AUTONOMOUS NAVIGATION OF AN OMNI-DIRECTIONAL ROBOT IN A CLUTTERED INDOOR ENVIRONMENT

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ABSTRACT

This paper proposes an omni-directional robot that uses mecanum wheels, which is capable of efficiently navigating in a cluttered environment. Omni directional robots are robots that can move in any given direction, making the robot very versatile. This is particularly useful in bypassing obstacles the robot would encounter in its path, in an efficient manner. The robot should position itself with reference to the target path, and correct its motion every time it diverts due to an obstacle. The design and the operation of the robot s presented, along with the kinematic analysis. Autonomous navigation was tested in an arena with fixed shaped obstacles.

1. INTRODUCTION

Robots are machines with intelligence to achieve extreme tasks which cannot be achieved by humans. Particularly in industrial robots, the ability to move in multi directions can improve the efficiency of maneuvering in a cluttered environment. The main advantage of a multi-directional/ Omni-directional robot against a differential drive robot is its ability to move in sideways, move at any angle. This is especially helpful when having to maneuver in a tight environment such as a factory floor. This multi directional ability is obtained mainly by two different types of special wheels adopted for this. Omni wheels (Figure 1 (B)) - wheels with small discs around the circumference which are perpendicular to the turning direction. Mecanum wheels (Figure 1 (A)) - conventional wheels with series of rollers attached to the circumference.

(A)

(B)

Figure 1: (A) Typical mecanum wheel consisting of 45 ° Rollers, very similar to the one used on this robot. (B) Omni direction wheel with discs

The scope of this project is to develop and analyze the behavior of an autonomous mecanum wheel robot showcasing its ability of multi directional movements.

2. BACKGROUND

In robotics industry it is very common to observe the prevalence of differential wheel driven robots. These can only take left or right turns by changing the orientation of the wheels plus the body of the robot, but there are situations where it is convenient to use a robot such that it can move sideways left/right without changing the direction the robot is facing (i.e. without changing its orientation)

As a solution to this problem omni-directional robots using either omni-wheels [1] or mecanum wheels [2] are developed. The focus of this project is to develop a mecanum wheel driven robot as a solution to the above mentioned problem. Mecanum wheels provide all the facilities of using normal wheels plus the ability of moving side by side as well.

Mecanum wheels contain rollers set on a 45° rotational axis parallel to the main rotational axis of the wheel. This unique feature can be used to create force vectors in multiple directions. The proposed design consists of a robot with 4 mecanum wheels. Therefore to move the robot in a particular direction each of the wheels has a separate rotational direction and speed contributing to the overall movement of the robot.

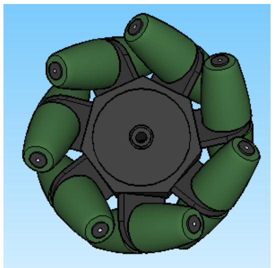


Figure 2: basic structure of the Mecanum Wheel, consisting of seven rollers fixed at 45° to the axis of rotation

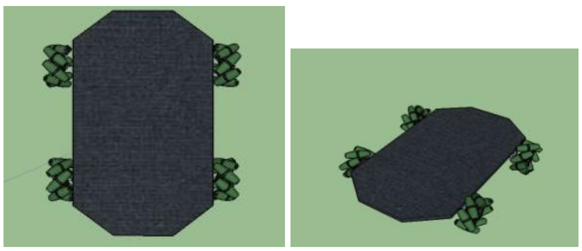
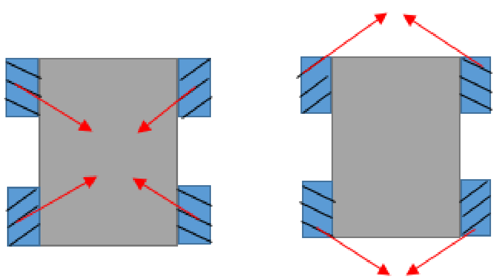


Figure 3: Top and Side views of the robot layout

The basic design is fairly similar to any differential drive robot. However the placement of the mecanum wheels has greater importance.

There are two possible configurations of the wheels. The rollers on the wheel are directed towards the center (Figure 4A) or the rollers are directed perpendicular to the previous case (Figure 4B). The first configuration was chosen, which brings stability to the robots control mechanism, without any unwanted movements.



(a) (b)

Figure 4 (a): 1st Orientation of wheels, with rollers pointed inward, Figure 4 (b): 2nd Orientation of wheels, with rollers pointed outward.

3. CALCULATIONS

To control the robot into a desired path, it was essential to establish vector equations which give needed velocity values for each wheel to move in a given direction. The control system is as follows

When considering a mecanum wheel driven system there are 3 main factors that we should give attention to.

- Desired Angle in which the robot should translate
- Desired Magnitude of speed in which the robot should move
- Desired Rotation on which how fast the robot can change the direction it faces

Assume

Vx=voltage multiplier for the xth wheel

Vd=Desired robot speed [−1,1]

Xd=X component of desired force vector

Yd=Y component of desired force vector

θd=Desired robot angle [0,2π]

Vθ=Desired speed for changing direction [−1,1]

Rotate the axis by 45 degrees

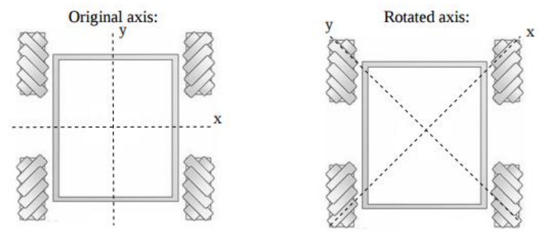


Figure 5: Axis Orientation, highlighting the axis when rotated by 45 °

The components for the desired force vector (on the rotated axis) using the desired force vector as the hypotenuse of a triangle

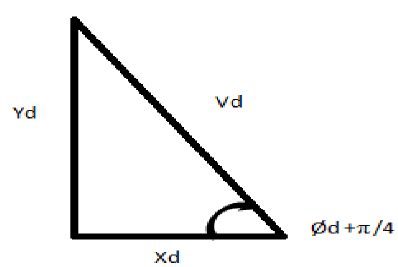


Figure 6: Force Vector Diagram, the forces acting on the rotated axis

By using known trigonometric identities following components for the overall force vector were ca

$Xd=Vd\cos(\varnothing d + \pi/4)$ - (1)

$Yd=Vd\sin(\varnothing d + \pi/4)$ - (2)

These components can then be assigned to specific wheels based upon the direction of the rollers on the wheels. Wheel 1 (Front Left) has rollers going in the y-direction, so it gets assigned the y-component. Wheel 2 (Front Right) has rollers going in the x-direction, so it gets assigned the x-component. Wheel 3 (Rear Left) has rollers going in the x-direction, so it gets assigned the x-component. Wheel 4 (Rear Right) has rollers going in the y-direction, so it gets assigned the y-component.

$V1=Vd\sin(\varnothing d + \pi/4)$ - (3)

$V2=Vd\cos(\varnothing d + \pi/4)$ - (4)

$V3=Vd\cos(\varnothing d + \pi/4)$ - (5)

$V4=Vd\sin(\varnothing d3 + \pi/4)$ - (6)

You can then adjust the sensitivity of the rotation by scaling $V\theta$ appropriately. Thereby giving the final equations.

$V1=Vd\sin(\varnothing d + \pi/4) + v\varnothing$ - (7)

$V2=Vd\cos(\varnothing d + \pi/4) - v\varnothing$ - (8)

$V3=Vd\cos(\varnothing d + \pi/4) + v\varnothing$ - (9)

$V4=Vd\sin(\varnothing d + \pi/4) - v\varnothing$ - (10)

Figure 7 shows the basic movements and how they are achieved. Appropriate velocities are given to individual wheels. These velocities are calculated from the equations above. In addition to the movements below, there are numerous other translations, to any given angle achievable by using the equations above.

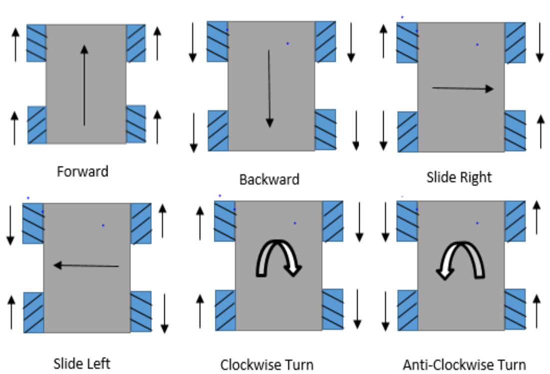


Figure 7- Achievable Movements, by changing directions of individual wheels [3]

4. IMPLEMENTATION

Before building the prototype, a software to simulate various movements achievable by mecanum wheels was used. VREP was used as it already has mecanum wheel library included. A total of 6 different movements were simulated these include, straight ahead, sideways, diagonal, concerning about a wheel , 360 turn around, turn around about rear axis. Figure 8 shows a sample image from the simulations carried out.

Furthermore the robot should be able to move to any user given angle. To do this the equations above was used and VREP to verify whether the desired angle was achieved. This was an essential step as the robot could now move in any angle depending on the situation.

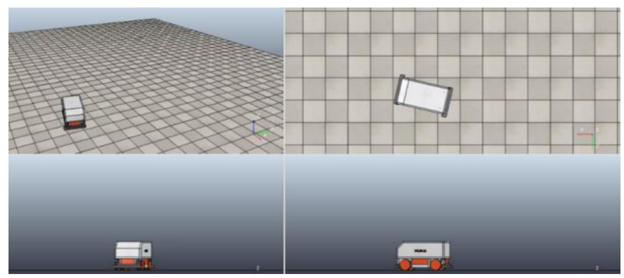


Figure 8- V-REP® Simulations

The main control unit is the PIC 18F45K22, which is connected to two L293D motor drivers, as 4 individual wheels needs to be controlled. 3 Ultra sonic sensors are needed to detect obstacles in front and in both sides.

The main components and the Power Ratings

Component	Quantity	Power Ratings
Ultrasonic sensor	3	5V each
DC Motors	4	12V each
Micro Controller Circuit	1	5V
Motor-Driver Circuit	2	12V/5V

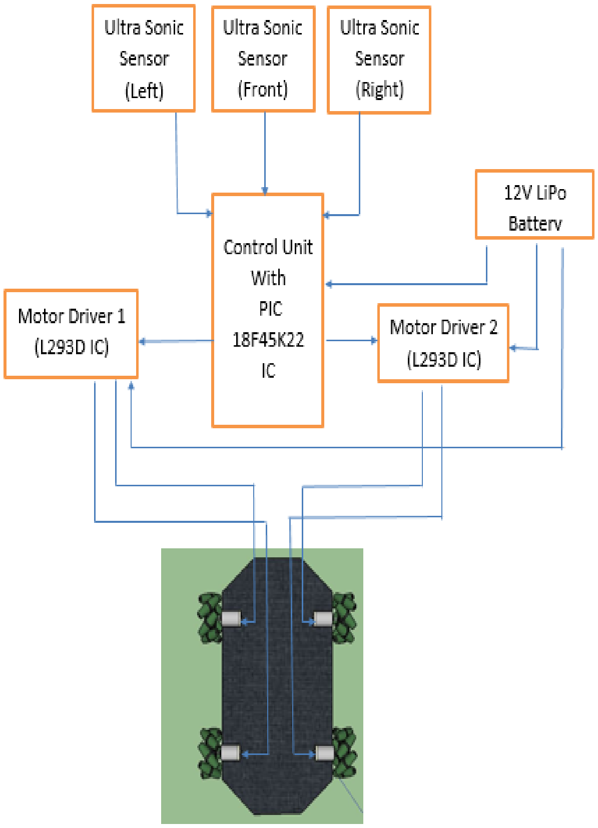


Figure 9–System Diagram

Images of the prototype are shown below.

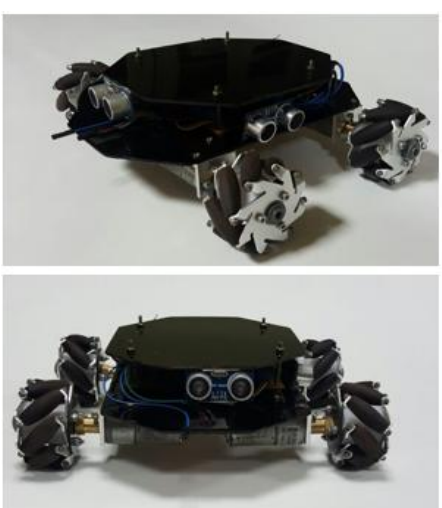


Figure 10 – Prototype Front and Top views

5. DEMONSTRATION

The prototype consists of 3 ultrasonic sensors, one in the front and two in the two sides, left and right. The sensors in the two sides are at right angles to the one in the front. The robot should navigate a path consisting of movable and stationary obstacles, thus showcasing its omni directional advantages. Our robot is tested for its capabilities on a test track. Which consists of a fixed starting point and finish point, the robot will have to use its wide range of movements and navigate to the end point. The test track consists of two arenas. One contains fixed obstacles and the other has movable obstacles, where the audience is given the chance to move the obstacles. A sample layout of the test arena is given in Figure 11, with the obstacles placed throughout randomly.

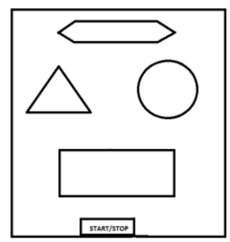


Figure 11 – Arena 1, with stationary obstacles

6. REFERENCES

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[3] F. Adăscăliței, and I.Doroftei *"Practical Applications for Mobile Robots based on Mecanum Wheels -a Systematic Survey"*: Proceedings of International Conference On Innovations, Recent Trends And Challenges in Mechatronics, pp. 112-123, 2011.