Control of an Omnidirectional Mobile Base with Multiple Spherical Robots

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Outline

Introduction

- Mobile base are widely used for different types of robots such as human assisting robots, surveillance and reconnaissance etc
- The major requirement of these robots is to maneuveur easily through indoor cluttered environment.
- Mobile base with omnidirectional wheels have the advantage of unrestricted maneuverability.
- We investigate the use of spherical robots as omnidirectional wheels.

Introduction

- A three link assembly with snap joint for each robot is designed.
- In order to co-ordinate three robots, kinematics model is developed and experiments using PI controller for waypoint navigation and circular path is demonstrated.

Assembly of three spheros

- Sphero mini is a programmable COTS spherical robot based on Internal driving unit. It has a IMU sensor and LEDs for status indication and the robot can be operated using Bluetooth communication.
- The Mobile base is 3D printed to hold the spherical robots using a snap fit. These robots here are used as wheels

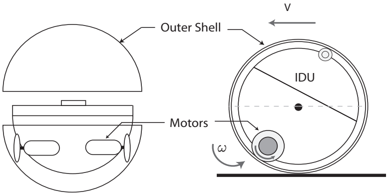


Figure: Sphero mini

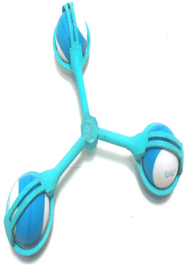


Figure: Three link assembly of Mobile base

Kinematics of Mobile base

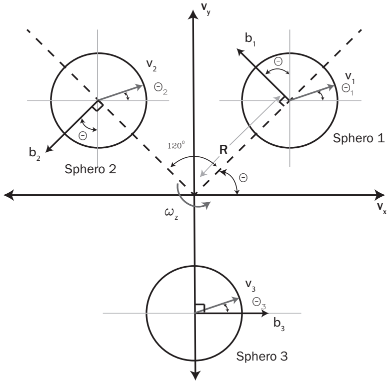
Following are the representation used.

- Linear velocities of base is v_x and v_y.
- Angular velocity of base be ω_z and the angle of rotation beθ.
- R is the distance from center of mobile base to spherical robot.
- The linear velocities of individual spheros are $v_{\mathbf{1}}$, $v_{\mathbf{2}}$ and $v_{\mathbf{3}}$.
- The angles $\theta_{\mathbf{1}}$, $\theta_{\mathbf{2}}$, $\theta_{\mathbf{3}}$ are the heading angles of the spheros with respect to the x axis.

$$v_{\mathbf{1}} = (v_x - v_x \sin(\theta))\hat{i} + (v_y + v_y \cos(\theta))\hat{j}. \quad (1)$$

$$v_{\mathbf{2}} = (v_x - v_x \cos(60 - \theta))\hat{i} + (v_y - v_y \sin(60 - \theta))\hat{j}. \quad (2)$$

$$v_{\mathbf{3}} = (v_x + v_x)\hat{i} + (v_y)\hat{j}. \quad (3)$$

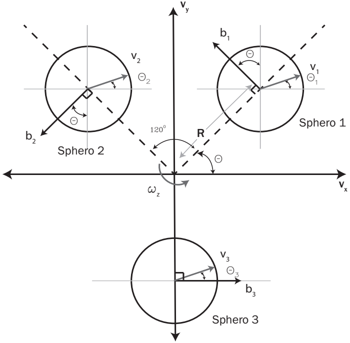


$$\theta_{\mathbf{1}} = \arctan \frac{v_y - R\omega_z \cos(\theta)}{v_x - R\omega_z \sin(\theta))}. \quad (4)$$

$$\theta_{\mathbf{2}} = \arctan \frac{v_y - R\omega_z \sin(60 - \theta)}{v_x - R\omega_z \cos(60 - \theta)}. \quad (5)$$

$$\theta_{\mathbf{3}} = \arctan \frac{v_y}{v_x + R\omega_z}. \quad (6)$$

$$\begin{bmatrix} v_{\mathbf{1}} \\ v_{\mathbf{2}} \\ v_{\mathbf{3}} \end{bmatrix} = \begin{bmatrix} 1 - \sin(\theta) & 1 + \cos(\theta) \\ 1 - \cos(60 - \theta) & 1 + \sin(60 - \theta) \\ 2 & 1 \end{bmatrix} \begin{bmatrix} v_x \\ v_y \end{bmatrix} \quad (7)$$



Experimental Setup

- We put $\theta = 30^\circ$ $R = 0.1$ m . The spheros does not have magnetometer so Yaw angles are calculated by sensor fusion of accelerometer and gyro data.
- .The spheros communicate to the Laptop using Bluetooth commnunication, the position of the mobile base is acquired using the vicon motion capture systems
- For implementation ROS interface is used which runs different software nodes for generating waypoints/leader points to PI controller with position feedback from vicon.
- Kinematic model gets input as $v_x v_y$ and θ and generates v_1, v_2, v_3 from equation (7)
- The heading angles of spherical wheels is computed using equations (4), (5), (6)

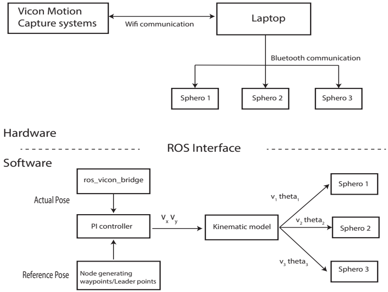


Figure: Experimental setup

Circular Trajectory tracking

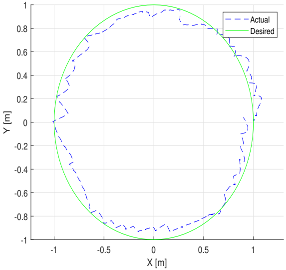
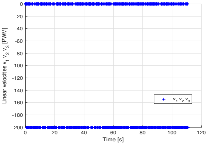
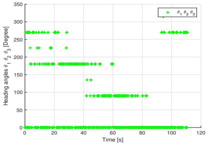


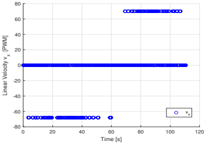
Figure: Circular Trajectory Tracking.



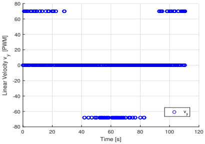
(a) v_1, v_2, v_3



(b) θ_1, θ_2, θ_3



(c) Linear Velocity v_x



(d) Linear Velocity v_y

As seen above the mobile base has following the circular path generated by the reference leader points.

Waypoint Navigation

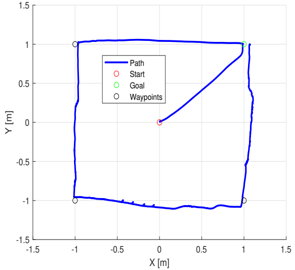
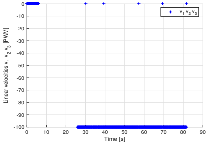
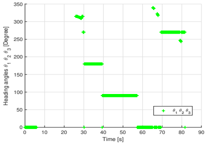


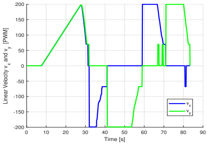
Figure: Waypoint Navigation



(a) v_1, v_2, v_3



(b) θ_1, θ_2, θ_3



(c) Linear Velocity v_x v_y

Similarly the mobile base reaches the different waypoints given.

RMSE for circular trajectory

- The maximum RMSE 0.0156 m.
- Thus experiments shows that the designed mobile base has omnidirectional maneuverability.

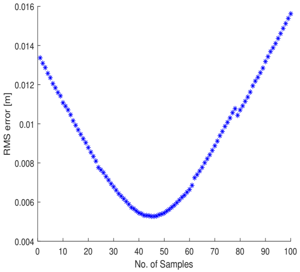


Figure: RMSE for Circular Trajectory

Conclusion and Future work

- The mobile base is successfully able to maneuver circular path and perform waypoint navigation using kinematic model for the spherical robots as wheels.
- The developed mobile base has promising applications as an autonomous robot navigating in indoor cluttered environment with unrestricted maneuverability.
- The future work involves developing controllers for trajectory optimization with unrestricted maneuverability. Investigation of using three link assembly in overcoming small obstacles or gaps is another future direction.