SPHERICAL DRIVE ROBOTIC PLATFORM

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Objectives

- Currently, the ways robots move are not as maneuverable for traveling in multiple directions
- Our mission is to create a robot that can be more flexible, agile, and overall more maneuverable
- The current goal is to start building a prototype for a self-balancing robot

Backgrounds

- We are trying to create the possibilities for robots to stand on the spherical ball and define it a novel way to move.
- (limitations of current vehicles and robots)
- The future of the spherical driving robots is unlimited. The possible applications and potential industrial extensions of this project can be in several aspects, such as
  - Goodyear car or some other driven machines
  - Assistant home robot, etc.

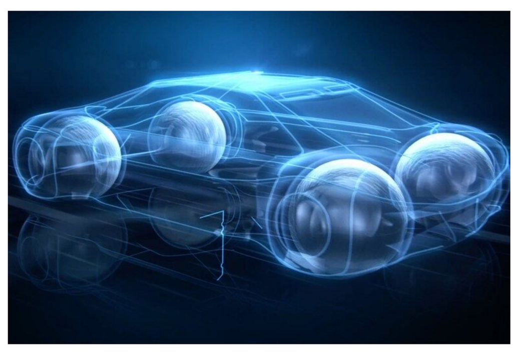

Fig. 1. Goodyear car concept
(Figure from: https://www.motortrend.com/news/spherical-tires-autonomous-cars-borne-on-airless-basketballs-technologue/)

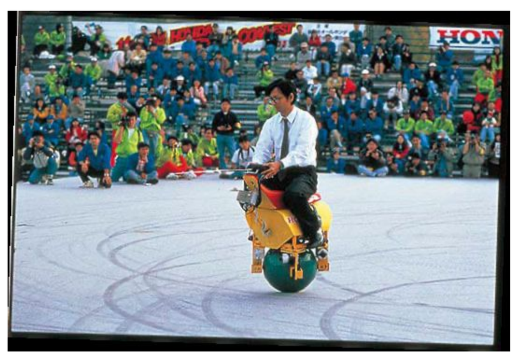

Fig. 2. The Uni-ball idea presented
(Figure from https://asimo.honda.com/news/the-u3-x-challenge-mobility-that-unites-rider-and-vehicle/newsarticle_0091/)

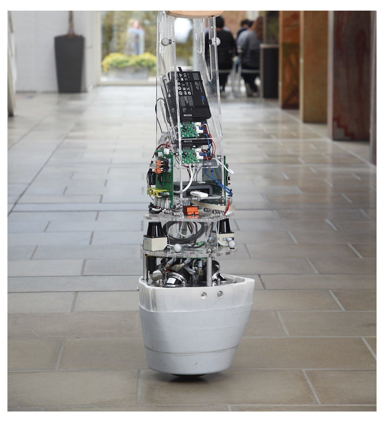

Fig. 3. The Kugle ballbot idea
(Figure from https://en.wikipedia.org/wiki/Ballbot)

System Modeling and Simulations

We started by breaking down our systems into two separate mechanisms. We studied the model of a DC motor and analyzed its torque. Then we turned to analyze the classical inverted pendulum example to study the similarity between the example and our system. Lastly, we combined the two models together to obtain our final model.
Our final system model includes three main parts: robot body, motors and wheels, and sphere. We assume no slip condition, which means that when the motor rotates angle Ψ in counterclockwise direction and the body will be able to tilt angle θ in the clockwise direction.

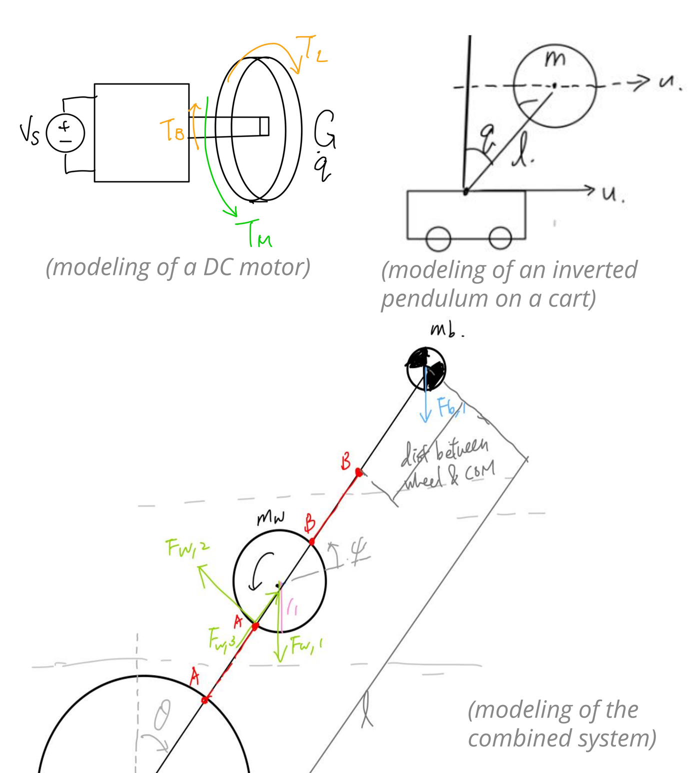

Fig. 4. System diagrams of the break-down systems
(Diagrams created by the team)

$$x = \begin{bmatrix}\theta \\ \dot{\theta}\end{bmatrix}$$ *(state variable x)*

$$\dot{x} = \begin{bmatrix}\dot{\theta} \\ \ddot{\theta}\end{bmatrix} = \begin{bmatrix}\dot{\theta} \\ -[\frac{r_2^2(bR+K^2)}{r_1^2 JR}]\dot{\theta} + [\frac{C_{rr} r_2 (m_b+m_w)g)}{J}]cos\theta + [\frac{(m_w(r_1+r_2)+m_b l)g}{J}]sin\theta - [\frac{r_2 K}{r_1 JR}]V\end{bmatrix}$$

$$\dot{x} = Ax + BV = \begin{bmatrix}0 & 1 \\ [\frac{(m_w(r_1+r_2)+m_b l)g}{J}] & -[\frac{r_2^2(bR+K^2)}{r_1^2 JR}]\end{bmatrix} x - \begin{bmatrix}0 \\ -\frac{r_2 K}{r_1 JR}\end{bmatrix} V$$ *(Linearized equation)*

$$V = [-\frac{r_1 JR}{r_2 K}]\ddot{\theta}_{desired} + [\frac{r_2(bR+K^2)}{r_1 K}]\dot{\theta} + [\frac{(m_w(r_1+r_2)+m_b l)g r_1 R}{r_2 K}]\theta$$ *(required voltage)*

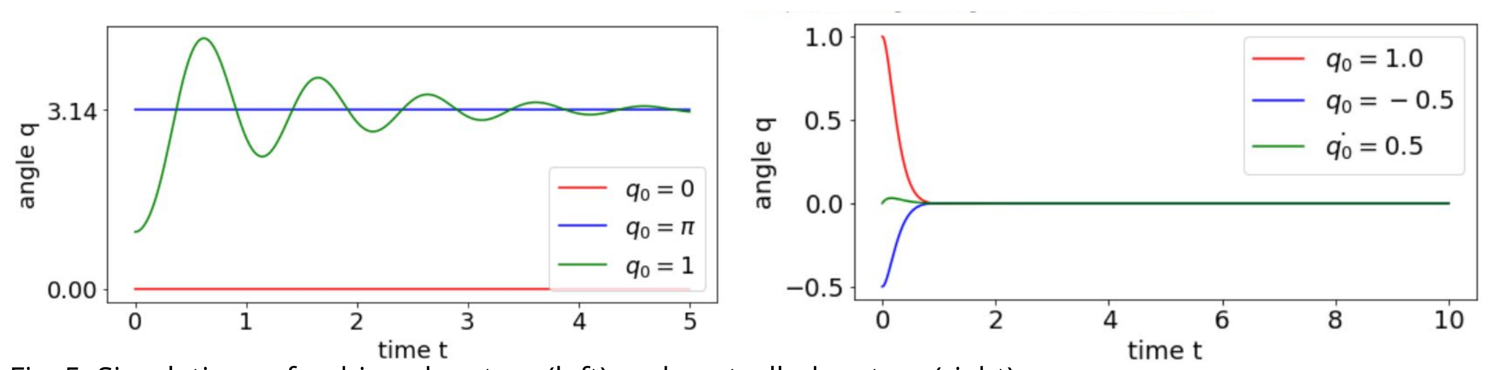

Fig. 5. Simulations of unbiased system (left) and controlled system (right)
(Diagrams created by the team)

The simulation on the left shows the transient response of the system without input voltage. One can see that any angle > 0 will converges to **π**. The simulation on the right shows the result of the controlled system. All angles will converge to 0.

Structural Design

- This CAD model is composed of two structures: the top robot and the bottom spherical ball
  - The top robot can also be divided into several parts and each part has different functions.
  - The **top box** has two layers: the top one carries the load and the other one contains all the electronic components.
  - The **middle ring and wheels** control the movement of the sphere.
  - The **bottom four arms** hold the ball and make the robot not slip from the ball.

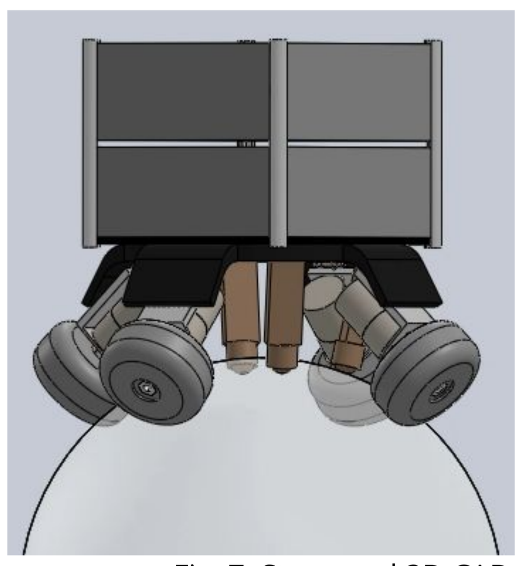

Fig. 7. Structural 3D CAD
(Design created by the team with SolidWorks)

Electrical Interface

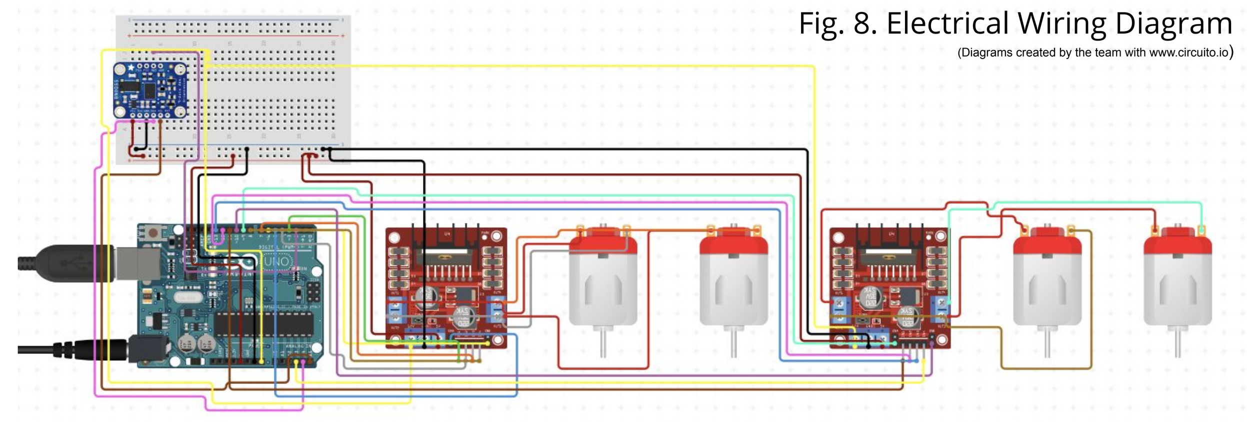

Fig. 8. Electrical Wiring Diagram
(Diagrams created by the team with www.circuito.io)

The electrical interface includes two main systems: the power system and the data lines. The power system includes 4 Li-ion batteries for power supply, a DC buck converter, and in-line 10A, 15A fuses to protect from overcurrent. The data lines includes the main computing unit Arduino Uno, two dual-port H-bridge motor drivers, a Adafruit 9DOF IMU sensor, and four DC brushed motors.

Final Deliverable

The final deliverable is capable of balancing itself on a stationary sphere. By reading the angles from the IMU sensor, we were able to adjust the angle with the motor force calculated by the PID control model. The deliverable successfully met the requirements of what we tried to do so far.

Fig. 9. The final deliverable of the ball-balancing robot
(Picture credit: the Piqard team)

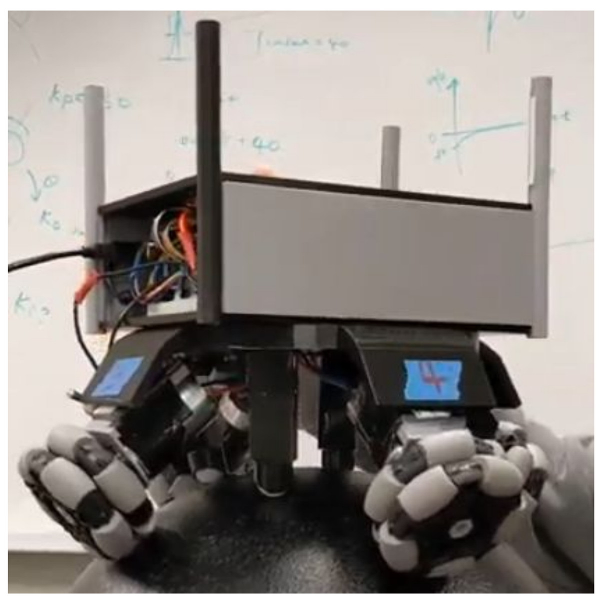

Fig. 10. The close-up look of the ball-balancing robot
(Picture credit: the Piqard team)

Future developments

The project development and future implementation can be divided into three parts - the self-balancing robot on a sphere, the spherical drive robots, and the real industry application. In the future, we may make the robot control the movement of the spherical ball and also have the chance to put the load on the spherical robot and give it more functions.

Fig. 11. The timeline of the future development
(Picture credit: the Piqard team)

Acknowledgements and References

Special thanks to our industrial sponsor Mr. Torsten Hirche from Piqard, our faculty advisor Professor Blake Hannaford, and our teaching assistant Daniel King.

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