DESIGN AND DEVELOPMENT OF AN OMNI-DIRECTIONAL WHEELED MOBILE ROBOT

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ABSTRACT

Mobile robotic systems are mechatronic devices that are currently becoming more and more complex. To design such a system, a combination of expertise from the fields of mechanical, electrical and computer engineering is required.This paper presents a novel design of an Omni-directional mobile robot that can move in any direction at any angle and has good mobility and maneuverability in order to move in tight areas and to avoid obstacles along its path. Our Omni directional mobile robot is a 4 wheeled oval shaped robot composed of two motors drives on the internal driving unit where one motor drive will be used for a couple of wheels. Its motion analysis, kinematics as well as about its electronics and control strategies are presented.

1. INTRODUCTION

Omni directional mobile robot is a robot that can move in any direction at any angle without rotating beforehand. Specialty of the Omni directional wheels is that they are able to move freely in two directions. It can either roll like a normal wheel or laterally using the wheels along its circumference. Omnidirectional wheels have become popular for mobile robots,because they allow them to drive on a straight path from a given location on the floor to another without having to rotate first.Moreover, translational movement along any desired path can be combined with a rotation, so that the robot arrives to itsdestination at the correct angle. Omni directional wheels allow a robot to convert from a non-holonomic robot to a holonomic robot. A normal nonholonomic robot would have 1.5degrees of freedom meaning that it can move in both X and Y direction but requires complex motions to achieve the X direction. A holonomic robot would have 2 degrees of freedom so that it can move in both the X and Y plane freely.

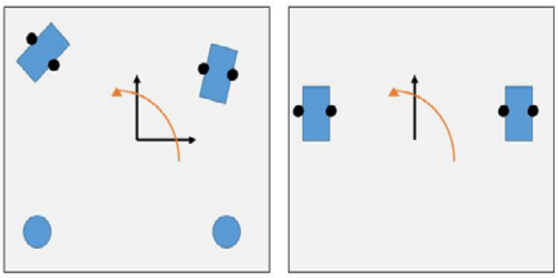


Figure 1: (a) Omni directional drive with three degrees of freedom (b) Normal drive (Non-holonomic robot) with two degrees of freedom.

There are many different methods of creating an omnidirectional drive system. These can be created by using conventional wheels or by using specially designed wheels arranged in a way that enables Omni directional movement. Specially designed wheels include Omni directional wheels and Mecanum wheels.

2. BACKGROUND

For our project, we decided to use the Omni wheel instead of mecanum wheel due to some advantages that the Omni wheel did not. These advantages were, Omni directional wheels roll forward like normal wheels, but slide sideways with almost no friction (no skidding during turns) andby using Omni wheels, the robot can turn smoothly or build a holonomic drivetrain

Omni directional wheels are based on a general principle which states that,while the wheel provides traction in the direction normal to the motor axis, so that it can roll passively in the direction of the motor axis. Each wheel provides a torque in the direction normal to the motor axis and parallel to the floor. The torques adds up and provide a translational rotational motion for the robot. If two orthogonal omnidirectional wheels under the center of a robot with a circular base, then driving the robot would be trivial. To give the robot a speed (vx, vy), with respect to a cartesian coordinate system, each wheel would have to provide one of the two speeds.

However, asthe motors need some space, a simple arrangement is not possible. The wheels are put on the periphery so that 4 omni wheels can be used.Using 4 omni wheels is an advantage because itcancels out any rotational torque which would make difficultly in driving the robot on a straight path and provides balance to the robot. While the wheels move forward the robot's frame is also rotated. Using geometry, the center of gravity can be found. The diagram below shows the angle of the wheels with respect to the horizontal axis (the x-direction). When the four motors are activated, four traction forces F1, F2, F3, F4 are obtained from the motors, which add up to a translational force and a rotational torque. The sum of the forces depends on the geometry of the wheels arrangement.

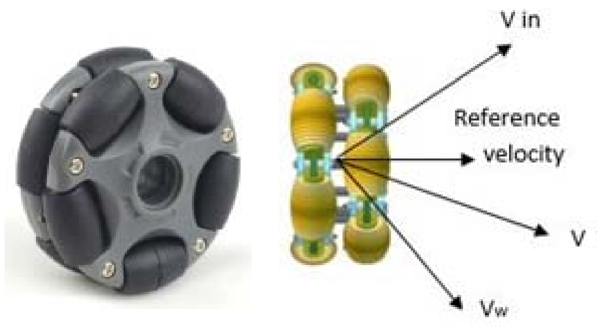


Figure 2 : A 48mm Omni wheel for Lego NXT and velocity Components acting on an Omni wheel

3. ANALYSIS

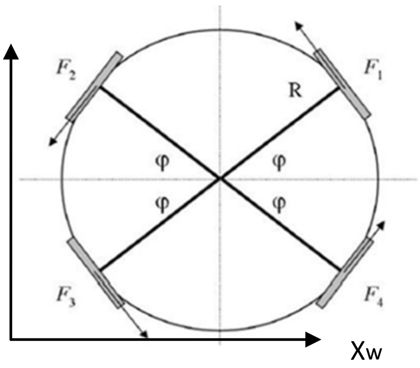


Figure 3: Forces Acting on the Omni Wheel Robot

3.1 DYNAMICS

The dynamic model for the system needed to be derived so that the robot could be properly represented while running both computer and hardware simulations.The translational acceleration of the center of mass of the robot -

The robot moves forward in the Y direction and zero in the X direction, therefore the translational acceleration is given by;

$$a = \frac{F1 + F2 + F3 + F4}{M}$$

where M is the Mass of the robot and F1, F2, F3 and F4 are the traction forces (Refer Figure 3)

Rotational acceleration is obtained by;

$$\alpha = \frac{R}{I}(f1 + f2 + f3 + f4)$$

where R is the radius of the robot, I is the moment of inertia, and f is the magnitude of the force

X, Y components of robot acceleration

$$ay = \frac{-f1cos\phi - f2cos\phi + f3cos\phi + f4cos\phi}{M}$$

$$ax = \frac{f1sin\phi - f2sin\phi - f3sin\phi + f4sin\phi}{M}$$

3.2 KINEMATICS

The kinematic equations for this project will be determined so that to motion of the robot can be represented without considering the forces. If, Vty is forward – backward motion (positive forward), Vtx is sideways motion (positive to the right) and ω is angular speed (positive counter-clockwise)

- Drive forward:

$Vty = ft/s, \quad Vtx = 0, \quad \omega = 0$

- Spin in place counter-clockwise:

$Vty = 0, \quad Vtx = 0, \quad \omega = 5rad/s$

- Drive forward while turning to the right:

$Vty = 10ft/s, \ Vtx = 0, \quad \omega = -1rad/s$

- Circle strafe' to the right:

$Vty = 0ft/s, \quad Vtx = 5ft/s, \quad \omega = 2rad/s$

3.2.1 VELOCITY AT A POINT

Given Vt (translational velocity of the center of the robot) and ω, determine the velocity V of some other point on the robot (e.g., the velocity at a particular wheel)
Once the velocity at a wheel is known, we can calculate the speed at which to turn that wheel (and possibly the orientation of that wheel)

r is a vector giving the position of a point on the robot (e.g., the position of a wheel) relative to the center of the robot

Vector approach:

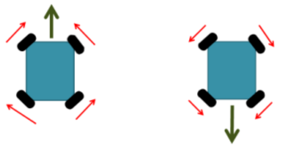
$$V = Vt + \omega \, x \, r$$

Scalar approach:

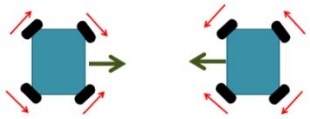
$$Vx = Vtx - \omega.ry$$

$$Vy = Vty + \omega.rx$$

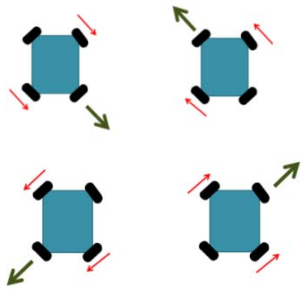
- Forward and backwards



- Right and Left



- Diagonal Movements



- Rotational Movements

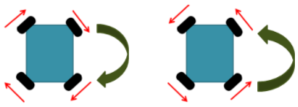


Figure 4: Robot locomotion

4. DESIGN AND IMPLEMENTATION

This is an Oval shaped mobile robot that can move forward, backward as well as to sides, and move along 45 angle using Omni wheels. The physical design of the mobile robot is very effective, because it is a combination of various physical (hardware) and computational (software) elements that integrate the subsystems of the mobile robot to work in one unit. The round shape design takes up less space than a square designed robot, and a round shaped robot makes it easier to rotate and to pass through small bearings.4 Omni wheels have been used. A four wheeled Omni robot is more efficient than a three wheeled Omni robot, because in a three wheel design, no more than one wheel will ever be aligned with the direction of motion, but with four wheel design, two wheels cam move at 100% efficiency, while the other two remain idle. One motor drive for a couple of wheels –In our design there will be two motor drives since we have four wheels and one motor drive will be used for a couple of wheels. Therefore there will be two circuits and when considering our basic shape, the two circuits will be on top of each other.

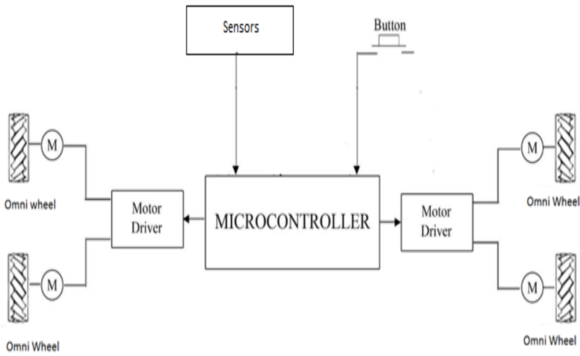


Figure 5: System block diagram

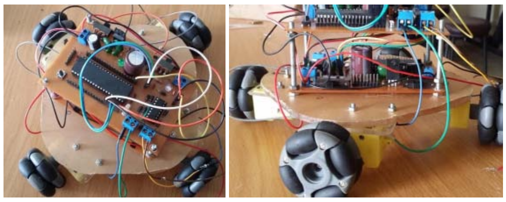


Figure 6: Omni wheeled robot prototype

5. CONCLUSION

In conclusion, an Omni directional mobile robot has been successfully developed and the kinematic and dynamic analysis of a proposed robot has been conducted . This robot can navigate in any direction with or without changing its orientation, surpassing the conventional differential-drive method in propelling a mobile robot. The motion control system of a robot was developed and various experiments were conducted. Subsequently, the influence of the double-layer structure on robot motion is analyzed theoretically to solve the problem of movement instability.

6. REFERENCES

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