

Master Thesis

Design and implementation of a remote controlled segway

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This is the abstract

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Figure 1: Picture of a commercial *segway hover-board*

1 Objective

The objective of this project is to build a dynamic robot in order to experiment with reinforcement learning algorithm with real data. We wish to make this experiments easy and cheap to reproduce so we will try minimize its components and fabrication cost.

The chosen robot is inspired in a *segway hover-board*, similar to the one in Figure 1. The two wheels are controlled with classic control algorithms and the inclination of the central body is controlled with a reinforcement learning algorithm.



Figure 2: Isometric render view



Figure 3: Front render view

2 Design

The design of the body is done with a 3D design software Free-cad. All part files are uploaded to the GitHub repository <https://github.com/tarragoesteve/TFM> under the hardware folder. You can see the main views on Figure 2, 3, 4 and 5

We included three actuators in the robot because we want to control 3 degrees of freedom (inclination and speed of both wheels). Furthermore we introduced a fly-wheel to control the inclination of the body.

We ensured symmetry along the axis formed by all motors in order to have an equilibrium in all possible inclinations without the need of external forces. We also took in consideration that the reinforcement learning algorithm starts being clumsy so none of the configurations should intersect with the ground. Figure 5 illustrates this restriction.

2.1 Flywheel design

To control the inclination of the body two strategies were taken in to account. Creating torque by a pendulum or by the acceleration of flywheel. In order to experiment with both of them we designed a part to allow both configuration by placing weights in different spots, figure 7.

One of the weight can be placed along a rail so when it has radius different from

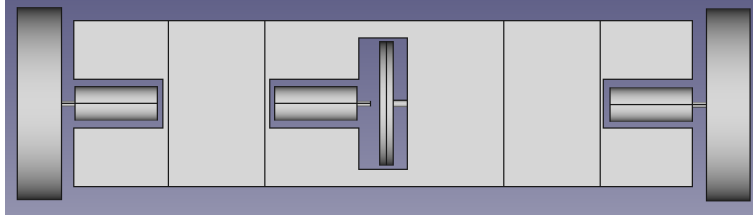


Figure 4: Top render view

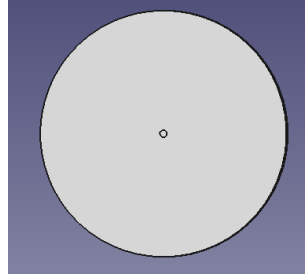


Figure 5: Side render view

maximum the flywheel has a torque. The pendulum torque τ , considering the masses are cylinders of width w and radius r_c , and the flywheel has a radius r_f is the following:

Each mass weights:

$$m = \rho * w * \pi * r_c^2$$

All mass will be compensate the opposed one except the two with different radius. The maximum torque take place when these two masses are aligned horizontal with respect the ground.

$$\tau_{max}(r_c) = m * (r_f - r_c) - m * r_c = m * (r_f - 2 * r_c)$$

In order to maximize it we first compute the derivative:

$$\frac{\partial \tau_{max}(r_c)}{\partial r_c} = \frac{\partial m}{\partial r_c} * (r_f - 2 * r_c) - m * 2$$

$$\frac{\partial m}{\partial r_c} = 2 * \rho * w * \pi * r_c$$

An make it zero to find the maximum:

$$\frac{\partial \tau_{max}(r_c)}{\partial r_c} = 0$$

Substituting and simplifying we get:

$$\frac{\partial m}{\partial r_c} * (r_f - 2 * r_c) = m * 2 \Rightarrow 2 * \rho * w * \pi * r_c * (r_f - 2 * r_c) = \rho * w * \pi * r_c^2 * 2$$

$$\Rightarrow r_c * (r_f - 2 * r_c) = r_c^2 \Rightarrow (r_f - 2 * r_c) = r_c \Rightarrow r_f = 3 * r_c$$

The circumradius R from the center of a regular polygon to one of the vertices is related to the side length s by

$$R = \frac{s}{2 * \sin \frac{\pi}{n}}$$

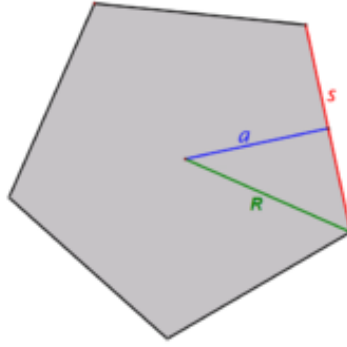


Figure 6: Polygon parameters

In our case:

$$R = r_f - r_c;$$

$$s = 2 * r_c$$

Substituting in the circumradius equation we get $n = 6$, so we will use 6 masses in our flywheel.

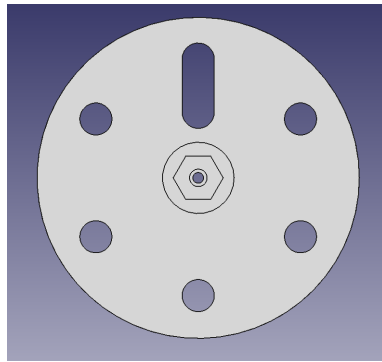


Figure 7: Fly wheel side render view

3 Mechanical study

Hello