Hand Gesture Controlled Robotic Vehicle Using Wireless Communication

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***Abstract*—In today's time, robotic systems are widely used in numerous applications such as smart manufacturing – machine tool industry, outer space exploration etc. If we look from the industrial perspective, in order to achieve the aim of increased productivity, control of electro-mechanical systems such as robots has become essential which can be achieved by means of model-based control algorithms. Control system executes specific sets of motions and forces in the presence of some unforeseen errors. Some of the control systems which are used for robotics include motion controlled, voice recognition or touch controlled robots. This project is a study of example of hand gesture controlled robotic vehicle using wireless communication which is available on Arduino project hub at below link.**

https://create.arduino.cc/projecthub/raunak-oberai/gesture-control-robot-ff1307

Keywords—Robot, Control, Gesture, Arduino, Accelerometer, RF Transmitter Receiver

I. Introduction

A robot or robotic manipulator can be defined as an electro-mechanical system that is operated by computer program. There are numerous languages in which we can code the program which can be utilized to actuate and control the robotic manipulators. Robots can be autonomous or semi-autonomous. A robot which acts on its own by sensing its environment which affects its working is called as autonomous robot. Robot manipulators are made up of the links which are connected by different joints which thus form the kinematic chain. There are two basic joints which are used in robotic manipulators which are prismatic and revolute joint as other joints can be formed from the combination of these two basic joints A revolute joint causes the relative rotation between two links connected to it and the rotation is possible by the torque applied to the joint with the help of motor. A prismatic joint causes the relative translational motion between two links connected to it. The dynamics of robot can be called as the study of the manipulator that undergoes changes in motion at different instance of time. The robot control may be defined as the desired motion of its end effector. The robots can also be classified based upon the method of control implemented into two categories such as servo robots and non-servo robots. Non-servo robots are basically the open loop control robots in which the real time information of the end-effector position and orientation is not used. Servo control robots uses the closed loop computer control to accurately position and orient the end effector. The control of robot can be point to point or continuous path. In point to point controlling, robot is guided on discrete points located in the path of motion however entire path of motion is not controlled. On the other side, continuous path-controlled robots can control the path of entire motion. Such type of control is significant in certain applications of robots such as welding, drilling, clamping etc. Some of the control systems which are used for robotics include motion controlled, voice recognition or touch controlled robots. One of the most often used motion-controlled technique is the control of robots using hand gestures.

II. Objective

The objective of this project is to present the simple control method of robot which is hand gestured control. This main objective can be split into following distinct objectives.

- To understand the role of accelerometer in controlling the robots using gestures
- To understand the wireless communication of human hands using RF transmitter & receiver pair and the role of Arduino micro-controller in driving the motors for controlling the robot car

III. System Overview/Background/Application

Robots are generally programmed to execute the tasks which human cannot do or the tasks which require more precision and accuracy with high repeatability. There has been increased use of robots where conditions are not certain such as fire fighting or rescue operations or the conditions such as underwater operations. In those conditions, robots can be programmed to follow the instructions of human who is controlling the robot. This means that the decisions are taken by the human and the action is performed by the robot. In such conditions, controlling of the robot with hand gestures or voice recognition makes it fairly possible for the robot to execute the given commands in fast manner. This project motivates from this idea and thus presents the working of hand gesture-controlled robot and the principle of working here can be applied to any other robotic manipulator which needs to be controlled by hand gestures.

IV. Literature survey

In the paper [1], hand gesture sensor depends on accelerometer and gyroscope. Gyroscope is the sensor which is used to capture the position the operator hand when he is working in underwater operated vehicle and it is attached with a hand.

The paper [2] demonstrates the development of robotic arm by use of flex sensor and 3 servo motors connected to Arduino Uno which is controlled by processing software.

Harish Kumar Kaura, Vipul Honrao, Sayali Patil "Gesture Controlled Robot using Image Processing". This paper demonstrates the development of wireless robot which can take user commands given through the gesture of palm. These command signals navigate the robot in the specified direction in the program.

V. System Architecture & Working Principle

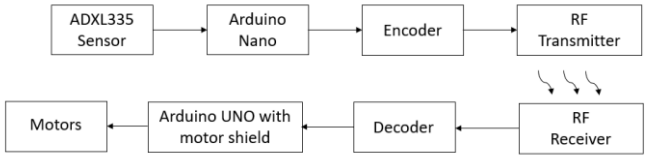
This project consists of two sections which are transmitter and receiver. In this project, we have used RF-433 transmitter and receiver & ADXL335 accelerometer. In order to understand the principle of operation, let us divide the whole working in three parts.

At first, Arduino Nano micro-controller receives the data from accelerometer (ADXL335). Based on the predefined parameters, it sends the data to RF transmitter.

In the second part, there is a communication of data between RF transmitter and RF receiver.

Finally, in third part, the data from RF receiver is send to motor drivers to control the motors.

Below is block diagram of the system architecture.



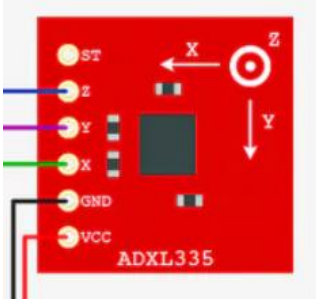
VI. System Components

Below is the description of the components used in the system.

Components used in Transmitter section:

1. ADXL335 Accelerometer:

Accelerometer is a sensor which gives an analog data of acceleration along three principle axes x, y & z. ADXL335 is a product of Adafruit which can measure the acceleration with minimum full-scale range of ±3g. The picture of this sensor is shown below.



This sensor consists of the arrow directions for measuring the acceleration. This accelerometer consists of six pins where the function of each pin is as listed below.

Pin 1 – Vcc pin is used to give 3.3V supply to sensor.

Pin 2 – GND pin is connected to ground for biasing.

Pin 3 – X pin will receive acceleration in X direction.

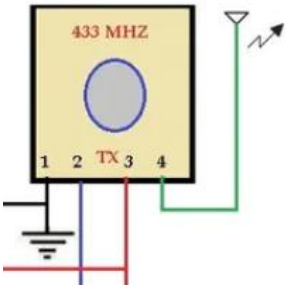
Pin 4 – Y pin will receive acceleration in Y direction.

Pin 5 – Z pin will receive acceleration in Z direction.

Pin 6 – ST pin is used to adjust the sensitivity of accelerometer (2g or 3g or 4g).

2. RF-433 Transmitter:

The function of RF transmitter is to transmit the received data from encoder to the RF receiver. This transmitter uses radio waves at 433 MHZ frequency and therefore it is named as RF-433 transmitter. This transmitter is wireless with minimum and maximum transmission distance as 3 meters and 100 meters, respectively. Data is transmitted at 10 kbps. The picture of the RF-433 transmitter used in our project is shown below.



There are four pins on RF transmitter and the function of each pin is as below.

Pin 1 – GND pin is connected to ground for biasing.

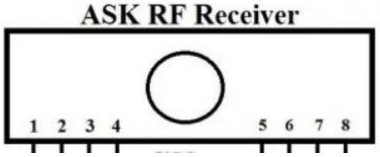
Pin 2 – Data to be transmitted is sent to this pin.

Pin 3 – Power is supplied to this pin.

Pin 4 – Solder wire/Antenna to improve the range (not mandatory).

3. RF-433 Receiver:

The function of receiver is to receive the data sent from transmitter and pass it to decoder. As like, transmitter, receiver also uses waves at 433 MHZ frequency and therefore it is named as RF-433 receiver. The specifications of data transmission to decoder and transmission distance is same as that of RF-433 transmitter. The picture of ASK receiver module used in the project is shown below.



There are eight pins on RF transmitter and the function of each pin is as below.

Pin 1,6 & 7 – These can be connected to ground for biasing.

Pin 2 & 3 – Can be used for data transmission to decoder.

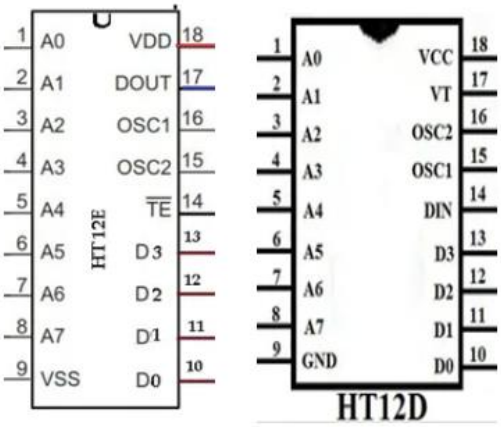
Pin 4 & 5 – Power can be supplied to these pins.

Pin 8 – Solder wire/Antenna to improve the range (not mandatory).

4. HT-12 Encoder & Decoder:

HT-12 encoder and decoder are used in pair to transmit and receive the 12 bits of data serially. Encoder receives the data from Arduino micro-controller and passes it to RF transmitter. Decoder decodes the data which is received from RF-receiver. Encoder coverts 12-bit parallel data into serial output which can be passed to transmitter. 12-bit parallel data is divided into 8 address bits and 4 data bits. It can operate with the supply voltage

ranging from 2.4V to 12V. It is available in 18 pin as well as 20 pin. We have used 18 pin encoder and decoder as shown in the picture below.



Encoder pin specifications		
Pin	***Pin Name***	***Description***
1 to 8	A0, A1, A2, A3, A4, A5, A6 & A7	8-bit address pins to protect the data
9	GND	Connected to ground
10 to 13	D0, D1, D2 & D3	4-bit data pins
14	Transmission Enable (TE)	Connected to ground to enable the transmission.
15 & 16	Oscillator pins	To use in built oscillator
17	DOUT	Encoded 12-bit output data
18	VDD	Power supply

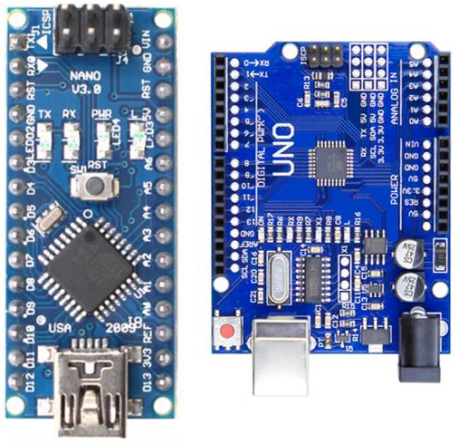
Decoder pin specifications		
Pin	***Pin Name***	***Description***
1 to 8	A0, A1, A2, A3, A4, A5, A6 & A7	8-bit address pins to protect the data
9	GND	Connected to ground
10 to 13	D0, D1, D2 & D3	Obtain data bits by decoding the data from encoder
14	DIN	Encoded data from encoder
15 & 16	Oscillator pins	To use in built oscillator
17	VT	This pin shows high when data is received.
18	VCC	Power supply

5. Motor Shield:

The motor shield is a driver module for the motor that can be used when we use Arduino micro-controller to control the speed and direction of the motor. The Adafruit has a library for motor shield called 'AFMotor' which can be called in the code written for Arduino UNO controller. The motor shield can drive up to 4 motors bi-directionally.

6. Arduino Micro-controllers:

In this project, we have used both Nano and Uno micro-controllers. The purpose for using both is to wirelessly communicate the data from the accelerometer. The Nano is used in transmitter section where Uno is used in receiver section to drive the motors of four wheels therefore the Arduino code for Uno requires motor shield library from Adafruit.



Arduino Micro-controllers

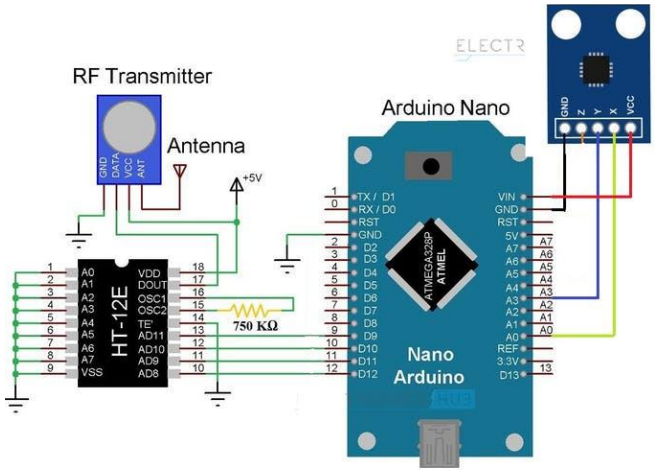
VII. Final System (Construction)

Now, in the final we combine all the system components to make the entire system work.

Let us take a look at the individual circuits and parallelly we can discuss on overall working of the final system.

1. Transmitter Circuit:

Below picture shows the circuit schematic of transmitter section.



Transmitter Section circuit/schematic

The transmitter circuit has RF transmitter, encoder, accelerometer and Arduino Nano micro-controller. The Arduino continuously receives the data from accelerometer and sends this data to encoder. Pins 10, 11, 12 & 13 are data in pins of encoder and are connected to digital pins 9 to 12 of Nano. These digital pins of Nano will output the command data (when HIGH) as:

Pin 9 – Forward direction

Pin 10 – Backward direction

Pin 11 – Left turn

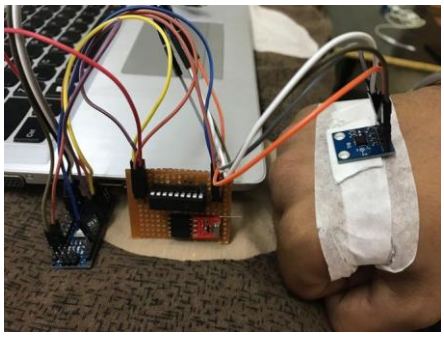
Pin 12 – Right turn

These pins are given command of digitalWrite based upon the inputs from accelerometer. We have incorporated this in the code. We are only reading the outputs in x & y direction and thus x & y pins are connected to analog pins A0 and A3 of Nano.

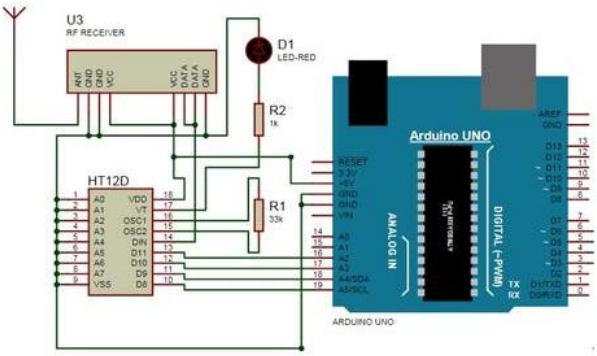
As we discussed previously, pin17 on encoder is the data output pin which is connected to Data pin on the transmitter in order to send the data from encoder to transmitter.

2. Receiver Circuit:

We are using Uno micro-controller in receiver section so that we can use motor shield to control the motor instead of using motor drivers.

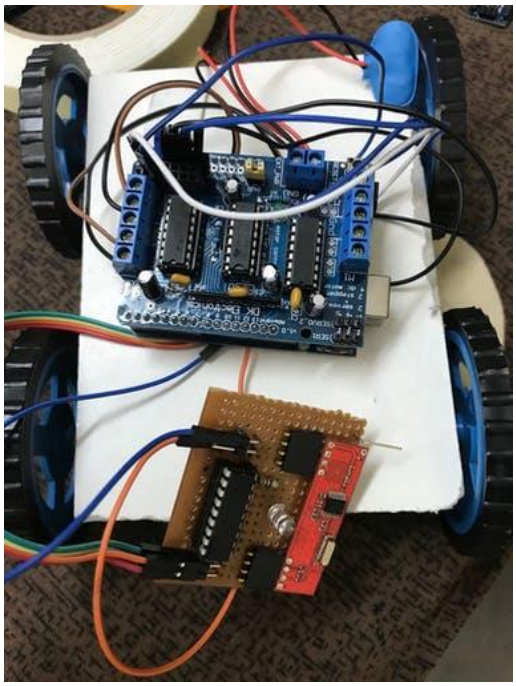


Nano Transmitter module



Receiver Section circuit/schematic

Since motor shield uses digital pins of Arduino Uno, we will be using analog pins to read the receiver data. Pins 10 to 13 are data out pins are connected to analog pins A2, A3, A4 & A5. The data output pins from receiver are connected to data input pin 14 of the decoder. Decoder has an internal oscillator and an external resistor of 33KΩ is connected between OSC1 & OSC2 pins. An LED in series with 470Ω is connected to pin 17 which indicates the valid data transmission. When the valid data is present. This pin will be set to HIGH and LED will glow.



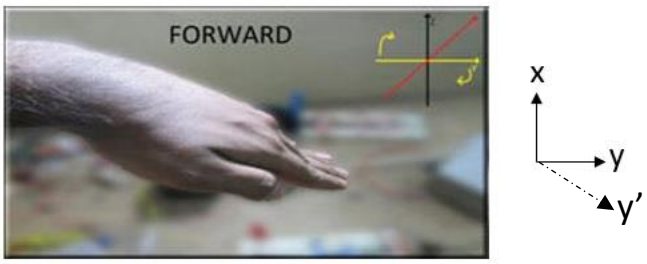
Robot car with receiver and shield

VIII. System Working

The robot is controlled by hand gestures. Due to the movement of hand, the angle of x & y axis changes with vertical and thus the accelerometer data changes proportionally. There are four movements of hand which control the robot. These are explained below.

1. Forward & Backward movement:

When the hand is tilted as shown below, the horizontal y axis is rotated and its angle changes with the vertical axis.



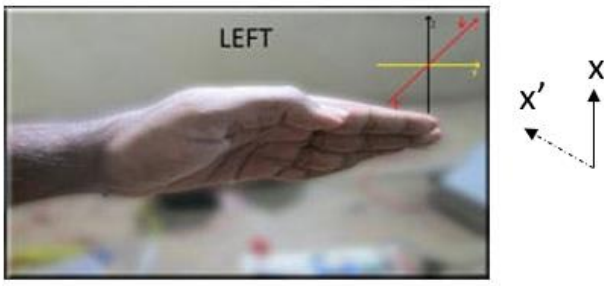
Movement of hand for forward motion of robot

Movement of hand for reverse motion of robot

2. Right & left movement:

When the hand is moved as shown below, the vertical x axis is rotated and its angle changes with the vertical axis.

Movement of hand for turning the robot towards right



Movement of hand for turning the robot towards left

As mentioned previously, the gesture-controlled robot is a wireless operated robot. When the robot is powered on, the transmitter part which contains accelerometer, Arduino Nano, Encoder & RF transmitter continuously monitor the ADXL335 sensor. ADXL335 output ranges from 0 to Vcc and is read by analog pins of Arduino Nano. We get the values in the range of 0 to 1024 (due to ADC). The different orientation of hand results in different analog value and these values are mapped to different robot movements. The output data of this sensor is captured by Arduino Nano pins A0 & A3 which is sent to encoder. Encoder converts the parallel data into 12-bit serial data which it sends to RF transmitter.

At the receiver section, RF receiver receives the data transmitted by RF transmitter and send it to decoder. The decoder will then convert the serial data to parallel data and this parallel data is given to Arduino Uno with motor shield. Based on the data from Arduino Uno pins 9, 10, 11 & 12, the movement of robot is defined in following ways.

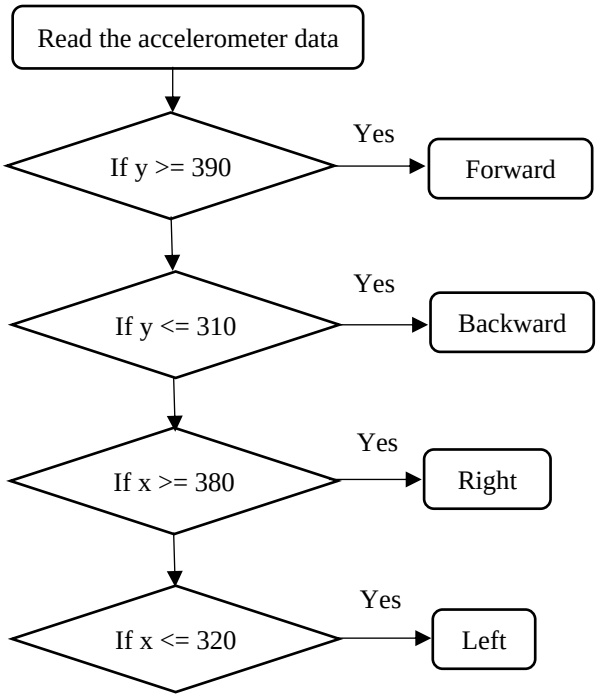
There are total 4 motors which are driving 4 wheels.

Right motors are connected parallel in each other and left motors are connected parallel in each other.

There are 2 9V batteries connected in parallel to give power input to motor shield so that we have enough power to run all four motors. Depending upon the movements decides from the accelerometer values, DC motors are actuated in below manner.

Moment of Hand	**Channels connected to motor pairs**		**Direction**
	Channel 3	***Channel 4***	
Static	0	0	Hold
Forward	1	1	Forward
Backward	1	1	Backward
Tilt Right	1	0	Turn right
Tilt Left	0	1	Turn left

The working of the four motors based on the accelerometer data can be summarized in the flow chart below.



IX. Result

Finally, when the code is uploaded to Arduino and the commands are given by moving the hand, we were able to drive the motors connected to each wheel of the robotic car.

1. When the hand is tilted in forward direction, all four motors are driven in the forward direction to make the car go ahead.
2. When the hand is tilted in backward direction, all four motors are driven in the opposite direction to make the car travel in reverse.
3. When the hand is rotated on right side, right pair of motors are driven to make the right turn.
4. When the hand is rotated on left side, left pair of motors are driven to make the left turn.

The result is shown in the form of video which can be viewed on below link.

https://youtu.be/-6s2odk1T2k

X. Conclusion

This project presents one of the methods for controlling the robotic vehicle which is hand-gesture controlled.

Because of the wireless communication, this system gets rid of numerous buttons and joystick controls.
The accelerometer is an input device which is a low cost and can be easily implemented as a way to interact with the robot.

XI. Future work

1. As we have used, Arduino Uno with motor shield for controlling the motors, one can replace this with motor drivers and compare the performance between two.
2. There is an opportunity to further upgrade this system by attaching an ultrasonic sensor to robot such that when it is operated with hand gestures it can also be programmed to avoid the obstacles.

References

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