ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/332846909

MATLAB modelling of Mecanum wheeled mobile robot platform with extended capabilities of forming Swarms

Preprint · May 2019

DOI: 10.13140/RG.2.2.29872.81928

CITATIONS
0

READS
1,623

1 author:

Aaditya Ajaykumar Patel
Carleton University

3 PUBLICATIONS **0** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project Performance Evaluation of Deep Cryogenic Treatment on M2 HSS Tool Steel View project

Project Smart Materials & Structures View project

All content following this page was uploaded by Aaditya Ajaykumar Patel on 03 May 2019.

The user has requested enhancement of the downloaded file.

MATLAB modelling of Mecanum wheeled mobile robot platform with extended capabilities of forming Swarms

Aaditya Ajaykumar Patel (ID: 300098706)
Department of Mechanical and Aerospace Engineering
Carleton University
Ottawa, Ontario K1S 5B6, Canada
aadityaajaykumarpate@cmail.carleton.ca

***Abstract* – The present work was aimed to explore two relatively new and less explored domains of robotics in general that are Mecanum wheeled robots and Swarm robotics. MATLAB's current capabilities were extensively used to obtain the kinematics of Mecanum wheeled drives and this was further incorporated into a way point following logic using Pure Pursuit algorithm to get a sense of its functionality in the real-world environment. Finally, a simplified demonstration of Swarm robotics was carried out to explain how a group of robots can form teams which can be used to accomplish complex tasks. Further study needs to be conducted to achieve the objective of Mecanum wheeled robots with swarm forming capabilities.**

Keywords – Mecanum Wheel drive, kinematics, Pure Pursuit algorithm, Robot Swarms, multi-robot environment

I. Introduction

In recent years, applications of autonomous mobile vehicles have reached great heights, from planetary exploration on Mars to autonomous self-driving vehicles slowing turning into a reality. Another possible application involving mobile robotic systems can be automating high freight density work environments involving large manpower doing monotonous and heavy lifting work. In such working conditions there is a high probability of accidents occurring due to human fatigue and inefficiencies, which ultimately leads to huge time and monetary losses. Introduction of mobile robotic platforms with superior manueverability and high load carrying capacity can turn out to be an excellent solution to this problem and can lead to manifold increase in the efficiency of the tasks being performed. Marine environment like seaports, large warehouses, military uses involving movement of heavy loads are some of the places where such robotic platforms can find their application.

Superior manueverability can be achieved by the usage of omnidirectional wheels such as Mecanum wheels. A significant amount of work has been done on studying omnidirectional wheels and its applications [1] but mobile robotic platforms using Mecanum wheels are not fully explored. Yet another capability that is not focused upon is the ability of a group of robots to work together as a team by forming swarms. This project focuses on utilizing the capabilities available with MATLAB's Mobile Robotic Simulation Toolbox to perform kinematic analysis of Mecanum wheeled robotic platforms and explore the domain of swarm robotics.

A. *Mecanum Wheel Drives*

Mecanum wheel also called Ilon wheel or the Swedish wheel is the most common omnidirectional wheel designs, patented in 1972 by Bengt Ilon, an engineer working for the Swedish company Mecanum AB [2]. In this design, similar to the Omni wheel, there are a series of free moving rollers attached to the hub but with an 45° of angle about the hub's circumference. See Fig. 1[3].

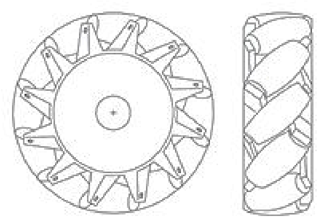

Fig. 1 Conventional Mecanum wheel design [3]

These rollers are shaped such that the geometry of the omnidirectional wheel is circular. 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 produces a total force vector in any desired direction, thus allowing the platform to move unrestricted in direction of the resulting force vector, without changing the wheel angles [4] as it would be in the case of traditional wheel design with a differential drive. Also, a vehicle equipped with Mecanum wheels drive facilitates 3 degrees of freedom which is composed of wheel rotation, roller rotation and rotational slip about the vertical axis passing through the point of contact.

II. MATHEMATICAL MODELLING AND SIMULATION

The following section details the kinematics of a Mecanum wheel drive robotic platform which will be followed by incorporation of this model into a waypoint following logic using Pure Pursuit algorithm and finally delving into multi-Robot environment i.e. capability of a group of Robots to assemble in a team for accomplishing a bigger task. These mathematical models are developed with the help of Mobile Robotics Simulation Toolbox available with MATLAB [5].

To understand the kinematics of Mecanum wheel drives we first need to differentiate it with the existing kinematic models of traditional immobile manipulator arm robots and the ones with differential drives having two or four wheels in general. A stationary manipulator arm uses joint and link parameters as the inputs to derive the position of end effector (forward kinematics) and vice-versa for deriving its inverse kinematics. If we analyse the case of mobile robots with differential drives, they use wheel angular velocities, radius and wheel base to calculate its forward kinematics i.e. linear and angular velocities of robot. Also, a four-wheel drive mobile robot can essentially be modelled as one with two wheels front and rear using bicycle model concept. But when it comes to the case of Mecanum wheel drive there are significant differences that we need to take into account.

A. *Kinematic Modelling*

A Mecanum wheeled robot is equipped with at least 4 wheels which are actuated by individual drives operating independent from others. Also, one of the most significant distinction with such drives is that they don't involve steering of wheels to achieve movement in specific direction as it is with the case of traditional 4 wheeled robots. For the purpose of analysis, the model represented in Fig. 2 consists of Mecanum wheels that are of same size and symmetrical i.e. all the wheels have same radius, r and same roller tilt of α =±45° respectively.

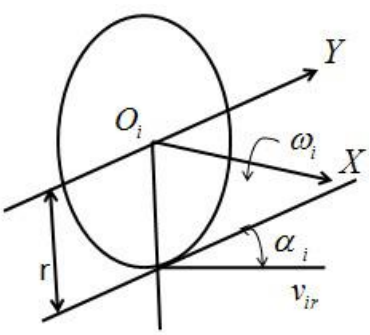

Fig. 2 Mecanum wheel parameters [6]

To calculate the forward kinematics the user needs to provide the wheel speeds and the basic dimensions of the platform which includes wheel base (L_y), wheel track (L_x) and wheel radius (R) as shown in Fig. 3. The forward kinematics matrix describes the relation between the vehicles known parameters and gives us the velocity (both longitudinal and translational) and angular velocity of the centre point of the vehicle.

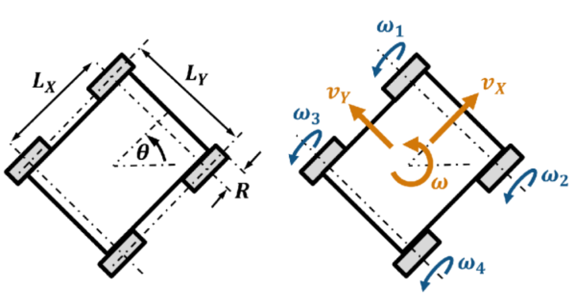

Fig. 2-D representation of a Mecanum wheel drive platform [5]

Equation (1) describes the forward kinematics matrix of a Mecanum wheel drive robot having 4 wheels [7] where it can be seen that the longitudinal and translational velocity are sole function of the wheel angular speeds and its radius whereas angular velocity of the robot also varies additionally with respect to the wheel base and wheel track.

$$\begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix} = \frac{R}{4}\begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & 1 & -1 \\ \frac{-2}{(L_x + L_y)} & \frac{2}{(L_x + L_y)} & \frac{-2}{(L_x + L_y)} & \frac{2}{(L_x + L_y)} \end{bmatrix}\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} \quad (1)$$

Where,

Longitudinal velocity, $v_x(t) = (\omega_1 + \omega_2 + \omega_3 + \omega_4).\frac{R}{4}$

Translational velocity, $v_y(t) = (-\omega_1 + \omega_2 + \omega_3 - \omega_4).\frac{R}{4}$

Angular Velocity, $\omega(t) = (-\omega_1 + \omega_2 - \omega_3 + \omega_4).\frac{R}{2(L_x + L_y)}$

The inverse kinematics matrix reflects the mapping between the speeds of the four Mecanum wheels and the centre speed of the moving mechanism. The qualities of the Jacobian matrix directly reflect the nature and characteristics of the mobile robot. If the robots' Jacobian matrix of the inverse kinematics equation is not fully ranked, then the moving mechanism will have singularity, and this means the robot will lose some of its degrees of freedom, and cannot achieve a full-directional movement. Equation (5) describes the inverse kinematics relation of the robotic platform equipped with Mecanum wheels.

$$\begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = \frac{1}{R}\begin{bmatrix} 1 & -1 & -(L_x + L_y)/2 \\ 1 & 1 & (L_x + L_y)/2 \\ 1 & 1 & -(L_x + L_y)/2 \\ 1 & -1 & (L_x + L_y)/2 \end{bmatrix}\begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix} \quad (2)$$

Where,

$\omega_1 = \frac{1}{R}\left(v_x - v_y - \left(L_x + L_y\right)\omega/2\right)$

$\omega_2 = \frac{1}{R}\left(v_x + v_y + \left(L_x + L_y\right)\omega/2\right)$

$\omega_3 = \frac{1}{R}\left(v_x + v_y - \left(L_x + L_y\right)\omega/2\right)$

$\omega_4 = \frac{1}{R}\left(v_x - v_y + \left(L_x + L_y\right)\omega/2\right)$

The above forward and inverse kinematics matrix are used as functions in MATLAB to analyse the kinematics of the robot.

B. *Way point tracking with Pure Pursuit algorithm*

The following flow charts explains the logic of the code used to achieve the desired goal of following way points.

Kinematic Description of Robot
↓
Way Points Description
↓
Visualizer 2-D
↓
Pure Pursuit Controller definition
↓
Simulation Loop

Firstly, the kinematic description derived from previous section is defined, subsequently the way points are described which the vehicle needs to follow. The next step is to create a 2-D visualized which constantly updates the graphic when the robot moves. A Pure Pursuit algorithm available with MATLAB is used to define the lidar sensor, look ahead distance and maximum velocity to make robot navigate through the defined way points. Lastly, a simulation loop is used to constantly update the forward and inverse kinematics of robot and also its pose during the motion.

C. Team formation in a Multi-Robot environment

The following flow chart describes the logic of the code used to achieve the desired objective.

Multi-Robot environment creation
↓
Robot Detector function
↓
Adding team definition and bias
↓
Swarm team Controller definition
↓
Simulation Loop

In this algorithm, robots are described as having a circular profile. The first step is to define the number of robots that are working in the environment and then equipping the robot with a robot detector tool that involves the use lidar sensors for identifying fellow robot teammates. The swarm team controller is used to define the search movement of robot that involves their poses, index to form into teams based on the defined bias. Finally, a simulation loop is used to update the poses of robots and get the real time visual.

III. RESULTS AND DISCUSSION

A. Manueverability analysis of Mecanum wheel drives

Based on the kinematic model derived in the previous section, manueverability analysis was carried out to check whether the robotic platform was capable of performing the motions described in Fig. 4. The Matlab code was given specified inputs of velocities in x and y direction to obtain angular velocities of wheels (inverse kinematics) and vice-versa to check the forward kinematics.

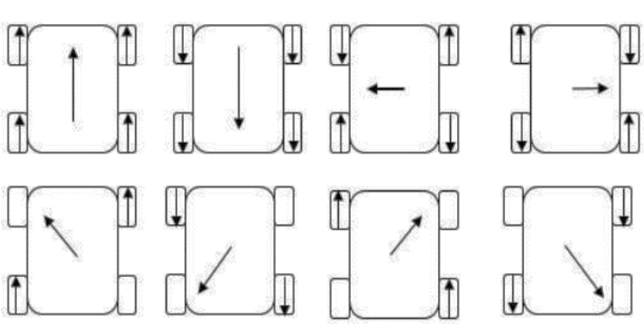

Fig. 4 Motions of robotic platform equipped with Mecanum wheels [6]

For example, if we carefully look at Table 1, we find that when a velocity of 2.5 m/s is given in x direction only the vehicle must move forward in that direction. This is observed by the values of angular speeds of all the four wheels which are positive and having same magnitude of 10 rad/s.

B. Way Point following using Pure Pursuit algorithm

This algorithm was performed essentially to give a perspective of real-world application of such robotic platforms. The way points describe in fig. 5a can be considered as stops the robotic platform has to make from initial point to final point with two intermediate stations to load material onto them. This situation is generally encountered at seaports where container loading and unloading takes place and the robotic platform needs to sense the places where loading of container takes place and then move a place where it is finally transferred to a truck or general docking area. Fig. 5b shows the result of simulation of Pure Pursuit algorithm applied to Mecanum wheeled robotic platform.

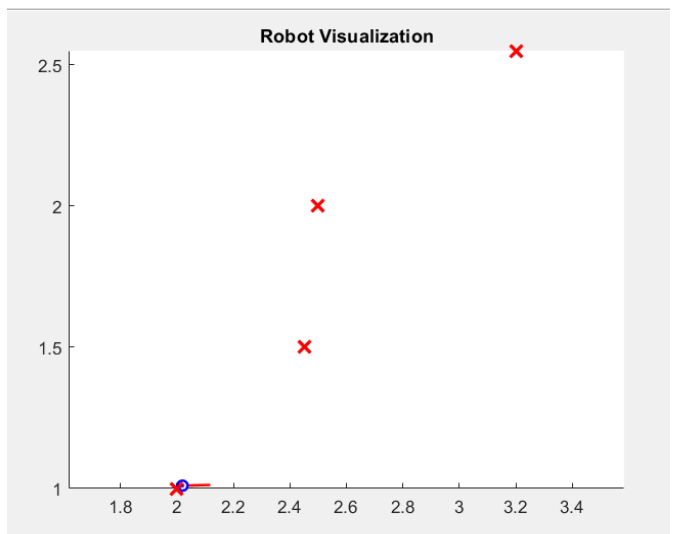

Fig. 5a Way points description

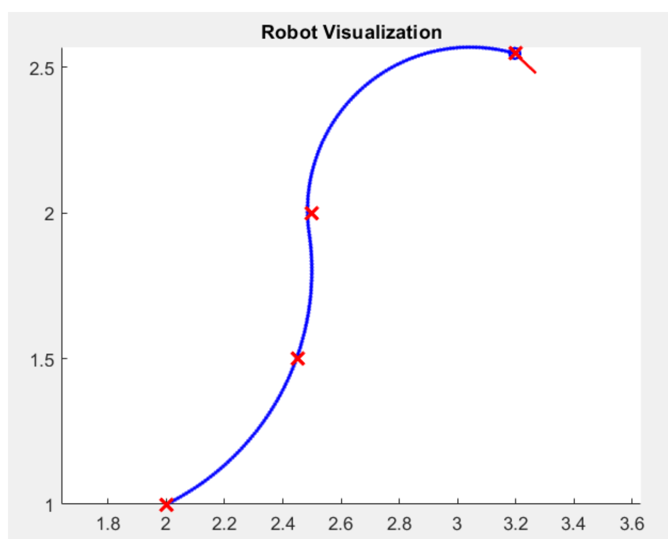

Fig. 5b Path followed by the robot

TABLE 1 MANUEVERABILITY ANALYSIS OF MECANUM WHEEL DRIVE

Movement Direction	v_x	v_y	ω	Wheel1	Wheel2	Wheel3	Wheel4
Forward (Along x)	2.5	0	0	10	10	10	10
Backward	-2.5	0	0	-10	-10	-10	-10
Left (Along y)	0	2.5	0	-10	10	10	-10
Right	0	-2.5	0	10	-10	-10	10
Left Diagonal Forward	2.5	2.5	0	0	20	20	0
Left Diagonal Backward	-2.5	2.5	0	-20	0	0	-20
Right Diagonal Forward	2.5	-2.5	0	20	0	0	20
Right Diagonal Backward	-2.5	-2.5	0	0	-20	-20	0

A more detailed study can be carried out using other complex algorithms to optimize the path being followed and also to give a more visual appeal.

C. Multi-Robot Environment

Having capability of forming swarms is an asset a group of robots can possess, especially when the tasks becomes too big to handle for a single robot. Such feature can be showcased using MATLAB's multi-robot environment simulation algorithm. For the purpose of simplicity, this algorithm defined robot as a circular entity which is equipped with a lidar sensor to detect fellow robots that were assigned to be working on the same team.

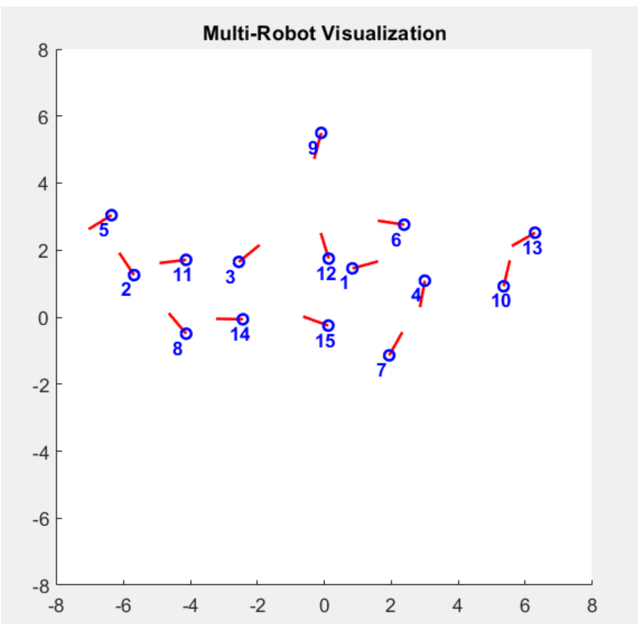

Fig. 6a Random orientation of robots

Fig. 6a represents 15 robots working at their designated places and Fig. 6b shows the formation of 3 teams after the simulation was performed. These teams can be used to perform tasks such as carrying of large freight for military application.

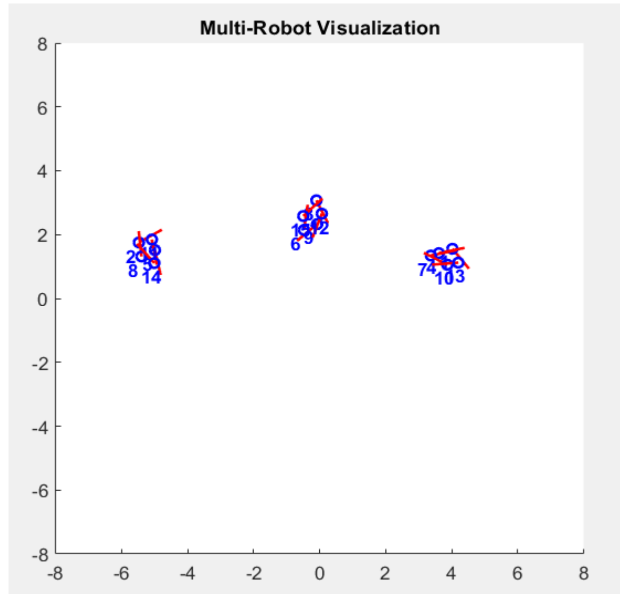

Fig. 6b Team formation based on logic

The above simulation only explores the multi-robot environment visualization and can be further developed to incorporate Mecanum wheeled platforms in it. Also, this feature in MATLAB can be used in conjunction with 3D visualization software such as ArGOS to analyse real time behaviour of a group of robots.

IV. CONCLUSION

A mobile robot platform equipped with Mecanum wheel drive showcased far superior manueverability as compared to traditional mobile robots with differential drives. This was proved by carrying out analysis in MATLAB which concluded that just by actuating wheels with different velocities and direction, a total of 8 different motions were obtained. The variety in motions can be further be increased by simultaneous changing velocities as well as angular speeds. Further study was carried out to incorporate Mecanum kinematics into a way point tracking algorithm to get the perspective of the robot working in real world environment. Finally, an attempt was made to demonstrate swarm capabilities of Mecanum wheel robots. This objective was partially achieved as the multi-robot environment simulation was carried out only using generalized description of a robot. A possible extension of this project can to solve this problem and use a 3-D visualization software in conjunction with MATLAB.

ACKNOWLEDGMENT

The author would sincerely like to thank Dr. Bumsoo Kim for giving guidance on the project and also the creators of Mobile Robotics Simulation toolbox in MATLAB, which is a special toolbox created for the purpose of student competitions involving mobile robots.

REFERENCES

[1] Y. Tian *et al*, "Research on a new omnidirectional mobile platform with heavy loading and flexible motion," *Advances in Mechanical Engineering*, vol. 9, *(9)*, pp. 1-15, 2017.

[2] O. Diegel, A. Badve, G. Bright, J. Potgieter, and S. Tlale, “Improved Mecanum Wheel Design for Omni-directional Robots,” no. November, pp. 27–29, 2002.

[3] Doroftei, V. Grosu, and V. Spinu, *Omnidirectional Mobile Robot - Design and Implementation, Bioinspiration and Robotics Walking and Climbing Robots*, no. September. I-Tech, 2007.

[4] R. P. A. van Haendel, “Design of an omnidirectional universal mobile platform,” National University of Singapore, 2005.

[5] MATLAB and Mobile Robotics Simulation Toolbox, Release 2018b, The MathWorks, Inc., Natick, Massachusetts, United States.

[6] H. Taheri, B. Qiao and N. Ghaeminezhad, "Kinematic Model of a Four Mecanum Wheeled Mobile Robot," *International Journal of Computer Applications*, vol. 113, (3), pp. 6-9, 2015

[7] Y. Jia, X. Song and S. S. Xu, "Modeling and motion analysis of four-mecanum wheel omni-directional mobile platform," in 2013. DOI: 10.1109/CACS.2013.6734155.

View publication stats