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Sphero Droid - Pendulum Based Spherical Robot

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Abstract — ***Considerable amount of researches are being done on mobile robot from last century, over different aspects like control, motion, sensing, and many more. In terms of motions various designs are available from usage of limbs or actuators. For a spherical robot, it possesses various advantages in terms of motion, navigation. A spherical robot also offers almost zero friction due to very unique property of sphere i.e. single contact point. But by using rolling motion, a limbless robot can be made. The rolling motion is created by use of rotation done by sphere. This leads us to the development of the Spherical Mobile Robots. These spherical robots possess various advantages in terms of motion, strength, and ease of motion over rough terrine. The spherical shaped robots can also be made gas and liquid proof depending over situations.***

This paper is about design and development of a spherical robot (termed 'Sphero Droid') using pendulum principal. Presently droid is controlled with help of remote.

Keywords — Arduino Mega, Bluetooth, Remote-Control, Pendulum

I. INTRODUCTION

Spherical robot design poses many advantages, that being said they are becoming a very attractive research interest over last two decade. The very first is of maneuverability. They can be holonomic in nature, to aid the movement in any directions. Due to this, it decreases the chances of robot being trapped at corners, while improving the options available for navigation about articles in surroundings. There will be no cases of toppling of robot, due to spherical nature of its shape. Robots using wheels for motion pose difficulties when they get in bottom up position. But there is no such situation with spherical robots.

Traditional robots also face problems when they are climbing stairs or are near ledges, but spherical robots have no problems as such with these things. This aspect of spherical robots tolerates conditions like being thrown or dropped from height. They also suffer minimal damage when they collide with any obstacles present around them in surroundings. This very feature will prove to be very helpful in case of swarm applications, when many similar droids will be moving and clustering together in close vicinity, and due to spherical design they will not provide any kind of opposition or obstruction to other robots in motion. As the robots possess spherical shape, they are completely sealed, which is optimal for perilous situations. This spherical shell also offers dampening naturally over multitude of collisions over surface navigation. The circuit and all other required mechanisms are completely sealed inside of spherical shell. This allows us to use the robots in situations or environments involving mud, snow and water too.

These spherical robots can be smaller than wheeled robots, and at the same time inexpensive compared to counterparts available in markets. They could be employed for lengthy durations or could be made disposable in nature. As per applications part, these robots can be deployed in field such as reconnaissance, environment assessment, could be used as toys for entertainment or as extreme as space exploration.

II. Literature Survey

- **Shourov Bhattacharya, Sunil K. Agrawal, "Design, experiments and motion planning of a spherical rolling robot", April 2000**
  In this paper description of a prototype and analytical studies of a spherical rolling robot was performed. A new design involving a non-holonomic system was devised. The spherical robot used was driven by two remotely controlled and internally mounted rotors were used to rotate and move the spherical shell over given surface. It could be tracked on the surface with help a camera mounted on the gimbal. The paper also consisted of a comprehensive mathematical model of robot's motion which was used to develop non-holonomic constraints on its motion. For a various simple motions, experimentally model agreed well with the results with mathematical model. Methods were devised for creating feasible, minimal time and energy trajectories for given spherical robot. These methods were illustrated with the help of both mathematical simulation as well as hardware experiments on ground.

- **Masaki Nagai, Thesis on "Control System for a Spherical Robot", August 2008**
  In this paper, a comprehensive study was done on construction of a spherical robot. The proposed system consisted of two main components: the spherical robot and a ground station for controlling. The robot was consisted of an in-board computer, a power source, communication system, and multitude of sensors for purpose of controlling, and feedback towards ground station. It used a pendulum based system to produce motion in the robot and to move it over the surface. It had two servo motors for movement and a single DC motor to rotate the pendulum for driving the robot. It used a magnetic compass and gyroscope for controlling its roll angle and velocity of the ball.

- **Jack A. Jones, "Inflatable Robotics for Planetary Applications", I-SAIRAS, June 2001**
  In this paper, a wind propelled spherical robot for planetary exploration of Mars is proposed. It consisted of a large inflatable ball with scientific instruments placed inside its 6m – diameter body. Three such robots were considered together to create a tricycle like structure. For controlling, a simple procedure was proposed, where a partial deflation and could be driven anew by fully inflation. The general idea for such design was to allow the robot or rover to travel over rocks instead of around them. At present all rovers travel around the rocks and obstacles, by allowing a rover to travel over a given obstacle will improve its efficiency to perform a given task, speed, and range of its operation by a large margin.

- **Tomi Ylikorpi, Jussi Suomela, "Mars Ball", 2005**
  Here very same principal like of Jones is used. The robot used an inflatable ball as its body but also housed a pendulum. The provided two-degree-of-freedom inside for active motion, and used fins to harness the winds present on Mars for its passive motion over surface. The biggest drawback to these wind driven robots was that they could produce very small amount of torque to rotate themself. This gave arise to problems when robot was required to overcome obstacles and uphill climbing motion was required.

- **Deepak Pokhrel, Nutan Raj Luitel, Sukanta Das, Dip Narayan Ray, "Design and Development of a Spherical Robot", December 2013**
  In this paper, a spherical robot was designed called "SpheRobot". The paper contained mathematical modeling, experimental, and analysis of model. A wireless camera was mounted on the gimbal to transmit images to the ground station for monitoring purposes. The proposed SpheRobot was remote controlled. The system used Arduino UNO board along with three axis compass for controlling the motion of the robot. Combination of DC motor and servo motor was used to drive the SpheRobot in four direction i.e. Front, Back, Left, Right. RF remote was used to control and operate the SpheRobot. Wireless camera could transmit audio-video visuals to ground station. Paper also proposed that it is possible to add various other mounts or modules depending upon the requirement of the user, as shell will have a quite amount of empty space. Which will allow us for further expansion of the SpheRobot.

- **Vincent A. Crossley, "A Literature Review on the Design of Spherical Rolling Robots", January 2006**
  This paper contained a review of various design regarding spherical robots. Various propulsion mechanisms are discussed. Like Wheel based models, Models having Independent Hemispheres, Pendulum design, Motions using centre of gravity, Wind powered, as well as Deforming mechanism. The paper also showcased dynamics related to the spherical robots with the help of mathematical modeling.

- **Akash Singh, Anshul Paigwar, Sai Teja Manchukanti, Manish Saroya, Manish Maurya, Shital Chiddarwar, "Design and implementation of Omni-directional spherical modular snake robot", February 2017**
  This paper presented overall design of and construction of omni-directional planar snake robot containing software and mechanical links using spherical robots as base modules. The paper presented mathematical, 3D model, and a prototype models. The spherical units used a gear train model to provide motion to the units instead to pendulum or various techniques used earlier. This paper presented a swarm type use and approach of the spherical robots in the field of robotics.

- **Richard Chase, Abhilash Pandya,"A Review of Active Mechanical Driving Principles of Spherical Robot", November 2012**
  This paper contained a review of various design present for constructing spherical robots. Various pendulum related mechanisms are discussed. Designs involving shell transformation and using memory alloy to create shell for robot is also discussed in length. Paper also contained a table which show cased different factors affecting while using any of above mentioned design considering what kind of force will act on robot to produce motion.

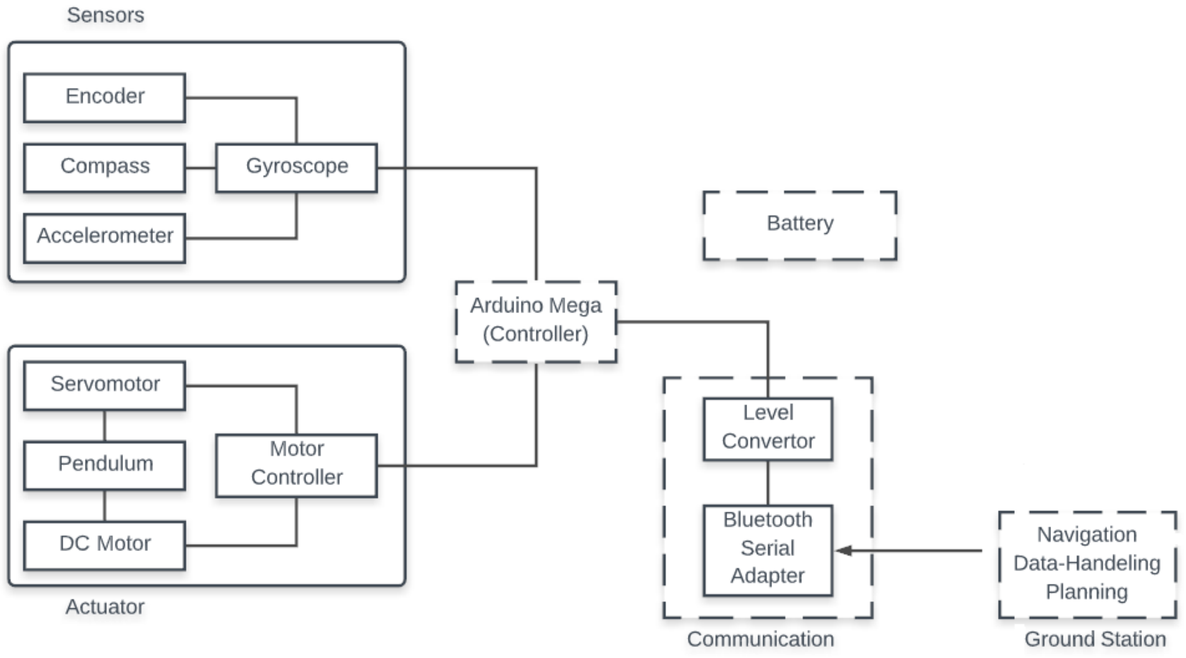

Fig- System Architecture

III. Block Diagram

Sensors – Sensors will be used to control the Sphero Driod remotely. Encoder here is used to control the rotation speed of the motors to provide precise control over the motion of the droid. Compass and accelerometer are used to aid the navigation of the droid over various surfaces.

Actuator – Servomotors are used to control the swing of the pendulum, which in term will affect the direction as well as rotation of the droid in a direction. DC motors are used to drive the droid and rotate the spherical shell, to provide the required motion to propel the droid. The motor controller is used to control the speed of both motors linearly.

Arduino Mega (Controller) – Arduino board will act as main controller, to which all required sensors will be attached. The board used here is Mega, which is based on ATmega2560. It has 54 digital i/o pins of which 14 can be used as PWM outputs. These 14 pins will be used to drive motors along with motor controller to get required motion and movement of the droid.
Communication – For communication Bluetooth module is used. The Bluetooth can provide range of 50 To 60mtrs without any losses. A serial adapter and level converter will be also used to convert the required signals for Arduino board as it does not has built in level converter.

Battery – A rechargeable or disposable Li-ion battery will be used to power the whole system or droid. The battery will be of 12 V. The battery will kept in the shell and will also act as pendulum weight, as the droid uses pendulum system to navigate over multitude of the surfaces.

Ground Station – It controller which will communicate with Bluetooth module place inside the shell to aid the controlling of the droid. We can use a RF controller or a separate remote computer for controlling purpose when different sensors like camera module, voice module are used along with gimbal in the shell.

IV. Conclusion

This technology is still under research and surely it will be a breakthrough in field of robotics. A spherical robot is easy to construct, has a sealed shell to protect its hardware and it is a new design to accommodate current needs of the society. Sphero Droid is still in its beginning stages, but improvements are being made rapidly, and soon this technology will be used in our daily lives. This paper describes the design, modeling and experimentation of a mobile robot with a spherical shape. This robot was designed to act as a platform to carry wireless camera in an environment where the conditions are harsh or the stability of the mechanical platform is critical. Mobility is one of the important issues during the development of mobile robots for rough terrain, typically faced in outdoor missions or in space. Wheels, legs or their combinations are used by various types of mobile robots for locomotion. However, these kinds of systems require most efficient and versatile mechanisms of locomotion for working in rough and uneven terrains. Spherical mobile robot can achieve different kinds of unique motion, such as all-direction driving and motion on rough ground, without losing stability.

V. Future Scope

Spherical Robots or Sphero Droids are new and emerging robotic technology in the market. These robots are available for multitude of uses form toys to actually deploying them in fields to perform some task which otherwise prove harmful for human life. The spherical robots still need lot of research as better and more compact IDUs are required to shrink the size of the droid without sacrificing any functionality. With better path searching algorithms and techniques these droids can also be deployed in field to perform trivial task and reduce human efforts like sample collection and otherwise.

The upward motion is a tricky problem which needs to be addressed quickly to make the spherical robots useful in more adverse conditions. It is sometimes a disadvantage for a robot for not being able to climb steep inclines. Jumping motion would allow robot to overcome obstacles and holes. Perhaps a hole at the bottom of the robot which will a rod to be poked through quickly, coming into contact with the ground and produce spring like action. Or maybe there could be a flap on the bottom of the sphere that can open quickly, launching the robot upwards with some push. Another option is for an internal mass to be oscillation to use momentum to produce jumping motion. There are lot of different properties of spherical robots which are yet to be fully explored.

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