ISSN 2348 – 7968

Motion Analysis of A Mobile Robot With Three Omni-Directional Wheels

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Abstract

This paper demonstrates the kinematics motion analysis of the three wheeled omni-directional mobile robot. The mobile robot is equipped with the three omni-directional wheels which are arranged at the vertices of an equilateral triangle and the wheel axels are aligned with the lines from the center of the equilateral triangle to each of the three wheels. Model of this omni-directional wheeled robot is developed and shown the different trajectory motion of the mobile robot by controlling the DC gear motor with different combination.

Keywords: ***Mobile robot, Omni-directional wheel, Trajectory motion.***

1. Introduction

In modern automated industry the mobile robots are more flexible and can perform more tasks effectively. An omni-directional wheeled mobile robot is a special class of mobile robot now a days. These robot can drive along a straight line from one point to another point, while rotating along

2. Design and Development of Three Wheeled Omni-directional Robot

In figure 2.1, the three wheeled omni-directional robot is presented. To make this robot, the following parts are needed: a robot body frame, omni-directional wheel, DC gear motor, microcontroller, motor driver, power supply and DPDT switch.

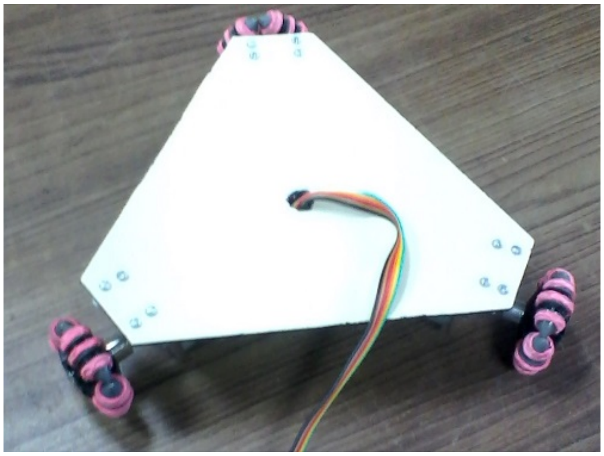

Figure 2.1: Three wheeled omni-directional robot

the full assembly view of three wheeled omni-directional robot, where each wheels (W_1, W_2, W_3) are 120^0 apart, also the three DC gear motors are aligned in same way. All motors are mounted on the mobile robot platform by clamp and screw. All omni-directional wheels are properly adjusted with DC gear motor’s external shaft and all the motors are connected with the Arduino microcontroller through L293D motor driver. Three DPDT switches are mounted on control board to operate the robot wheels. The control board is connected with the Arduino through an eight wire bus. From the input of DPDT switch Arduino microcontroller moves the robot in the desired direction. The omni-directional wheels that provide very good manoeuvrability and enhanced mobility compared with traditional wheels. This type of wheels has small rollers to allow the wheels to move freely on any direction. They move along the primary diameter, just as any other wheel. Though, the smaller rollers along the outside of this diameter allow free rotating along an orthogonal direction to the powered rotation. The motors are coupled directly to the omni wheels simplifying the mechanics.

2.1 Kinematic model of mobile robot platform

Fig.2.2 shows the schematic view of three wheeled omni-directional robot, where each wheels (W_1, W_2, W_3) are 120^0 apart, "R" is the length from robot centre mass to each wheels. V_{W1}, V_{W2}, V_{W3} are linear velocities of wheel 1, 2 and 3. 'r' is the radius of each omni-directional wheels. From the kinematics equation all forces are divided into two components vertically 'Y' axis 'sin' component and horizontal 'X' axis 'cosine' component.

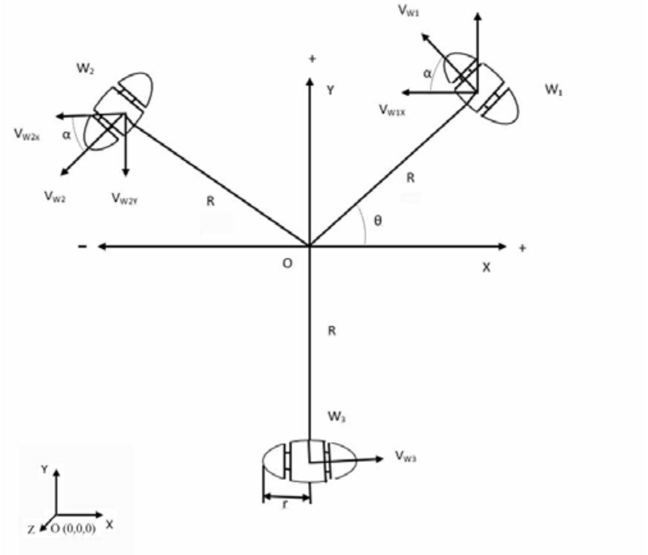

Fig. 2.2 Schematic model of three wheeled omni-directional robot.

For wheel 1 (W_1),

$$V_{W1X} = (-)\, V_{W1} \cos(\alpha) \qquad (4.1)$$

$$V_{W1Y} = (+)\, V_{W1} \sin(\alpha) \qquad (4.2)$$

For wheel 2 (W_2),

$$V_{W2X} = (-)\, V_{W2} \cos(\alpha) \qquad (4.3)$$

$$V_{W2Y} = (+)\, V_{W2} \sin(\alpha) \qquad (4.4)$$

$$V_{WX} = V_{W3} - V_{W1} \cos(\alpha) - V_{W2} \cos(\alpha) \qquad (4.5)$$

$$V_{WY} = V_{W1} \sin(\alpha) - V_{W2} \sin(\alpha) \qquad (4.6)$$

$$V_{\theta} = V_{W1}/L + V_{W2}/L + V_{W3}/L \qquad (4.7)$$

$$V_{Wi\,(1,2,3)} = \omega\,.r \qquad (4.8)$$

ω = Angular velocity of the omni-directional wheel (rad/sec).
r = Omni-directional wheel radius (cm).
V_{θ} = Robot movement velocity.

Fig.4.2 shows the wheels are arranged in symmetrical manner 120^0 apart,
So, $\alpha = 60^0$, put this value in equation (4.5) to (4.6),

$$V_{WX} = V_{W3} - V_{W1}\,(1/2) - V_{W2}(1/2) \qquad (4.9)$$

$$V_{WY} = V_{W1}(\sqrt{3}/2) - V_{W2}\,(\sqrt{3}/2) \qquad (4.10)$$

Equations (4.7),(4.9) and (4.10) can be rewritten in matrix from:

$$\begin{bmatrix} Vwx \\ Vwy \\ V\theta \end{bmatrix} = \begin{bmatrix} -1/2 & -1/2 & 1 \\ \sqrt{3}/2 & -\sqrt{3}/2 & 0 \\ 1/R & 1/R & 1/R \end{bmatrix} \begin{bmatrix} Vw1 \\ Vw2 \\ Vw3 \end{bmatrix} \qquad (4.11)$$

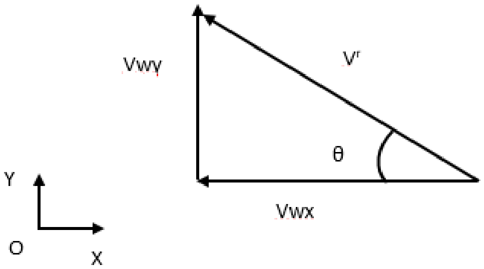

Fig.2.3 Schematic model of three wheeled omni-directional robot velocity and orientation.

From Fig.4.3 the velocity of robot and orientation at any point the following the equation:

$$V^r = \sqrt{V^2 wx + V^2 wy} \qquad (4.12)$$

$$\theta = \tan^{-1}\frac{Vwy}{Vwx} \qquad (4.13)$$

where, *Vwx* and *Vwy* vectors are acts along ‘X’ and ‘Y’ direction , V^r is resultant vector.

3. Experimental Test

The experiments are done by six different combinations of the three omni-directional wheeled robot starting points and each combination is used three times to different tests. When all three wheels are ON state, a tachometer is used to measure the omni-directional wheel rotation. Same as above procedure has followed the rest of tests i.e. one wheel is ON in clockwise direction and two wheels are stopped OFF, two wheels are ON in clockwise direction and one wheel is OFF, one wheel is OFF and two wheels are ON, three wheels are ON with one opposite direction. A white marker/chalk is used to mark the trajectory of above cases.

4. Results and Discussion

Different motions of three wheeled omni-directional robot has been studied based on six criteria. The results’ concern the velocity and direction of motion for the whole system are given in the following tables 4.1, 4.2, 4.3, 4.4, 4.5, 4.6. The inputs’ data are V_{W1}, V_{W2} and V_{W3} which denote the wheels velocities (DC gear motor rotation) and V_W is robot velocity.

Table 4.1: One wheel “ON” and Two wheels “OFF”

No of Exp.	V_{W1}	V_{W2}	V_{W3}	V_{WX} (cm)	V_{WY} (cm)	V_W (cm)
1	0	0	1	16.29	0	16.29
2	0	1	0	-8.145	-14.10	16.29
3	1	0	0	-8.145	14.10	16.29
4	0	0	-1	-16.29	0	16.29
5	0	-1	0	8.145	14.10	16.29
6	-1	0	0	8.145	-14.10	16.29

In table 4.1, when only one wheel is “ON” and two wheels are “OFF”, the three wheeled omni-directional robot have same value with different input. The direction of motion is the same as the “ON” wheel; the obtained circular path is rotation of the robot around the external centre. The maximum circular path is achieved by making tangent to the “ON” wheel

Table 4.2: Two wheels “ON” and One wheel “OFF”

No of Exp.	V_{W1}	V_{W2}	V_{W3}	V_{WX} (cm)	V_{WY} (cm)	V_W (cm)
1	0	1	1	7.26	-12.57	14.52
2	1	1	0	-14.52	0	14.52
3	1	0	1	7.26	12.57	14.52
4	0	-1	-1	-7.26	12.57	14.52
5	-1	-1	0	14.52	0	14.52
6	-1	0	-1	-7.26	-12.57	14.52

Table 4.2 shows when two wheels is “ON” same direction and one wheel “OFF”, then the robot is make a curved path of rotation around the “OFF” wheel and the robot The minimum curved path is achieved here due to the rotation around the “OFF” wheel.

Table 4.3: Two wheels “ON” opposite direction and One wheel “OFF”

No of Exp.	V_{W1}	V_{W2}	V_{W3}	V_{WX} (cm)	V_{WY} (cm)	V_{W} (cm)
1	0	1	-1	-21.57	-12.47	14.35
2	0	-1	1	21.57	12.42	14.35
3	1	-1	0	0	0	14.35
4	-1	1	0	0	0	14.35
5	1	0	-1	-21.57	-12.42	14.35
6	-1	0	1	21.57	12.42	14.35

In table 4.3, when two wheels are “ON” with one of the wheel is opposite direction, thus one trying to rotate the robot clockwise and the other anticlockwise, then the robot moves in a straight line (forward motion) only with no rotation.

Table 4.4: Three wheels “ON” opposite direction

No of Exp.	V_{W1}	V_{W2}	V_{W3}	V_{WX} (cm)	V_{WY} (cm)	V_{W} (cm)
1	1	1	1	0	0	0

Table 4.5: Three wheels “ON” same direction

No of Exp.	V_{W1}	V_{W2}	V_{W3}	V_{WX} (cm)	V_{WY} (cm)	V_{W} (cm)
1	1	1	1	0	0	0

Table 4.4 and 4.5 when all wheels are “on” in same and opposite direction the robot will rotates about its own centre of mass.

Table 4.6: Three wheels “ON” and One wheel opposite direction

No of Exp.	V_{W1}	V_{W2}	V_{W3}	V_{WX} (cm)	V_{WY} (cm)	V_{W} (cm)
1	-1	1	1	13.76	-23.83	13.76
2	1	-1	1	13.76	23.83	13.76
3	1	1	-1	-27.52	0	13.76
4	-1	-1	1	27.52	0	13.76
5	-1	1	-1	-13.76	-23.83	13.76
6	1	-1	-1	-13.76	23.83	13.76

In table 4.6, when the three wheels are “ON” and one wheel is opposite direction, the obtained circular path is the rotation of the robot around external centre, the maximum circular path is achieved by making tangent to the “ON” wheel.

5. Conclusions

The model is derived assuming no wheel slip as is interesting in most standard robotic applications. By controlling motion of the three omni-directional wheels, immediate forward, backward, sideways and rotational motion, in other words, omni-directional motion is generated successfully. A mathematical kinematic model of the robot is done and velocity vector analysis each omni-directional wheel. A low-level program is created to simplify access to basic functionality of the robot. It can be easily built up with high-level algorithms for localization, trajectory planning and tracking. A straight line motion can be achieved by running two wheels only in opposite direction. The rotation of the system around its center can be obtained by running the three wheels in same direction. If the three wheels on and one of hem rotates opposite irection, the path of motion is circular.

6. Future work

The work presented is a part of vast area. Further work will include upcoming some future test with different prototypes including prototypes with braking system. The model can also be enlarged to include the limits for slippage and movement with controlled slip for the purpose of the learning traction problem. Kinematical and dynamical models are needed in this work and that can be used to study the limitations of the mechanical configuration and future enhancements of both mechanical configuration and controlling the device. This work will enable effective full comparison of three wheeled systems.

Acknowledgments

I wish to express my sincere gratitude to NITTTR-KOLKATA for providing all the necessary facilities for the research. I would like to convey my sincere gratitude to Dr. Samiran Mandal, Professor, Head Of Mechanical Engineering Department in NITTTR-KOLKATA for his valuable advices and encouragement during the project.

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Third Author I am working as Senior Professor and Head Of Mechanical Engineering Department in NITTTR-KOLKATA. This project has been completed under my guidance.