OMNI-DIRECTIONAL SPHERICAL ROBOT

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ABSTRACT

Moving robots are a novel application in automating advanced surveillance, inspection and transportation tasks in various fields. Moving robots are also capable of localization and navigation. Omni-Directional locomotion is an important feature which enhances maneuverability and efficiency of mobile robots. Omni-directional robots use external mechanical arms or wheels to move. Therefore limitations of terrains on which the ODM robots can navigate are unavoidable. In this paper an Omni-Directional Spherical robot is presented to overcome above limitations. The higher stability and internal driving mechanism protected by a shell are additional benefits. Basicallythe ball is moved by continuous rotation of an unbalanced point weight around the horizontal axis of the sphere. The Sphere bears an internal platform in direct contact with the shell on which the driving mechanism is installed. Lagrangian mechanics analysis of driving of the sphere is explained in the paper. The behaviour of linear acceleration and velocity of the ball by controlling angle of the pendulums are presented as useful results.

***Key words*:** localization, Navigation, Omni Directional Robot

1. INTRODUCTION

A spherical structure can freely rotate in any direction and all positions are stable. The shape of a sphere provides complete symmetry and a soft, safe, and friendly look without any sharp corners or protrusions, which is advantageous when a robotic device is dealing with people. The technical challenge is to install an internal driving mechanism to move the robot.The general solution for mobility of a Spherical robot is the deviation of the robot's centre of gravity1 (cog).

Several models of spherical robots have been presented in history. In 1996 A. Halme presented a Spherical robot with an internal driving unit2. Antonio designed a spherical robot by putting a two-wheeled car into a hollow ball3. S. Bhattacharya proposed a spherical robot with two perpendicular motors attached to the spherical shell which is based on the conservation of angular momentum4. Mukherjee gave a design of a spherical robot with four spokes extending from its geometrical center and each spoke has a movable mass, and the omni-directional motion was achieved by driving those masses to move along each spoke so as to change the center of gravity of the robot5.We have presented a model which uses two continuous rotation pendulums to drive the sphere forward and steer sideways.

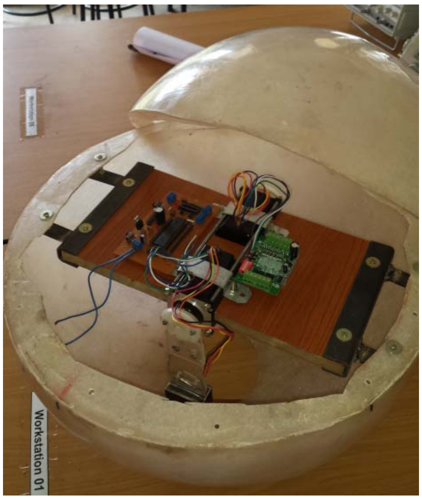


Figure 1 Spherical mobile robot

2. BACKGROUND

In this prototype two pendulums are driven by two continuous rotation stepper motors about the horizontal axis which generates an eccentric moment by which the robot can roll linearly or steer left or right by controlling the angle of rotation of one pendulum relative to the other. The torque is created by the inertia of a rotating mass. The rotating mass (pendulums) accelerates and generates a counter-torque that drives the ball in the opposite direction. The nonzero tilt angle of the unbalanced mass (pendulums) may activate the robot to accelerate. It also implies that the desired velocity of the robot in linear motion can be obtained by giving the proper tilt angle, that is, the position of the robot is controllable. A large diameter for the robot helps to generate greater driving torque and, at the same time, resistive torque from environmental objects such as stones or doorsteps remains lower. Hence large size is a benefit, while the overall mass then tends to increase. While the propulsion system is located inside the ball it can be hermetically sealed to provide the best possible shield for the inner component

3. DESIGN

The pendulums are fixed to the platform which is internally fixed to the hemisphere so that they can freely rotate without any obstacle. The platform is installed so as to position the weights symmetrically around the axis. As explained in the background section the torque generated from the rotating pendulums applies a torque in the opposite direction on the sphere.

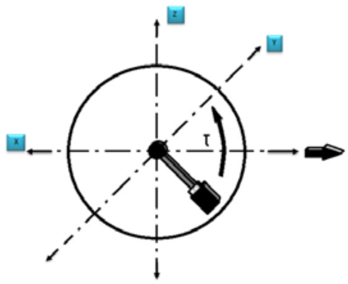


Figure 2: Forward driving mechanism

The Lagrangian mechanics Analysis of the driving mechanism is shown below:

(Dynamic parameters)

θ= angle of pendulum to Z-axis.

$\dot{\theta}$= angular velocity of pendulum about Y-axis.

$\ddot{\theta}$= angular acc. of pendulum about Y-axis.

τ = Torque of the pendulum about Y-axis.

$\ddot{y}$= linear acc. of the sphere in X-direction.

(Static parameters)

M= mass of the pendulum + mounting hub+ shaft.

m = mass of the sphere + mounting board

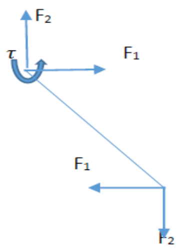


Figure 3: Transformation of forces to Sphere F1-F2

L = T – U

L = ½m (r$\ddot{\theta}$)2 -mgr(1-cos θ)

$$^{d}/_{dt}\,(^{\partial L}/_{\partial \theta}) - (^{\partial L}/_{\partial \ddot{\theta}}) = \tau$$

-

mgr(sin θ) – mr2$\ddot{\theta}$ = 0

$$\ddot{\theta} = \frac{-g \sin \theta}{r}$$

Kinetic Energy
= K. E of pendulum + K.E of sphere + R. E of sphere

$$=\left\{\tfrac{1}{2}m\left(\dot{y} + r\dot{\theta}\cos\theta\right)^2 + \tfrac{1}{2}m\left(r\dot{\theta}\sin\theta\right)^2\right\} + \tfrac{1}{2}M\dot{y}^2 + \tfrac{1}{2}I\dot{\alpha}^2$$

Potential Energy = - mgrcos θ

L = T – U

$$L=\tfrac{1}{2}m\left(\dot{y} + r\dot{\theta}\cos\theta\right)^2 + \tfrac{1}{2}m\left(r\dot{\theta}\sin\theta\right)^2 + \tfrac{1}{2}M\dot{y}^2 + \tfrac{1}{2}I\dot{\alpha}^2 + \mathrm{mgr}\cos\theta$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) - \frac{\partial L}{\partial \theta} = \tau$$

$$\ddot{y} = \frac{2mgr\sin\theta - mgR\sin\theta + mrR\dot{\theta}^2\sin\theta}{\left\{R\left(M+m+\frac{1}{R^2}\right) - mr\cos\theta + \frac{mr^2}{R} - mr\right\}}$$

$$\mathrm{m}r^2\ddot{\theta} + mr\ddot{y}\cos\theta + mgr\sin\theta = \tau$$

$$(\mathrm{M+m})\ddot{y} + \frac{I\ddot{y}}{R^2} + mr\ddot{\theta}\cos\theta - mr\ddot{\theta}\cos\theta - mr\dot{\theta}^2\sin\theta = \frac{\tau}{R}$$

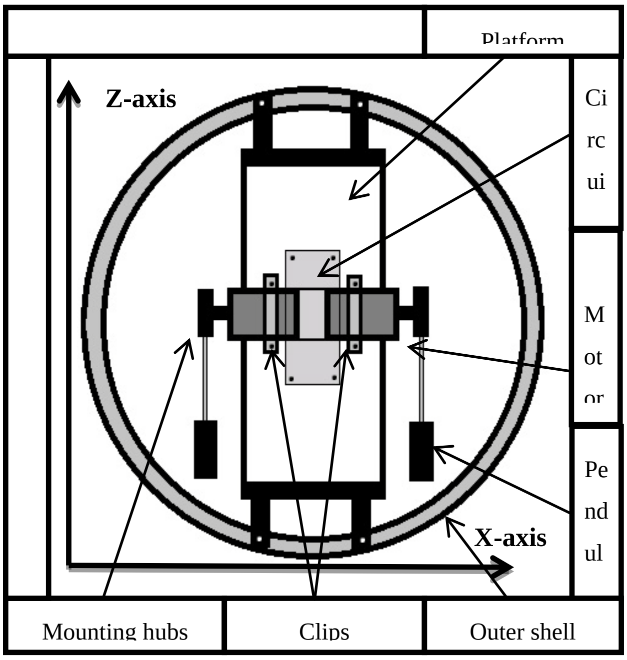


Figure04 – Describes the Arrangement of electrical components and how they are implemented in moving the ball using its top

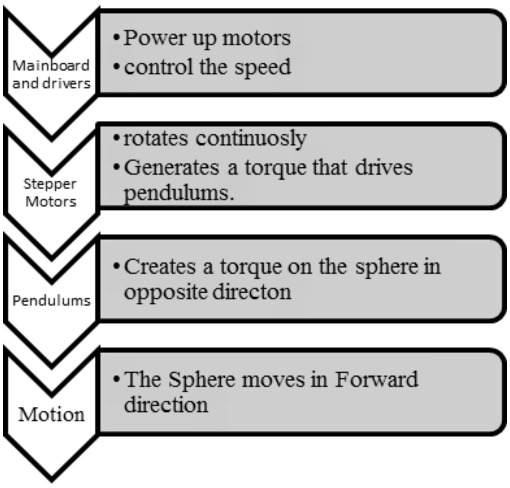


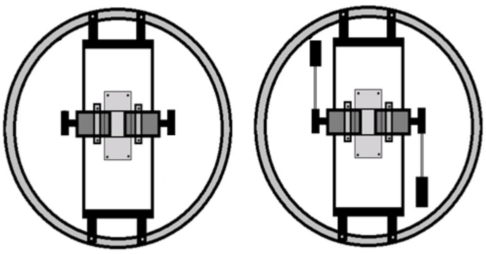
Table 1:Specifications of the components

Component	Specification
Stepper Motor	13Kgcm/24V
Motor Driver	24V/3.0A
Pendulums	0.396Kg
Battery	Lithium Ion/24V

4. IMPLEMENTATION

Linear motion can be achieved by incrementing the angle of the 2 pendulums asynchronously in the same direction. The angular velocity of the pendulums will be governed by the input from the gyroscope.

The Turning Sequence for the robot is as follows.



Step 1 –Both pendulums at angle 0^0

Step 2 – left pendulum at $+30^0$ and right at -30^0

Figure 4: Turning Sequence

Multiple tests were carried out to identify the above sequence and it will ensure a stable and controllable tilting motion which can be used to turn the ball. Readings from the gyroscope will be used to control the tilting of the robot.

5. RESULTS

Above equations derived using Lagrangian mechanics were used to develop some useful graphs. The following figures depict the response of the system according to the angle taken by the pendulums.

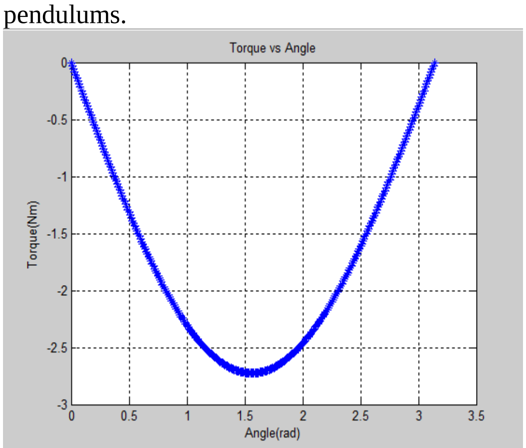


Figure 5

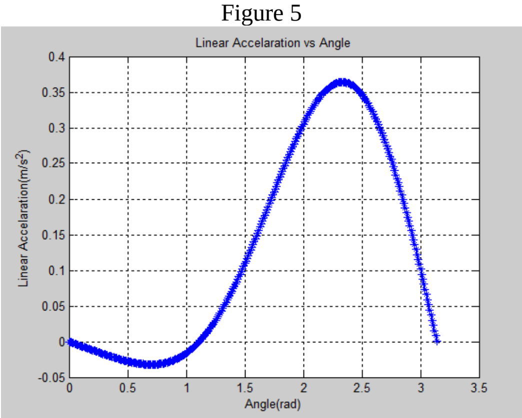


Figure 6

6. CONCLUSION

Analysis of motion of robot such as the linear motion, turning motion has been discussed. The kinematics equations of the spherical robot are deduced and its controllability is being researched on as an on-going project. Two typical motion simulation examples are provided to explain that the angle of rotation has a big impact on the acceleration of the robot. The produced graphs can be further developed to programme the robot to perform accurate navigation and localization. The controllability of the robot can be improved further with application of a gyroscope to the robot.

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