DESIGN AND PERFORMANCE ANALYSIS ON MOVEMENT OF SQUARE, TRIANGULAR AND OCTAGONAL STRUCTURED OMNIDIRECTIONAL MOBILE ROBOT

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Abstract:

This paper addresses the issue of development of a three wheel, four wheels and eight wheel Omni directional mobile robot. The Omni directional wheel is used in this research consists of 8 rollers made from synthetic rubber coated polypropylene rollers. All Omni wheel are independently powered using 3, 4 and 8 units of precision gear DC motors and the wheel/ motors assemblies where mounted directly to the robot chassis made using an aluminum frame. Basic mobility algorithm was developed to test the basic mobility capability and test the qualitative view of the systems and mobility performance. An experiment was setup to analysis the motion characteristics of the mobile robot motion in y-axis, x-axis and rotary motion. Data from the experiment will be used for mathematically model for mobile robot platform and speed controller modeling and design. The combination of mechanical design on the wheel and chassis, motion control allow the exploration of large number of control algorithm and software to be implemented to the robot for practical applications.

Keywords: Omni Directional Mobile Robot, square & triangular structured robot, octagonal structured robot, motion control.

Introduction:

In industries the applications of mobile robots are continuously gaining in importance. They are already widely used for surveillance, inspection and transportation tasks. A further emerging market is that of mobile entertainment robots. One of the main requirements of an autonomous mobile robot is its ability to move through the operational space, avoiding obstacles and finding its way

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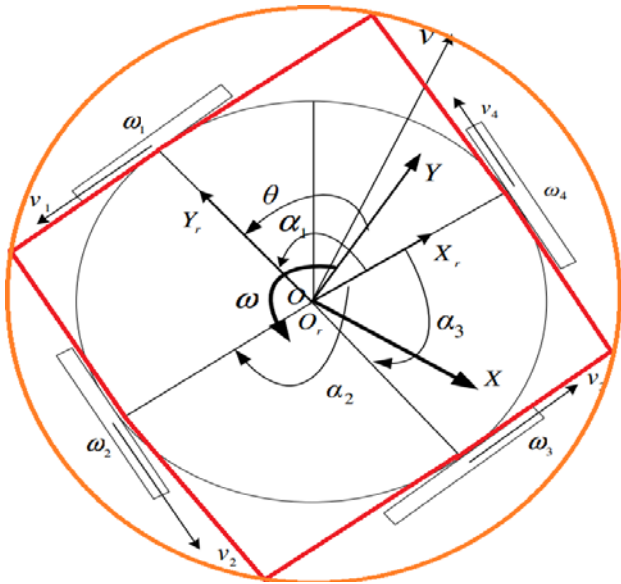
to the next location, in order to perform its task. In order to know where to go, the robot must have accurate knowledge of its current location. In means, it should use a great variety of sensors, wheels and algorithm. In order to move in tight areas and to avoid obstacles mobile robot should have good mobility and maneuverability. These are capabilities mainly depends on the wheels design. Research is continuously going on this field, to improve the autonomous navigation capability of mobile robotic systems.

Kinematic Model:

Figure shows a top view of an Square structured Omni Directional Mobile Robot (SSODMR). The coordinate X_r, O_r, Y_r is attached to the robot body and XOY denotes the world coordinate. The radius of the wheel and the radius of the robot body denoted by r and b respectively. The angle between the axles of the wheels are denoted by α_i(i = 1,2,3,4) respectively. The angular velocity of each wheel is denoted by ω_i (i= 1,2,3,4) and the direction of the linear velocity of the of the wheel is indicated by v_i (i = 1,2,3,4) with respect to coordinate X_r, O_r, Y_r. The angle between the coordinates $X_r, O_r, Y_{r \text{ and}}$ XOY is denoted by θ. The linear and angular velocities of the robot are denoted by v=[v_x, v_y]^T and ω respectively.

The overall dimensions of the physical robot are : 283mm (Diameter formed from the square) X 110 mm (Height). The CAD drawing can be found I Figure 2.

Figure 1. Square structured Omni Directional Mobile Robot kinematic model
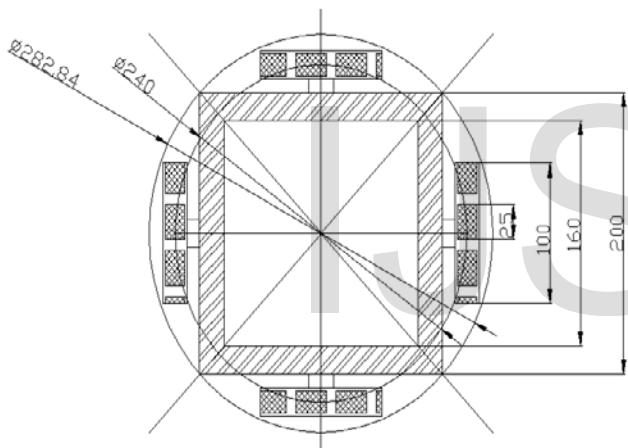

Figure 2. Square structured Omni Directional Mobile Robot AUTO CAD diagram with dimensions

Physical arrangement of a Triangular structured Omni Directional Mobile Robot
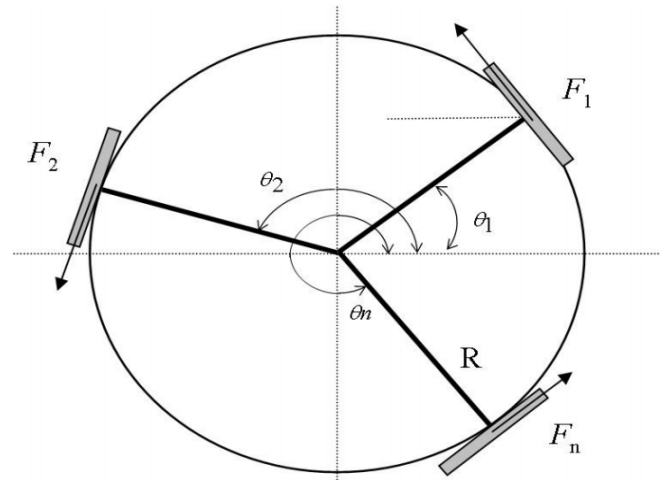

Figure 3. Arrangement of 3 wheels and distribution of forces

Each wheel can move the robot forward, but since they are located on the periphery of the robot, they can also rotate the robot's frame. In order to derive the relationship between the motors' torques and the movement of the robot, we need to analyze the geometry of the problem. Let us use a robot with $n \geq 3$ wheels, as shown in the diagram (Fig. 2). All the angles of the motor axis are measured relative to the x direction in the coordinate system of the robot. Call the angles of the motor axis for the n wheels $\theta1, \theta2, . . . ,\theta n$. The driving direction of the i-th wheel is therefore $\theta i + \pi/2$. When the n motors are activated, we obtain n traction forces F1, F2, . . . ,Fn from the motors, which add up to a translational force and a rotational torque. Each traction force Fi is the torque of the motor multiplied by the radius of the wheel. The sum of the forces depends on the exact wheel arrangement.
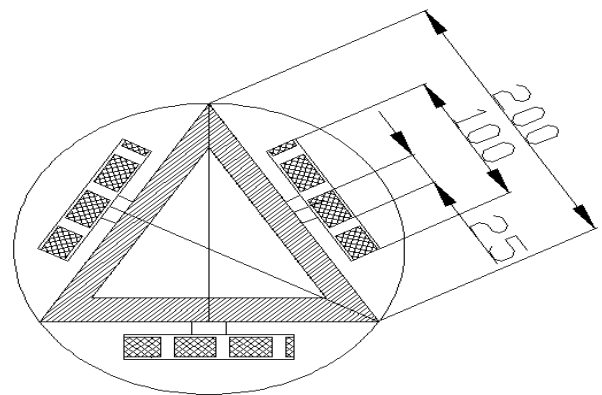

Figure 4. AutoCAD drawing of Triangular structured omni directional mobile robot

Omni-directional wheels are unique as they are able to roll freely in two directions. It can either 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 robot 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/backwards 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 are able to overcome this problem, as it is a highlymaneuverable. 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, slides sideways, and rotates at the same position. This ability allows the robot being built tobe able to search the ball and maneuver to it faster and more efficiently than the opponents.

Omni-wheels are usually mounted on an equilateral triangular base with each wheel taking a side. Using vector summation and by individual control of the speed of each motor, the robot is able to turn in any direction quicker than robots on normal wheels. The diagram depicts the different waysthe robot can move using omni-directional wheels. However, this equilateral triangular base design was not suitable for the soccer-bot as it was inadequate for maintaining stability in a fast paced environment and it lacked the capability to mount all the different actuators, effectors and sensors needed on the player in order for it to function properly.

Materials And Methods :

As this was a complete Mechatronic project incorporating mechanical, electronic and software development, the different areas were developed synergistically thus allowing interactions between the disciplines to be viewed and managed. It also meant that all three core disciplines needed to be developed to a certain stage before any one area could be further worked on. Although it was physically possible to use other means to develop the core areas independently, a synergistic approach tends to be more efficient. Even though this parallel design approach was used, the areas of development shall be discussed in sections assuming that other sections have already been completed to a certain level and are referenced where necessary.

Figure 5. Omni Directional Wheel with single row- bought from Robo kits.com

Specifications:

S.No	Description	Size
1	Effective Diameter:	100 mm +- .5 mm
2	Wheel Width:	25mm without hub
3	Shaft Hole Diameter:	6.1mm
4	Number of rollers:	8
5	Weight:	~90 grams
6	Load capacity:	5Kg

Developments and implementation: The development for this project can be divided into the major process, the mechanical design for Meccanum wheel and mobile robot chassis, electronics design for 4 channel motor driver and interfacing with BasicStamp microcontroller board and software development for motion control

Electronic design:

Four channel bi-directional motor driver been design to drive all four Omni directional wheels. The specifications developed for the necessary driver
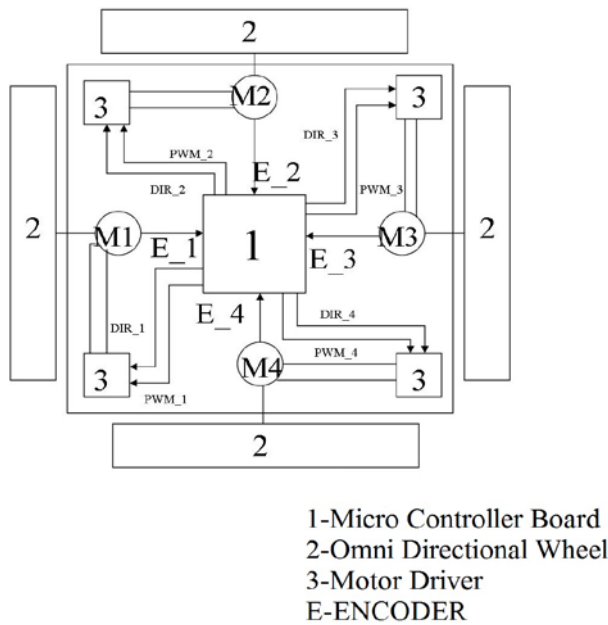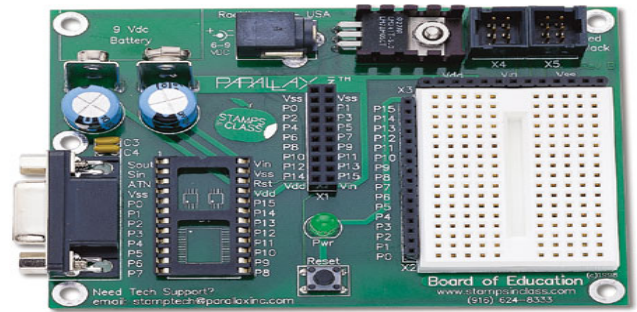
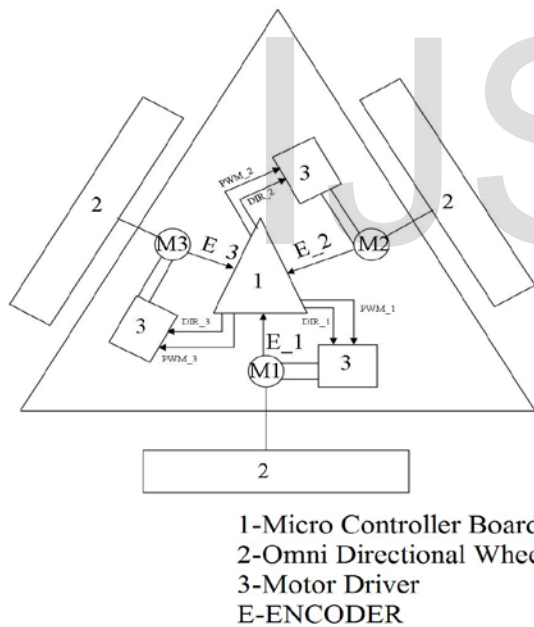Figure 6. System hardware architecture for square structured robot

Figure 6a. System hardware architecture for triangular structured robot

Microcontroller: In order to give the existing robot any intelligent functionality some form of on-board processor was essential. Microcontrollers are ideally suited for such an application as they are compact, have many built-in hardware features such as timers and UARTS, have a significant number of digital I/O lines and have low power requirements. The essential microcontroller specification for this project was its ability to generate four independent PWM signals. Other general requirements were; high speed operation to ensure environmental data could be processed at real-time. BASIC Stamp micro-controllers have been chosen this project for well-known for their ease of use, comfortable programming language and easy debugging using a PC.

Figure 7. Back Stamp micro controller board

Experiment setup:

With the use of the prototype motor driver board and test software to programming the microcontroller output as list in Table 1, the basic mobility control was gained via programming the basic motion software to the microcontroller. This setup allowed the following motions as well as the increase and decrease of speed.

➤ Forward – Right side wheel and Left side **wheel** rotate forward, front and back **rollers** rotate forward

➤ Backward – Right side wheel and Left side **wheel** rotate backward, front and back **rollers** rotate backward,

➤ Right slide – Front and Back **wheel** rotate Clockwise, RSW and LSW **rollers** rotate.

➤ Left slide – Front and Back **wheel** rotate Counter - Clockwise, RSW and LSW **rollers** rotate.

➤ Clockwise - All wheels will rotate in same speed in Clockwise

➤ Counter-Clockwise – All wheels will rotate in same speed in Counter-Clockwise

The following list in Table 1, show the basic motion of omni directional wheel mobile robot with their corresponding wheel direction. By varying the individual motor/wheel speed we can achieve driving direction along any vector in X-Y axis. The actuation required for these movements can be seen in Figures.
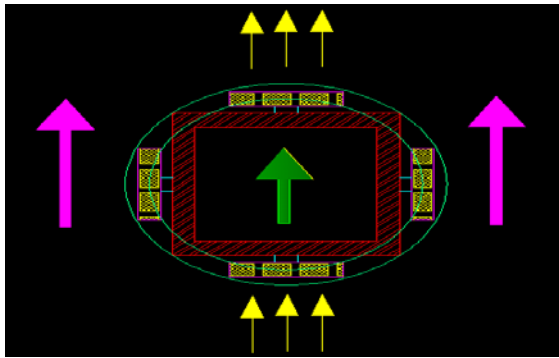
Figure 8. Square structured Omni Directional Mobile Robot-Front movement and rotation of wheel and roller directions
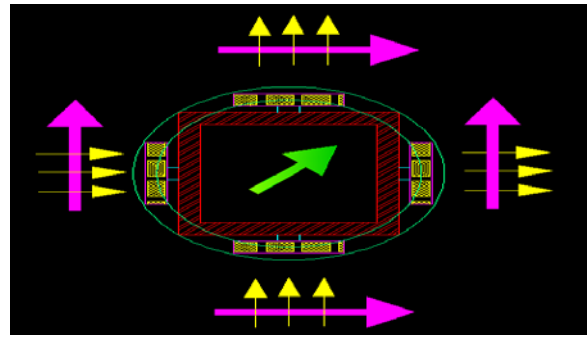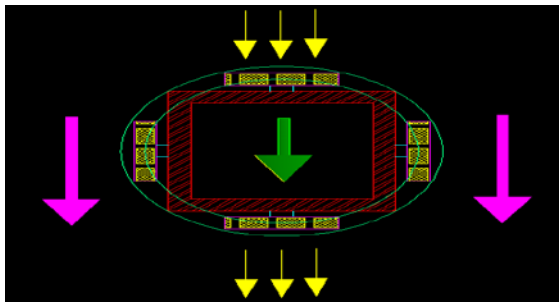

Figure 9. Square structured Omni Directional Mobile Robot-Back movement and rotation of wheel and roller directions
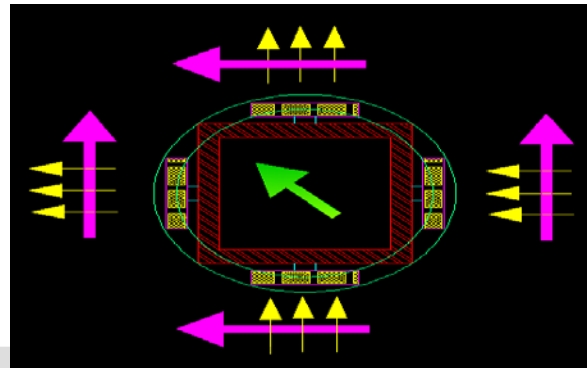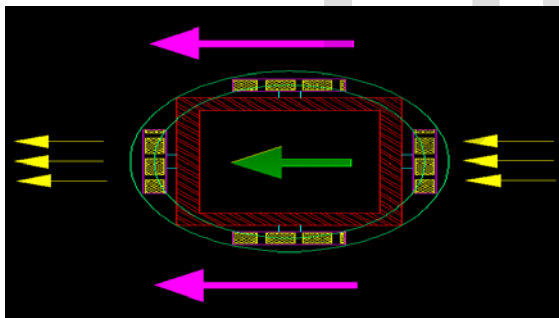

Figure 10. Square structured Omni Directional Mobile Robot-Left side movement and rotation of wheel and roller directions
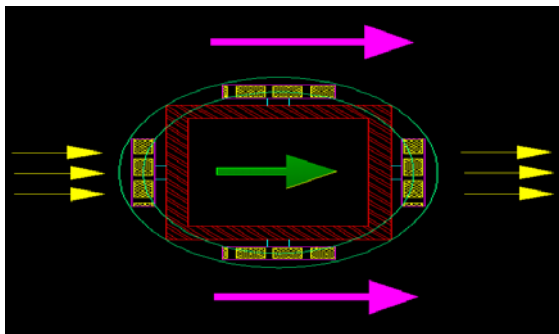

Figure 11. Square structured Omni Directional Mobile Robot-Right side movement and rotation of wheel and roller directions

Figure 12. Square structured Omni Directional Mobile Robot-Right & Front (cross) movement and rotation of wheel and roller directions

Figure 13. Square structured Omni Directional Mobile Robot- Left & Front (cross) movement and rotation of wheel and roller directions

Triangular structured Omni Directional Mobile Robot Movement:

➢ Forward – Right side wheel and Left side **wheel** rotate forward, back **rollers** rotate forward, Right side wheel and Left side wheel rollers will rotate according to the direction.

➢ Backward – Right side wheel and Left side **wheel** rotate backward, back **rollers** rotate backward, Right side wheel and Left side wheel rollers will rotate according to the direction.

➢ Right slide – Back **wheel** rotate Clockwise, RSW and LSW rotate, Right side wheel and Left side wheel rollers will rotate according to the direction.

➢ Left slide – Back **wheel** rotate counter -Clockwise, RSW and LSW rotate. Right side wheel and Left side wheel rollers will rotate according to the direction.

➢ Clockwise - All wheels will rotate in same speed in Clockwise

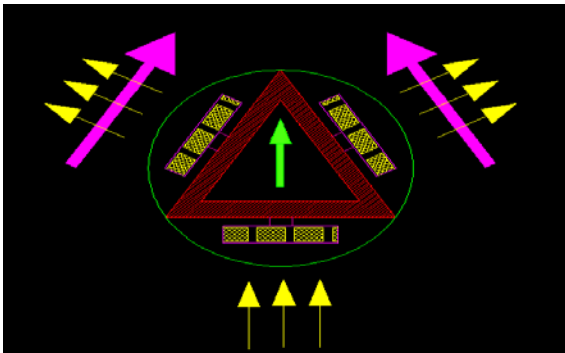➢ Counter-Clockwise – All wheels will rotate in same speed in Counter-Clockwise

Figure 14. Triangular structured Omni Directional Mobile Robot-Front movement and rotation of wheel and roller directions

Figure 15. Triangular structured Omni Directional Mobile Robot-Back movement and rotation of wheel and roller directions
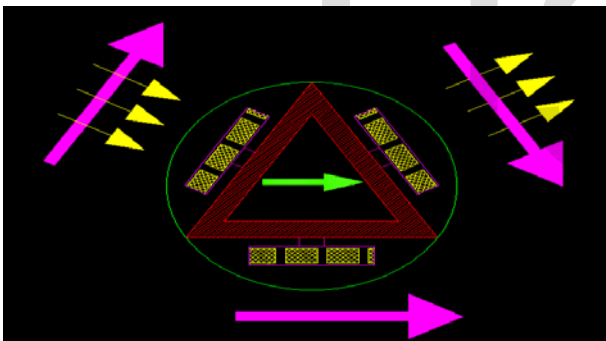

Figure 16. Triangular structured Omni Directional Mobile Robot-Right movement and rotation of wheel and roller directions
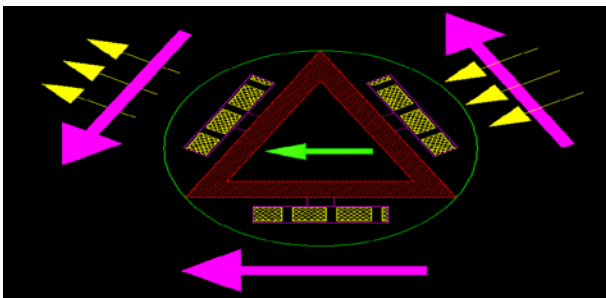

Figure 17. Triangular structured Omni Directional Mobile Robot-Left movement and rotation of wheel and roller directions
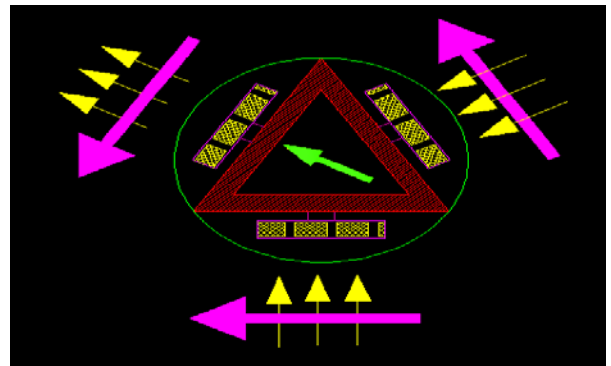

Figure 18. Triangular structured Omni Directional Mobile Robot-Cross movement and rotation of wheel and roller directions

Future work:

Octagonal Structured Omni Directional Mobile Robot Movement:

In square structured Omni directional wheel is having advantages and disadvantages. In this square structured robot the control and movement is very easy, but accuracy may miss. The number of usage of motors should be minimum 4. In Triangular structured robot control will be little bit difficult, very fast in movement and accuracy will be high. Usage of motor is 3. In this research the combination of square and triangular structured has been proposed. The shape is octagonal structure. The movement will be easy as well as the accuracy of the robot.
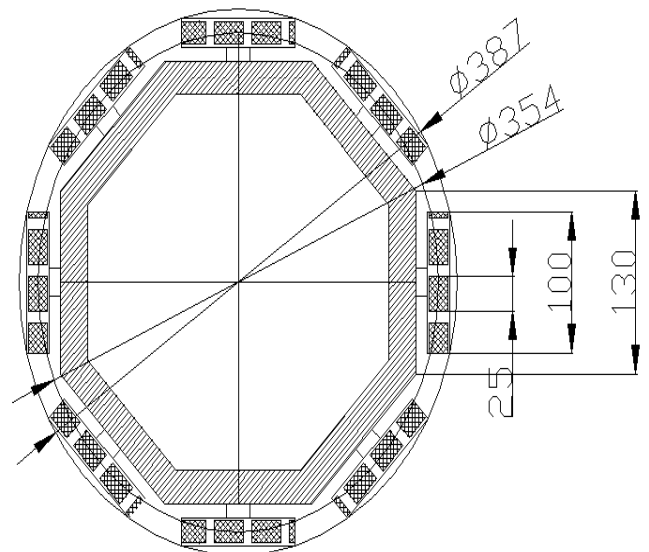

Figure 19. AutoCAD diagram with dimensions of Octagonal structured Omni Directional Mobile Robot-Front movement and rotation of wheel and roller directions

CONCLUSION:

This paper presents an overview over the primary design stage of Omni-directional mobile robot using 3,4,8 wheels. In the usage of 3 wheels the accuracy is good but the control of the motor and wheel movement is very tough. In the square structured 4 wheel, the accuracy of movement is not good, but the control of the wheel is very easy. The combination of square and triangular structured robot has been tried in the Octagonal shaped 8 wheel Omni directional robot. In this accuracy, control of the motor and wheel movement will be good, compared with both square and triangular structure. This research has to address lots of issues like sensor integration, real-world modeling, actuator and sensor control, path planning and navigation, task-level planning and execution and the control of the robotic system as a whole. This research provides new concepts and approaches in both mechanical design for different Omni directional structured wheel and overall mobile robot chassis and also the design for electronic hardware and software. By using Octagonal structured Omni directional robot the movement, control and accuracy will be good and load carrying capacity can be increased.

REFERENCES:

1. Fiegel, O., A. Badve and G. Bright, et al., 2002. Improved mecanum wheel design for omni directional robots. Proc. Australasian Conf. Robotics and Automation, 27-29 Nov., pp: 117-121.

2. Regan, T., 1999. A DMOS 3A,55V H-Bridge: LMD18200. National SemiconductorApplicationNote 868.

3. Phillips, J.G., 2000. Mechatronic design and construction of an intelligent mobile robot for educational purposes. Master of Technology Thesis, Massey University, Palmerston North, New Zealand, pp: 150.

4. S. Behnke et al.: "Predicting away the Delay", RoboCup-2003: Robot Soccer World Cup VII, Springer-Verlag, 2004.

5. D. J. Daniel et al.: "Kinematics and Open-Loop Control of an Ilonator-Based Mobile Platform", Proc. of the IEEE Int. Conf. on Robotics and Automation, 1985.

6. A. Egorova et al.: "FU Fighters Small Size Team 2004", RoboCup-2004: Robot Soccer World Cup VIII, Springer-Verlag, 2005.

7. D. Feng et al.: "The Servo-Control System for an Omnidirec-tional Mobile Robot", Proc. of the IEEE Int. Conf. on Robotics and Automation, 1989.

8. A. Gloye: "Learning Methods for Autonomous Mobile Robots", PhD thesis, FreieUniversiẗat Berlin, 2005.

9. A. Gloye et al.: "Learning to Drive and Simulate Autonomous Mobile Robots", RoboCup-2004: Robot Soccer World Cup VIII, Springer-Verlag, 2005.

10. L. Huang et al.: "Design and Analysis of a Four-wheel Omni-directional Mobile Robot", Proc. of the 2nd Int. Conf. on Au-tonomous Robots and Agents, 2004.

11. Y. Liu et al.: "Omni-Directional Mobile Robot Controller Design by Trajectory Linearization." Proc. of the 2003 American Control Conference, 2003.

12. T. Kalm´ar-Nagy et al.: "Near-optimal dynamic trajectory gen-eration and control of an omnidirectional vehicle", Robotics andAutonomous Systems, vol. 46, no. 1, Elsevier, 2004.

13. M. Oubbati et al.: "Velocity Control of an Omnidirectional RobCup Player with Recurrent Neural Networks", RoboCup-2005 - Proc. of the Int. Symposium, preprint, 2006.

14. O. Purwin et al.: "Trajectory Generation and Control for Four Wheeled Omnidirectional Vehicles", Proc. American Control Conference, 2005.