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Lunar Scout: Task 1

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Lunar Scout - Task 1 :

Why this task?

Any self-balancing vehicle is commonly modeled after some variant of the *“Inverted Pendulum”* dynamical system. The Lunar Scout is also a self-balancing bike and thus it becomes essential to learn, observe & experiment with the *dynamics* of the physical system that the bike is based on, i.e. ***" Rotary Inverted Pendulum "***

Task 1 is further divided into two parts.

Task 1A - Mathematical Modeling

This is the first step, which will walk us through the steps to derive dynamics equations of the system, analyzing the behavior of the system from the math and applying appropriate control strategy on the system to balance the system in an inherently unstable position. The software that we learnt in the Task 0B should help us make this easier - **" Octave "**

Task 1B - Intro to CoppeliaSim

After we have the math solved, we should simulate the system’s behavior and visually observe how the dynamics behaves under gravity. For this we’ll have to use a simulator equipped with physics engine, and a perfect fit for this would be **" CoppeliaSim "**

There are various control strategies that can be used to balance the system. We’ll learn a popular one called **" Linear Quadratic Regulator "** in the Task 1A. But, to be able to fine tune it, we should observe the simulated behavior, and this is where CoppeliaSim becomes necessary. This will make it easier to deal with the actual hardware system.

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Getting to know the Rotary Inverted Pendulum !

The **Rotary Inverted Pendulum** system will have an *oscillatory open-loop response*, even if initial conditions are just slightly different from either of the equilibrium points. The cylindrical rotary arm in horizontal plane rotates about a pivot joint & similarly pendulum(another cylinder) in vertical plane rotates about the arm's axis about another free joint.

Both the rotations are **coupled** with each other,

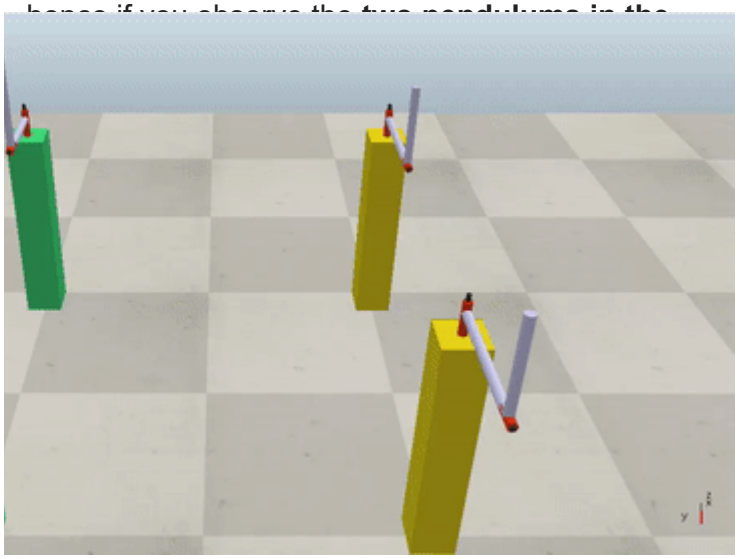

Figure 1: Rotary Pendulums open loop response

- After a little initial disturbance, this potential energy is slowly converted into kinetic energy of pendulum as it swings in vertical plane.
- But as time passes, the amplitude of the vertical oscillations of the pendulum decrease because the rotary arm oscillation starts increasing and energy is shared or say it transitions among both.
- Cool, isn't it ? 😯

Now give it a thought…

- which of these pendulum's oscillations damp fast and why?
- the green pendulums have a shorter arm but longer pendulum rod, whereas the yellow pendulums are the opposite. Which one would be easy to balance if you're controlling arm joint only?

The pair of pendulums on the back side are having a disabled motorized arm pivot…

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- which means that it acts as if there is a **DC geared motor** but *it's not powered*. So how would that act? see for yourself in the GIF shown above!
- Let me make it clear, it's neither friction nor a trick. Try doing a free fall experiment as such with DC gear motors of different torque ratings and you'll know 😉
- By the way, the pendulums on front(free pivot) and the pair on back(geared pivot) are identical. The geared pivot pendulums fall slower than free pivot, but the oscillation amplitude of free pivot pendulum's rod dampens faster than the geared ones… why? 👀

So, as we start to dive deep in the world of control systems, there are a ***few references given below***, which we feel should give a nice flavor of what we're dealing with. If you keep your eyes open for it, you'll see that there's pretty cool stuff happening around in this space !!
Happy Exploring !!

🤠 Try googling :

- Kinematics vs Dynamics?
- What are degrees of freedom ? How many does a car or a drone have ? What about Rotary Pendulum then?
- Newtonian vs Lagrangian Mechanics?
- What are Rotation Matrices?
- What are open loop & closed loop systems?
- What is a state space model ? How is it different from transfer function ?
- What are linear & Non-linear systems?
- What is an Under-Actuated System?

References :

- We Ignore it, but wikipedia is still one of the most powerful tools 😉 **Inverted pendulum - Wikipedia**
- Most popular Rotary Inverted Pendulum around - you can find jackpot of papers on it **Rotary Inverted Pendulum - Quanser**
- Did you know this Nickname ? 😯🙊 **Furuta pendulum - Wikipedia**
- You must be knowing Brian, don't you?
  - **https://www.youtube.com/playlist?list=PLfqhYmT4ggAtpuB1g8NbgH912Pw**

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Yjn_We
    - https://www.youtube.com/playlist?list=PLn8PRpmsu08pQBgjxYFXSsODEF3Jqmm-y
- Whoa, is this a full giveaway or what ?
    - https://www.youtube.com/playlist?list=PLMrJAkhIeNNR20Mz-VpzgfQs5zrYi085m

Deadline: ⏳

> The deadline for both Task 1A & Task 1B will be **October 10th, 2023.** 📆🚨🤺🤺🚀

🔗 Task 1B practical

🔗 [Announcement] For teams who are mid-way

Unlisted on Sep 15, 2023

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