in order to provide efficient control of the speed and direction of the DC motors.
- A compact and user-friendly system is designed that can be used by beginners on embedded systems and robotics.
- Delivered a scalable platform, capable of being expanded with sensors to support automation, detection of obstacles and advanced robot functions.

1.3 Organization of the Paper

The paper is systematically written to make it easy to understand how the wireless remote-controlled vehicle was designed and implemented. Section 1 presents the idea and purpose of the system, which is the necessity of the low-cost and efficient robotic control solutions. Section 2 proposes the literature review as it introduces available technologies and other works in the field of wireless communication and robotics. Section 3 outlines the designed system, the hardware aspect which includes Arduino Uno, IR receiver module, and the L298N motor driver module, and how the system should work. Section 4 describes methodology and system design, including connections in the circuit and control logic. Section 5 will comment on the prototype developed and the outcome gotten. Lastly, Section 6 ends the paper with the advancements in the future, including the addition of sensors to enhance automation and avoid obstacles.

2. Related work

One example of a smart pedestrian crossing is the design by **Saad et al.,(2020)**, who used Bluetooth and PIR sensors to create a smart wireless pedestrian crossing. The system is automated to regulate the traffic lights according to the presence of people to enhance security, minimize accidents and give a cost effective and efficient energy solution.

Muda et al.,(2024) designed the remote-controlled combat robot that was equipped with thermal detection and mines identification sensors. The robot allows bringing about more military safety since the risk to humans is minimized and they are able to perform real time surveillance and multi-task roles in hostile environments.

Garlow et al.,(2023) suggested the autonomous Magnetic docking and IR beacon UAV landing. The system facilitates the effective landing of moving platforms and facilitates self recharge, making the UAV missions more efficient in different environmental conditions.

Hong et al.,(2020) created an IoRT-based robot system on an EV3 kit and block-programmed. The much better creativity, problem-solving capabilities, and learning rate of learning robotics through the system is achieved by the use of ultrasonic sensors and mobile applications to control the system.

It was **Akpan et al.,(2021)** who created an autonomous car, which has obstacle detection, gas, and smoke sensors. The system offers real-time surveillance and alerts; it is based on IoT technologies which enhance safety within the risky environment and supplement surveillance applications.

Table 1 Comparison for related work

Ref. No.	Author & Year	Technology Used	Working Contribution	Result Achieved
11	Hong Xing (2023)	ISCC + Edge AI	Integrated sensing, computation, and communication for edge intelligence	Faster latency and energy usage, enhanced real-time processing.
12	Zhanserik Nurlan (2021)	WSN + WMN	Integration framework for wireless sensor and mesh networks	Better bandwidth, reliability and scalability.
13	Karolayne Teixeira (2023)	Machine Learning in UAVs	Survey of ML techniques in UAV applications	Determined significant areas and enhanced the UAV functionality.
14	P.Ilampiray (2021)	Arduino + Ultrasonic Sensors	Automated railway gate control system	Minimized accidents and manual operation has been removed.
15	S.Pragadeswaran (2021)	Wireless Sensor Networks (WSN)	Review of military applications of WSN	New surveillance, monitoring and defense systems.

Table 1. A comparative study of different works on it is given in Table 1 in regards to advanced technologies in IoT, wireless networks, and automation systems. All of these studies deal with various domains like the artificial intelligence of edges, wireless sensor networks, the application of UAV, and automated control systems. The table shows the technologies involved, significant contributions and contributions made by the various authors. It finds that most works are intended to enhance efficiency, reliability, and automation of real time systems. To give an example, ISCC implements edge processing or WSN integration can make the network performance better. By all, intelligent, low-latency, and scalable solution to the current-engineering applications is a developing tendency in the comparison.

3. *PROPOSED METHODOLOGY*

The new system is aimed at creating the wireless controlled vehicle that is remote controlled by using infrared (IR) communication. The entire process starts with an IR remote sending out coded signals based on what the user wants to do like forward, reverse, left, and right. An IR receiver module is mounted on the vehicle and receives these signals after which it is processed by the Arduino Uno. The Arduino interprets the signals sent by a handheld IR reader and converts it to particular motor control commands. Depending on the command decoded, the Arduino transmits control signals to the L298N motor driver module which controls the direction and speed of the DC motors. A motor driver is an interface between the low power microcontroller and high power motors which allows efficient and smooth movement of the vehicle. A battery supply used is to power the system, making it portable. The complete system is mounted on a chassis attached with two DC motors to move around. The methodology guarantees real-time response, valid communication and easy implementation. Also, sensors of obstacle detection can be added to the system and autonomous navigation is possible.

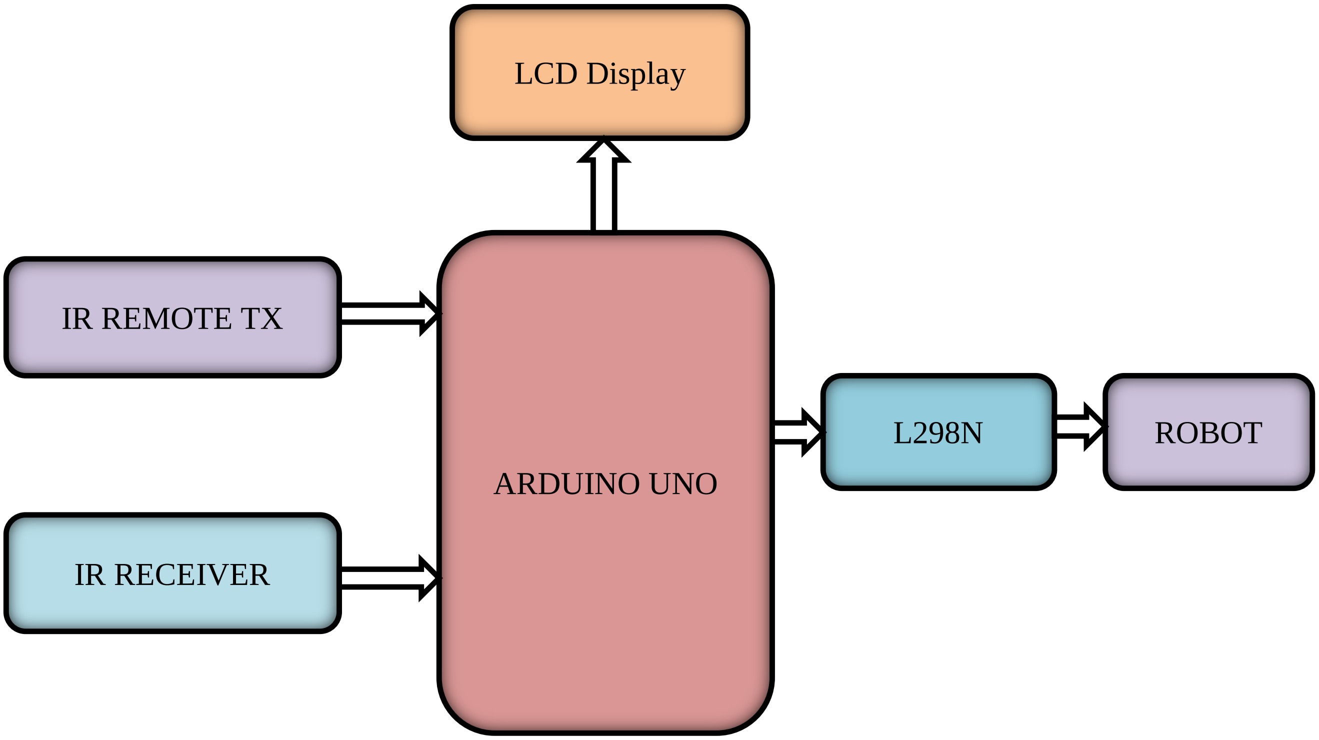

Fig 1: Block Diagram proposed methodology

3.1 Remote Sensing and Processing Operations

The proposed framework comprises two parts: a back-end part and a front-end part (comprising of vehicles with GPSs and thermal camera sensors). The remote sensing task workflow that is involved in the disease infection recognition is rather represented. It begins with the data collection and concludes with the decision making of whether there is need to have an intervention in order to check the spread of the infection. To be more exact, the following stages are taken into consideration.

Data acquisition stage: In detecting the suspected cases, the initial phase in the process is the data acquisition, which utilises Vehicle to Pedestrian (V2P) communications. Police cars and ambulances are emergency and patrol cars. outfitted with thermal cameras that will monitor the body temperature and estimate the breathing rate of people walking on the street. To be more specific, every thermal camera will be programmed to scan the bodies of pedestrians on either side of the streets, however, the movements could also be controlled by the operator either to reach narrow areas or to cover the broad ones. The system can measure the rate at which the temperature of the nasal area falls and rises as one inhales and exhales thus able to estimate the rate at which one is breathing, and also whether an individual is experiencing shortness of breath.

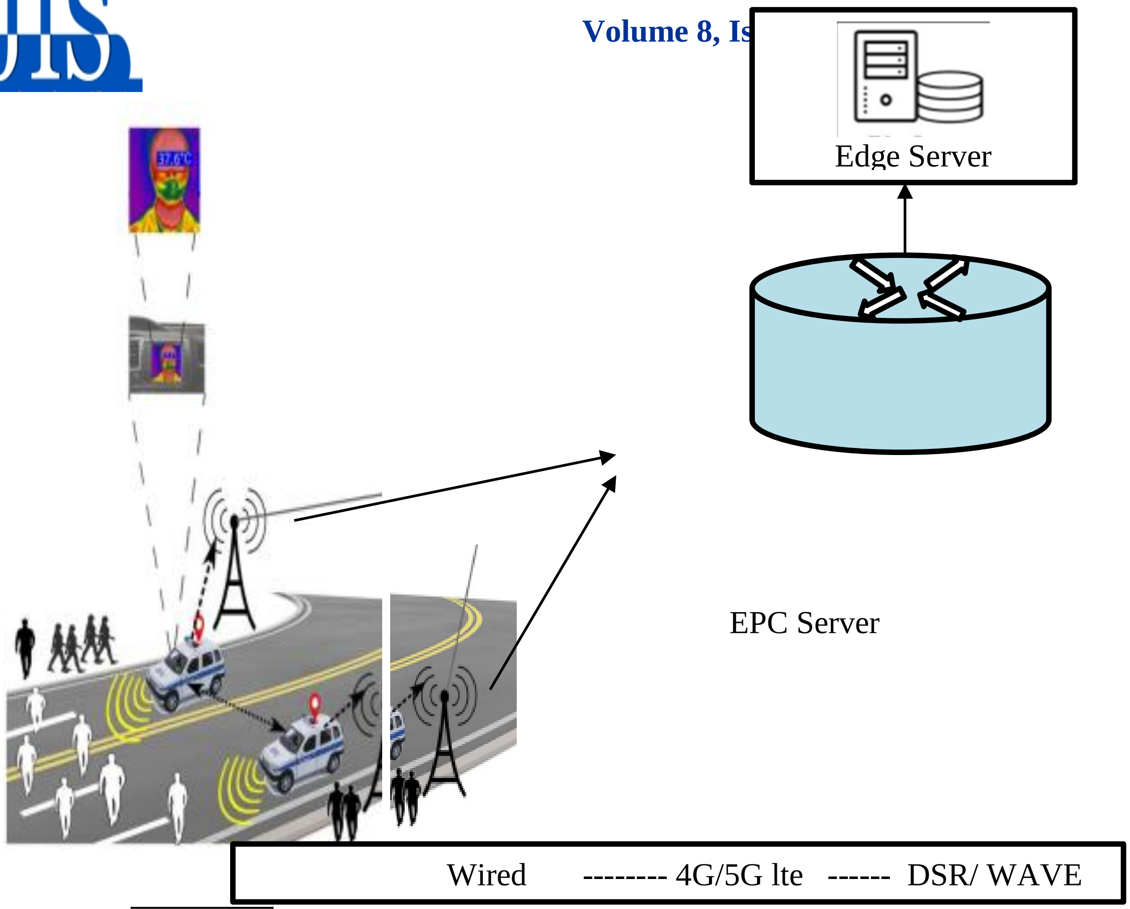

Fig 2: The proposed model for identifying suspected cases of the COVID-19 virus.

Sending data stage: It involves a two-stage transfer in conveying the data regarding. suspected cases and their position to the edge server. To start with, vehicles provide real time data to the closed Road Side Unit (RSU), using Vehicle-to-Road Infrastructure (V2I) communications. Next, the RSU is taking advantage of Vehicleto-Broadband Cloud (V2B) communication by taking advantage of 4G/5G LTE technology to patrol city streets and streets, and advances the data to the edge server, in figure Decision and aggregation It includes the technique of combining, storing and examining in the edge server all the data generated by the sensors in real time. The output of this stage is the generation of geographical heatmap reports, which can be sent to the Health Ministry for a prompt assessment. This will make it possible to make decisions that. can stop or deter the infection of sicknesses such as COVID-19, such as quarantining and putting people under medical surveillance, performing. viral tests and sending alerts messages by using online social networks (OSN) or SMS.

3.2 IR Receiver

Infrared (IR) Receiver is a gadget designed to detect IR signals sent by the IR remote. An IR receiver typically contains a photodiode, amplifier, a band-pass filter, and a demodulator all put together in common modules such as the TSOP series. The IR transmitter (remote control) sends modulated signals using infrared light normally at 38kHz. The photodiode component inside the receiver detects IR light and generates electrical current.

3.2.1 Photodiode Current Equation

The photodiode curren $I = R \times P$explains Pformula helps understand the working of the photodiode in generating electrical current using infrared light energy. In the formula, Irepresents the current generated by the photodiode while Prepresents the input optical power. R stands for responsivity (the rate of converting optical power to electrical currents). The amount of electrical current produced by the photodiode is directly related to the light energy:

$$I = R \times P \qquad (1)$$

Where in equation (1) the equation $I = R \times P$ the current output generated by photodiodes is proportional to the product of optical power and responsivity.

3.2.2 Output Voltage Equation

The equation for output voltage given by $V = I \times R_L$ shows how the current from the photodiode is transformed into an output voltage. In the equation above, V represents output voltage, I represents current from the photodiode, and RL represents resistance in the load resistor. As infrared light strikes the photodiode, the current flows through the load resistor and results in a change in the voltage based on Ohm's law. The increase in current or resistance increases the output voltage and facilitates easy signal detection. The current produced gets converted into voltage:

$$V = I \times R_L \qquad (2)$$

The equation above (2), $V = I \times R_L$ showcases the fact that output voltage depends on the current from the photodiode and the load resistance; increasing current or resistance results in increased output voltage.

3.2.3 Modulated Signal Equation

Modulation of an infrared signal takes place using the following equation: $S(t) = A\sin(2\pi f t)$ This is the equation for the modulated signal. It shows how an infrared signal can be transmitted under control. Here, A represents amplitude, f stands for the carrier frequency (38 kHz), and t denotes time. When using infrared signals, the real information is put on top of the wave to make sure there is no noise. This is how the receiver picks up the signal and then decodes it into commands. The modulated signal is detected by an IR receiver. This is the equation for the modulated signal (3):

$$\mathrm{S(t) = Asin(2\pi ft)} \qquad (3)$$

The formula (3), the modulated signal equation $S(t) = A\sin(2\pi f t)$ illustrates the role of amplitude (signal strength), frequency (transmission speed ≈38 kHz), and time (signal changes).

3.3 Robot

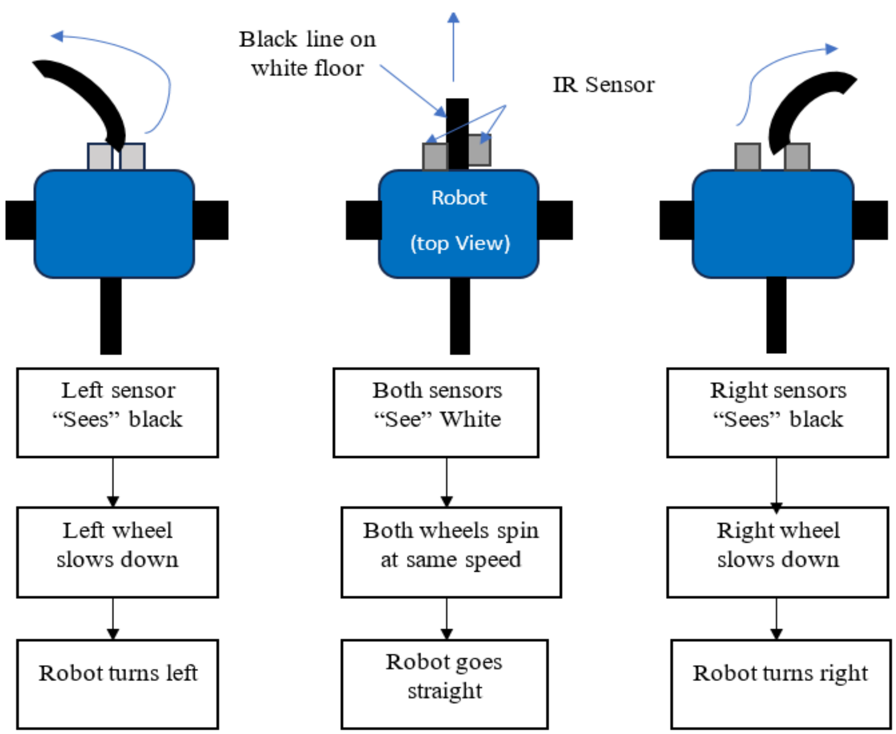

Fig 3: Robot Architecture

This diagram shows how the line follower robot works with the use of two sensors (left and right). It tracks a pathway (normally the black color against the white background) and then changes its position according to the path that it is tracking. When both sensors see the white color, it means that the robot is moving perfectly on the path, thus the two wheels turn at the same pace, and therefore the robot will move straightly. In the case that the left sensor picks the black color, it means that the robot has shifted from its path to the right-hand side. Therefore, in order to adjust, the robot turns left by slowing down the left wheel. The opposite happens when the right sensor sees the black color.

3.3.1 Wheel Linear Velocity

Linear velocity of wheel is defined as the speed at which the wheel of the robot moves in a straight line. The formula that governs linear velocity is given by the equation v = r x ω, where vis linear velocity, r is the radius of the wheel, and ω is angular velocity. From this formula, it can be deduced that the speed at which the robot travels is dependent on the angular velocity of the wheel and the radius. An increase in either the wheel size or rotation will result in increased velocity.

$v = r x \omega$ (4)

Where equation (4), v is the linear velocity of the wheel, r is the wheel radius, and omega is the angular velocity that dictates the rotational velocity of the wheel.

3.3.2 Robot Forward Velocity

The angular or turning velocity indicates the rate at which a robot rotates while traveling. In the case of differential drive robots, the turning relies on the disparity between the velocities of the two wheels $V = \frac{V_L + V_R}{2}$ where V_L is the velocity of the left wheel, while V_R is the velocity of the right wheel. represent the velocities of the right and left wheels, respectively, and d represents the distance between the two wheels. When the two wheels have the same velocities, \omega equals zero, hence causing the robot to move in a straight path. However, when the right wheel's velocity is higher, the robot makes a left turn, and vice versa.

$$V = \frac{V_L + V_R}{2} \qquad (5)$$

where equation (2), $V = \frac{V_L + V_R}{2}$ gives the forward velocity of the robot as an average of the two wheels' velocity; a straight-line motion takes place whenever the two wheels move at an equal pace, while a deviation occurs when their velocities are not equal.

3.3.3 Turning (Angular Velocity)

The turning or angular velocity is a measure of the rate of rotation in a robot. The angular velocity in a differential drive robot is calculated from the difference between the velocities of the left and right wheels using the formula $\omega = \frac{V_R - V_L}{d}$, where $\omega$is angular velocity, $V_R$and $V_L$are right and left wheel velocities, and $d$is the distance between the wheels. When both wheels move at the same speed, $\omega = 0$, when the two wheels have the same velocities, meaning that the robot makes a straight motion. When the velocity of the right wheel is greater than the left one, then the robot rotates to its left, otherwise, it rotates to the right.

$$\omega = \frac{V_R - V_L}{d} \qquad (6)$$

where equation (3), $\omega = \frac{V_R - V_L}{d}$ demonstrates the relationship between angular velocity and the speed difference and wheelbase; the greater the speed difference, the higher the rate of rotation, whereas equal speed leads to zero rotation.

3.3.4 Motor Voltage Relation

The motor voltage is explained by the dependence of the voltage applied to a DC motor in a robot. This concept relies on Ohm's law $V = I \times R$, where V stands for the applied voltage, I is the current, and R is the resistance inside the motor. When there is an applied voltage, a current passes through the windings of the motor, creating a magnetic field that causes the motor to rotate. The higher the voltage, the larger the current will be for the same resistance, resulting in increased torque and speed. In robotics, voltage controllers such as L298N manage motor movement by regulating the input voltage, which may be increased or decreased using PWM technique.

$$V = I \times R \qquad (7)$$

Where equation (7), Equation $V = I \times R$ states that voltage is equal to the product of current and resistance; increase in either the current or resistance increases voltage; controlling the operation and speed of electric motors.

3.3.5 Sensor Detection Logic

Sensor detection logic refers to the way in which a robot translates inputs from the sensors into actions for movement. In a line-following robot, two sensors (one left and one right) detect the surface colour, either white or black. The sensors give a binary output (0 or 1 depending on detection); the controller receives these values according to logic that has been programmed beforehand. For instance, if both sensors detect white surfaces (0,0), the robot goes straight; if the left sensor detects a black surface (1,0), the robot turns left, while the right sensor detecting black (0,1) means the robot will turn right.

$$S = f(L, R) \qquad (8)$$

Equation (8), $S = f(L, R)$ where sensor logic dictates output depending on sensor input (Left and Right) for robot movements such as moving forward, left, or right (for example 0,0 -Straight, 1,0-Turn left, 0,1-Turn right).

4. Result and discussion

The IR communication system is tested and analyzed according to the following parameters: distance, response time, signal strength and accuracy. The infrared signal is intense at lower distances (0-2 meters), which means that the response is quick and the vehicle can be accurately controlled. The strength of the signal declines gradually as distance (25 meters) grows and leads to a small delay in the response and a small decline in accuracy. After 5 meters, it is weak, causing a slow or unreliable functioning. Others that influence performance are the external light, barriers and the position of the transmitter and receiver. This system is most effective in an indoor environment that has few interferences. In general, the IR communication system is a dependable and efficient means of control in a small range, which is appropriate in the short-distance robotic wireless communication, however, it is disadvantageous in the long-range communication.

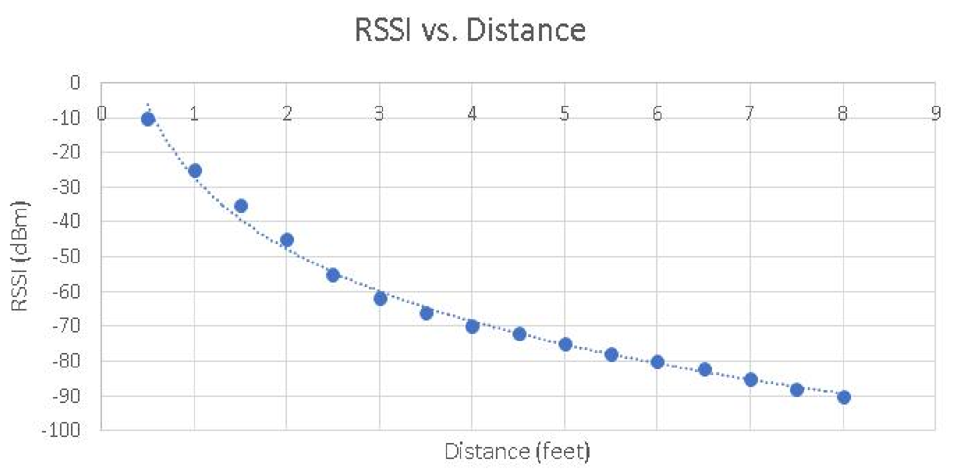

Fig 4: Performance Analysis of IR Communication System

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The Fig.4 shows the relationship between RSSI (Received Signal Strength Indicator) and distance in an IR communication system. With increase in distance the value of RSSI reduces which shows attenuation of signal. The signal strength towards smaller distances (approximately 1-2 feet) is high (approximately 0 dBm), which implies that communication will be reliable and fast. The signal attenuates greatly in the farther region of over 3-5 feet contributing to poorer reception and potential delay in feedback. At even greater distances (more than 7 8 feet), RSSI takes extremely low values (approximately -90 dBm), this can lead to unstable, or even no communication. This behavior shows that IR signals are extremely distance-dependent and can be effectively used on short distance applications. It is also inconsistent (nonlinear) as the curve decreases rapidly at beginning and gradually. This analysis will aid in deciding the operating range of the IR-controlled robotic system.

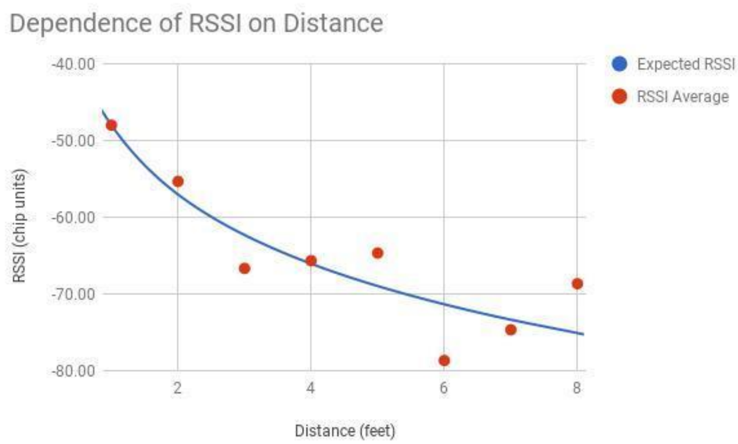

Fig 5: Effect of Distance on IR Signal Strength

The Fig.5 shows an infrared (IR) signal is weaker and the farther the receiver and transmitter are, the weaker the signal. The signal is strong and easily sensed at a short distance leading to a quick and good response. The further the distance the more the signal is dispersed and its energy is lost through attenuation and hence the intensity decays. The consequence is slower response and detecting errors of the signals. At further length, the signal is extremely small and it might not be detected at all causing communication loss. Signal strength is also influenced by factors outside the system, like obstacles, ambient light, and alignment. This is an inverse relationship, with the signal power decreasing exponentially with distance. Thus, IR systems can be successfully implemented in short-range communication.

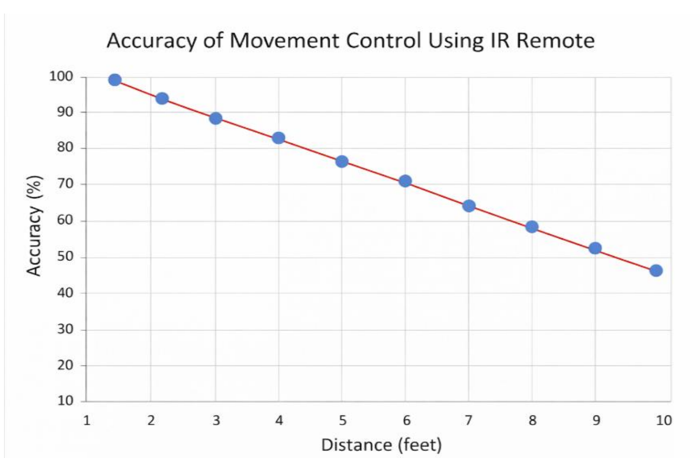

Fig 6: Accuracy of Movement Control Using IR Remote

The Fig.6 shows that the precision of movement in a robot that uses IR changes with range. However, the accuracy at a shorter range (1-2 feet) is extremely high, almost 100 percent since the infrared signal is high and well detected by the sensor. The farther the distance, the weaker is the signal strength which results in a lesser accuracy in interpreting commands. The robot will work stably though with some deviations and delays within 3 to 6 feet. After a distance of 7 feet, the accuracy is highly diminished by poor reception of the signal, potential interference and a lack of alignment between the receiver and transmitter. This causes incorrect or sluggish movements. The graph indicates a gradual decrease in accuracy implying that IR communication is very distance-sensitive. Thus, robots that have an IR control would be most commonly applicable to the short-range scenarios when the exact and stable control over the movement is needed.

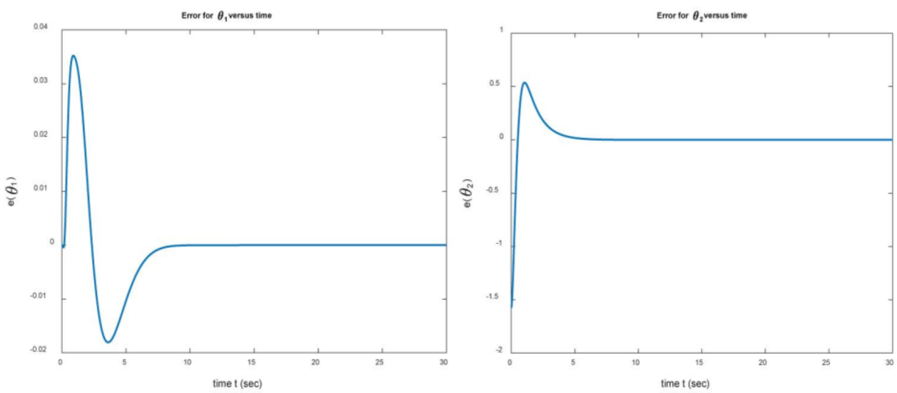

Fig 7: Comparison of Expected vs Actual Robot Response

The Fig.7 given plots show the error response (e) of two variables, \theta_1and \theta_2, with respect to time, which represents the difference between the expected (desired) and actual robot response. In the case of image 1, the error is initially overshot small positively before gradually approaching zero. This is a case of a small amplitude oscillatory behavior with overshoot and undershoot, however, the system settles rapidly (less than 810 seconds), indicating a well-damped system. In the case of theta 2, the error takes a great negative value, rapidly increases to a positive peak (overshoot) and then reduces gradually to zero. It has both a higher initial error and over shoot, but also stabilizes in a brief interval in comparison to theta_1. Generally speaking, these two answers indicate a control system which stays unstable, because mistakes tend to be zero. The temporary errors (overshoot and undershoot) are caused by the system dynamic but appropriate damping guarantees appropriate final positioning.

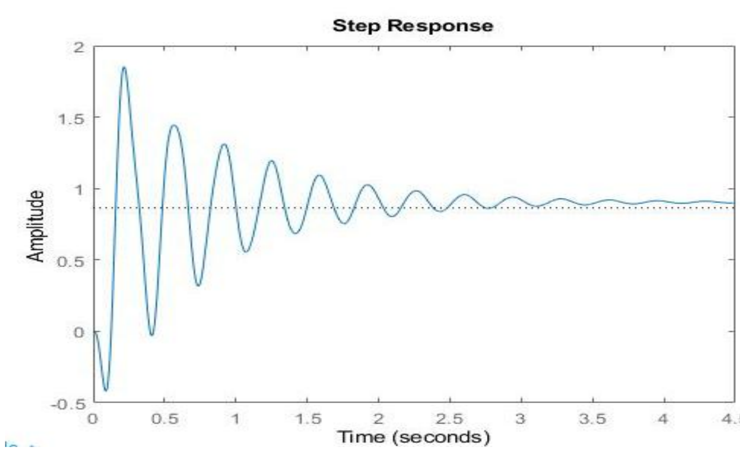

Fig 8: Signal Interference and System Stability Analysis

The Fig.8 shows given graph is the step response of a control system that tells how the control system responds to a sudden input (step signal) over time. In the beginning, there is a steep increase in the output reaching a peak of overshoot (more than 1) before stabilizing at the desired value. This is because of the inertia of the system and delay in corrective action. Subsequently, the response decreases to a lower desirable value forming an undershoot and remains oscillating further. Such oscillations are decreasing in amplitude thus there is damping in the system. With time, the oscillations decrease and the response approaches the steady-state value (around 1). This indicates that the system is stable in that, it eventually stabilizes and reaches the desired output. The settling time is referred to as the settling time and the initial peaks are transient response. In general, the system is under damped, because it displays oscillations until stabilized, yet it does get the right final output.

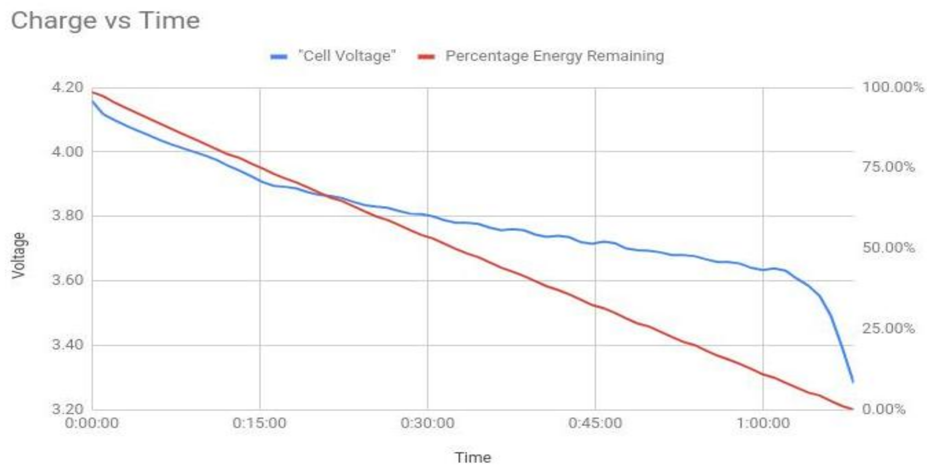

Fig 9: Power Consumption vs Operating Time

The data provided above is a graph of charge vs time and it can be observed that the voltage and percentage of energy used by the battery are reducing as it works. The blue line (cell voltage) begins at approximately 4.2V which means that a fully charged battery and decreases gradually as time goes on. This is not a linear decrease but demonstrates instead an ongoing decrease but at a slower rate, and eventually the decrease becomes sharp towards the end. This drastic decline means that the battery is now in the cut-off area and is unable to provide constant power any longer.The red line (percentage of energy left) indicates that there is almost a linear change between a 100 percent and 0 percent indicating that there is an on-going consumption of energy over time. The implication is that there is a reasonably stable load on the system. Generally, the graph represents normal discharging behaviour of batteries. The system is initially stable, although its performance may suffer as the voltage decreases considerably towards the end of its operation, and the critical role of dealing with power properly

5. Conclusion

The project based on IR Sensor enabled, Wireless Remote-Controlled Vehicle is an effective example of how embedded systems and wireless communication can be used to control a robotic. Incorporating the Arduino Uno, an IR receiver, and an L298N motor driver, the system essentially converts the remote signals with the motor moves to a precise motor movement, allowing the smooth movement in every direction. The project turns out to be cost-efficient and easy to use not involving the complicated networking and operates over short ranges. The system is restrained however, by the range and line-of-sight that IR communication has, which can be influenced by obstacles and ambient light interference. Nevertheless, the overall performance is predictable and can be used in simple robotics. This project is a good base to do further improvements in the future like to provide obstacle detection sensors, better communication by RF or Bluetooth, autonomous navigation. It is therefore a great learning platform with regards to robotics and control systems as well as real time embedded applications.

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