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Design and Development Of Spherical Robot Used For Measurement Of Humidity In Agricultural Field

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ABSTRACT

Robotics and automation is taking place of humans in almost every work place there by reducing human effort, so the use of spherical robot is an attempt towards agricultural automation. Spherical robot characterized by its spherical shape can travel in any direction so restricted motion is not a liability. It can also be used in narrow spaces, bumpy surfaces in agricultural sites. Because of its spherical shape, effect of wind on its motion will be reduced. It protects mechanism and electronic devices within the spherical shell. The device is wireless enabled which enhances its coverage. The combination of hygrometer and a wireless camera module is used in this robot. While hygrometer continuously measures humidity, wireless camera captures readings of humidity from display of hygrometer. It can also show directions to the robot. Communication is done over radio frequencies and results are achieved.

Keywords— **Microcontroller, DC motors, RF module, Wireless camera, Hygrometer, LCD Display**

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I. INTRODUCTION

Humidity is an expression of the amount moisture in air. It is an invisible gas that varies between 1-4% of our atmosphere by volume. Humidity can be the most difficult environmental factor to control in greenhouses. Maintaining set points and correcting for too little or too much humidity can be a challenge for even the most sophisticated monitoring and control equipment. Humidity levels fluctuate with changes in air temperature, and plants are constantly adding water to the air through transpiration. Although automated controls have added a higher level of precision to the art of sensing and correcting humidity levels, it is still important to have a good understanding of the dynamics of atmospheric water vapors. There is a natural tendency with sophisticated equipment to just 'set it and forget it'. However, lost yields, plant stress, disease outbreaks, and wasted energy are still as possible as ever unless we realize the limitations of our equipment and the implications of environmental control decisions. Farmers are adapting latest techniques by implementing modern technologies for producing better agricultural products.

Spherical robot may be the most preferred design due to its holonomic nature, omnidirectional movement. As a result the robot can navigate around any object easily and the chance of getting stuck in corners is reduced. Due to its shape there is no question of overturning as often found in case of traditional wheeled robots. This feature also allows them to be thrown or dropped. Another major advantage of spherical robot is that being completely sealed, they are ideal for agricultural environments. This enables the robot for operation in snow, mud and if sealed properly, even in water also. The current research work attempted to design and development of spherical robot used for measurement of humidity in agricultural field. Unlike other spherical robots using pendulum mechanism spherical robot can move forward and backward, can take turn at any angle. This paper is organized as follows: after this introduction there is literature review. Section III describes proposed design with specification. Section IV Dynamic modeling has been presented through simulation. Finally there is conclusion.

II. LITERATURE REVIEW

This paper talks about design and development of a spherical robot using the principle of inverted pendulum. A wireless camera has been mounted on a Gimbal system inside the Spherical Robot. The images are transmitted to the command station for monitoring. Here the robot is being controlled remotely. [1] This paper talks about autonomous positioning and navigation system for spherical robot. This spherical mobile robot contains two parts: two hemispherical shells and the inner actuator. The two parts connect together with the flanges. Two hemispherical shells, as the moving parts, can drive the robot to make motions. When the two shells have the same speed of rotation, the robot walks a straight line. When the two shells have the different speeds, the robot turns a corner to the side of slow shell. The GPS system is used for the robot to position and navigate in a long distance, and the robot compare the robot's GPS data and the target's GPS data to get the relative position between both, which guides the direction of motion for the robot later. The visual processor is adopted in the close distance, and when the robot is away from the target in some distance, the visual processor is launched and searches the target. [2] This paper talks about a spherical mobile robot, rolling on a plane with the help of two internal rotors and working on the principle of conservation of angular momentum. Hall Effect sensor is used to measure the speed and according to the sensor speed of the angular momentum generating motors will be controlled to follow the decide path. The main controller in the system is a blue tooth enabled PC, which generates control signals according to the algorithm programmed. [3] This paper talks about the design and initial prototype of a miniature mobile robot designed to carry out surveillance and reconnaissance missions in an urban environment. This initial prototype is spherical in shape, with a diameter of 5.5 inches, and weighs only 4.5 pounds. A novel inertial steering system, along with the robot's robust control and communication systems, make it useful for covert video surveillance and reconnaissance in tightly constrained spaces. [4] This paper talks about HIT Spherical Robot which designed on the principle of carrying out the turning and driving motions independently in order to reduce dynamic complexity and realize real-time detection. After introducing the decoupling principle implemented in the working processing, the dynamic equations derived about the two fundamental motions, i.e., rolling and turning. Hardware and software of the open-loop control system are introduced briefly [5] this paper talks about the spherical robot system applied to intra-crop moisture measurements. Furthermore, some experiments were carried out in an early stage corn field in order to build a geo-referenced WSI map.[6] this paper talks about drive system with two pendulums on the inside. Paired with a double pendulum, this allows the robot to turn in place. Parameters such as speed and maximum incline are not optimized in this design because the research is focused mainly on proof of concept and path planning. Springs are added to the system to dampen impacts on the internal mechanisms when traversing rough terrain or large bumps. The literature presents the theory, which is verified by simulation, and is then demonstrated on a proof-of-concept physical prototype. [7]

III DESIGN OF SPHERICAL ROBOT

The above study reveals that the pendulum-based drive system may be preferred to other driving mechanisms as the design is relatively simple and there are limited restrictions on how the shell must be made. The proposed model consists of three basic units; namely outer shell, inner drive unit and pendulum arrangement. The pendulums which are driven by two continuous rotation servo motors can rotate about the horizontal axis and vertical axis (Both axis in the plane parallel to ground) which generates an eccentric moment by which the robot can roll linearly or steer left or right. The design of spherical robot is shown in fig.1. Consist of 1. Plate for mounting the actuators and circuit. 2. Motors attached directly to the pendulum to provide forward and backward motion 3. Lithium Polymer Battery as the power supply 4. Motors attached to the Hemispherical shell to steer the robot (Left and Right motion) 5. Hemispherical Shell.

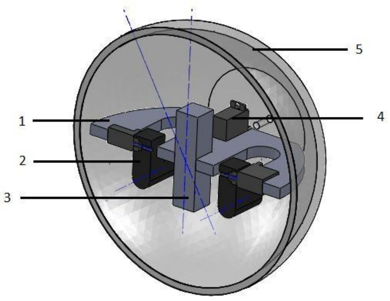


Fig.1. conceptual view of spherical robot.

The motion of the spherical robot is achieved from instructions of a microcontroller. The camera present is always stationary irrespective of the movement of the robot hemispherical shells. In short, the camera shall move only when the robot turns sideways. Else it is just recording video and audio in the forward direction. The images and video are relayed to a laptop computer by using TV tuner card. The spherical robot can be used to measure humidity in agricultural fields. The installed hygrometer shall be assembled along with the spherical robot and the camera shall point downwards so that we can view the humidity shown on the hygrometer.

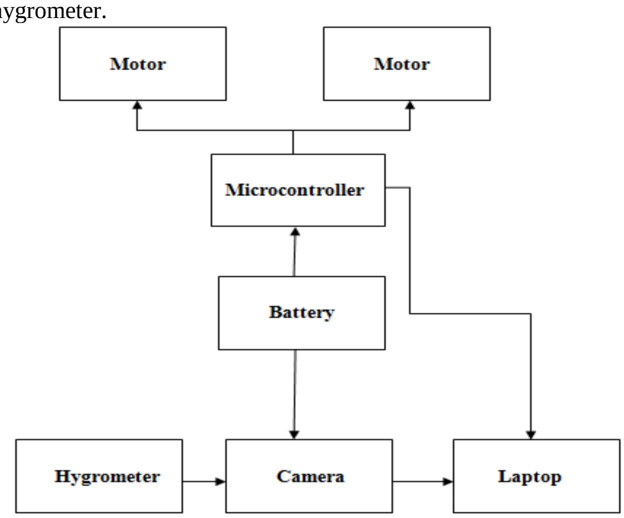


Fig. 2. Block diagram of spherical robot.

The motion of the robot is controlled by two continuous rotation servo motors can rotate pendulum about the horizontal axis and vertical axis (Both axis in the plane parallel to ground) which generates an eccentric moment by which the robot can roll linearly or steer left or right. The decoded signal from the on-board receiver is fed to the Arduino microcontroller board for precise control. The respective modified control signal is then sent to the driving servo motors. A small wireless camera has been installed on the system and the video is transmitted to the monitoring station. The transmitted video is captured and saved automatically using a USB-based tuner card. The on-board power is supplied from a 2 cell 1300mah, 20-30C rechargeable lithium Polymer battery bank.

IV DYNAMIC MODEL OF LINEAR MOTION

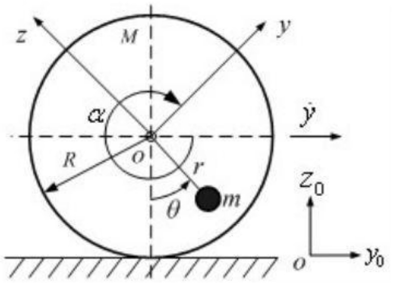
The Dynamics of the robot are derived under following assumptions:

1. There is no slip between the shell and the floor.

2. The two pendulums rotate synchronously without any difference in the angle.

The dynamics for the forward and backward motion of the robot are derived as given below:

LAGRANGIAN MECHANICS



Let,
M = Mass of the Sphere (with plate)
Ms= Mass of the Sphere
mp= Mass of the pendulums (with plate)
$\dot{y}$= velocity of the sphere along y axis
$\dot{x}$= velocity of the sphere along x axis
m= Total Mass of the Pendulums
R= Radius of the Sphere
k= vertical distance of centre of mass of combined plate and pendulum system from the centre of the sphere
r= Radius of gyration of pendulum
Θ= angle turned by pendulum with respect to the ground frame(Y-Z plane)
α= angle turned by the sphere with respect to the ground frame
Ø= Angle turned by pendulums with respect to the ground frame(X-Z plane)
I= Moment of inertia of sphere and plate along x-axis at centre of sphere
Ip= Moment of Inertia of pendulum and plate along the y-axis at the centre of the sphere
Is= Moment of Inertia of Sphere along the y-axis at the centre of the sphere
Generalized Coordinates= y, Θ

Kinetic Energy of Sphere=
$1/2M\dot{y}^2+1/2I\dot{\alpha}^2$

Kinetic Energy of Pendulums:
$1/2m(\dot{y}+r\dot{\Theta}\cos\Theta)^2+ 12m(r\dot{\Theta}\sin\theta)^2$

Potential Energy of Pendulums:
$-mgr\cos\Theta$

Lagrangian (L) = Total Kinetic Energy – Total Potential Energy $=1/2M\dot{y}^2+1/2I\dot{\alpha}^2+1/2m(\dot{y}+r\dot{\Theta}\cos\Theta)^2+ 1/2m(r\dot{\Theta}\sin\theta)^2+ mgr\cos\Theta$

According to the Lagrange Equations,

$d/dt(\partial L/\partial \dot{q}i)-(\partial L/\partial qi)=Qi$

Where,
qi = Generalised Coordinates
Qi= Generalised Forces
τ=Torque of the motors

Therefore
$d/dt(\partial L/\partial\dot{\theta})-(\partial L/\partial\theta)=\tau$

$\partial L/\partial\theta= -mgr\sin\theta-mr\dot{y}\dot{\theta}\sin\theta$

$\partial L/\partial\dot{\theta}=mr^2\,\dot{\theta}+mr\dot{y}\cos\theta$

$d/dt(\partial L/\partial\dot{\theta})=mr^2\,\ddot{\theta}+mr\ddot{y}\cos\theta-mr\dot{y}\dot{\theta}\sin\theta$

$d/dt(\partial L/\partial\dot{\theta})-(\partial L/\partial\theta)= mr^2\,\ddot{\theta}+mr\ddot{y}\cos\theta+mgr\sin\theta=\tau$

Also,
$\partial L/\partial y=0$

$\partial L/\partial\dot{y}= (M+m)\dot{y}+I\dot{y}/R^2+mr\dot{\theta}\cos\theta$

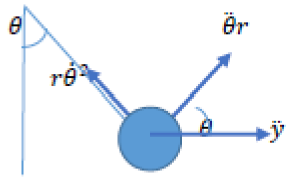
$d/dt(\partial L/\partial\dot{y})= (M+m)\ddot{y}+I\ddot{y}/R^2+mr\ddot{\theta}\cos\theta-mr\dot{\theta}^2\sin\theta=\tau R$

Equating above two equations,

$$y= \frac{mr^2\,\ddot{\theta}+mrR\dot{\theta}^2\sin\theta-mrR\ddot{\theta}\cos\theta+mgr\sin\theta R}{(M+m+I/R^2)-mr\cos\theta}$$

CLASSICAL MECHANICS

Acceleration Diagram of the pendulum:



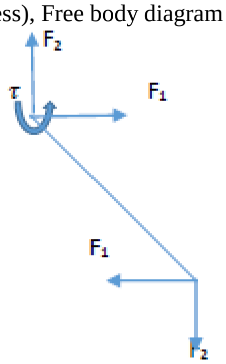
Net forward acceleration = $\ddot{y}+\ddot{\theta}r\cos\theta-\dot{\theta}^2r\sin\theta$

Net vertical acceleration = $\dot{\theta}^2r\cos\theta+\ddot{\theta}r\sin\theta$

Net force acting on the mass in forward direction: $F_1=m[\ddot{y}+\ddot{\theta}r\cos\theta-\dot{\theta}^2r\sin\theta]$

Net force in vertical direction: $F_2-mg=m[\dot{\theta}^2r\cos\theta+\ddot{\theta}r\sin\theta]$

This force is provided to the pendulum by the rod (assumed massless), Free body diagram of the rod:

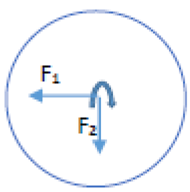


Therefore,

$\tau=r(F_1\cos\theta+F_2\sin\theta)$

$\tau=m[\ddot{\theta}r^2+\ddot{y}r\cos\theta+gr\sin\theta]$

Now forces acting on the sphere are as shown below:



Net acceleration of the sphere with respect to the ground frame =

$\ddot{y}\,f_r-F_1=M\ddot{y}$

$f_r=M\ddot{y}+F_1$

Also,

$\tau - f_r R = I\alpha s$

By no slipping condition,

$R_\alpha s = \ddot{y}$

$\tau = \ddot{y} I/R + f_r R$

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

Similarly equations of motion for the steering (leftward or rightward) are given below:

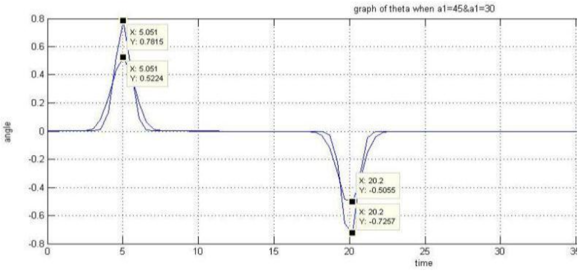
$\tau_x = I_p \ddot{\emptyset} + m_p \ddot{x} k \cos\emptyset + m_p g k \sin\emptyset$

$(M_s+m_p)\ddot{x} + I/s\ddot{x}R^2 + mr\ddot{\emptyset}\cos\emptyset - mr\dot{\emptyset}^2 \sin\emptyset = \tau x/R$

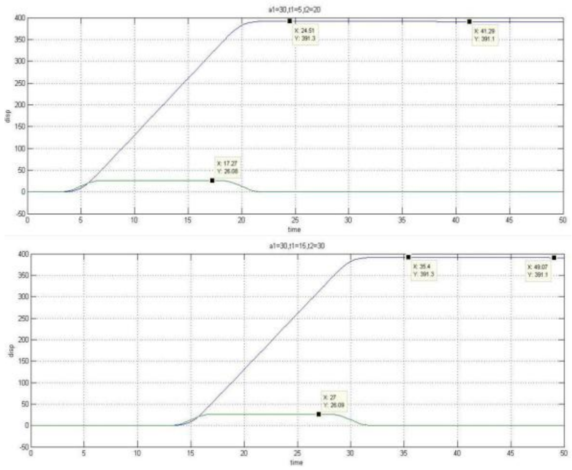
Trajectory Planning of Linear Motion
The nonzero tilt angle of the pendulums may activate the robot to accelerate. It is also implies that the desired velocity of the robot in linear motion can be obtained by given the proper tilt angle, that is, the position of the robot is controllable.
A smooth trajectory for tilt angle of the pendulums based on normal distribution function is proposed as:

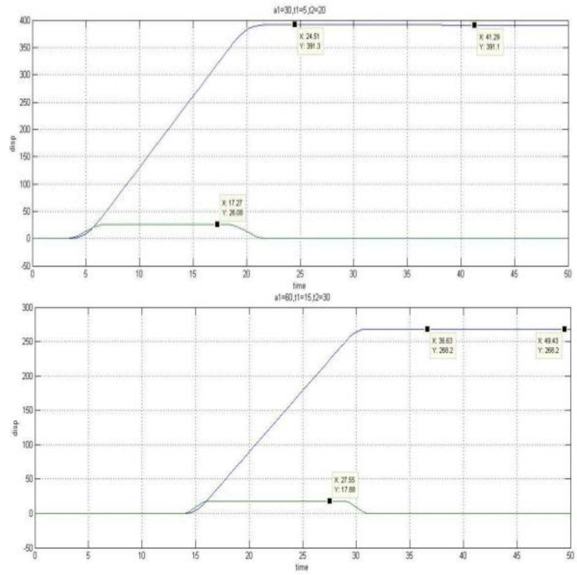
$\theta(t) = \theta_1 e^{-\mu(t-t1)^2} + \theta_2 e^{-\mu(t-t2)^2}$

Where θ_1 and θ_2 are the amplitudes of the normal distribution function, t1 and t2 are the time the tilt angle reaches the peak. Regulation of these parameters can change the state of the robot in linear motion.
Numerically solved by MATLAB the curve of tilt angle of pendulums is as shown below



The graph of the velocity and displacement of the sphere, under the action of the pendulums is shown below. The accelerating state, uniform velocity state and decelerating state can be seen clearly:
(Green line represents velocity vs time graph & blue line represents displacement vs time graph)





V. Conclusion

The conceptual design of spherical robot is described. This robot is useful to carry hygrometer and wireless camera in an environment where the condition is harsh or stability of surface is critical. Mobility is important issue during the measurement of moisture in farms where the surfaces are uneven. Spherical robot can help to achieve different kind of unique motion such as all directional driving motion on rough surfaces without losing stability so spherical robot can use in critical areas in agricultural fields.

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References

[1] Deepak Pokhrel,Nutan Raj Luitel, Sukanta Das “Design and development of a spherical robot,” international conference on machines and mechanism. Dec 2013, pp. 735-741
[2]Kang Hou,Hanxu, “An autonous positioning and navigation system for spherical mobile robot,” science direct 29 dec2012, pp. 2556-2561.
[3] Vrunda Joshi, Ravi Banavar, “Design and analysis of spherical mobile robot,” mechanism and machine theory at science direct 2010, pp. 130-136
[4] Brian Chemel, E. Mutschler, H. Schempf, “Cyclops: Miniature Robotic Reconnaissance System,” Robotics Institute Carnegie Mellon University 5000 Forbes Ave.Pittsburgh, PA 15213
[5] Yue Ming, Deng Zongquan, Yu Xinyi and Yu Weizhen, “Introducing HIT Spherical Robot: Dynamic Modeling and Analysis Based on Decoupled Subsystem, IEEE International Conference on Robotics and Biomimetics December 2006, Kunming, China, 2014, pp. 1-6.
[6] Juan D. Hernández*, David Sanz, Jorge Barrientos, João Valente, Jaime Del Cerro, Antonio Barrientos,“ Non invasive moisture measurement in agricultural fields using a rolling spherical robot”. International Conference on Robotics and

associated High-technologies and Equipment for Agriculture Hosted by the University of Pisa, Italy, 2012
[7] Richard Chase and Abhilash Pandya "A Review of Active Mechanical Driving Principles of Spherical

