TM Homework 2 BIG

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Link back to GitHub

1 Acknowledgements

I would like to thank the following people:

1. Ekaterina Mozhegova and Mikhail Terentev for teaching how to work with Arduino Uno. I learned how to get the measurements from the cart pole system. Also for the table they did to understand how does the Arduino in cart pole system measures the values. Since there are not degrees and cm, but just some units. You may see the `.ino` file in the folder `collect_data`

2. Muhammadrizo Maribjonov for providing the plots from the data we got during the experiments. But his code does not work on my computer, so, I did it by my own with his help. I used the `.csv` files he did.

3. Leonid Novikov and Elina Murtazina for helping to conduct the experiments, measure the needed values and checking the formulas.

4. Ahmed Abid for measuring the pole length and a bit help with data tables.

2 Task description

1. Obtain the required measurements of the stand (like needed masses, lengths and so on).

2. Gather the positions and velocities of the stand. You should run the same experiment 3 times each.

Initial conditions:

1.$x = 0, \phi = 15^o, \dot{x} = 0, \dot{\phi} = 0, t = 0$;

2.$x = 0.25$ m, $\phi = 45^o, \dot{x} = 0, \dot{\phi} = 0, t = 0$;

3.$x = 0.25$ m, $\phi = -135^o, \dot{x} = 0, \dot{\phi} = 0, t = 0$;

3. Substitute a real data to your math model from HW 7, 8 (you can choose any method your like) and compare the results (propose and justify the metric).

4. Explain, what affects the difference between math model and real data. Is it difference significant?

5. If so, change the model (add new forces, change the object representation), gather new needed data and compare it again.

6. Make a conclusion.

3 List of used tools

1. Cart pole system with sensors for measuring the position of the cart and the angle of the pendulum
2. Arduino Uno for measuring the values from the sensors
3. Arduino IDE for working with Arduino Uno
4. Bubble line level to check the level of the table to exclude the cart's movement along Y-axis
5. Scales to measure the mass of the cart and ingot (Rus. *"болванка"*)

4 Measurements

To measure all the needed details I carefully reassembled the system, measure what I need, and assembled again.

We got that:

1. Mass of the cart = 266 g
2. Mass of the ingot = 154 g
3. Mass of the carbon pole = 21 g (we can neglect)
4. Length of the pole = 38 cm

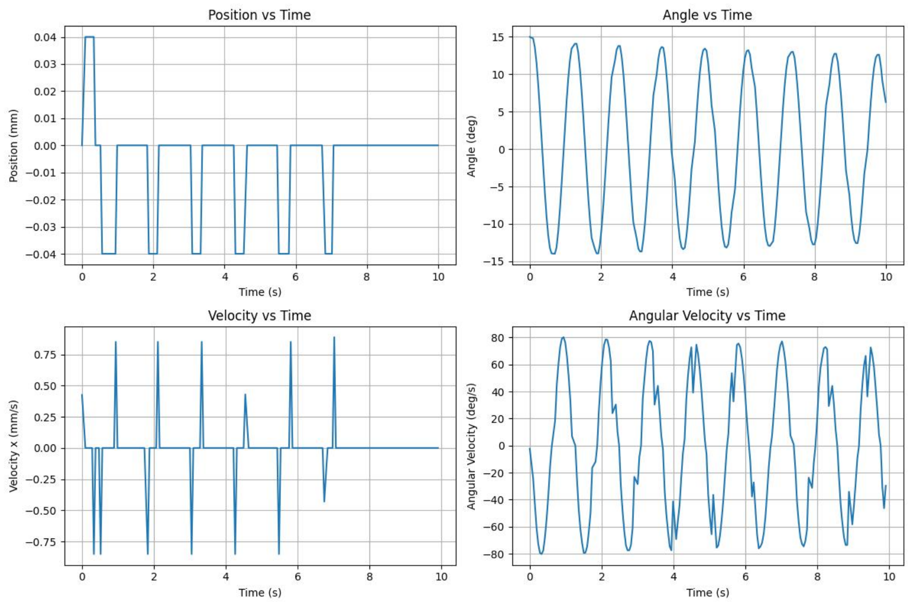
5 Conducting experiments

You may see this video on YouTube. There is a comparison of experiments we conducted.

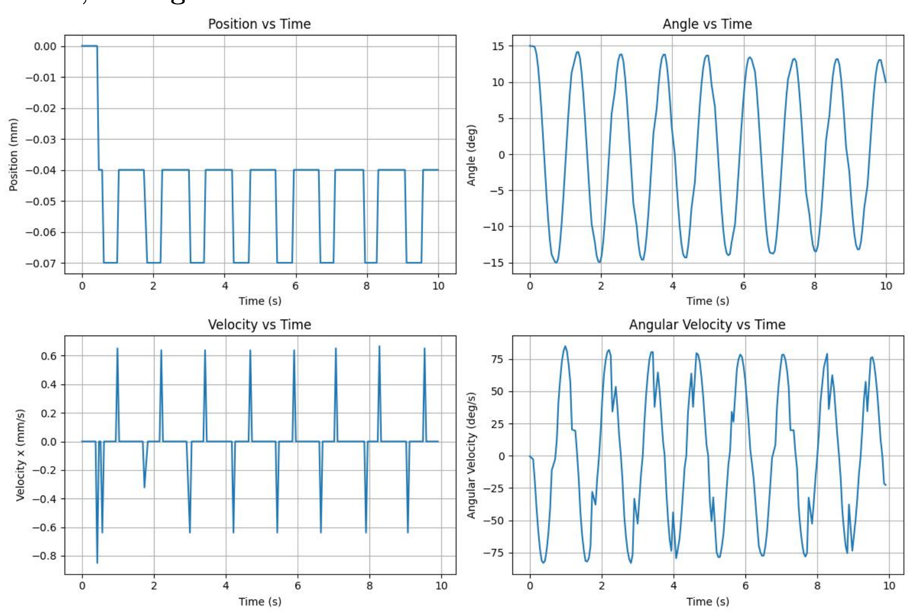
Probably I'll make another short video what we did.

5.1 Plots for 3 tests

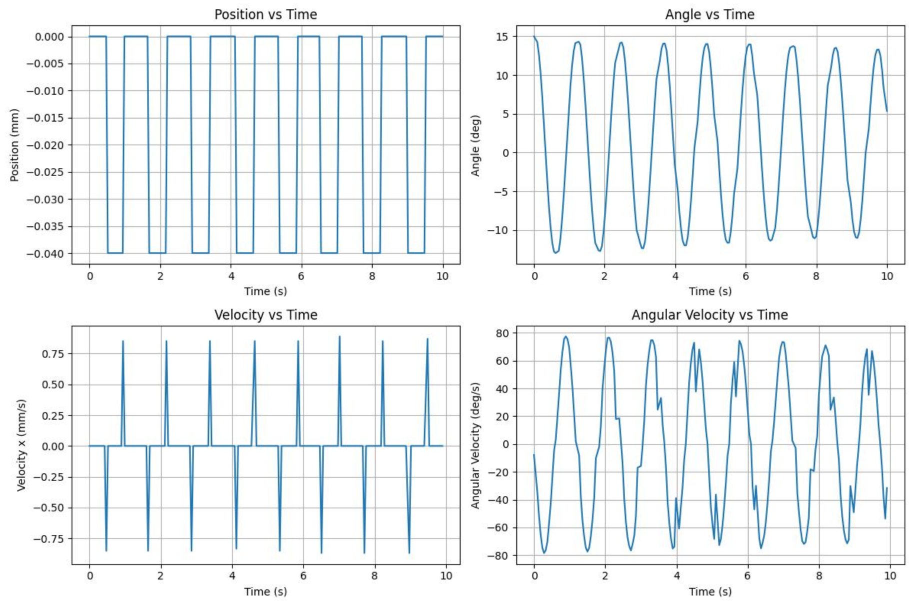
Test 1, 15 degrees



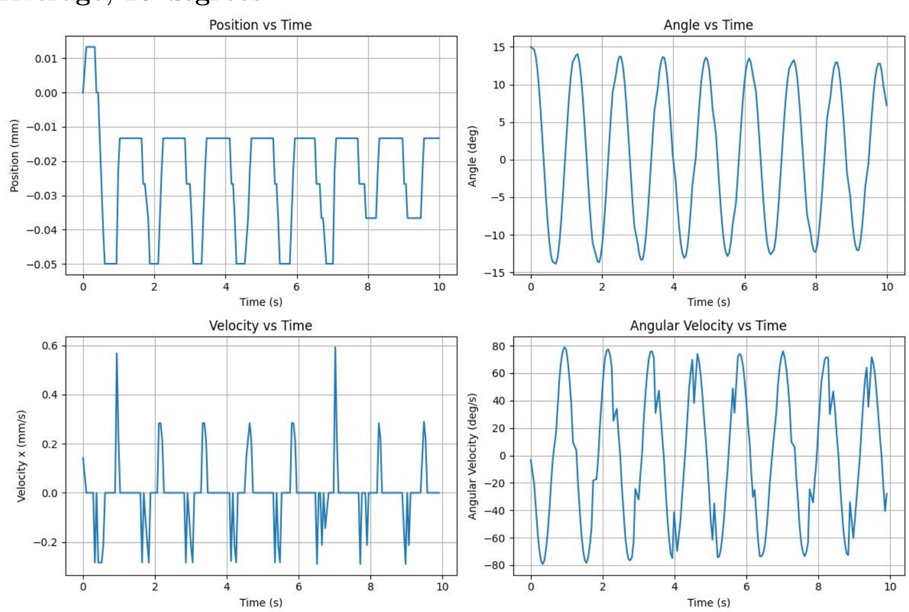
Test 2, 15 degrees



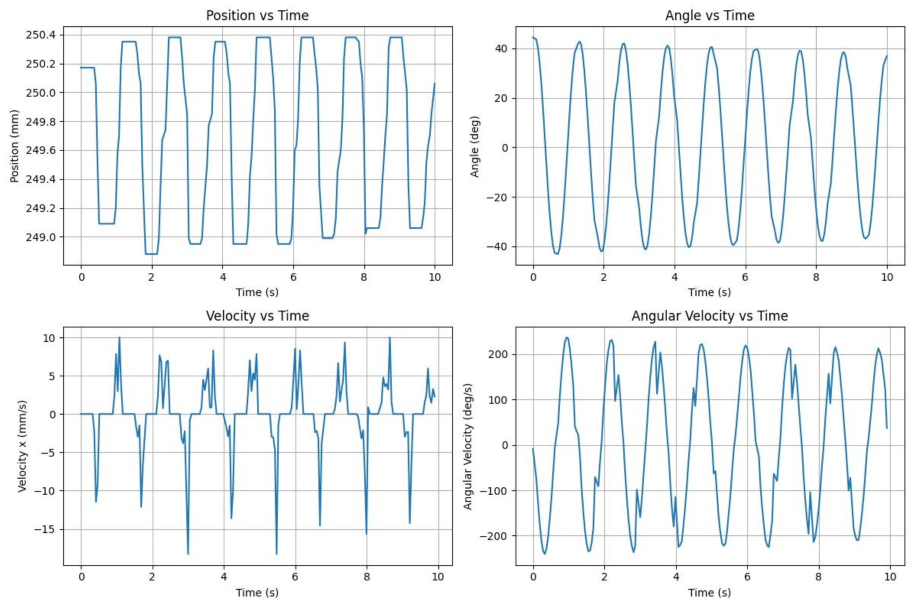
Test 3, 15 degrees



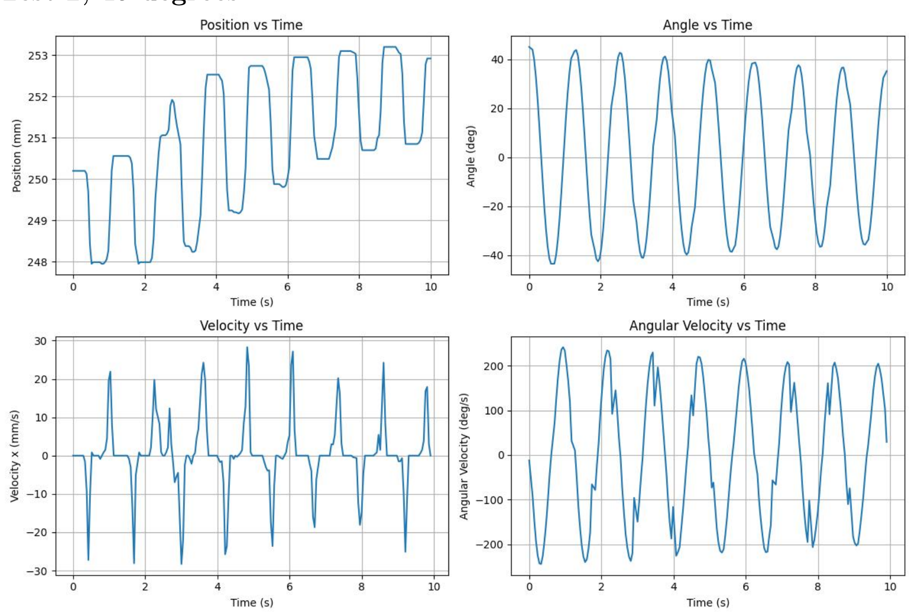
Average, 15 degrees



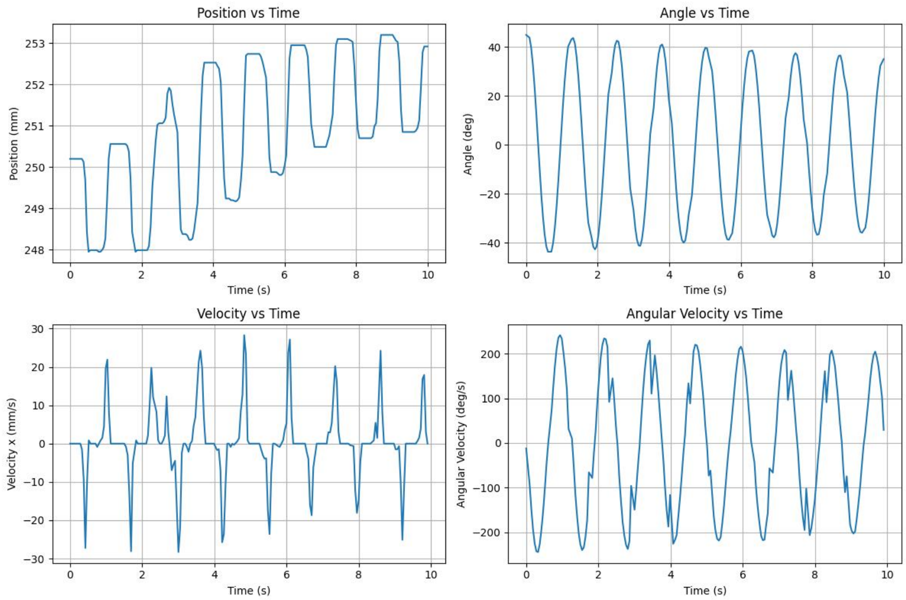
Test 1, 45 degrees



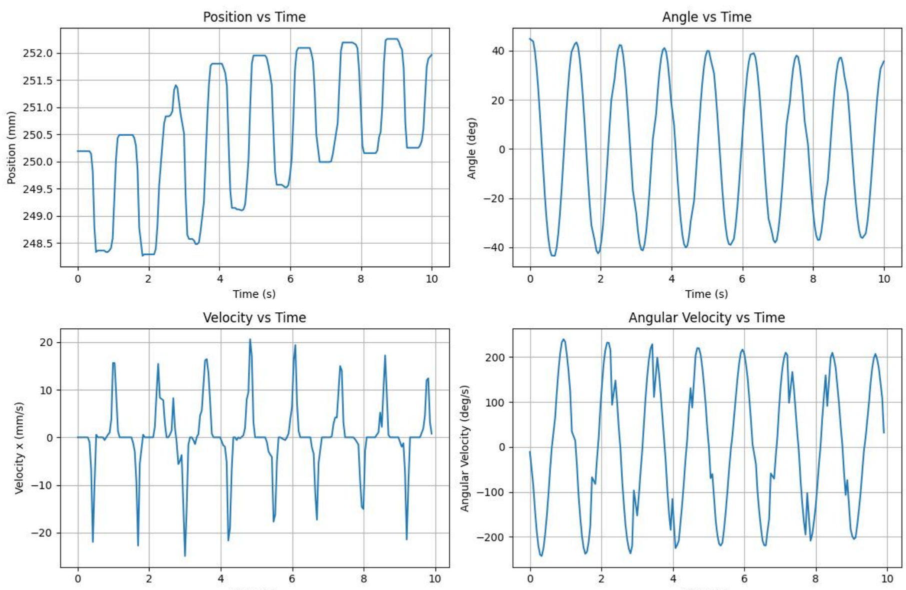
Test 2, 45 degrees



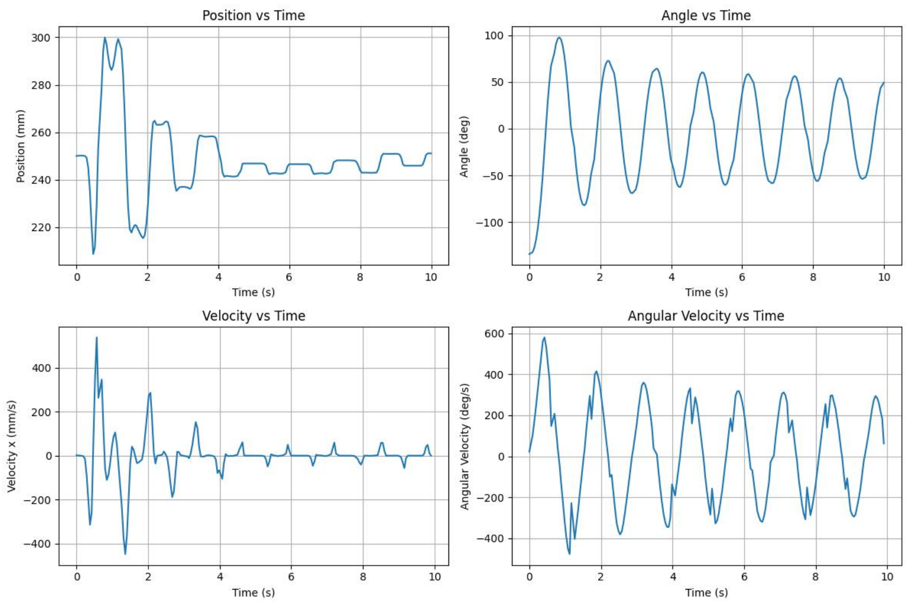
Test 3, 45 degrees



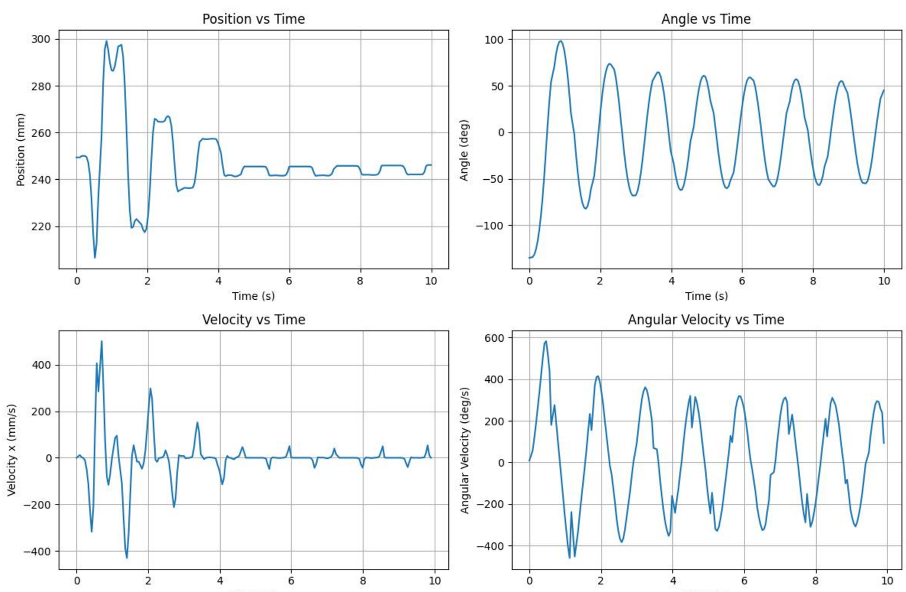
Average, 45 degrees



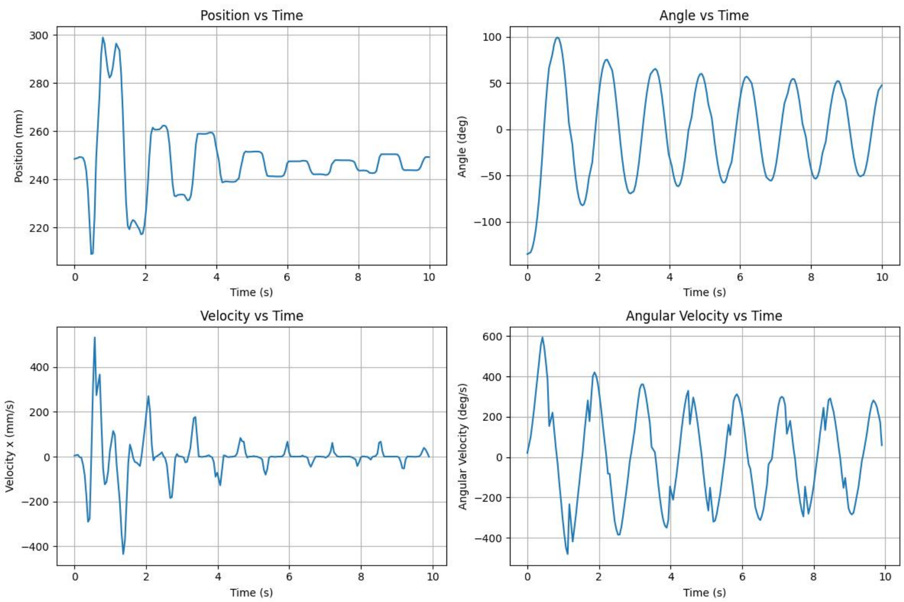
Test 1, -135 degrees



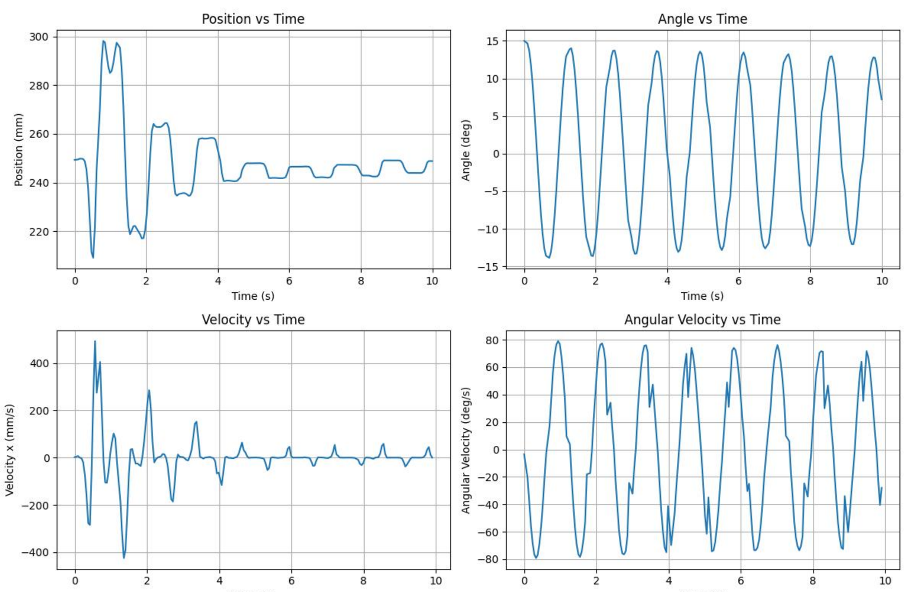
Test 2, -135 degrees



Test 3, -135 degrees



Average, -135 degrees



5.2 Explanation

For 15 degrees test there is a positive value for position that is 0.04 mm! That happened because of hand shaking while holding the pole. Also, to reduce this shaking I used a thread to hold it on the table and then release the thread. In fact the motion of the cart for such a small angle is very small, almost indistinguishable to the eye. Other inaccuracies are because of the sensors in the system.

6 Simulation

Well, I'll use Newton-Euler method, since I did it in HW7.

For more details see the `.ipynb` file in the folder.

Link to SIMULATION

Since in real world we cannot neglect the friction force and air drag force, therefore, we have to add to the system these forces:

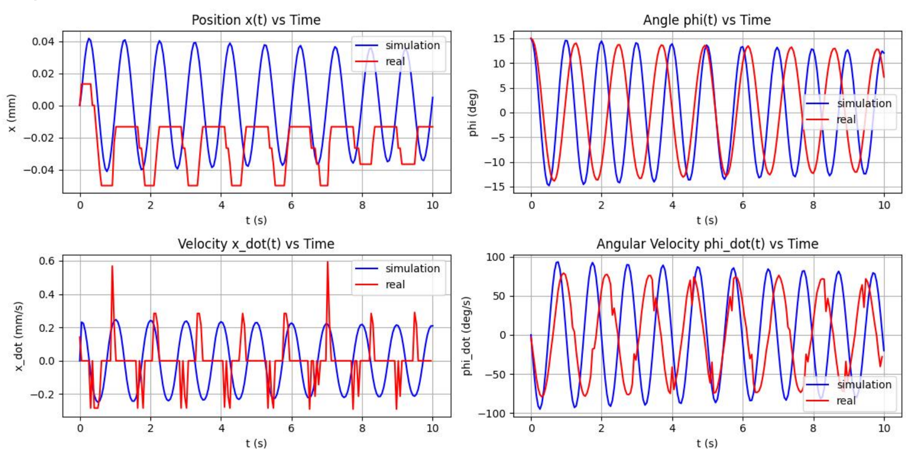
```
air_drag = ...  # Air drag coefficient for pendulum
friction = ...  # Friction coefficient for cart
```

We add it to the function that calculates the values

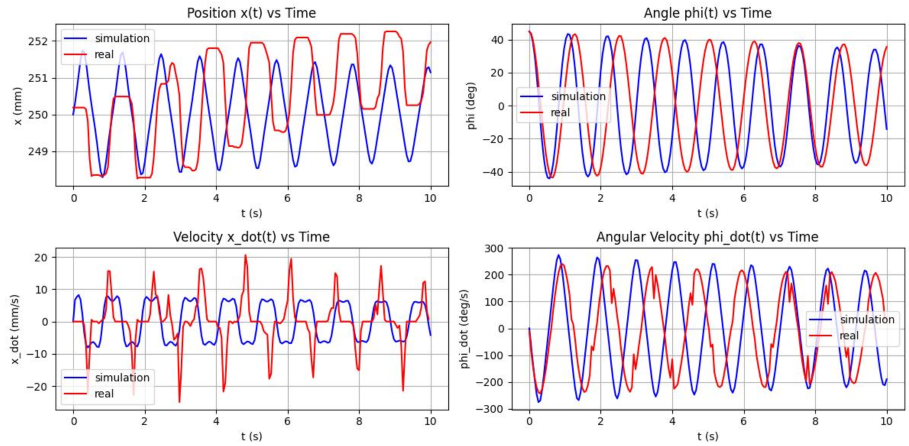
```
def equations(t, y):
```

6.1 Plots to compare

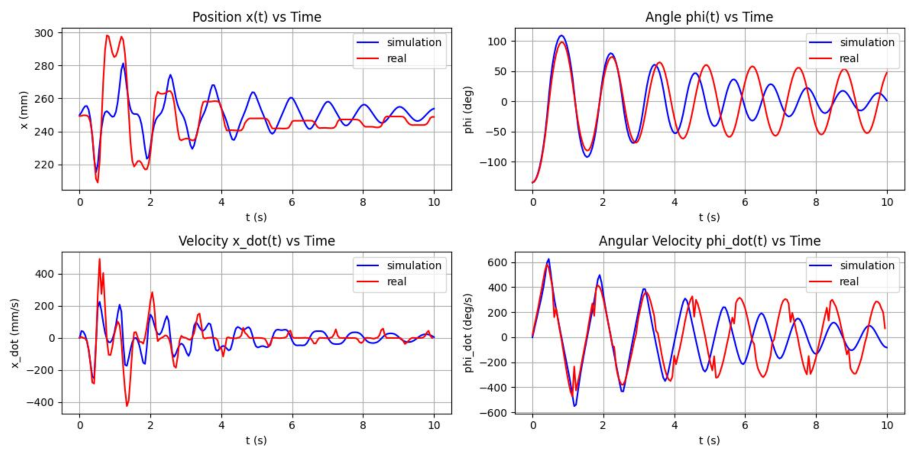
15 degrees test



45 degrees test



-135 degrees test



6.2 Explanation

About 15 degrees test. The values are very small (max 0.04 mm), so the difference between the graphs is just a measurement error. The encoder in the cart has not enough precision.

About 45 degrees test. Angle and angular velocity plots for both cases (simulation and real) have almost the same magnitude, but different frequency.

About -135 degrees test. As in the previous test, here angle and angular velocity plots for both cases also have almost the same magnitude, but only in the first 4 seconds and different frequency.

For the 15 degrees I used air drag = 0.038, friction = 12.

For the 45 degrees I used air drag = 0.006, friction = 120.

For the -135 degrees I used air drag = 0.05, friction = 15.

The values are different because for each test I had to change them to be similar to the real plot. That is because the formula I used for calculating the new values including the friction force and air drag is not so complex, as it should be. We could try to use Euler-Lagrange method to evaluate, but this is another story.

I think we can improve the correlation (or decrease the error) via constructing complex formula that would depend on time and the magnitude. For example, I noticed that in test -135 degrees the magnitude (max or min values) decreases almost exponentially. Maybe we can try to improve the model to satisfy this.

7 Conclusion and further work

To conclude I would like to thank Oleg for this homework. It is really interesting and challenging (you may see on the results). I have studied how to work with Arduino, how to conduct an experiment, how to model the system (at least try to model).

In the future I think we can try to control the system, but this topic is more about Control Theory course. I think we will be able to do something like this.

8 Meme

This is research work. I cannot put memes here.