Stabilization of a Robot Spherical

UNIVERSIDAD POLITÉCNICA PUERTO RICO

Kenneth J. González, Cristian Sánchez

Advisor: Othoniel Rodríguez

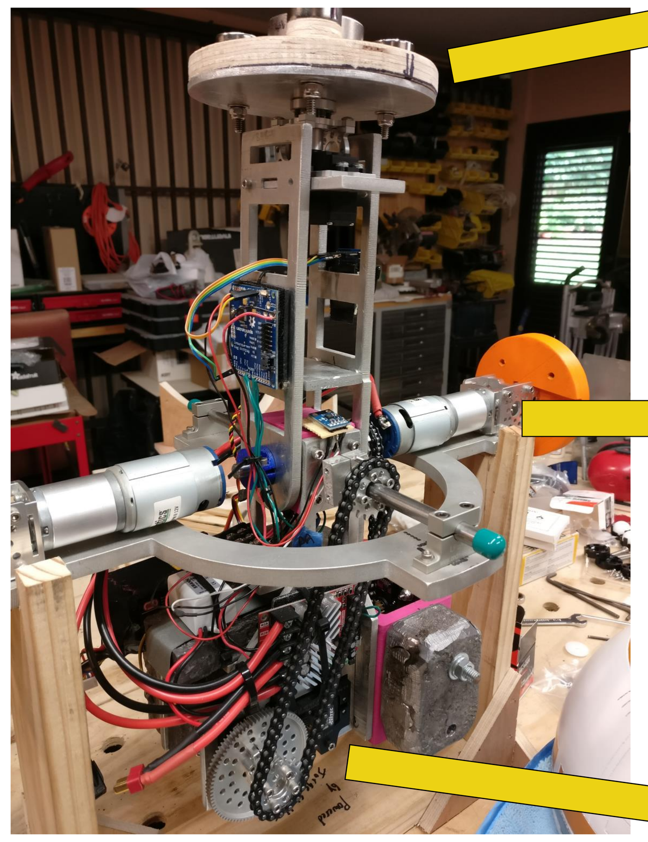
Electrical & Computer Engineering and Computer Science Department

Abstract

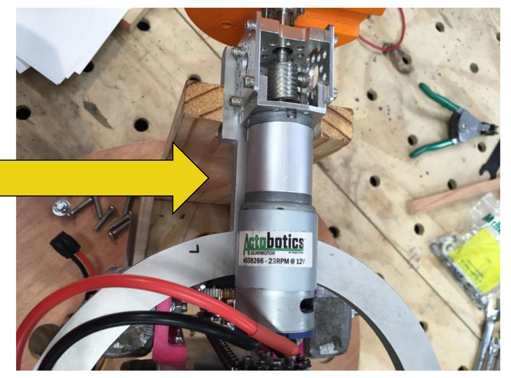
Robotics is a multidisciplinary branch of science which combines principles of mechanical, electrical, computer engineering and computer science to design automated systems. Our research continues the work started as part of a capstone project named BB-8 Robot Design. When the capstone project was finished they created a prototype robot that could displace itself using a joystick but had problems with its stability. Our goal was to improve the robot's stability by implementing a feedback control system. The robot's movement should be modelled to implement a feedback control system. We studied the robot's inner pendulum and the forces related to its movement. These forces were the translational force, the centripetal force and the rotational force. The scope of the project had to be modified due to technical difficulties with the robot's electrical system. The robot's battery and motor controller were damaged and had to be replaced. An electrical system with improved safety features was also installed to prevent this type of damage in the future.

Introduction

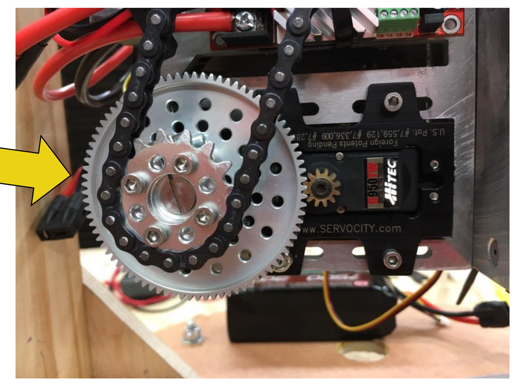
The research performed was intended to study spherical rolling robots and how these could achieve stable movements using a feedback control system. The objective was to apply these methods to the BB-8 Robot Design project and improve its components according to the recommendations made in the Capstone documentation (Alonso, Torres, Figueroa & Lopez, 2016).



Four magnets hold the robot's head on the sphere, while a servo motor drives the head's movement from side to side.



Two drive motors, located at the center of the sphere drive the robot's displacement by moving the pendulum forward.

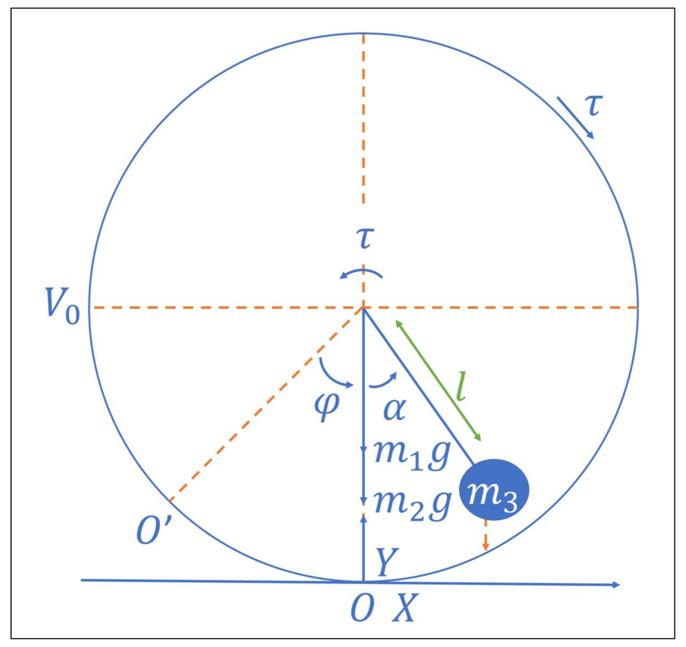


A servo motor drives the robot's turning by tilting the pendulum left and right.

(Alonso, Torres, Figueroa & Lopez, 2016)

Modelling the Robot's Kinematics

Position	1st Derivative (angular velocity)	2nd Derivative (angular acceleration)
$x_1 = R\varphi$	$\dot{x}_1 = R\dot{\varphi}$	$\ddot{x}_1 = R\ddot{\varphi}$
$y_1 = R$	$\dot{y}_1 = R\dot{\varphi}$	$\ddot{y}_1 = R\ddot{\varphi}$
$x_2 = lsin\alpha + R\varphi$	$\dot{x}_2 = lcos\alpha * \dot{\alpha} + R\dot{\varphi}$	$\ddot{x}_2 = lcos\alpha * \ddot{\alpha} - lsin\alpha * \dot{\alpha}^2 + R\ddot{\varphi}$
$y_2 = R - lcos\alpha$	$\dot{y}_2 = lsin\alpha * \dot{\alpha}$	$\ddot{y}_2 = lcos\alpha * \dot{\alpha}^2 - lsin\alpha * \ddot{\alpha}$



x_1, y_1 : coordinate of the mass center of the shell
x_2, y_2 : coordinate of the counter-weight
φ: spinning angle of the shell
α: swinging angle of the counter-weight mass
R: radius of the spherical shell, m

(Pokhrel, Luitel, Das, & Ray, 2013)

Modelling the Robot's Dynamics

The authors take the Lagrangian approach, finding $L = T - P$

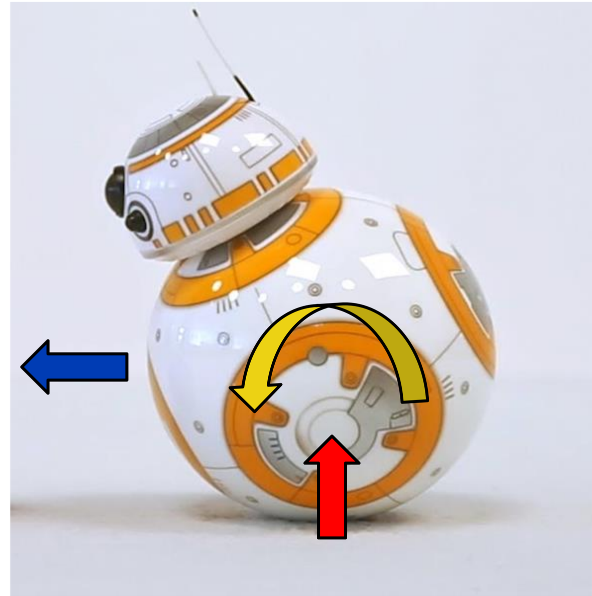
Kinetic energy by translational force: $T_1 = \frac{1}{2}\left(\frac{5}{3}m_1 + m_2 + m_3\right)R^2\dot{\varphi}^2$

Kinetic energy by rotational force: $T_2 = \frac{1}{2}(J_i + m_3 l^2)\dot{\alpha}^2$

Kinetic energy by centripetal force: $T_3 = -m_3 lR\dot{\alpha}\dot{\varphi}cos\alpha$

Potential energy: $P = -m_3 glcos\alpha$

$T =$ kinetic energy
$P =$ potential energy
$m_1 =$ mass of the shell
$m_2 =$ mass of the inner drive unit
$m_3 =$ mass of the counter-weight



$$L = \frac{1}{2}\left(\frac{5}{3}m_1 + m_2 + m_3\right)R^2\dot{\varphi}^2 + \frac{1}{2}(J_i + m_3 l^2)\dot{\alpha}^2 - m_3 lR\dot{\alpha}\dot{\varphi}cos\alpha + m_3 glcos\alpha$$

Euler-Lagrange motion equations:

$$\frac{d}{dt}\left(\frac{\partial\mathcal{L}}{\partial\dot{q}_1}\right) - \frac{\partial\mathcal{L}}{\partial q_1} = -\tau \qquad \frac{d}{dt}\left(\frac{\partial\mathcal{L}}{\partial\dot{q}_2}\right) - \frac{\partial\mathcal{L}}{\partial q_2} = \tau$$

Euler-Lagrange motion equations of robot:

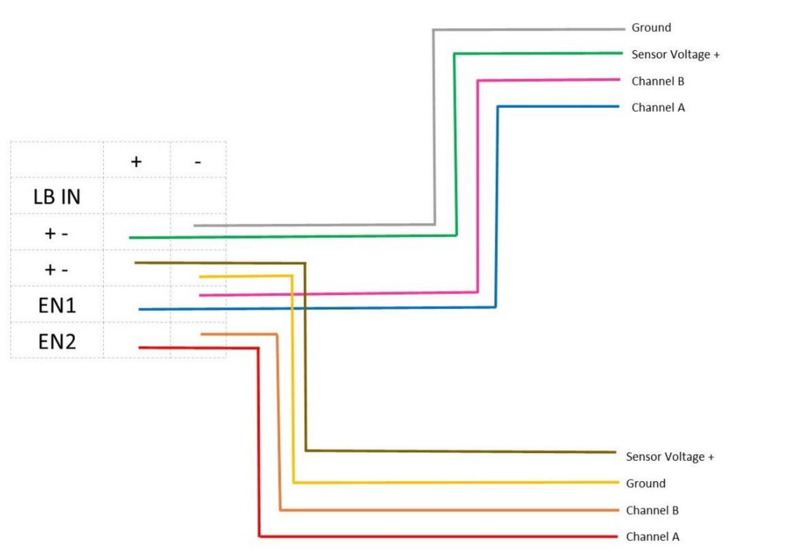
$$\left(\frac{5}{3}m_1 + m_2 + m_3\right)\ddot{q}_1 + m_3 lcosq_2\ddot{q}_2 - m_3 lsinq_2\,\dot{q}_2{}^2 = \left(\frac{1}{R}\right)\tau$$

$$m_3 lcosq_2\ddot{q}_1 + (J_i + m_3 l^2)\ddot{q}_2 + m_3 glsinq_2 = \tau$$

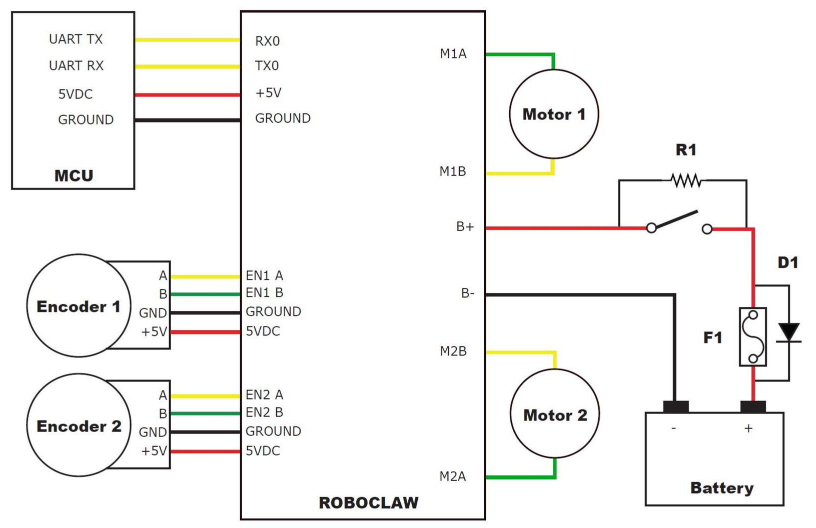
(Pokhrel, Luitel, Das, & Ray, 2013)

DC Motors and Motor Controller Upgrade

The two DC gear motors were upgraded from the 23 RPM HD Premium Planetary Gear Motor to the 23 RPM HD Premium Planetary Gear Motor with Encoder. The motor controller changed from a Roboclaw 2x45A Motor Controller with screw terminals to a Roboclaw 2x45A Motor Controller with pin headers. The safety wiring recommended by the manufacturer was also implemented. This facilitated the connection of the motor's encoders and facilitated other connections for future implementation. This could be used to collect information about the motor's movements and configure that information using the Arduino microcontrollers.



Wire color diagram between the motor controller and encoders



Safety wiring diagram obtained from ION Motion Control RoboClaw Series Brushed DC Motor Controllers User Manual

Conclusions

The objective of this research project was to stabilize the movement of a spherical robot with a pendulum drive. To do this, a feedback control system was going to be implemented. The control system would be designed based on the modelling of the robot's movement. However, during the research activities, the scope had to be modified due to technical difficulties with the robot's electrical system. The robot's battery and motor controller were damaged and had to be replaced. An electrical system with improved safety features was also installed to prevent this type of damage in the future. The drive motors were also replaced with additional functionalities. The robot is in working condition for future work.

References

Alonso, R., Torres, A., Figueroa, J., & Lopez, W. (2016). BB-8 Robot Design. Capstone Design Course EE4022-39 SP - FA/16.

Pokhrel, D., Luitel, N. R., Das, S., & Ray, D. N. (2013). Design and Development of a Spherical Robot (SpheRobot) (pp. 735–741). India: iNaCoMM2013.

Acknowledgements

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