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Three Wheeled Omnidirectional Soccer Robot Modelling and Wireless controlling using Bluetooth enabled PlayStation Controller

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Abstract

This paper presents a project designing and functioning of the Omni-Direction Holonomic Robot for Robo Soccer. It serves as an agile, fast, efficient, and energy-saving unit against all previously designed units of Omni-directional robots. Since This robot is remotely controlled via Bluetooth and a PS3 controller with help of an arduino uno, making it efficient and easy to maneuver out of all other designs as it saves a considerable amount from your pocket through a reduced manufacturing process and focuses on utilizing the resources in the best possible way. It's the first-ever made robot that functions on an integrated combination of Arduino Uno R3 with the Bluetooth enabled PlayStation controller. The direction calibration is done through the kinematic model and formulations, which helped the logic to access the root of the processors and helped us to enhance the functioning of the robot.

1. Introduction

The robotic platform resulting from attaching omnidirectional wheels to a chassis is called holonomic because the resulting vehicle can drive a path with independent orientation, and X-Y motion. The degrees of freedom that can be controlled is equal to all the degrees of freedom of the robot. Omnidirectional wheels roll forward like regular wheels but slide sideways with no friction (or very little friction). Omni wheels differs from a traditional Ackerman-steered vehicle or a tracked vehicle that must use skid-steering. An omnidirectional robot can perform movements in any direction without the need to reorient, allowing more mobility and increasing the robot's degree of freedom. This feature is accomplished by controlling the omnidirectional wheels, combining their vectorial forces and velocities. For a dynamic and kinematic model of the robot, it is necessary to consider magnitudes like speed, acceleration, and strength that is provided by the motors and the energy put into the system. To move in close regions and to maintain a strategic distance from hindrances, versatile robots ought to have improved mobility and maneuverability. These abilities mostly depend upon the wheel's design. Omni-Wheel Multi-Direction robots are particular as they can move freely in any direction based on the command. It can roll like a regular robot or move laterally. Omni-directional wheels with right frame permits a robot to change over from a non-holonomic robot to a holonomic robot. A non-holonomic robot utilizes ordinary common wheels and have just two out of three controllable DOF, that moves front/reverse and pivots. Conventional Wheel Mobile Robots (WMRs) are confined in their movement because they cannot move sideways during the initial maneuver. Three-wheeled frameworks are mechanically more straightforward, yet robots with four wheels have more acceleration with a similar sort of motors. Four-wheeled robots are relied upon to have a better surface traction, that is, less wheel slippage – expecting that all wheels are forced against the floor similarly. Obviously four-wheeled robots likewise have a greater expense in equipment, increased energy utilization, and may require a suspension to convey forces equally to all the wheels.

2. Literature Review

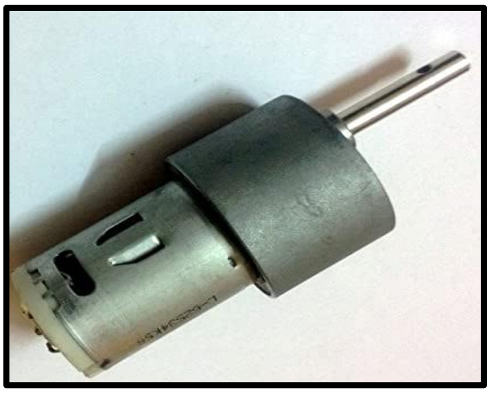
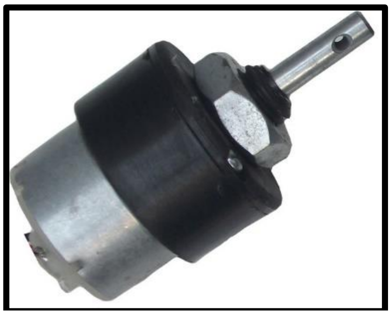
A special class of mobile robots are omnidirectional robots. These robots are designed for 2D planar motion and are capable of translation (x, y) and rotation around their center of gravity (θ): three degrees of freedom (3 DOF). Unlike conventional vehicles, omnidirectional robots can control each of their DOFs independently. In order to operate effectively, mobile robots should be able to keep track of their current position (localization), sense their surroundings (perception), be able to generate a path to their destination (path planning) and execute it (navigation) in an efficient manner. (Baede, T.A., 2006). Omni-directional robots are becoming a much-sought solution to mobile robotic applications. This kind of holonomic robots are interesting because they allow greater maneuverability and efficiency at the expense of some extra complexity. One of the most frequent solutions is to use some of Mecanum. A robot with 3 or more motorized wheels of this kind can have almost independent tangential, normal and angular velocities. Dynamical models for this kind of robots are not very common due to the difficulty in modeling the several internal frictions inside the wheels, making the model somewhat specific to the type of wheel being used. (Oliveira, 2008). The use of wheels is more energy-efficient than legged or treaded robots on hard and smooth surfaces. The most popular wheeled mobile robots use two independent fixed driving wheels with two degrees-of-freedom (DOF) instead of three DOF (x,y,θ). These robots, like for example domestic cleaners, have only two actuators, requires less space to rotate around any point and this also allows three DOF, but their limitation is that they cannot perform holonomic motion such as sideways movements. Omnidirectional mobile robot's devices offer interesting features when operating in tight spaces. shows a mobile robot design equipped with steerable wheels published by Wada and Mori. They allow both rotation and also sideways motion, but not simultaneously. Holonomic robots are based in the use of three or four omnidirectional wheels, which are composed. (Moreno, J., 2016)

The three-wheeled omnidirectional mobile robots can have three independent actuators and they can achieve two independent translational and one rotational DOF for the total of 3-DOF on a flat surface and maneuver and navigate in tight spaces such as in domestic environments. However, due to their high center of gravity, they have stability problems when they are moving on a ramp because of the triangular contact area with the ground. (Moreno, J., 2016)

3. Design Parameters

The Hardware model for the Omni-direction Holonomic Robot is a Tri-Axis stainless steel model where the 2mm Steel sheet was used to maintain the robust factor. Fabrication of the Components includes many components such as: -

Omni wheels (55mm): The structure of the Omni-directional wheels depends on alternate rollers with various sizes and shapes so as to reduce the space between the rollers. The omnidirectional wheel used have passive rollers whose axes are positioned tangent to the main base-wheel circumference. The below figure shows the movement of the omnidirectional wheels in all directions.

Movement of Omni-wheel; DC 12V 500 RPM Johnson Motor; 12V DC 1000 RPM Centre Shaft Motor

12V 500RPM DC Motor

The Johnson geared motor is famous for its compact size accompanies by decent torque. A torque as much as x3 as compared to the center shaft or side shaft geared motor. The motor comes with a metal gearbox, and off-centered shaft, also shaft has a metal bushing for wear resistance. Apart from the robotic application, they are also used in industrial applications, vending systems, hygiene and cleaning industry, and household electric appliance.

Specifications and Dimensions:

	Parameters	**Value**
	RPM	500
	Shaft Diameter	6mm (with internal hole)
	Shaft Length	15 mm
	Gearbox Diameter	37 mm
	Motor Diameter	28.5 mm
	Length (Body)	63 mm
	Weight	300 gm
	Torque	60 kg-cm
	Voltage	6 to 24 (nominal voltage – 12V)
	No-load Current	800 mA(max) Load Current = 9A(max).

12V 1000 RPM DC Motor

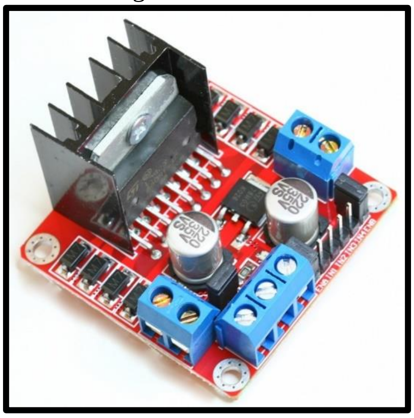
DC Geared motors with robust metal gear-box for heavy-duty applications, available in wide RPM ranges and ideally suited for robotics and industrial applications. Very easy to use and are available in a standard size. Nut and threads are present on the shaft to easily connect, and internally threaded shaft for easily connecting it to the wheel.

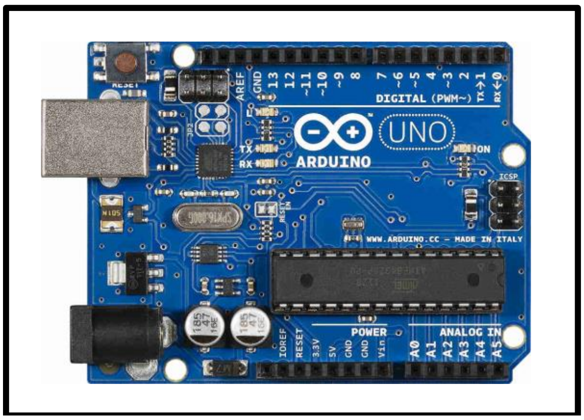
Specifications and Dimensions:

	Parameters	**Value**
	RPM	1000
	Voltage	12 V
	Shaft Diameter	6 mm
	No-load Current	70 Ma (Max)
	Torque	kg-cm

Motors Driver – L298 (Max V=46V, Max I=4A)

The L298 is an integrated monolithic circuit in a 15-lead Multi watt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together, and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.





Motor Driver; Arduino UNO R3

Specifications:-

Symbol	Parameter	Value	Unit
V_S	Power Supply	50	V
VSS	Logic Supply Voltage	7	V
VI,Ven	Input and Enable Voltage	–0.3 to 7	V
I_O	Peak Output Current (each Channel)		
	– Non-Repetitive (t = 100ms)	3	A
	–Repetitive (80% on –20% off; ton = 10ms)	2.5	A
	–DC Operation	2	A
Vsens	Sensing Voltage	–1 to 2.3	V
Ptot	Total Power Dissipation (Tcase = 75°C)	25	W
Top	Junction Operating Temperature	–25 to 130	°C
Tstg, Tj	Storage and Junction Temperature	–40 to 150	°C

Arduino UNO R3 (Input V=5V): The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which six can be used as PWM outputs, and six can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC Adaptor or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features an ATmega16U2 programmed as a USB-to-serial converter. This auxiliary microcontroller has a USB boot loader, which allows advanced users to reprogram it.

Specifications and Dimensions

	Parameters	Value
	Operating Voltage	5 V
	Input Voltage	7 – 12 V
	Digital I/O Pins	14
	Flash Memory	32 kb
	Clock Speed	16 MHz
	Length	68.6 mm
	Width	53.4 mm
	Weight	25 gm

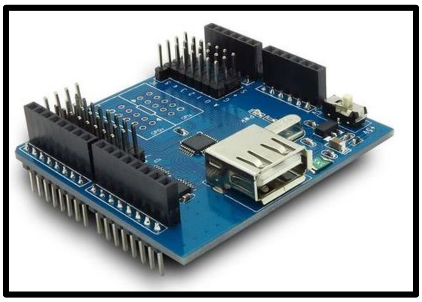
USB Host Shield

The USB Host Shield contains all of the digital logic and analog circuit necessary to implement a full-speed USB peripheral/host controller with Arduino. This shield adds USB Host capabilities to the popular Arduino platform. C Software support for new devices are constantly added; at the moment, code for USB keyboard and PS3 controller is ready with Bluetooth and digital cameras in the works.

Major Characteristics of USB Host Shield are:

- USB 2.0 Full Speed compatible
- 3.3/5V operation level compatible

- All GPIOx pins break-out
- USB Host 5V/500mA supply for USB protocol
- PCB Size – 56mm * 54mm * 1.6mm



USB Host Shield; USB Bluetooth Dongle; Sony PlayStation Controller (Wireless)

Specifications:

Parameter	**Min.**	**Max.**	**Unit**
Power voltage (Vlogic)	3	5.5	VDC
Input voltage VH	0.7 V logic		V
Input voltage VL		0.3 V logic	V
Current Consumption		70	mA

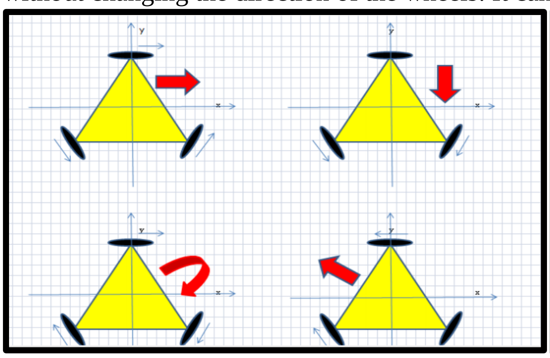
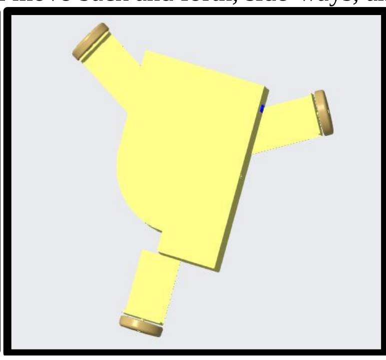
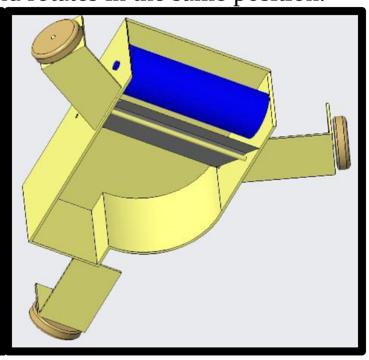
USB Bluetooth Dongle: It is used to establish Wireless data connectivity between computers and Bluetooth enabled devices such as cell phones, PDAs, PlayStation remote with the Bluetooth standard: Bluetooth V2.0 + EDR (Enhanced Data Rate) and data rate up to 3Mbps, it can be connected to all the devices. It can work within the distance up to 100 meters with no obstructions.

Sony PlayStation Controller (Wireless): The DualShock 3 wireless controller for the PlayStation 3 system provides the most intuitive game play experience with pressure sensors in each action button and the inclusion of the highly sensitive SIXAXIS™ motion sensing technology. Each hit and crash is more realistic when the user feels the rumble right in the palm of their hand. It can even detect natural movements for real-time and high precision interactive play, acting as a natural extension of the user's body. DualShock 3 wireless controller utilizes Bluetooth technology for wireless game play and the controllers USB cable to seamlessly and automatically charge the controller through the PlayStation 3 system at any time.

Dribbler: The dribbler is an integral component used to carry out one of the most important functions of the robo-soccer robot, i.e., to carry, and control the ball on the field. In this case the dribbler mechanism includes a cylindrical bar with rubber grip, a 12v DC motor and ball bearing bush, all attached to the frame of the robot using c-clamp. As the dribbler achieves the desired velocity, it creates a "suction field", which keeps the ball tight into the robot by giving it a backspin as it touches the dribbler while maneuvering on the field surface. For an efficient dribbler, the bar should be made of an appropriate material that gives good control over the ball during the robot's movement. The bar height and the point where the ball makes contact with the roller bar, and the velocity of rotation is the defining variable for better or worse control of the ball. The desired torque and height were obtained through various practical trials. Similarly, the dribbler can also be used for shooting by reversing the rotation and velocity of the motor. The different components required are jumper connectors, 24V lead battery, and 1.5mm thick stainless steel sheets.

4. Working of Holonomic Omni-Directional Robot

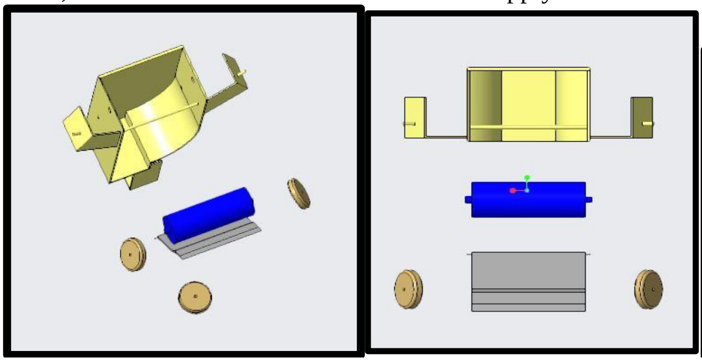
Omni-directional wheels are unique as they can roll freely in two directions. It can ether roll like a normal wheel or roll laterally using the wheels along its circumference. Omni-directional wheels allow a robot to convert from a non-holonomic to a holonomic robot. A non-holonomic robot that uses normal wheels has only 2 out of 3 controllable degrees-of-freedom which are, moving forward/backward and rotation. Not being able to move sideways makes a robot slower and less efficient in reaching its given goal. The holonomic Omni-directional wheels can overcome this problem, as it a highly maneuverable. Unlike normal non-holonomic robot, the holonomic Omni-directional robot can move in an arbitrary direction continuously without changing the direction of the wheels. It can move back and forth, side-ways, and rotates in the same position.

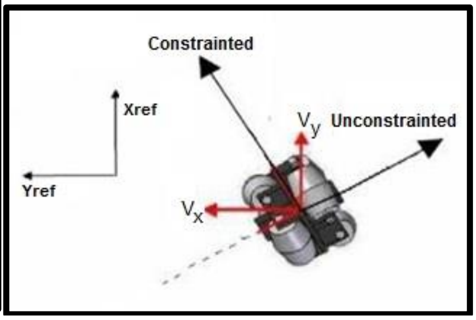




Working Principle of 3 Wheels Omni-Wheel Robot

Assembly of Robo Soccer

Modularity makes it easy for users to change the platform or add components to it. There are many robotic platforms that were developed to simplify the design of software and hardware. These platforms fall short of meeting the objectives of our design. These design objectives were: modularity, ease of use and construction, low cost, and an emphasis on straight forward control, in a mobile robot performing search algorithms; it must be intelligent enough to navigate the environment, avoid obstacles and finally locate the search target with the help of adequate sensors. Usually, works regarding robot autonomy were studied, and the usefulness of some ideas could apply and combined in an effective way to achieve.





Exploded View of Omni-Directional Robot; Kinematic Figure for Equation

The assembly consists of main wheels and transversal rollers, such as those used by most Robo Cup teams. Robots constructed with these wheels normally possess three driven Omni-directional wheels arranged in a Δ or Y manner. The basic three-axis structure of the Holonomic Omni wheel Robot, which is being developed in this project, would be as shown in the figure. The dribbler is being attached to the front section of the robot, which is depicted with the blue shades. Spot welding being the lightest and efficient for the robust design, was chosen to be used.

Using Figure, the kinematics equations of the drive system can be derived. Equations that are used in the robot control system are

$$V_x = V_3 - V_1 \cos(\delta) - V_2 \cos(\delta) \quad (1)$$

$$V_y = V_1 \sin(\delta) - V_2 \sin(\delta) \quad (2)$$

$$V_\Phi = V_1/L + V_2/L + V_3/L \quad (3)$$

$$V_{i(1,2,3)} = w \cdot r \quad (4)$$

Where;

r = Omni wheel radius (cm).

w = Angular velocity of the wheel (rad/sec).

So the velocity for each of the three wheels will be equal to the servomotor speed multiplied by wheels' radius in the theoretical analysis. As the wheels are arranged in a symmetrical manner (120°) apart, then δ = (60°). So, Equations (1) to (3) can be rewritten in a matrix form;

$$\begin{bmatrix} V_x \\ V_y \\ V_\phi \end{bmatrix} = \begin{bmatrix} \frac{-1}{2} & \frac{-1}{2} & 1 \\ \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} & 0 \\ \frac{1}{L} & \frac{1}{L} & \frac{1}{L} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \quad (5)$$

To find out the velocity and orientation at any point the following equations would be useful.

$$V = \sqrt{Vx^2 + Vy^2} \quad (6) \qquad \Psi = \tan^{-1}(Vy/Vx) \quad (7)$$

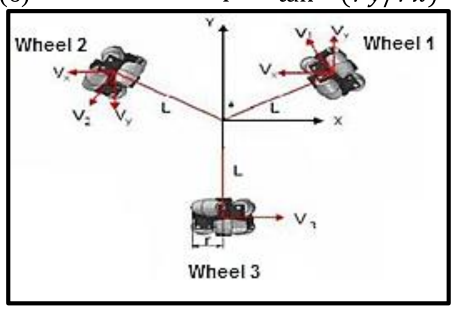


Fig 20. Orientation of Wheels

Robots are essentially motion devices. So, kinematics is a fundamental part of the multidisciplinary research area of robotics. The kinematic model of a manipulator describes the relationship between joint displacements and end effector motion. It is composed of position and velocity formulations. The position kinematic model relates joint positions and end-effector posture. Implementation of data collection using a series and done repeatedly to produce data that is appropriate. Before doing the data collection, learn the components first, then determine the measurement point.

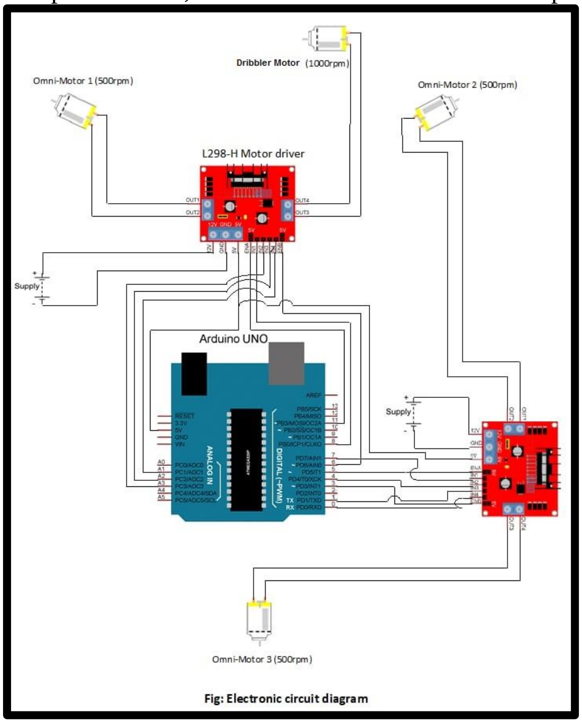
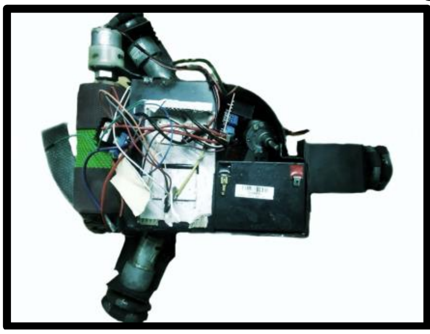


Fig 22. Electronic Circuit Diagram

The forward or direct kinematics analysis is the process of calculating the end-effector posture from the joint positions given. It is used in the design and simulation of robotic kinematic chains. Inverse kinematics analysis is the process of obtaining the joint positions necessary to establish the desired end-effector posture. Both analysis are important in motion study. It is essential for motion planning resolution algorithms. One problem of the inverse kinematics is the possibility of multiple solutions, or even infinite solutions if the kinematic chain is redundant.

Working Model Of Holonomic Omni-Directional Robot



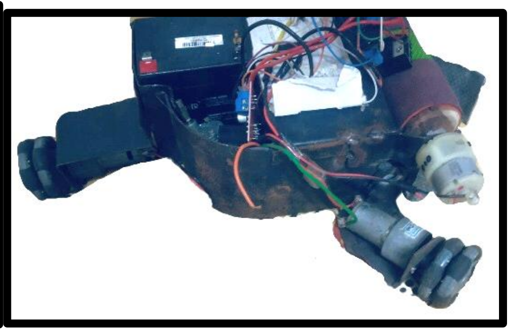


Fig 24. Top View of the Model; Fig 25. Bottom View of the Model; Fig 26. Wheel and scrubbing Mechanism

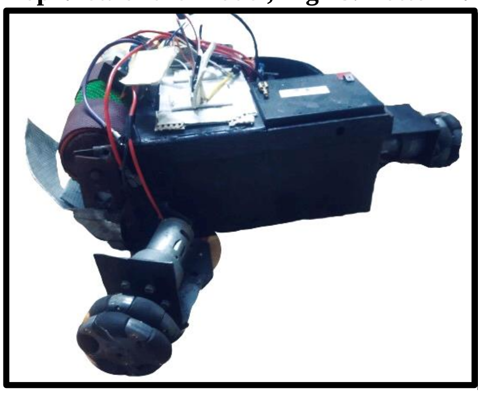
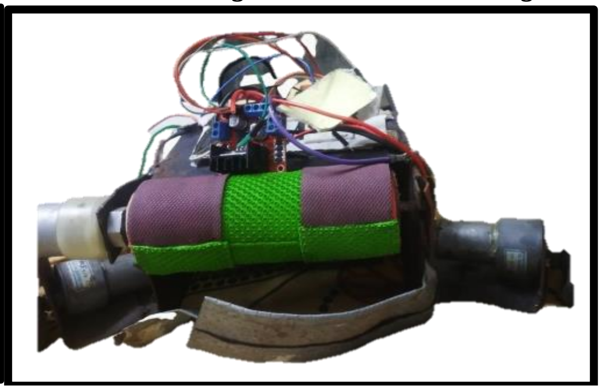



Fig 27. Roller Mechanism; Fig 28. Front View of Model

5. Conclusion

The Product developed is useful in the area of robot-soccer robots and by altering the design it can be also used for various other applications like cleaning or collecting. The important innovation of the project was to achieve compatibility between Omni wheels, Arduino uno and PS3 controller to obtain efficient and easy manoeuvrability while keeping low cost in mind. The compilation of code with the PS Controller is achieved, and the motor drivers are being set and coupled into the circuit to deliver the effective and most efficient response via Bluetooth. The Controlling agility is enhanced by the effective use of Arduino UNO R3. All the other omnidirectional robots which are being designed till now are based and coded either on the basis of Raspberry Pi, Beagelbone Black or some other costly microcontrollers. Simultaneous the Controllers which are being utilized for control of these omnidirectional robots are either 5 Channel or 7 Channel Heavy crafted Controllers. The integrated use of Processor and use of professional 7-channel Controller increases the overall Manufacturing cost of the Robot. Whereas by undergoing this trial to build efficient and effective robot functioning by utilizing the processing being done by Arduino UNO R3. The other element which increased the cost was the controlling unit. The controlling unit utilized in this project is a SONY PlayStation controller IC-409B. The Controlling doesn't require any sort of hosting mechanism but functions totally on the Bluetooth compatibility between the device and the controller. The main advantage of this project is that it utilized an efficient way to collectively integrate the processor with the controller in the cheapest possible manner.

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