Design and Implementation of Spherical Robot Actuated by Omni-Wheels

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***Abstract*—This paper presents a spherical robot which is actuated by three sets of omni-wheels for omni-directional motion. The motion is given by the help of an internal driving unit placed inside the hollow spherical shell. This provides better protection for the driving unit and also more precise control over its motion. This paper consists of the model of the spherical robot, its kinematics of motion and control system of the robot. The robot can be used in various surface conditions and it can also be used in inspection of pipelines and tunnels.**

Index Terms-Internal driving unit (IDU), spherical robot, mobile robot

I. INTRODUCTION

The spherical robot has been considered for research because of its certain advantages over the traditional wheeled mobile robots in mobile robot applications. The spherical structure of the robot gives it a complete freedom for its movements. Since the internal driving unit is placed inside the hollow spherical shell it acts as an efficient cover for sensory and driving equipment's. The outer shell also acts as an additional protection when carrying sensors, cameras, loads or other necessary equipment's. It has better capability and superior strength while facing collision with external obstacles. The advantage of spherical mobile robots is that it can be used for navigation in unknown or varying territories, such as lunar explorations or even disaster struck areas such as earth quakes, etc.

The unique mechanical structure of the spherical robot makes it more stable and reliable compared to other similar robots. The driving mechanism is placed inside a hollow spherical shell, and consists of three sets of actuated omni–wheels. These wheels provide the omni-directional motion for the robot. This mechanism helps in decreasing the slip between the inner driving system and outer spherical shell and thereby providing more precise control of the robot in various terrains.

II. LITERATURE REVIEW

H. Ghariblu [1] proposed a spherical robot with a driving mechanism which is placed within a hollow spherical case. The driving unit consists of three sets of omni–wheels for the motion of the robot. The mathematical model was also formulated using Newton–Euler formulation. W Chen [2] proposed an omnidirectional spherical robot which was designed and implemented using a driven ball installed inside the spherical shell and then driven by two orthogonally-mounted rollers. V A. Joshi [3] used a classic nonholonomic system. This was done using the help of two internal rotors and on the principle of conservation of angular momentum. A Halme [4] proposed a paper that deals with dynamics and control of a mobile robot that is designed to act as a small platform for carrying sensing devices and actuators in an environment where stability is critical. A Bicchi [5] introduced a special kind of mobile robot called sphericle whoes motion is derived from two classical nonholonomic systems i.e. a unicycle and a plate-ball system.

C Camicia[6] published a paper with the derivation of the kinematic model of the sphericle. It incorporated two types of nonholonomic constraints and its dynamic model. Amir H A [7] describes about a prototype of a spherical rolling robot which can arbitrarily move in any direction towards its target. The design consisted of an internal propulsion mechanism which distributes weights radially along spokes fixed inside the sphere and which in turn enables the robot to move constant velocity. Qiang Zhan [8] proposed an omni-directional spherical robot that is made of a lucent ball-shaped shell and an internal driving unit. Of the two motors installed in the internal driving unit, one motor is used to make the robot move straight and the other is used to make it steer. M. Kabala [9] introduced a robot called "RoBall," which has an internal gimbal mechanism. The robot has two wheels which forms the IDU. By changing the orientation of a heavy mass hanging on the IDU the contact points of the two wheels to the outer shell are varied and thus providing motion.

The spherical robots discussed above have various advantages and disadvantages. Few of them are costly, hard to implement and also hard to control. The proposed robot discussed in this paper is cost effective and easy to control. It consists of three sets of omni wheels connected to individual motors. Due to the unique structure of the IDU the robot is stable and easy to control.

III. DESIGN

The modelling of the structure is done in solidworks software. The solidworks software is chosen due to its simplicity and flexibility. The internal driving unit and the outer shell are individually modelled using the solidworks software. Then they are merged using the same. The internal driving unit is shown in the fig.1. The IDU consist of 3 omni wheels which are coupled to the motors placed on the edge of the links. The main frame of the IDU consists of three links that are placed orthogonally perpendicular to each other and fixed at a common point. This position of the links provides a conical structure to the frame there by providing a stable structure that can be easily kept inside the spherical shell. The lengths of the links are selected in such a way that the common point of the links does not touch the bottom of the shell. A round plate is then fixed touching the three links at a suitable height from the bottom of the IDU. This plate is used for placing the control system, sensors and battery of the IDU. The omni wheels are placed at the edge of the links so that the wheels are always in contact with the outer shell.

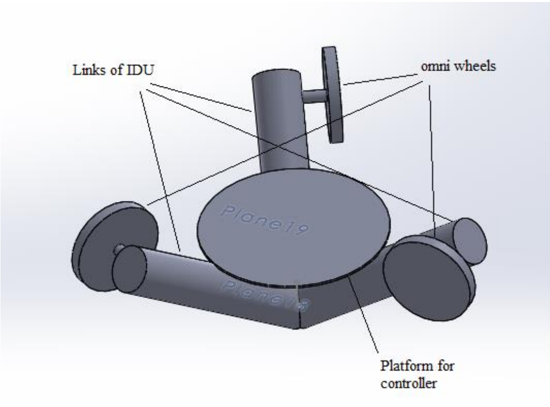

Fig.1 The internal driving unit

The outer shell is then modeled using the solidworks software. In order for easy understanding a hemisphere is considered here. Once the shell has been modeled the IDU is placed inside the shell. The diameter of the shell is considered such a way that all the three wheels touch the circumference of the hemisphere. Care is also taken so that the links does not touch the outer shell. The fig.2 shows the IDU placed inside the spherical shell. The fig.3 shows the wireframe model of the spherical robot. This model shows the clear picture of the links and wheels inside the spherical shell. It can be seen that the links does not touch the outer shell.

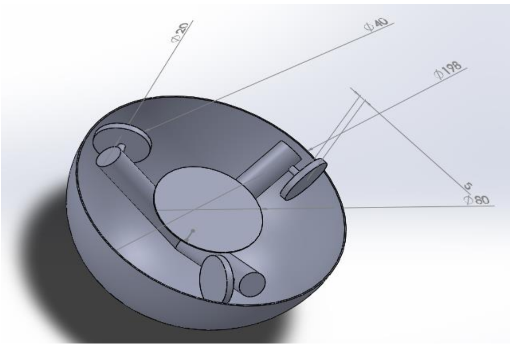

Fig.2 The internal driving unit placed inside the sperical shell

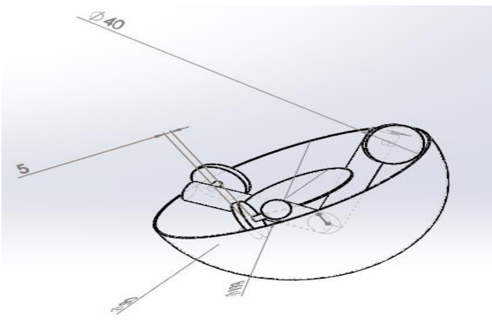

Fig.3 The wireframe model of spherical robot

IV. KINEMATICS OF MOTION

The equation for kinematics of motion has been given as equations (1), (2) and (3). These equations have been derived by the author H. Ghariblu [1] for a similar model of robot. The three equations represent the acceleration equations for the spherical robot along the three axis X, Y and Z. The angle γ is the angle of lifting for inner mass. This causes the robot to move forward or backward. The angle β causes robot to move in a curvi-linear path. R_i is the radius of the sphere.

$$a_{G,X,i} = \ddot{X} - r_i(-\ddot{\beta}s\beta s\gamma + \ddot{\gamma}c\beta c\gamma - (\dot{\beta}^2 + \dot{\gamma}^2)c\beta s\gamma - 2\dot{\beta}\dot{\gamma}s\beta c\gamma) \quad (1)$$

$$a_{G,Y,i} = \ddot{Y} - r_i(-\ddot{\beta}c\beta + \dot{\beta}^2 s\beta) \quad (2)$$

$$a_{G,Z,i} = -r_i(-\ddot{\beta}s\beta c\gamma - \ddot{\gamma}c\beta s\gamma - (\dot{\beta}^2 + \dot{\gamma}^2)c\beta c\gamma + 2\dot{\beta}\dot{\gamma}s\beta s\gamma) \quad (3)$$

Where, sx = sin(x), and, cx = cos(x), x = β, γ

V. CONTROL SYSTEM

The control system for the robot is shown in the fig.4. The main part of the control system is the microcontroller. The microcontroller used here is the arduino uno board. It consists of the ATmega 328 microcontroller. The arduino is selected because of its wide capabilities and it can be easily programmed using simple C language. The microcontroller is then connected to the motor driver. The motor driver consists of the L293D IC. This driver can easily be connected to the arduino. The motor driver is capable of handling all three motor necessary for the robot motion. The motors selected are low rpm dc geared motor.

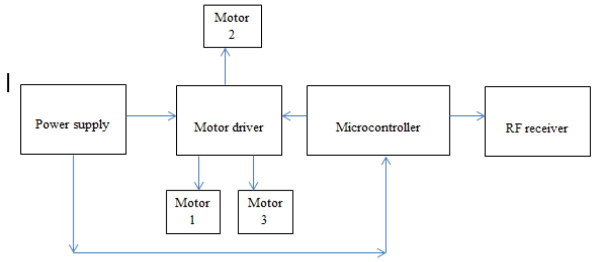

Fig.4 Control system for the internal driving unit

The omni wheels are coupled to the motor. The omni wheels provide motion in both forward and sideways. The power supply is given to both the microcontroller and motor driver individually. The robot is controlled wirelessly. In order to provide wireless capability a RF receiver is connected to the microcontroller. The RF transmitter consists of a number pad where each number can be used to activate each of the individual motors. Since the microcontroller has diverse application additional sensors can be connected if necessary.

VI. CONCLUSION

The spherical robot has many advantages over the most widely used wheeled mobile robots. The unique structure of the spherical robot provides more protection to the driving unit and also more stability. In this paper an efficient design for the spherical robot has been explained. This design for the robot gives more cost effective and stable structure for the robot. The control system for the robot has also been discussed in this paper. The construction and testing of the prototype is yet to be completed.

VII. REFERENCES

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