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Implementation of Wireless Control System for Omni Directional Mobile Robot

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***Abstract*— The functions of direction controlled Omnidirectional mobile robot are described in this paper. Omnidirectional mobile robot consists of four Mecanum wheels. The main concept of Mecanum wheels mobile robots is the newly designed wheel which consists of a hub carrying a number of free moving rollers angled at 45^0 about the hub's circumference. The strength of this wheel is the enhanced maneuverability of the mobile robot that needs extreme maneuverability in congested environment. The aim of this system is to drive on a straight path from a location on the floor to another without having to rotate first. The Omnidirectional mobile robot is controlled the robot's direction to move any direction by using joystick. It includes two main parts: one is transmitting and another is receiving. An introduction to the workings of a Mecanum wheel, the motion analysis and the kinematic modeling of a 4WD omnidirectional robot using Mecanum wheels and the comparison results between theoretical and experimental are presented.**

***Index Terms*— Omnidirectional mobile robot, Mecanum wheel, Kinematics model, Joystick controller, Wireless control using RF, Arduino Uno**

I. Introduction

Mobility is a key issue of assistive mobile robots. Omnidirectional drive mechanism is very attractive in that it guarantees excellent mobility even in small and narrow spaces. Many designs of omnidirectional and near omnidirectional vehicles have been proposed. These can generally be broken into two approaches: conventional wheel designs and special wheel designs.

Conventional wheels are mechanically simple, have high load capacity and high tolerance to work surface irregularities. However, due to their non-holonomic nature, they are not truly omnidirectional. Designs have been proposed to achieve near omnidirectional mobility using conventional wheel. Vehicles based on this design have at least two active wheels, each of which has both driving and steering actuators. They can move in any direction from any configurations. However, this type of system is not truly omnidirectional because it needs to stop and re-orient its wheels to the desired direction whenever it needs to travel in a trajectory with non-continuous curvatures.

Most special wheel designs are based on concept that achieves traction in one direction and allow passive motion in another, thus allowing greater flexibility in congested environments. One of the more common omnidirectional wheel designs is that of the Mecanum wheel, invented in 1973 by Bengt Ilon, an engineer with the Swedish company Mecanum AB. Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel. The angled peripheral roller translates a portion of the force in the rotational direction of the wheel to force normal to the wheel directional. Depending on each individual wheel direction and speed, the resulting combination of all these forces produces a total force vector in any desired direction thus allowing the platform to move freely in direction of resulting force vector, without changing the direction of the wheel. The overall block diagram of the system is shown in fig .1.

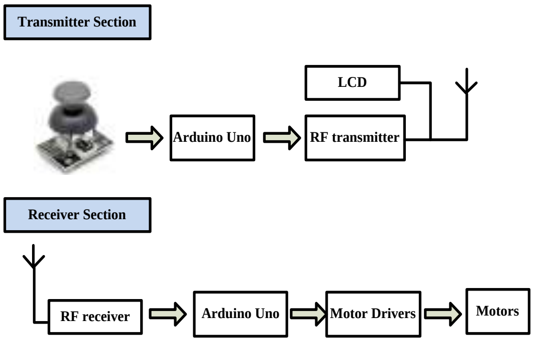

Fig.1. Overall Block Diagram of the System

Fig.1 shows the overall system of the robot. In this research, joystick is used for direction control in the remote controller. Firstly, the operator sends the signal with the help of joystick controller. When the circuits are started, Arduino Uno is reading the data from the operator and then sending data to RF transmitter that transmits data to the robot. During that time, RF receiver receives the data and Arduino Uno on the robot is processing and analyzing the data from the remote control. The Arduino Uno controls the motor drivers in accordance with the data received from RF receiver on the robot. Depending on the joystick directions, the four motors will be operated appropriate functions. Omnidirectional movement occurs according to the four motor directions by using four Mecanum wheels. In this research, the two circuits are needed to control the robot; transmitting circuit and receiving circuit. The operation of remote control circuit represents transmitting part and the operation of the motor control circuit represents receiving part. In the remote control circuit, Arduino Uno is the main controller interfacing with RF module and joystick. The RF module transmits serial data with the baud rate 9600bps.

The design process is clearly explained in the next section with detailed information regarding the components which are used, followed by the results and finally ends with comparison results for error checking and conclusion.

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II. Main Components and Design of Mecanum Wheel for Wireless Control Omnidirectional Mobile Robot System

In this design, the following main components are mainly used for controlling the omnidirectional mobile robot. In this paper, the system is mainly composed of five parts; the first part is the Mecanum wheel, the second is joystick, the third is RF transmitting and receiving data, the fourth is the Arduino Uno and the fifth is driving the motors. The robot is completely controlled by wireless remote. The control system consists of the following devices; RF modules, Arduino Uno, joystick, L298 Driver, DC motors, LCD are included.

A. Design of Mecanum Wheel

In this research, the omnidirectional mobile robot consists of four Mecanum wheels. The design of a Mecanum wheel includes rollers that are at a 45° angle to the x and y axis which translates a portion of the force in the rotational direction of the wheel to the direction normal to the wheel's direction. Since the rollers are in a 45° to the x axis and the y axis, the translated portion of the force to the direction normal to the wheel's direction will be equal to the force in the rotational axis of the wheel (as shown in fig. 2).

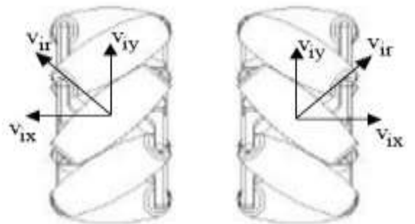
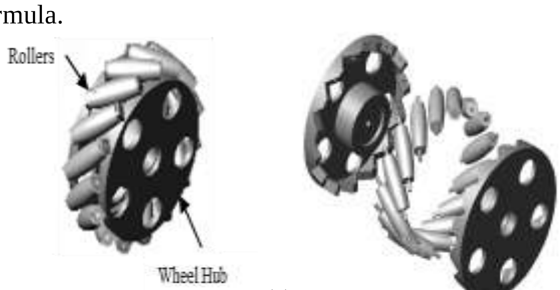


Fig.2.The velocity components of the Mecanum wheel (i = 1,2,3,4 depending on the wheel)

(a). Calculation of wheel parameters

The wheel itself consists of a hub carrying a number of free moving rollers angled at 45° about the hub's circumference. The angled peripheral rollers translate a portion of the force in the rotational direction of the wheel to a force normal to the wheel direction. Depending on each individual wheel direction and speed, the resulting combination of all these forces produce a total force vector in any desired direction thus allowing the platform to move freely in the direction of the resulting force vector, without changing of the wheels themselves.

The wheel parameters can be calculated with the following formula.



(i) (ii)

Fig.3. (i) Basis components of Mecanum wheel (ii) exploded view of Mecanum wheel

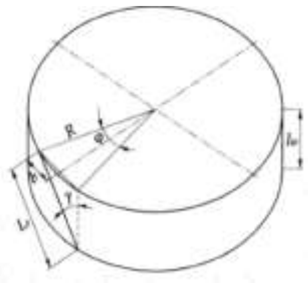


Fig.4. Wheel parameters

Where,

This shape should respect the equation:

$$\frac{1}{2}x^2 + y^2 = R^2 \tag{1}$$

Where, R is the external radius of the wheel.

The number of roller can be calculated by;

$$n = \frac{2\pi}{\varphi} \tag{2}$$

$$\varphi = 2\sin^{-1}\left[\sin\gamma \frac{L_r}{2R}\right] \tag{3}$$

The length of the roller (L_r) is,

$$L_r = 2R\frac{\sin\frac{\varphi}{2}}{\sin\gamma} = 2R\frac{\sin\frac{\pi}{n}}{\sin\gamma} \tag{4}$$

The wheel width (L_w) is,

$$L_w = L_r\cos\gamma = 2R\frac{\sin\frac{\pi}{n}}{\sin\gamma} * \cos\gamma = 2R\frac{\sin\frac{\pi}{n}}{\tan\gamma} \tag{5}$$

$For\ \gamma = 45^\circ$,

$$L_r = 2\sqrt{2}R\sin\frac{\pi}{n} \tag{6}$$

$$L_w = 2R\sin\frac{\pi}{n} \tag{7}$$

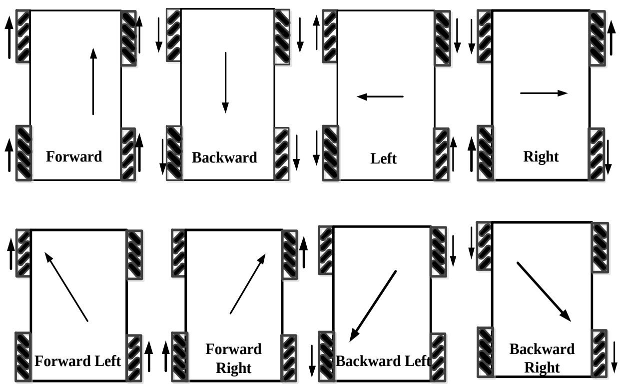


Fig.5. Robot motion according to the direction of the wheels

(b) Kinematic Model of Mecanum wheel

In order to control the Mecanum wheel based vehicle, it is critical to understand the kinematic equations involved. The explanation below gives the control equations for each motor based on a x, y, w (longitudinal, lateral and yaw) input.

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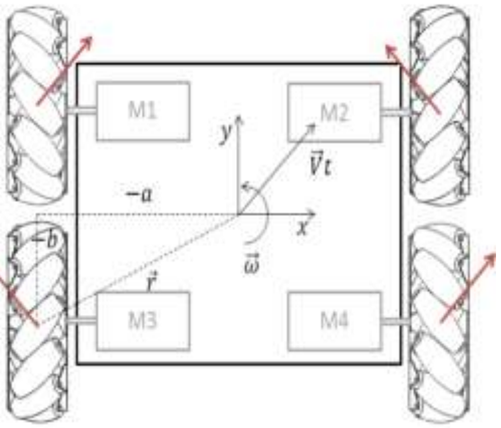
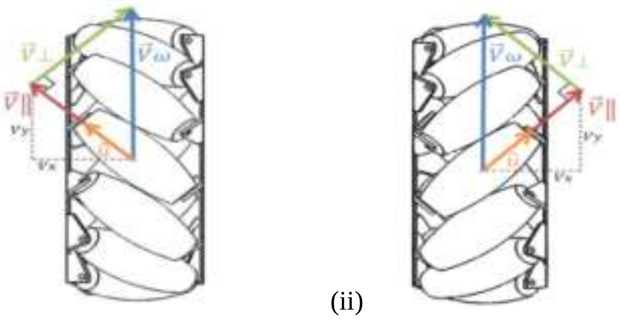


Fig.6. Bird's eye view of the Mecanum wheel layout

Fig.6. shows the force vectors resulting from the wheels being driven forward. It can be seen that if all four wheels are driven forward at the same speed the x-axis components cancel out and the platform will move forwards. Here $\vec{V}_t$ is the desired velocity of the platform, $\vec{\omega}$ is the rotational velocity of the platform and $\vec{r}$ is the distance from the center of the platform to the wheel contact point with a and b being the scalar components.



(i) (ii)

Fig.7. (i) Force vectors action on left Mecanum wheel, (ii) Force vectors action on left Mecanum wheel

The complete kinematic equations are;

$$V_{1w} = V_{ty} + V_{tx} - \omega(a+b) \quad \text{Left Front Motor} \tag{8}$$

$$V_{2w} = V_{ty} - V_{tx} + \omega(a+b) \quad \text{Right Front Motor} \tag{9}$$

$$V_{3w} = V_{ty} - V_{tx} - \omega(a+b) \quad \text{Left Rear Motor} \tag{10}$$

$$V_{4w} = V_{ty} + V_{tx} + \omega(a+b) \quad \text{Right Rear Motor} \tag{11}$$

The above equations are represented by,

The above equations are represented by,

$$\begin{bmatrix} V_{1w} \\ V_{2w} \\ V_{3w} \\ V_{4w} \end{bmatrix} = \begin{bmatrix} 1 & 1 & -(a+b) \\ -1 & 1 & (a+b) \\ -1 & 1 & -(a+b) \\ 1 & 1 & (a+b) \end{bmatrix} * \begin{bmatrix} V_x \\ V_y \\ \omega_z \end{bmatrix} \tag{12}$$

That V_x, V_y and ω_z are calculated through the inverse equation as follows.

$$\begin{bmatrix} Vx \\ Vy \\ \omega_z \end{bmatrix} = \frac{r}{4} * \begin{bmatrix} 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 \\ \frac{-1}{(a+b)} & \frac{1}{(a+b)} & \frac{-1}{(a+b)} & \frac{1}{(a+b)} \end{bmatrix} * \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} \tag{13}$$

Longitudinal Velocity:

$$V_x(t) = (\omega_1 - \omega_2 - \omega_3 + \omega_4) * \frac{r}{4} \tag{14}$$

Transversal Velocity:

$$V_y(t) = (\omega_1 + \omega_2 + \omega_3 + \omega_4) * \frac{r}{4} \tag{15}$$

Angular Velocity:

$$\omega_z(t) = (-\omega_1 + \omega_2 - \omega_3 + \omega_4) * \frac{r}{4(a+b)} \tag{16}$$

The resultant velocity and its direction in the stationery coordinate axis (x, y, z) can be achieved by the following equations:

$$\rho = \tan^{-1}\left(\frac{V_y}{V_x}\right) \tag{17}$$

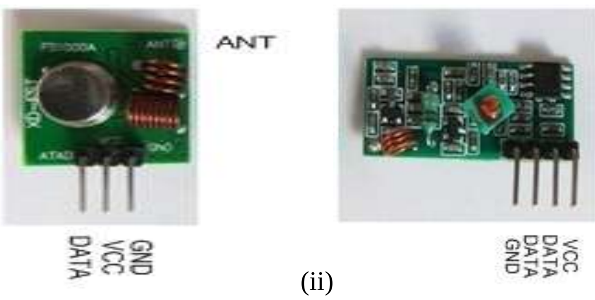
$$V_R = \sqrt{V_x^{\,2} + V_y^{\,2}} \tag{18}$$

TABLE I. PARAMETERS OF MECANUM WHEEL FOR 4cm WHEEL RADIUS AND 2.5cm ROLLER LENGTH

Wheel radius	4cm
Number of rollers	14
Length of the rollers	2.5cm
Wheel width	2cm
ϕ	26^0

A. *Wireless control with RF modules*

This radio frequency (RF) transmission system employs Amplitude Shift Keying (ASK) with transmitter/receiver (Tx/Rx) pair operating at 434 MHz. The transmitter module takes serial input and transmits these signals through RF. The transmitted data is received by an RF receiver operating at the same frequency as that of the transmitter. The maximum baud rate is 9600 bps.



(i) (ii)

Figure.8. (i) RF module transmitter (ii) RF module receiver

The maximum launch distance of transmitter is 200 meter ,transmitting power is 10mW, transmitting frequency is 433MHz and operating voltage is 3.5V to 12V.The receiver module has operating voltage is 5V. For motor control, in transmitting part, eleven push buttons are used to input the data for the RF transmitter. In receiving part, RF module receives data and sent signal to the controller to drive the motors.

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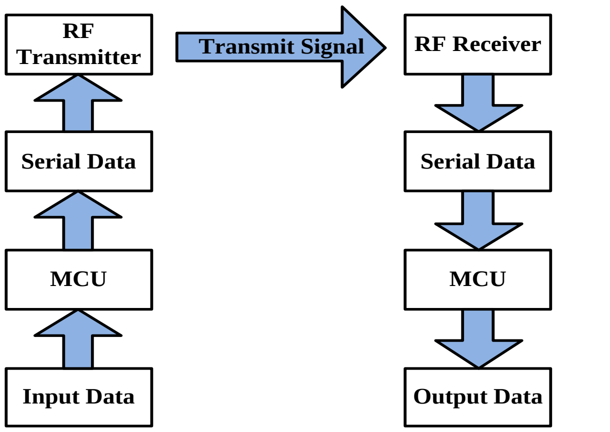

Figure.9. Wireless RF module transmitting and receiving system

III. System Block Diagram and Operation of the Control Circuit Of Omnidirectional Mobile Robot

A. Circuit Operation of the Transmitting Part

Using the information received from the joystick controller, RF module transmits signal as serial data to the robot. By pressing each corresponding stick movement, the operator can control simultaneously not only the robot movement but also extinguishing. The circuit is supported with 5V and 12V DC supply. The transmitting circuit diagram is shown in fig.10.

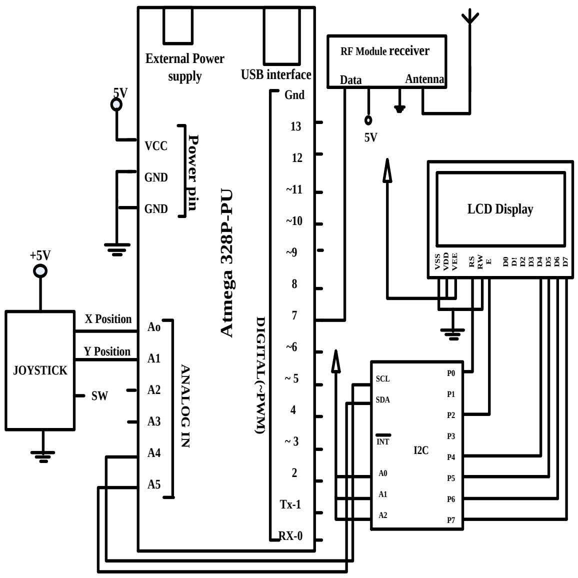

Fig.10. Transmitting Circuit

B. Circuit Operation of the Receiving Part

All the motors are driven by the command signal received from the remote control device. The Arduino Uno is also used as the main microcontroller to interface with other devices by receiving the data from RF receiver. The robot is moved to any direction with the help of four DC motors driven by L298. DC motors are used to turn the robot right/left or forward/backward or forward right/forward left or backward right/backward left and stop. The circuit is supported with 5V and 12V DC supply. The receiving circuit is described in fig 11.

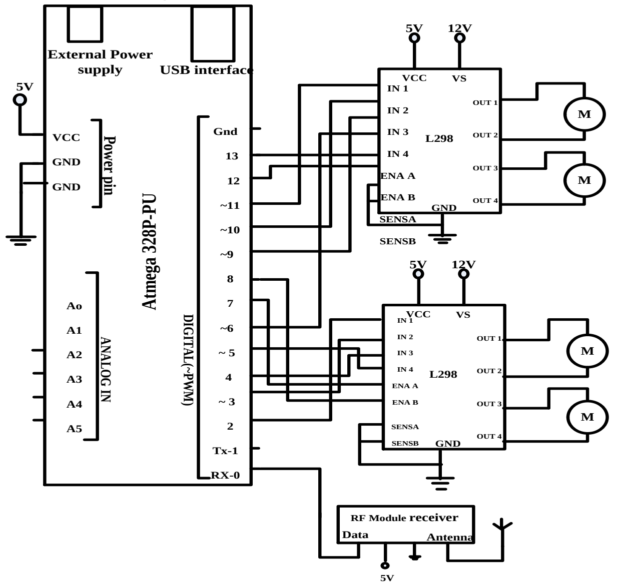

Fig.11. Receiving Circuit

IV. Software Implementation of The Control System

In this section, transmitting and receiving parts of motor control are mentioned. Arduino C programming language is applied in this research.

A. Transmitting Part

At the start of the system, defining register, creating variables and assigning I/O pins are operated by the Arduino Uno. The facts that whether joystick is pressed or not are firstly checked. When joystick is not pressed, no data is transmitted. If the desired joystick direction is pressed, the corresponding signal is transmitted in the form of serial data by the RF transmitter with the baud rate 9600 bps. The transmission flow chart is shown in figure.12.

B. Receiving Part

At the start of the system, defining register, creating variables and assigning I/O pins are operated by the Arduino Uno. The Arduino Uno receives the serial data from the remote control to interface with the drivers. There are four motors in the circuit. Each of these motors can be controlled to rotate forward or backward by the instruction of the program. The operating system flow chart for receiving part is described in fig.13.

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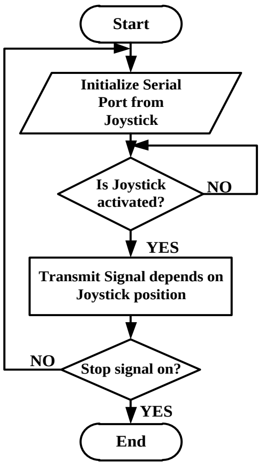

Fig.12. Operating system flow chart for transmitting part

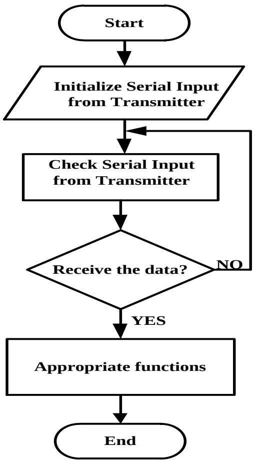

Fig.13. Operating system flow chart for receiving part

V. TEST AND RESULTS

In this system, the speed of motors is controlled by joystick, Arduino Uno and radio frequency module. In testing, the direction of motors can be changed by pressing the switches. For this system, Arduino Uno can be performed as a controller. In the transmitter section, the user enters the input signal from the switches and then these signals are sending from microcontroller to radio frequency module (RF). Radio frequency transmitter module sends these signals to the receiver section. In the receiver section, receiver module receives the signals that are sent from transmitter module. Depending on the received signals and the motor will be rotated according to the instructed direction. The motor will move forward when the simulation result of the system. Simulation result of the system is shown in Fig 14. Kinematics model of this type of robot has been calculated and compare with experimental result shown in Tables.

Results of testing conditions are displayed on the LCD as shown in Fig 15.Fig 16 and 17 show the hardware configuration for transmitting part and receiving part.

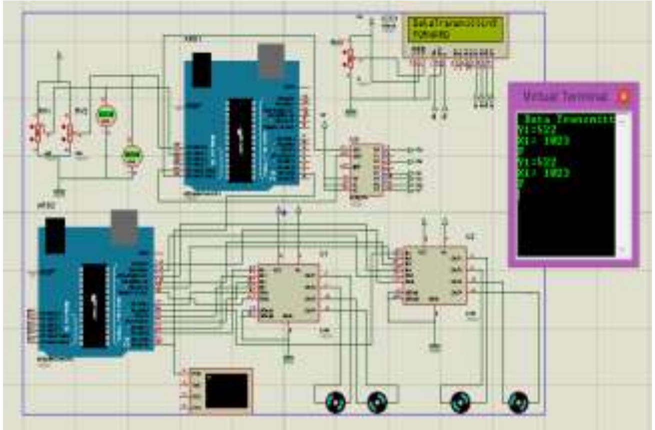

Fig.14.Simulation result of the system

Fig.15.Command Result on LCD

TABLE II. THEORETICAL RESULT

	V_x	V_y	V_t	ω	ρ
Forward	0	15.84	15.84	0	0
Backward	0	-15.84	15.84	0	0
Left	15.84	0	15.84	0	0
Right	-15.84	0	15.84	0	0
Forward Left	7.92	7.92	11.2	0	45^0
Forward Right	-7.92	7.92	11.2	0	-45^0
Backward Left	7.92	-7.92	11.2	0	-45^0
Backward Right	-7.92	-7.92	11.2	0	45^0

TABLE III. EXPERIMENTAL RESULT

	V_x	V_y	V_t	ω	ρ
Forward	0	11.43	11.43	0	0
Backward	0	-11.43	11.43	0	0
Left	11.43	0	11.43	0	0
Right	-11.43	0	11.43	0	0
Forward Left	5.72	5.72	5.72	0	45^0
Forward Right	-5.72	5.72	5.72	0	-45^0
Backward Left	5.72	-5.72	5.72	0	-45^0
Backward Right	-5.72	-5.72	5.72	0	45^0

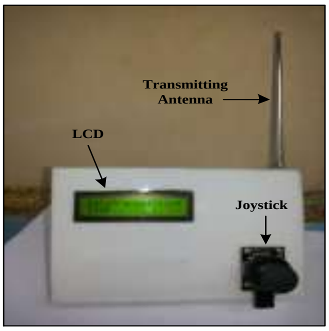

Fig.16.Hardware construction of transmitting part

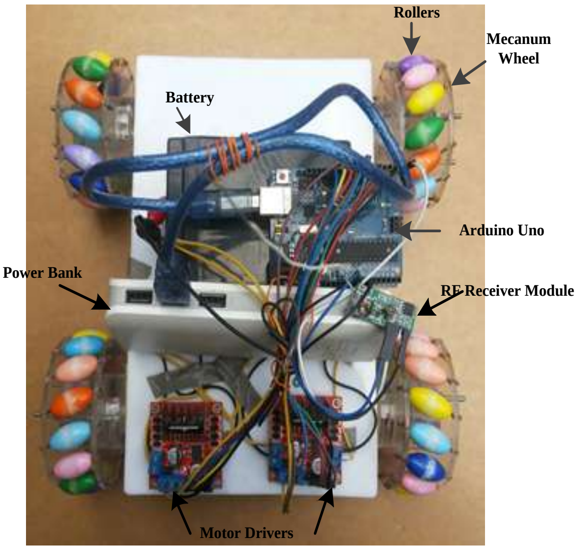

Fig.17.Hardware construction of receiving part

VI. CONCLUSION

This paper represents a wireless control Omni directional mobile robot using Mecanum wheel and it is designed for only as a sample. This sample can be based to construct Omni directional mobile robot practically used in dealing with many other applications. The Mecanum wheels present a number of advantages that makes them a real interest in development of the omnidirectional platforms. The suggested mobile robot has a squared mobile platform and four Mecanum wheels at each corner. By harmoniously coordinating the four Mecanum wheels, immediate forward/backward, lateral and rotational motion, in other words, omnidirectional motion is guaranteed. Such robots can be applied as long loads transportation, and indoor applications, like small goods transportation, powered robotic wheelchairs or shopping carts etc. are also controlled by wireless RF communication. For the future work, to get precise movement, this robot can be added a control law and can be considered the dynamic model of this type of robot.

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