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Development of an Accelerometer-Based Hand Gesture-Controlled Robotic Vehicle

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Abstract

The project is a proposed gesture-based controlled robotic car design and implementation which works on the basis of real-time data of hand-motions gathered using an inertial sensing device. An MPU-6050 accelerator-gyroscopes sensor is used to record the dynamic orientation and acceleration of the hand of the user to provide an intuitive and non-contact control over the robot. The sensor information is sent wirelessly to the robot by use of Radio Frequency (RF) communication connection and as such the system is able to move in a directional manner forward, backward, right and left in direct proportion to the user gesture. The proposed system eliminates the use of the traditional remote-control hardware, which makes it simpler in terms of mechanics and more accessible to users. A microcontroller platform is an Arduino-based system that can be used to process and autonomously actuate the onboard data, which is useful in helping the robot interpret and respond to gesture inputs efficiently. The prototype, created, has shown the possibility of inertial sensing and wireless communication as a means of human-robot interaction using gestures, and provided possible uses in assistive technology, hands free robots, and intelligent mobility.

Keywords
Accelerometer, Microcontroller, Motion, Hand Gesture, Robotic Vehicle.

1. Introduction
Robots are autonomous or semi autonomous electromechanical machines that perform duties by microcontrollers inbuilt in the robot or external control interfaces. These devices have now become essential in many of the highly automated industries, such as military systems, construction, high-technology manufacturing, and medical services, because they can help improve precision, utility, and dependability and decrease the workforce and resource usage of humans (Fernando, Y. et al., 2014, M. O. Qureshi and R. S. Syed, 2016). Besides industrial use, robotic systems are increasingly finding uses in assistive technologies, in which people with physical disabilities are helped to carry out tasks that might have been challenging or impossible to independently complete. The robotic platforms with their ability to be remotely controlled by other external devices (or by other human-machine interfaces) are one such example that offers more convenient ways of movement and interaction. There are two general categories of rooted systems, autonomous robots which work according to preprogrammed algorithms and environmental sensing (Siramshetti, B. et al., 2014), and gesture controlled robots which process human movements as control directions (Singh, R. et al., 2017). Gesture-controlled robots are one of such type and one of the most intuitive and user-friendly ways to conduct the interaction between a robot and a human being. The analysis of human gestures, and particularly of hand gestures, is a very difficult computationally and sensing problem because the machine has to respond to, recognize, and identify dynamic and often nonlinear motion patterns in real time.

An example of such type of system is a hand-powered robotic vehicle, which allows a user to control the system with the help of simple hand movements instead of using mechanical controllers or switches (Lakshmi, J. et al., 2020). To give the robotic vehicle directional instructions, the operator adjusts the hand position and orientation so that he can execute actions like forward movement, reversing and steering laterally with minimal physical exertion (Benjula Anbu Malar, P. R. & Kavi Priya, K. P., 2019). These systems promise a lot especially with people with limited mobility as they offer very easy and natural form of control. Several sensing modalities have been used in capturing and interpreting human gestures such as the use of vision based sensing involving cameras, sound signal processing, data gloves, tactile array sensors, inertial motion-sensing devices and infrared wave detection (Cao, S et al., 2020, Fang, B. et al., 2018, Gibbons, P. et al., 2012, Jost, C. et al., 2015, Liu, T. et al., 2015). Such embedded sensors are usually application specific but research is still being done to further refine these systems to attain greater accuracy, less power usage, smaller size of the device and greater reliability of the whole system. With the development of gesture-recognition technologies, they provide a great opportunity of more convenient, responsive, and cheaper human-robot interaction.

1.1 Objectives

The conventional wired and button-operated robot is swollen. In addition, it reduces the length of the distance that the robot can move. The robot car that can be controlled by using the hand gesture can be used together with a wearable hand glove. The hand movements are required as the input in the motion of the robot. The point of our scheme is to create a pattern that can distinguish the human interaction with it to accomplish the definite goal assigned to it. The wearable hand glove with a conducting device utilized in the hand designed in this project has an RF transmitter and accelerator. This system will instruct the robot to complete the necessary works such as forward and reverse movement, turning right, turning left and stopping. All these will be done by the user through hand gestures.

2. Literature Review

Robotics is the combination of engineering, science, and technology to produce the machine called a robot. Robotics is a field that deals with the creation and exploitation of robots. The robots are mostly applied to substitute humans in most activities (Erin, M. T. U. R. et al., 2024). Automation and robotics have been under research to design and develop user friendly robots over time. They apply various user interfaces such as touch screens and joysticks. Nonetheless, such processes are not so effective and precise. In addition to that, they are slow in responding. Gesture-controlled robots are more competent in this instance. The combination of a car with a hand gesture control or an automatic controlled car and an arm controller is new and effective. The mobile robot has been projected with a simple hand gesture recognition in [Noor Cholis Basjaruddin, E. R. et al., 2019] to allow the user to operate it effectively. The hand-gesture sensor used in the mobile robot is the ZX sensor, and the drive is the differential one. In addition, this drive is fitted on a Wi-Fi device. The result of this sensor is fed to a fuzzy logic controller. The fuzzy logic is concerned with numerous values between the unconditional values of 0 and 1 and is not necessarily linear [Farhan, A. et al., 2018]. The authors have suggested the idea of controlling the robots with the help of fuzzy logic and adjust the speed of the wheels when making smooth turns.

The systems of (Hsu, R. C. et al., 2020) are a human-robot gesture-based real-time and a proposition of the authors. They have created their scheme with the help of a Kinect sensor. The researchers have created an effective mobile robot to be used in experiments in (Ikegami, S. et al., 2018). They have verified the human control of the robot by hand-gestures. The hand belonging to the user in this paper is characterized by the color of his face skin. Face detection process has been applied in this case. The robot and a small and effective gesture-controlled robotic car have been designed and introduced (Patil, C. et al., 2019). One joystick drives and drives a robotic arm that was 3D-printed. On top of that, it has been operated by a wireless information hand gesture to control the executed robotic car. The hand gestures are converted into a signal by a microcontroller and an accelerator to make the robot move. In (Radha, R. et al., 2019), it was proposed to create a gesture control and obstacle avoidance robot. This robot can be operated by our hands so that we have it cleaned. It could be physical and automatic and could perform any type of cleaning mission say, wet cleaning, dry cleaning, and sweeping. In (Fulara, N. et al., 2019), a gesture-controlled car has been proposed to be operated by the movements of human hands. The person needs to use a glove that consists of a transmitter and an IR sensor. These sensors record the movements of the hands in a preferred direction. Therefore, it results in the motion of the robotic car. The proposed study by (Zia, H. et al., 2025) presents an autonomous driverless car controlled by a real-time, web-based hand-gesture recognition system based on YOLOv5s and runs on a Raspberry Pi, with an accuracy of 94.2 per cent, low-latency and sensorless human-robot interface, and supported by a browser. Moreover, (Prasad, N. H. et al., 2021) has proposed an IoT controlled robotic car which is a gesture-controlled car and uses accelerator based hand-moving detection and wireless communication to convert the movements of the user into directional and throttle specifications.

3. Methodology

The car which is controlled by gesture is a common example of demonstration of Human-Robot Interaction (HRI). The design suggests a robot, which can be operated by just making simple moves with hands. The end-user must wear a gesture device which will be able to identify the move of the hand in a given direction. Therefore, a wireless communication will control the movement of the robot in the respective orders. Thus, it is possible to make this communication more authentic using an accelerometer sensor which is connected to a hand glove. These kinds of illustrations are used to substitute the remote control with hand gloves in order to operate the car. Fig. 1 provides the block diagram of the proposed hand gesture-controlled car of a car (Figure 1).

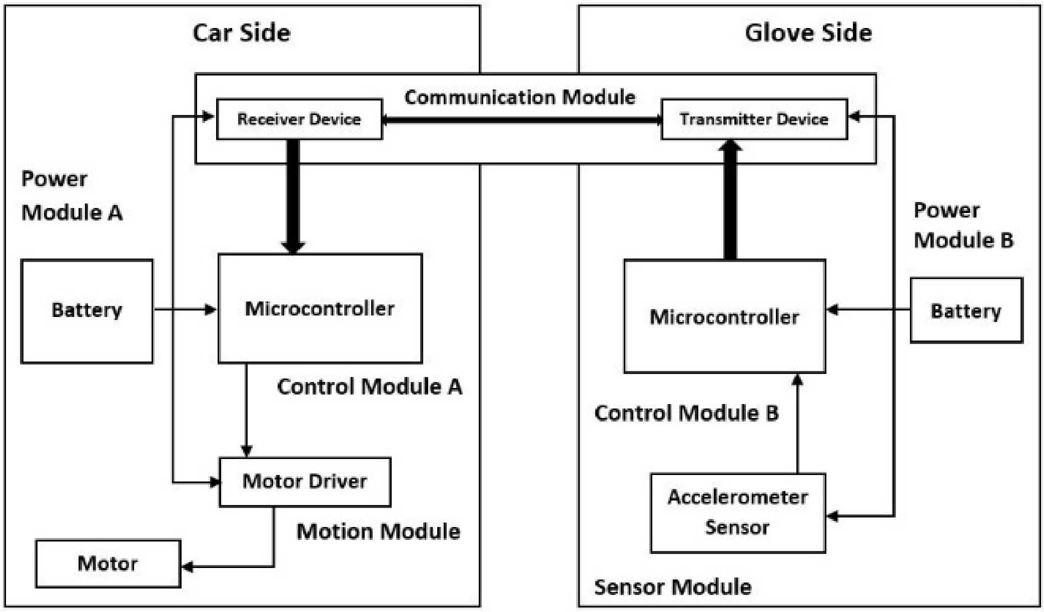

Figure 1. Block Diagram of Our Anticipated Scheme

The proposed work is based on the assumption of the control to the forward, back, leftward, and rightward movements over the same accelerator sensor to control the throttle of the car. Moreover the range is determined using these two values in each of the functions of the vehicle. At the same time, the contents set is specified regarding the movement of the robot car in a particular manner. The two motions are never going to be the hand of an operator. In addition, there is a different definition between actions of one step and the other. To illustrate, the values of the accelerator will not be on the side values of two directions (left turn and forward, left turn and backward, right turn and forward, right turn and back). It reverses its direction during the cutting turn without decelerating the speed. At this point, the car will begin moving in the direction of the right circle in case it is a right turn. Once again, in case it is left turn, the vehicle will move in the left circle direction. Table 1 represents the combination of Accelerometer axis and the accelerator value, angle and the motion of the car robot.

Table 1. Average Data of our designed Hand Gesture Controlled Robot Car

Accelerometer Axis	**Accelerometer Value**	**Angle**	**Robot Car Movement**
X-Axis	-6050	30˚	Forward
X-Axis	6050	-30˚	Backward
Y-Axis	-6100	45˚	Left
Y-Axis	6100	-45˚	Right
X, Y-Axis	(-6000) – (6000), (-6000) – (6000)	0˚	Stable

Ultimately, the system will decide the accelerator values which are above and the corresponding movement angle. In the event that the recognized information by the application falls within these set values, then we shall make the relevant decision. Then, this value of decision will be sent to the microcontroller that will interpret it in order to comprehend associated gesture. It will also send a signal to move the robot car after having known the motion.

The general functioning of the proposed system involves sequential and integrated workflow, which is aimed at allowing gesture-based robotic control. The first step that occurs involves the motion data that is obtained based on the hand gestures of the user; this data is converted to be sent to the microcontroller which then interprets the information and comes up with the relevant control instructions to the robot. These are then sent to the encoder integrated circuit (IC) which then encodes the commands in a format that can be transmitted wirelessly. The transmitter unit then sends out the coded signals to the receiver unit of the robotic vehicle. When it is received, the decoder recalls and deciphers the data sent out transforming them into control inputs that can be acted upon. Such decoded messages are sent to the motor driver module which controls the motors to make the necessary movements. In this process, the robotic vehicle executes directional movements, which closely match the movements of the hands of the user to allow the user to easily operate the robotic vehicle using gestures.

3.1 Flow Chart

Figure 2 illustrates the flowchart of our projected design. It describes an algorithm of interpreting accelerator sensor readings based on a threshold to operate a robot by gestures.

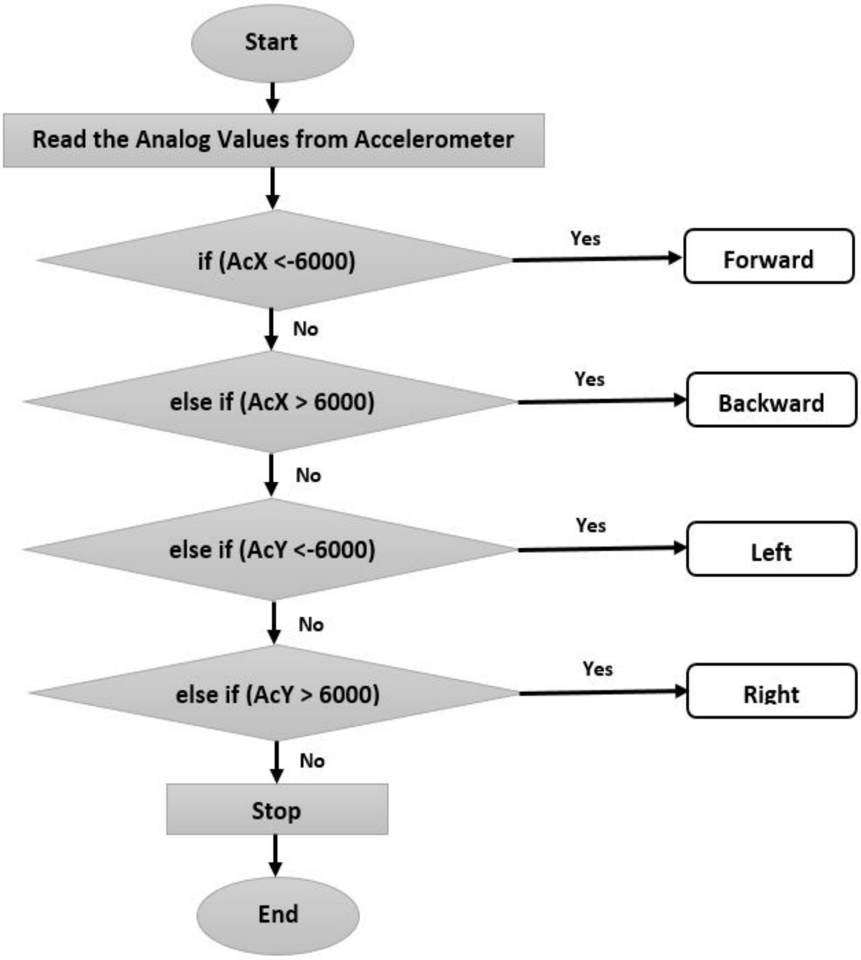

Figure 2. Flowchart of the Proposed Design

Once the microcontroller has been initialized, it repeatedly reads the values of X-axis (AcX) and Y-axis (AcY) acceleration values. This algorithm subsequently crosses them with predetermined thresholds to determine the desired gesture. A highly negative AcX (AcX < -6000) produces a forward command whereas a highly positive AcX (AcX > 6000) produces a backward command. In other cases, when neither of the two conditions is met, the system will conclude on AcY: a negative value (AcY < -6000) will be a left tilt and positive value (AcY > 6000) will be a right tilt. In the case where all thresholds fail to be passed, the system will send a stop command in order to prevent undesirable movements.

4. Result and Discussions

4.1 Stop or Stable Condition

Once the angle of the accelerator is parallel to the ground, the robot car stationary. The stable position of the hand gesture robot car is the reason. Figure 3 represents the stable position of our designed vehicle.

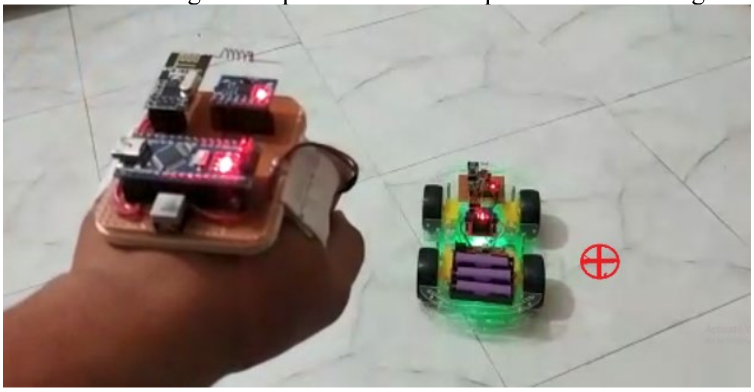

Figure 3. Stable position (Red mark is the starting point)

4.2 Forward Movement

When the accelerometer holding hand rotates 30 degrees or so in the Accelerator X-axis which is parallel to the Accelerator Y-axis, then it is moving upward in the parallel position; and the robot car moves forward. Figure 4 illustrates the forward movement of our designed car.

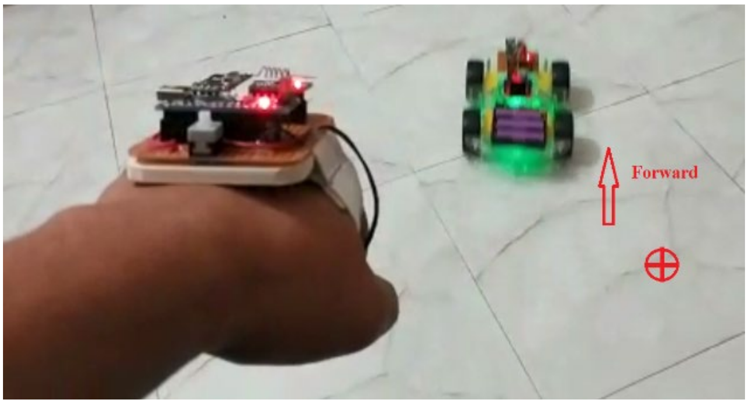

Figure 4. Forward Movement (Red mark is the starting point)

4.3 Backward Movement

In case the accelerator in the hand turns about -30 degrees in the direction of the Accelerometer X-axis, or down the parallel position, the robot car moves in reverse. Figure 5 shows the backward movement of our robotic vehicle.

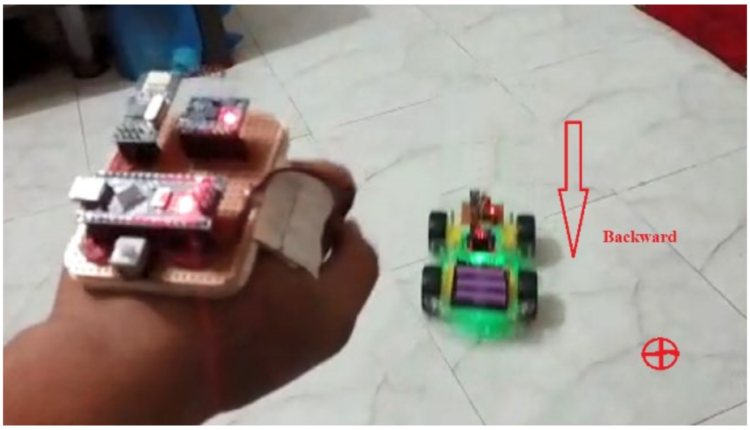

Figure 5. Backward Movement (Red mark is the starting point)

4.4 Left Movement

When the accelerator hand moves 45 degrees (based on the Accelerometer Y-axis), it implies that the user tilts the hand to the left; the robot car turns into the left side. The left movement of our robotic vehicle is shown in the Figure 6.

Figure 6. Left side Movement (Red mark is the starting point)

4.5 Right Movement

The right movement of our hand-gesture robotic car is illustrated in the Figure 7.When the hand with the accelerator turns around -45 degrees along Accelerometer Y-axis, it indicates that the user tilts the hand to the right, the robot car goes to the right.

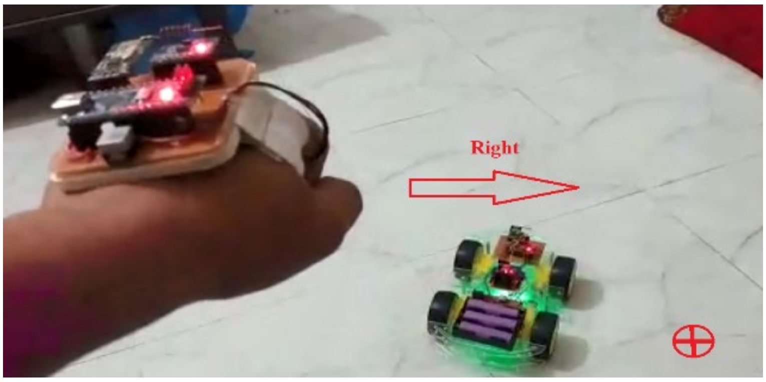

Figure 7. Right side Movement (Red mark is the starting point)

In general, the experimental results of the study prove the efficiency of hand gesture control with the use of an accelerometer as the means of robotic navigation. The system has a straightforward interface that is user friendly and direct converting angular hand motions to the respective robotic movement thereby making the system responsive and predictable. This control mechanism might be further optimized by tuning sensitivity thresholds to enhance the accuracy and also reduce unwanted movement.

5. Conclusion

The proposed robotic car system demonstrates the feasibility of using hand gestures and accelerometer-based data acquisition to enable intuitive and wireless control of mobility-assistive platforms. By capturing and transmitting arm-gesture information in real time, the system offers a promising solution for enhancing the independence and mobility of individuals with physical disabilities, particularly wheelchair users. To maximize the impact and usability of the proposed gesture-controlled robotic car, it is recommended that future work prioritize the development and integration of advanced assistive features such as voice-based command recognition, autonomous navigation algorithms, and real-time obstacle detection. Incorporating GPS/GPRS modules and camera-based monitoring will further enhance remote accessibility and situational awareness, making the system more suitable for practical deployment in assistive mobility applications. Additionally, rigorous user-centered testing with individuals who have mobility impairments should be conducted to refine the interface, improve reliability, and ensure that the system effectively addresses real-world needs. Continuous optimization of hardware and software will support scalability and help transition the prototype toward a fully functional assistive mobility solution.

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