Development of control systems for next generation Superattenuators

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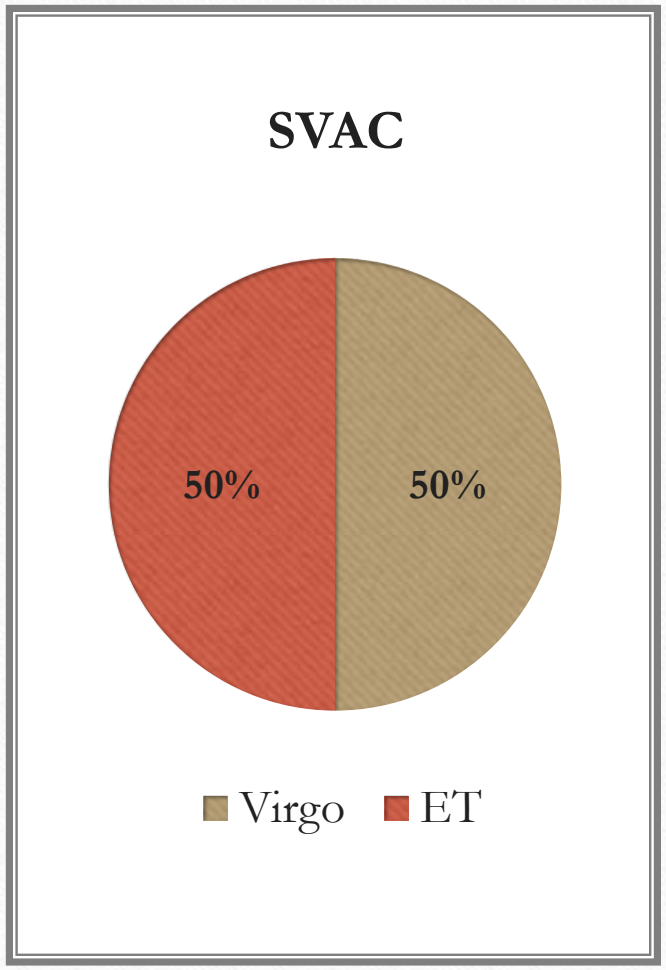
Virgo – ET Pisa Internal Workshop

Pisa, 22-23/05/2024



What's happened up to now

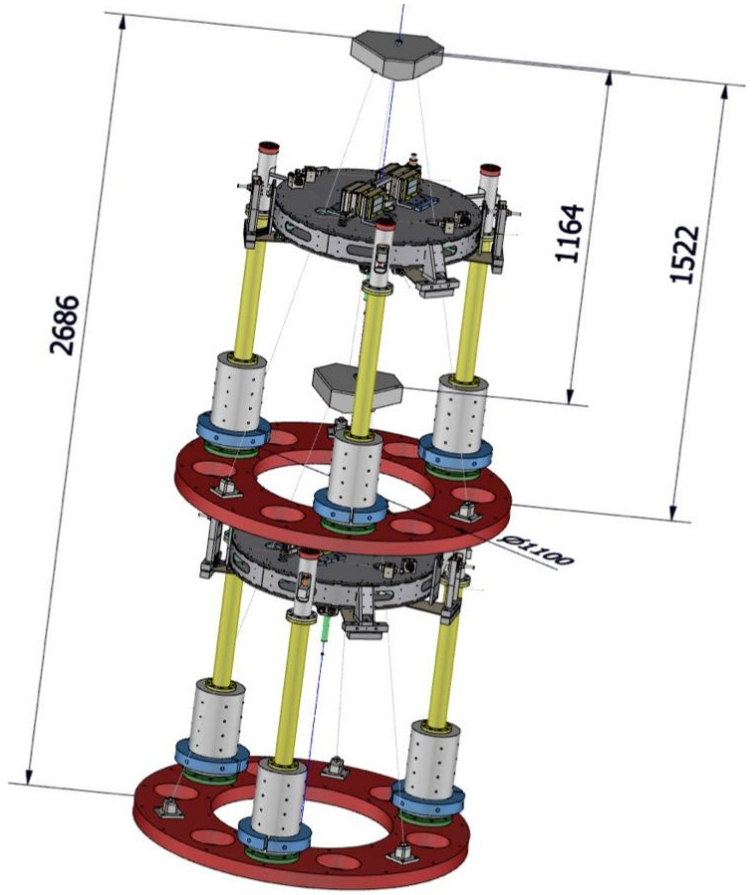
- December 2022: Master degree in particle physics (Belle II experiment)
- March 2023: beginning of PhD with PNRR funds (ETIC project) Supervisors: F. Fidecaro, M. Razzano
  - **PhD project**: experimental activities related to the seismic attenutation
  - **RRT shifts**: June '23, October '23, May '24
  - **Member of organizing committee**: GWADW 2023, GraSP23 Gravity Shape Pisa
  - **Outreach**: Virgo guided tour, Bright Night 2023

PhD Project:
Machine Learning for optimal control of next-generation seismic attenuation systems (see M. Razzano slides)

Ongoing activities:

- **Simple prototype (cartpole)**
- **Simulations and ML application of pendulum**

Drawing of PIP

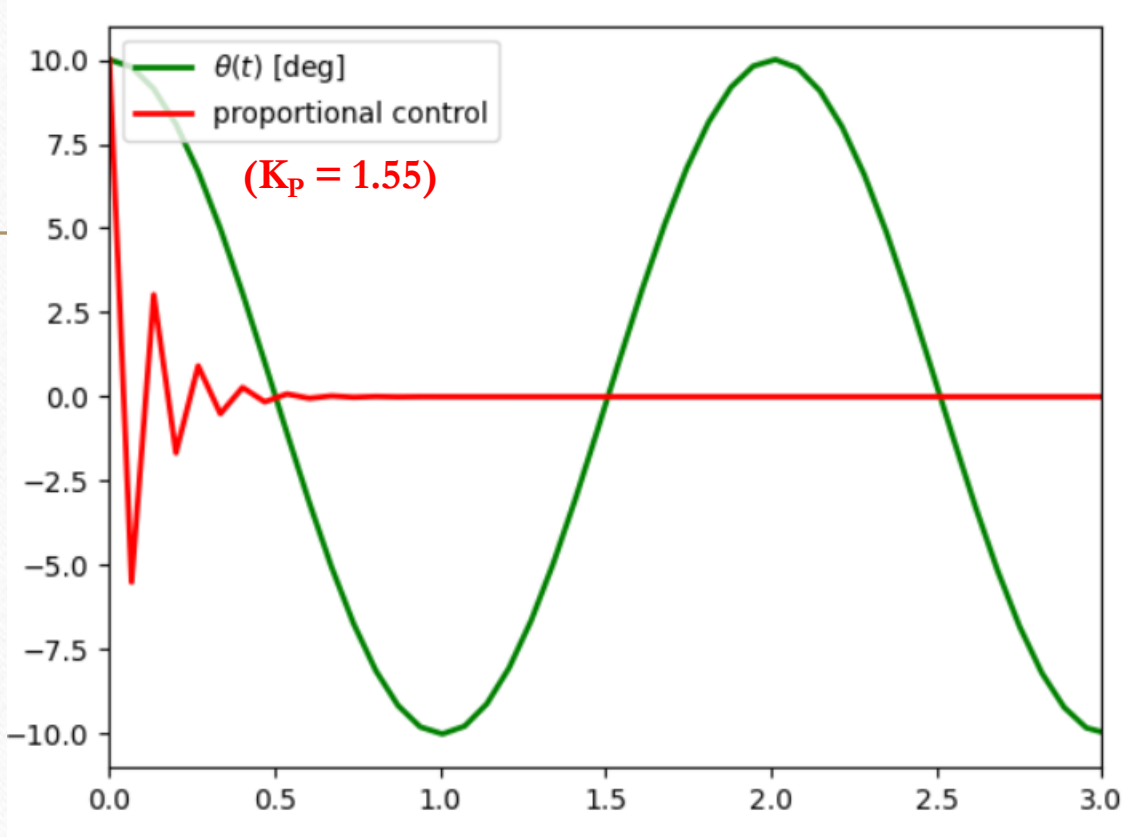


Open problem with PIP:
possibility to put sensors and actuators in intermediate positions (and not only at the top and bottom stage)

Simulations of a controlled pendulum

Goal: make the design of the control system for a more and more realistic system (corresponding to the PIP)

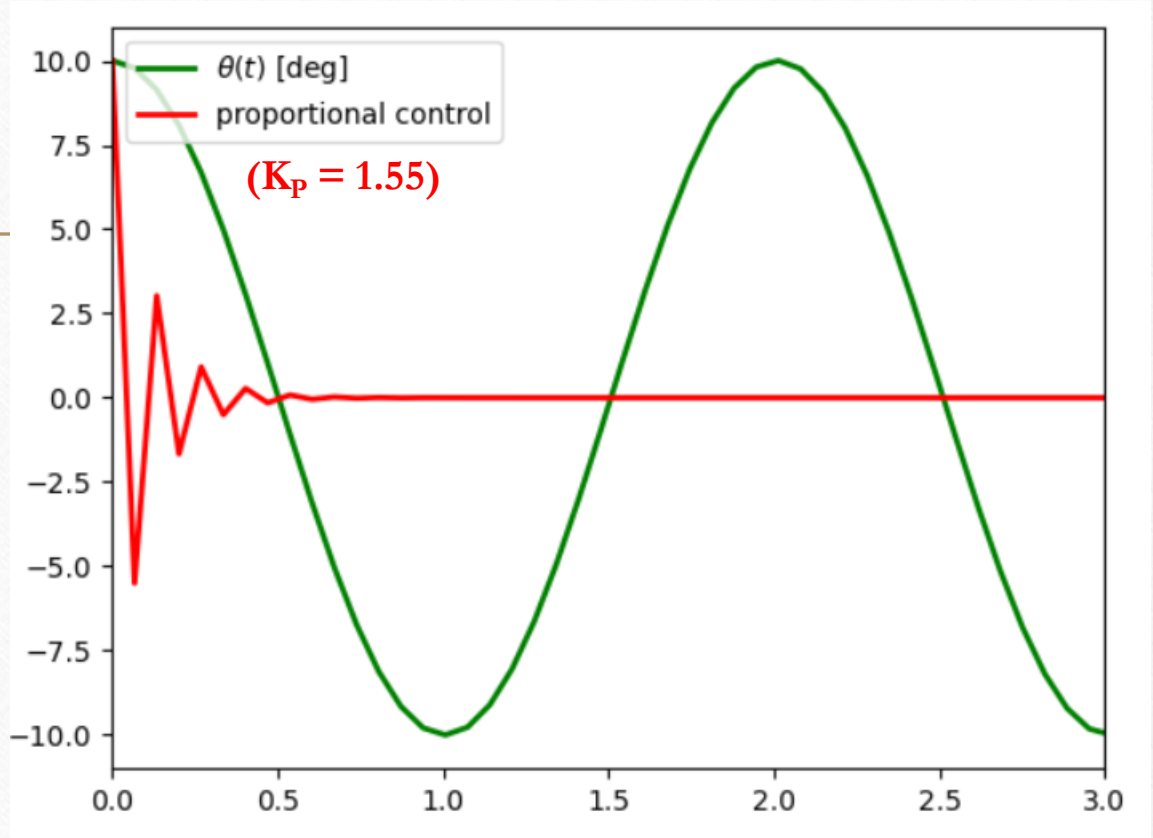
1. Toy model simulation: simple pendulum controlled by a proportional control



Simulations of a controlled pendulum

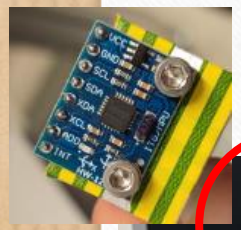
Goal: make the design of the control system for a more and more realistic system (corresponding to the PIP)

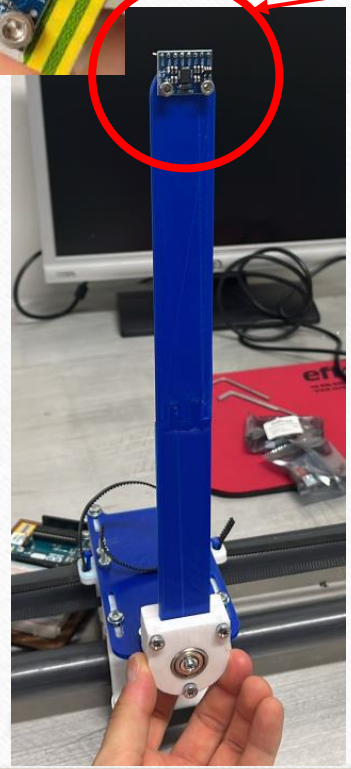
1. Toy model simulation: simple pendulum controlled by a proportional control
2. Implement other degrees of freedom (moving top and 2-d system) → **ongoing**
3. Using Octopyus to accurately simulate and control the PIP → **next step**



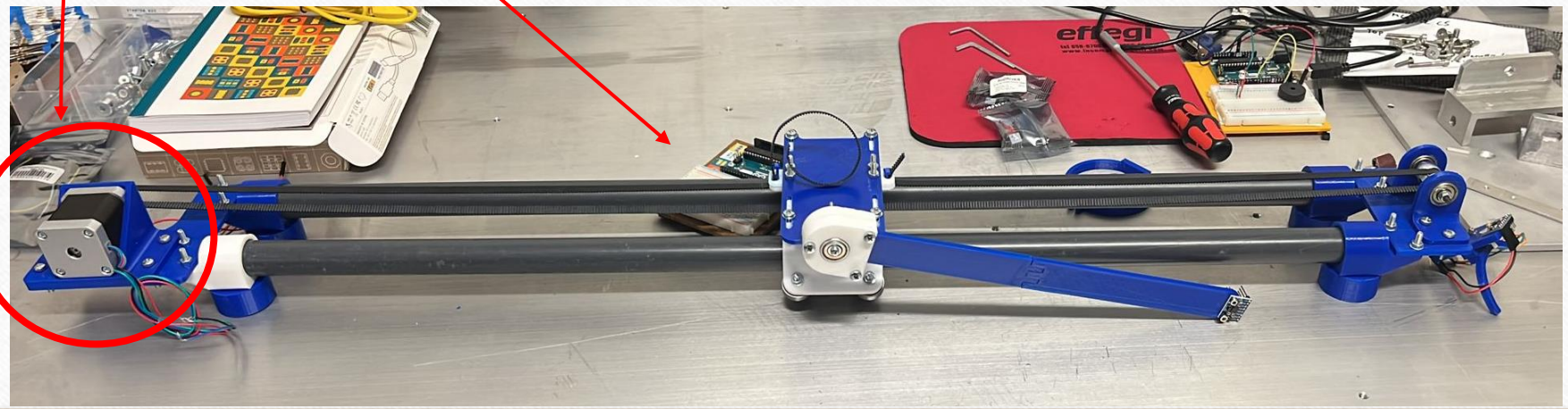
Cartpole control

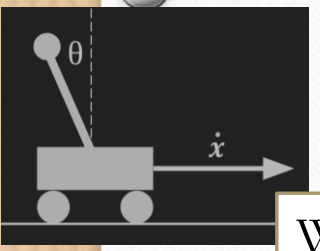
<u>Motivation</u>:
build a simple benchmark system for Machine Learning control





- **Sensor**: MPU-6050 Six-Axis (Gyro + Accelerometer)
- **Actuator**: Nema17 stepper motor
- Arduino UNO board

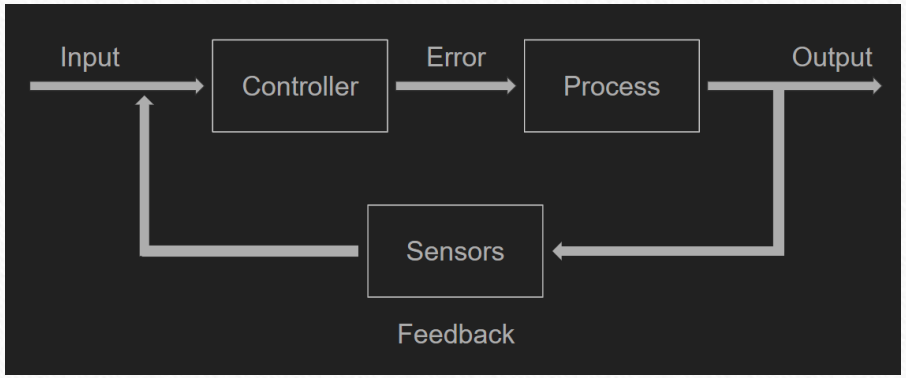


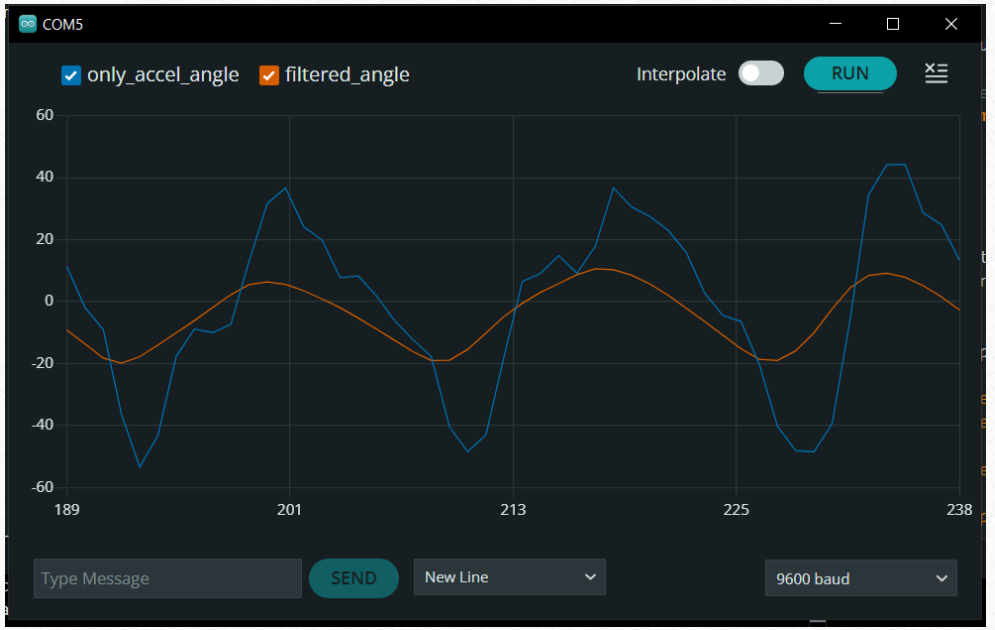


Basic control

Write an Arduino code to control in feedback the inverted pendulum with a PID control:

- Read the angle of inclination θ of the pole with a complementary filter
- Make the stepper motor move accordingly
- Repeat the process

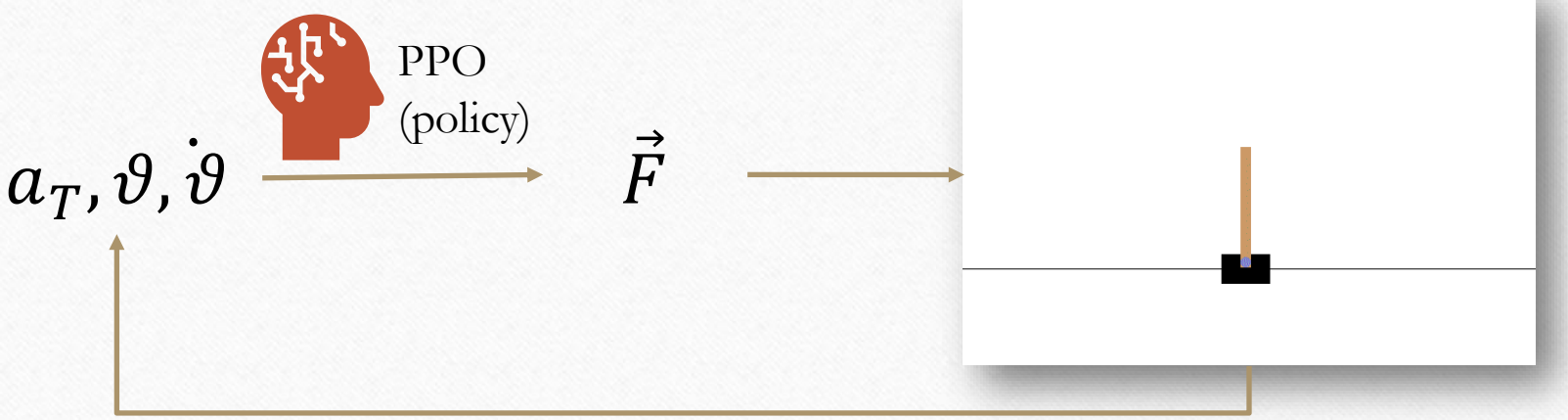




Differences in the reading of θ given by only the accelerometer and by the gyroscope + accelerometer

Reinforcement learning approach (G. Bartoli)

Reinforcement learning (RL) is a subset of machine learning that allows an AI-driven system (sometimes referred to as an agent) to learn through trial and error using feedback from its actions

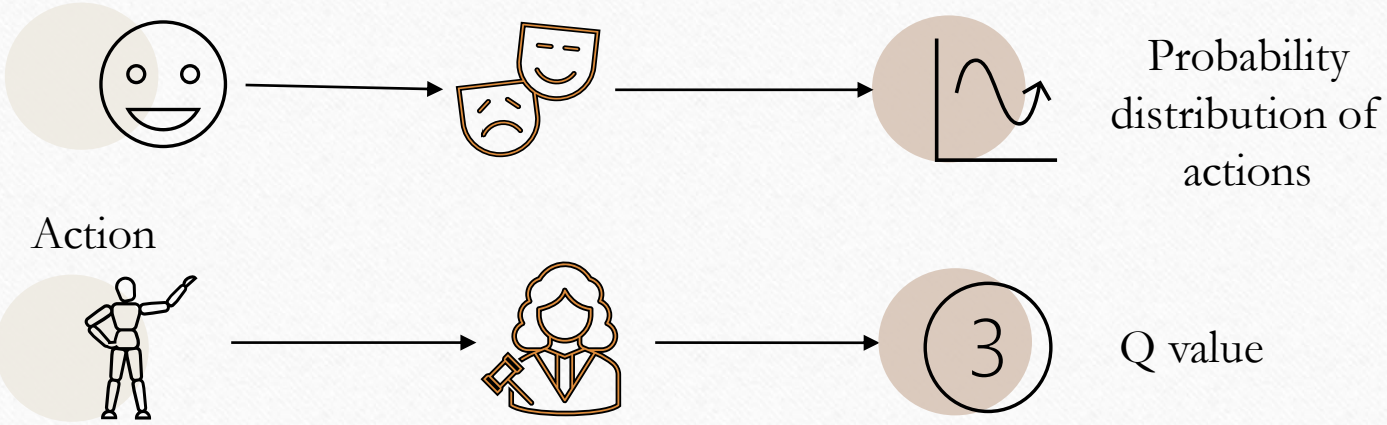


<u>End of the episode:</u>

- Pole fallen
- Cart bumping to borders
- Episode length greater than 1500

PPO implementation details

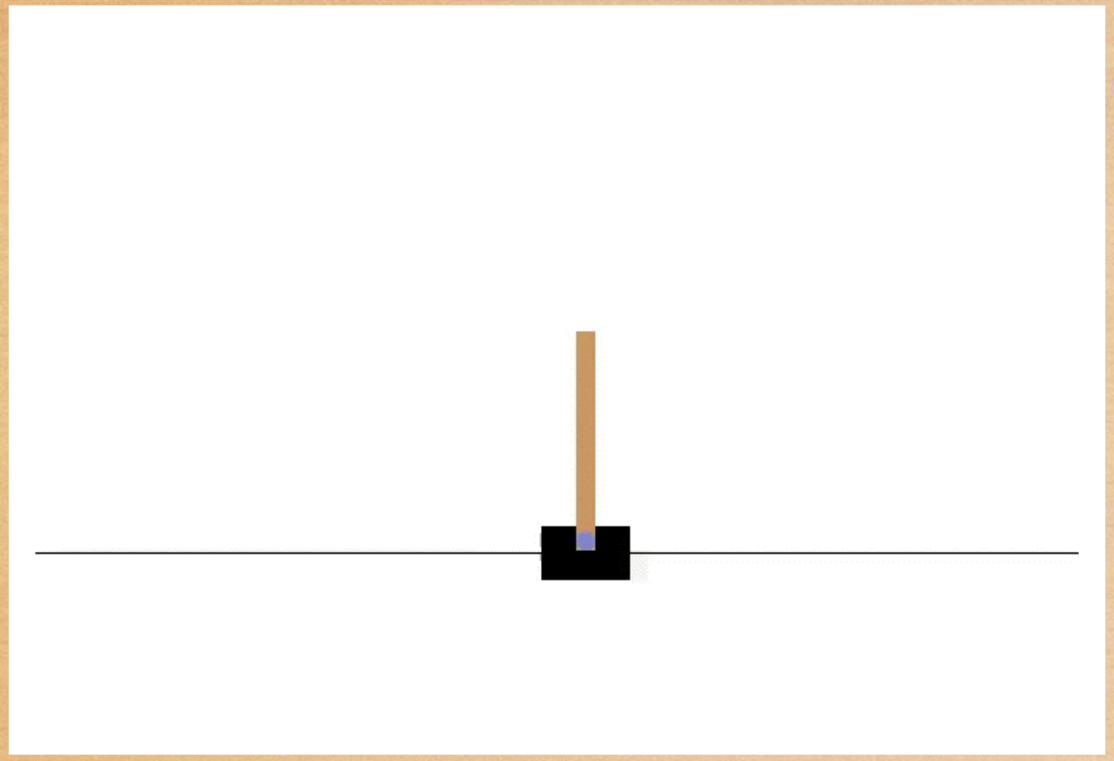
Actor-critic mechanism



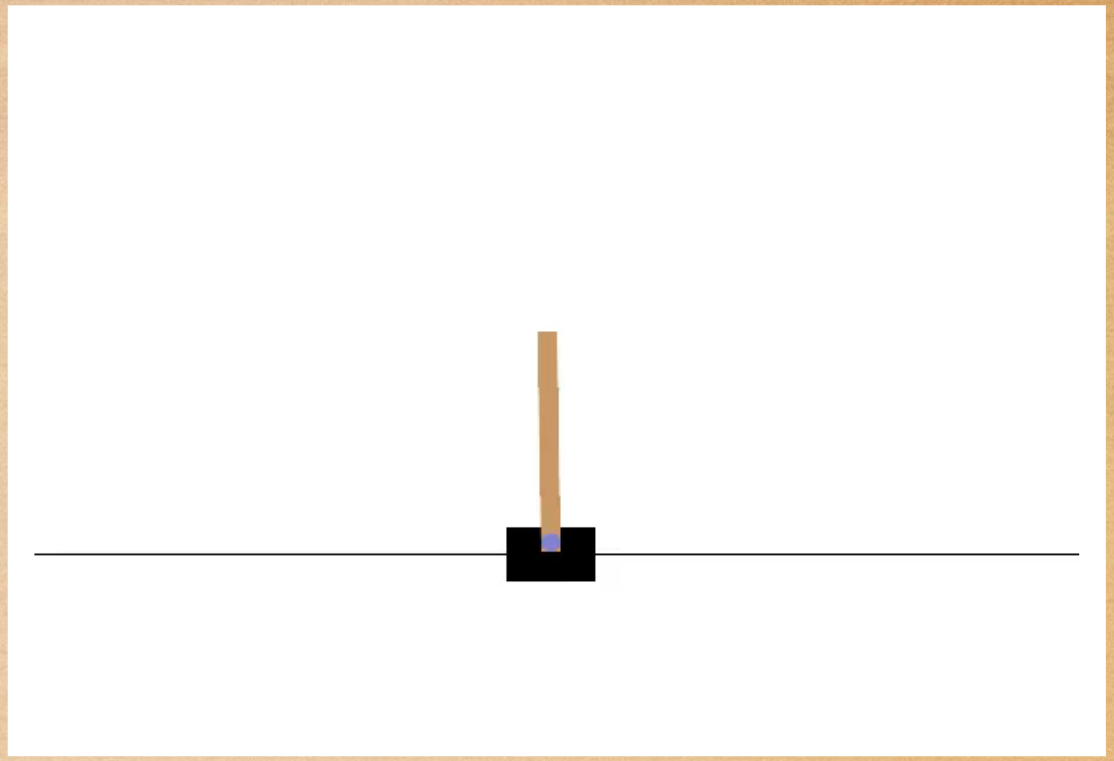
Policy clipped

Current policy should not differ too much from the previous one

Stable baseline PPO

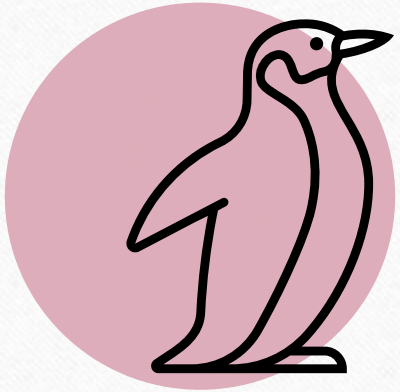


Our PPO

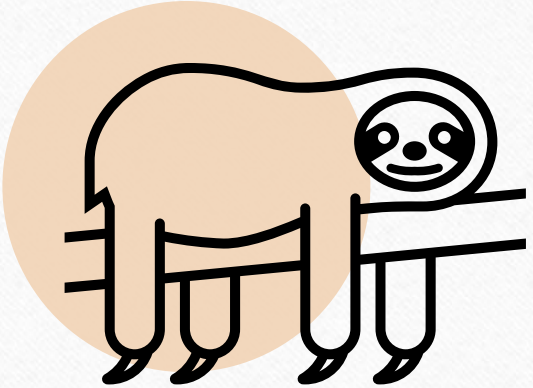


MEET OUR TEAM

FRANCESCO



MAX



GAIA

MARIA