Hanze

Hanze University of Applied Sciences
Institute of Engineering
Smart Systems Laboratory

Lab Session 3 - Optimizing the Pendulum Model by Tuning Parameters

1 | Aim

The aim of this lab is to optimize the model developed in Lab 1 by adjusting its parameters to identify the optimal set that minimizes the discrepancy between the observed data and the model's predictions.

2 | Preparation

For this lab session, you will need the following files:

- `Lab_3_model_optimization.py`; and
- `SOME_data.csv` (your previous recording).

Ensure that the Python file is located in the same directory as `Digital_Twin.py`, as the digital twin class will be imported from it.

3 | Procedure

We begin by pre-processing the data generated by our sensor system. The `SOME_data.csv` file contains a recorded dataset of the pendulum's motion. Before proceeding with model optimization, it is essential to ensure that the following prerequisites from Lab 2 are in place:

3.1. The sensor data is transformed to radians:

- Scale down the amplitude;
- Include logic to transform the data correctly; and
- Calibrate, as there is some offset in the data;

3.2. Optionally, a filter should already be implemented.

Once the data has been converted into radians, the following tasks should be completed:

3.3. Find the initial conditions in your recording. Edit the following function:

Algorithm 1: Function to determine the initial conditions of θ and $\dot{\theta}$.

```
def find_initial_state(df_theta, df_time):
  # Find the initial conditions of theta and theta_dot in the data
  theta = 0
  theta_dot = 0
  return theta, theta_dot
```

⚠ *Be aware*: if you recorded actions, you will also need to optimize the motor model, which is a *bonus point*. If you do not want to do this, use a recording without action for the time being. You could estimate the effect of the action if you have an optimal model for the pendulum, come up with a strategy to do so.

3.4. Specify a range of values for the parameters. Why do you choose this range and why the specific resolution? Resolution here says something about what discrete parameter values you are going to test. Once you have determined the initial condition and the ranges/resolutions for the parameters it is time to simulate and compare the outcomes to the real data by performing a simple grid search (refer to the definition in [1]).

4 | Tasks

4.1. How would adding the filtering effect the optimization?

4.2. How could the grid search be improved? Try to implement a better/more advanced method.

4.3. Can you change the code so that difference in sampling in the recording and simulation is minimized?

4.4. What are the optimal parameters? And is the error acceptable? If not, could you include additional parameters in your model? What would they be and why do you think so? Show the values in a table.

4.5. Optimizing a model can be computationally expensive. Discuss how you could further minimize the computation you would need for the optimization. Could you reduce the data you use? Could you evaluate in a sparse way, e.g. at random points? Could you automatically estimate the upper and lower range of the parameter values?

5 | References

[1] J. I. Myung, D. R. Cavagnaro, and M. A. Pitt, "A tutorial on adaptive design optimization," *Journal of mathematical psychology*, vol. 57, no. 3-4, pp. 53–67, 2013. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0022249613000503