Control system of a rotating double pendulum

By:
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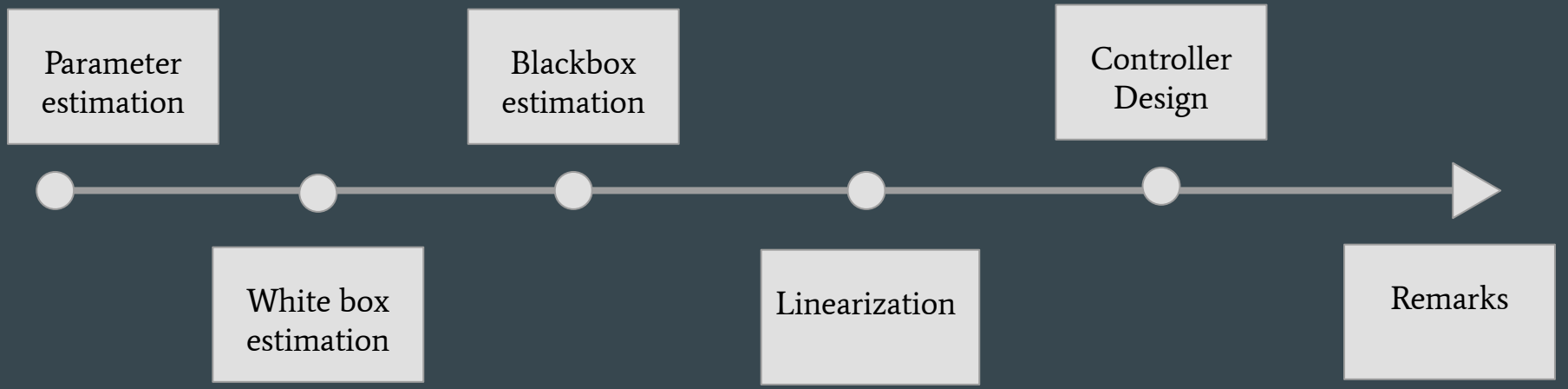
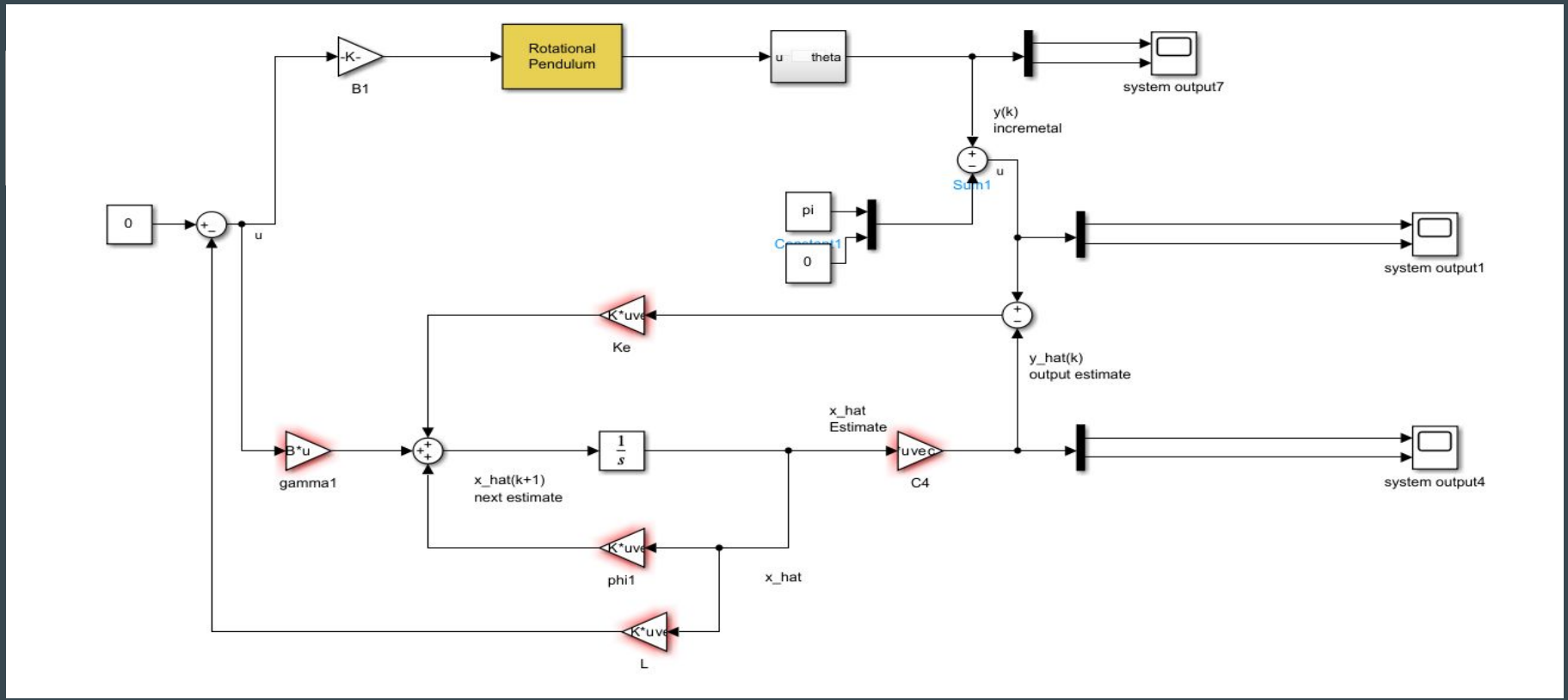
Introduction

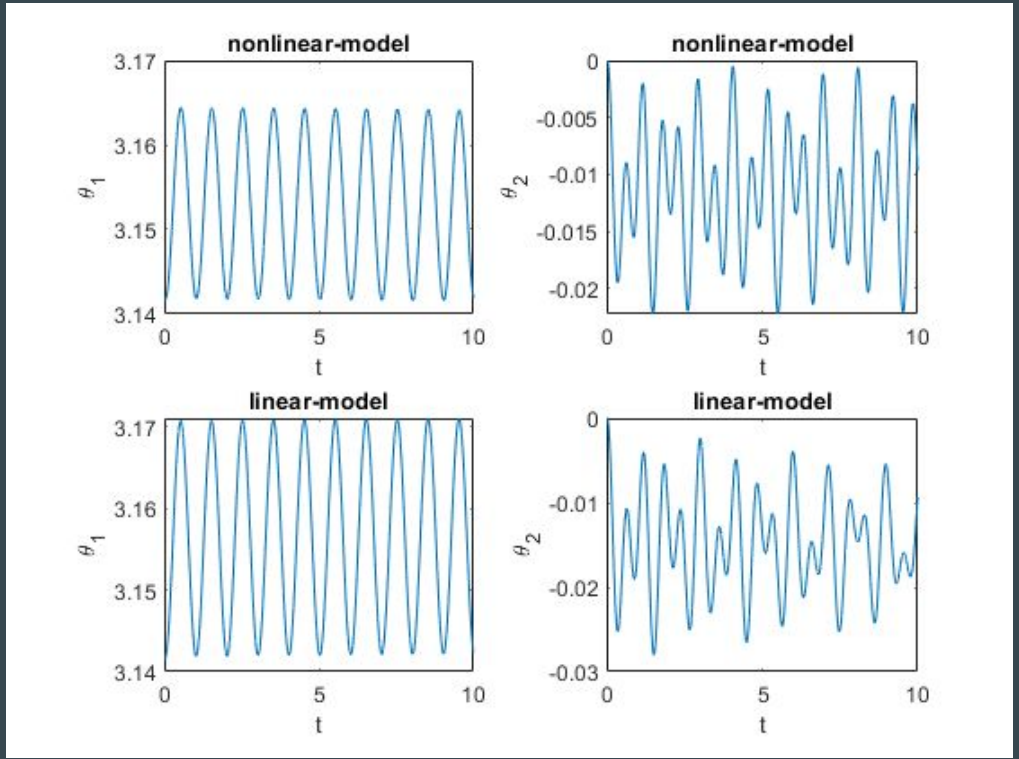


Introduction



System modelling in state space and linearization

- not a perfect fit
- similarities between linear and non-linear model

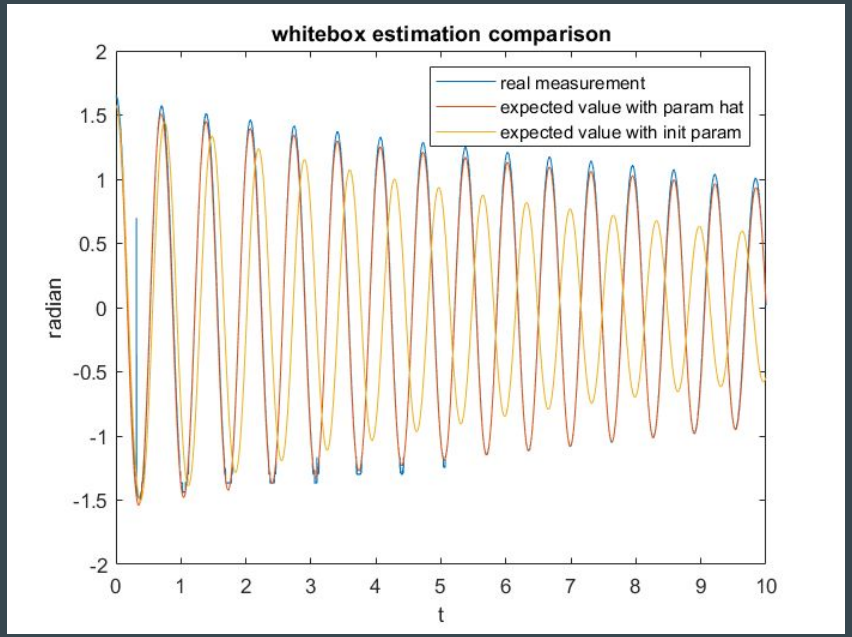


White box estimation

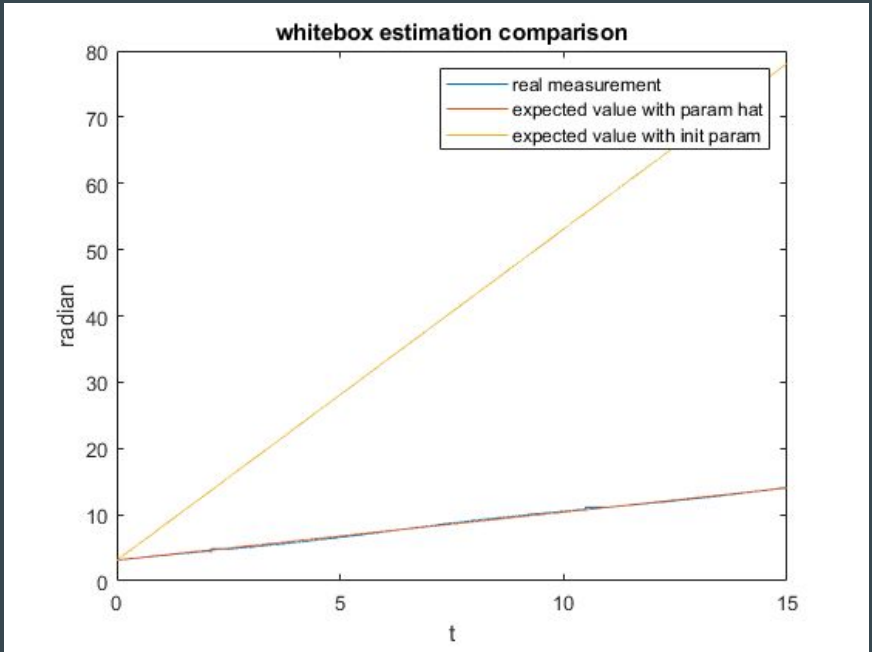
1. taking measurements of the pendulum.
2. optimizing the cost function to find the parameters.
3. lock these variables and move on to the beam.
4. making the beam rotate at a constant speed for the measurements.
5. optimizing this cost function as well to find all the remaining parameters.

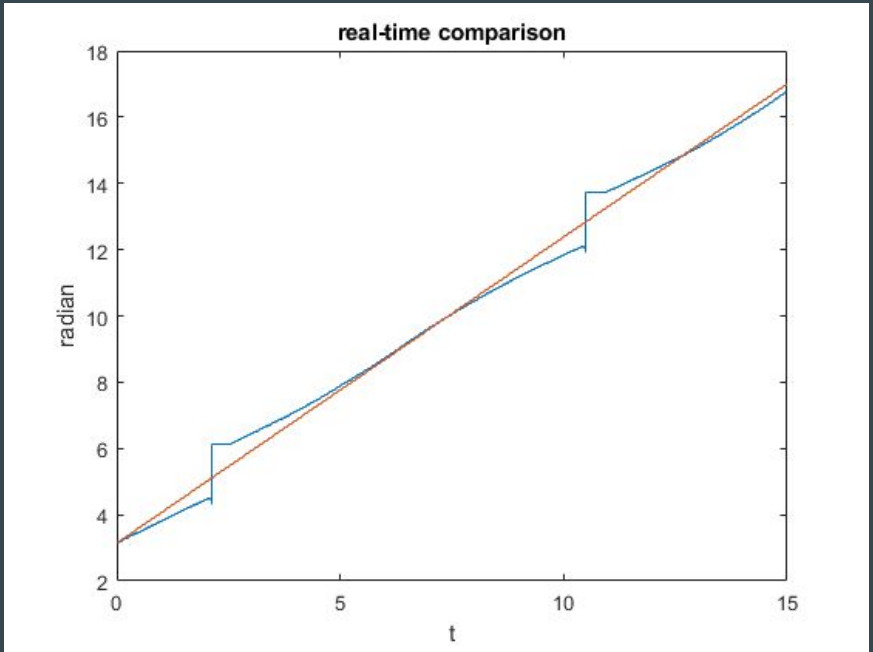
White box estimation: Pendulum

- measuring data of the pendulum drop
- holding the beam still to avoid backlash
- cost function optimization



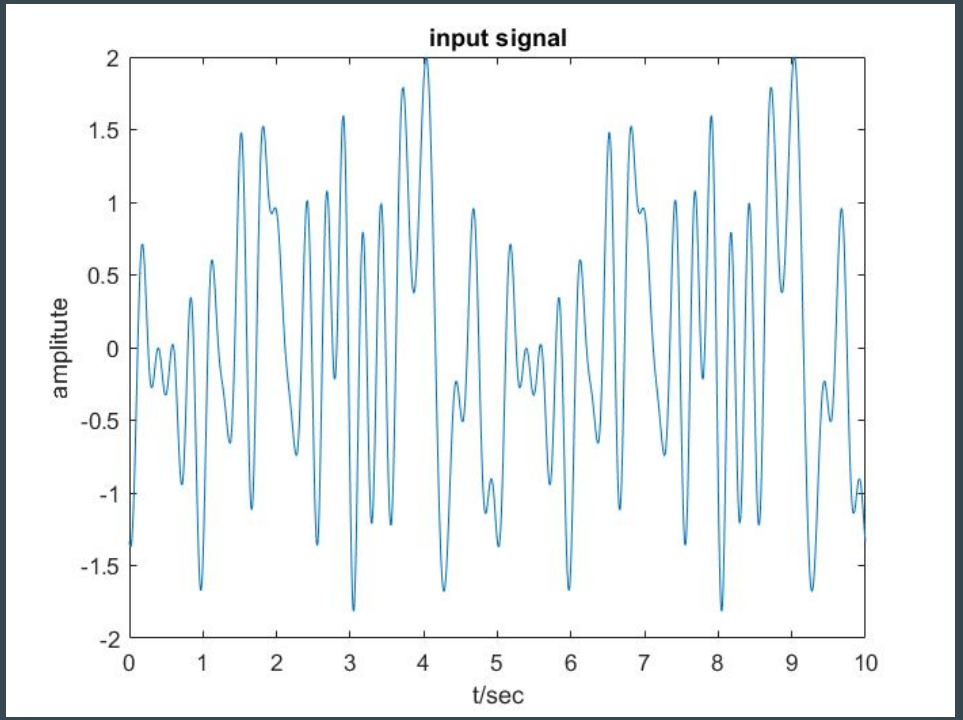
White box estimation: Beam



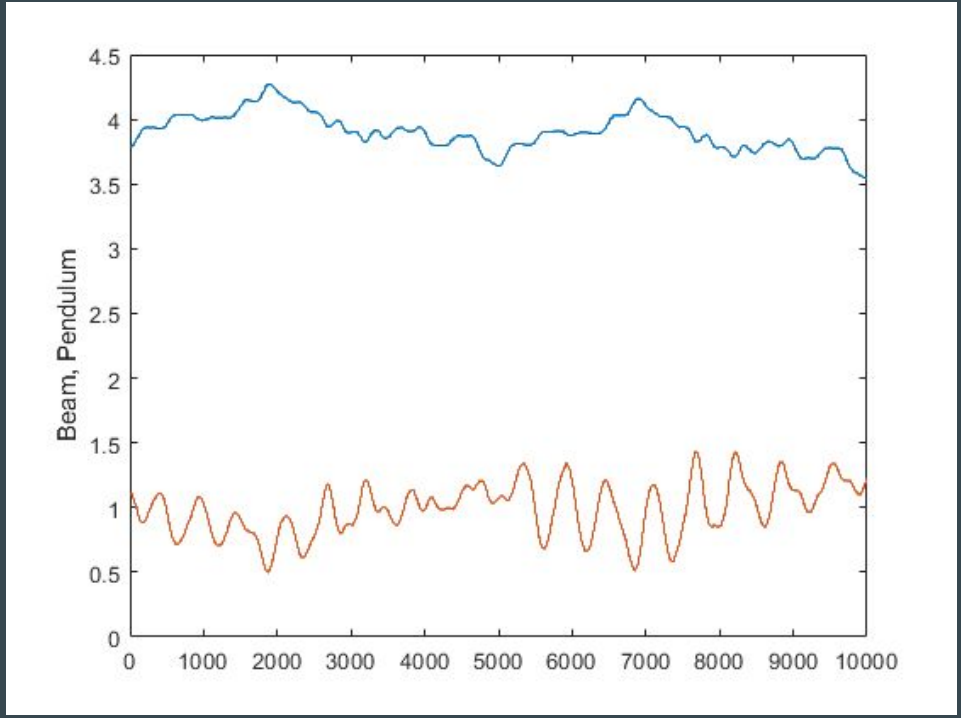


Black box estimation

- Amplitude range [-2, 2]
- keep error between sin(x) and x less than 2%
- keep the SNR large than 50
- Frequency range [0 30] Hz
- avoid backlash

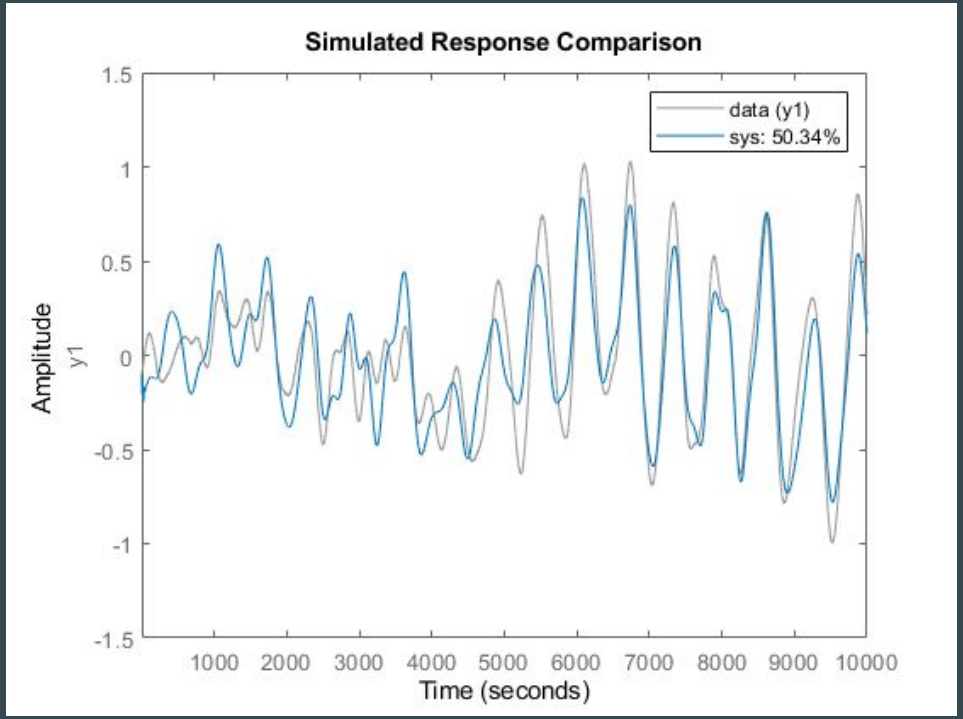


Black box estimation



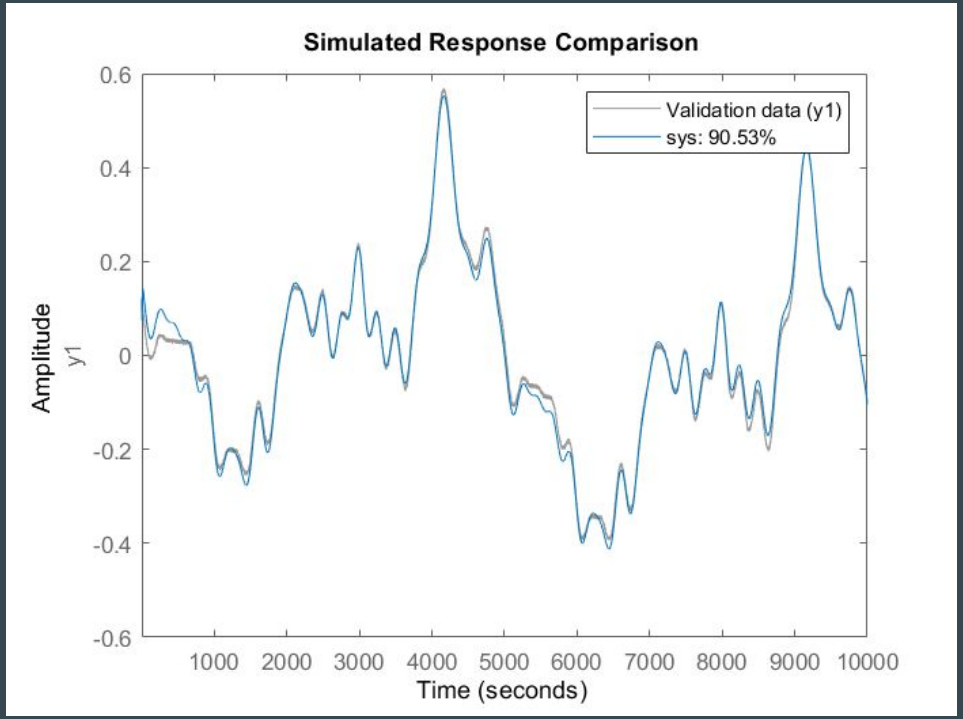
Black box estimation

- Model: Box-Jenkins ([7, 5, 5, 7, 0])
-
- For Pendulum:
- roughly follows the data
- only 50.34% accuracy
-
- average validation accuracy 35%



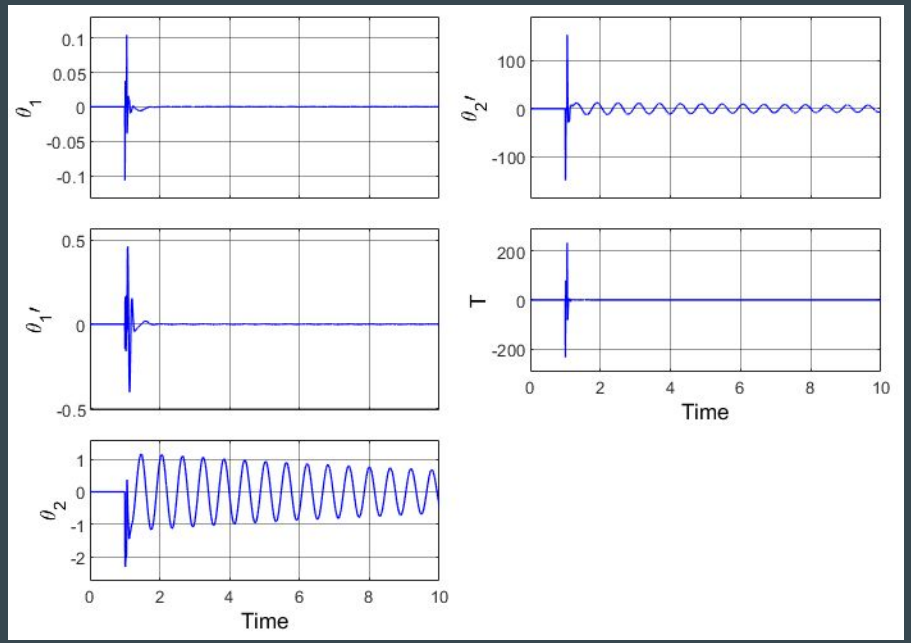
Black box estimation

- Model: Box-Jenkins ([7, 5, 5, 7, 0])
-
- For Beam:
- nice fit and 90% accuracy
-
- average validation accuracy 85%

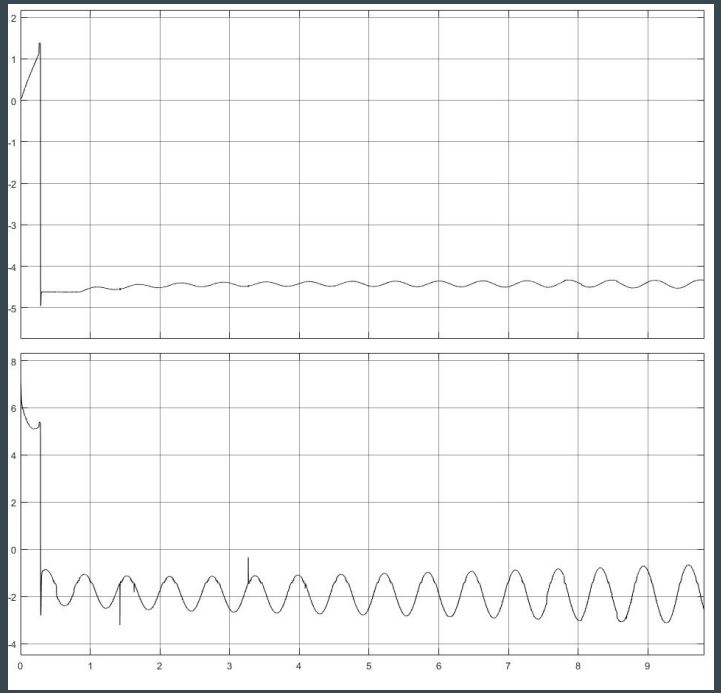


Observer design

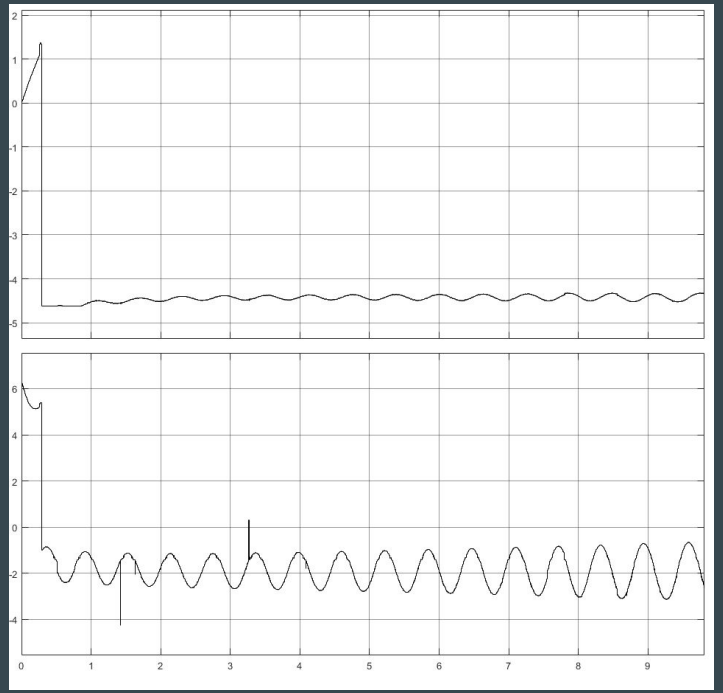
- compare output setup with output from the observer
- poles for the observer are [-202,-203,-204,-205,-220]



Observer design



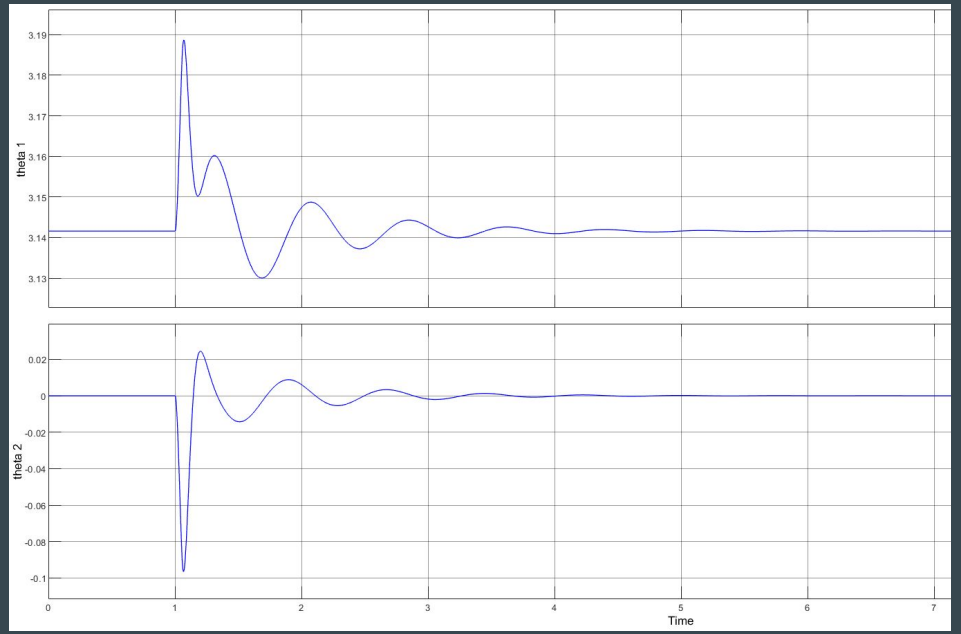
System output



Observer output

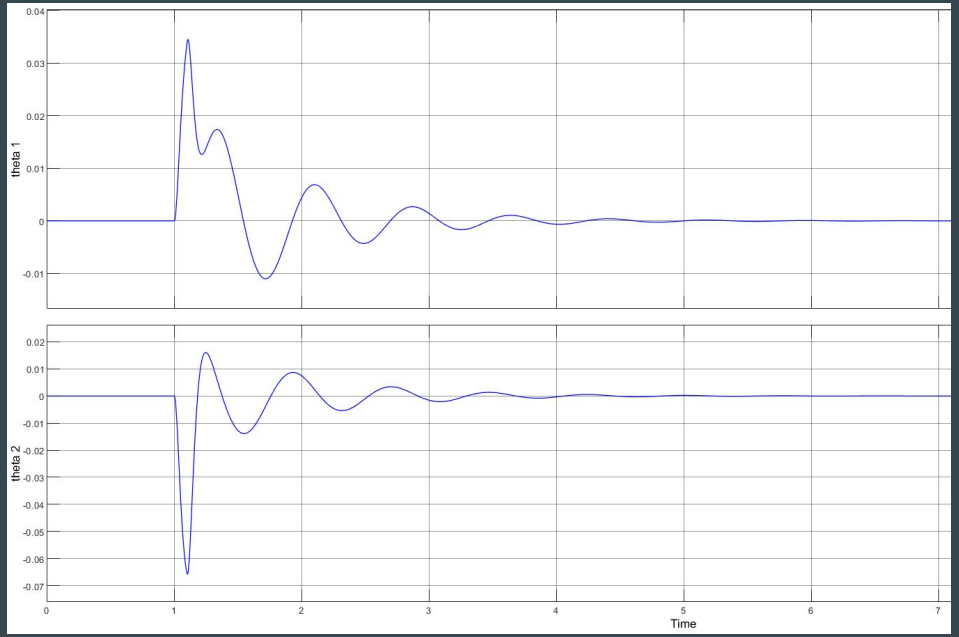
Controller 1: PID

- PID applied on linear model
- recovering from a distribution
-
- internal:
- [Kp, Ki, Kd] = [-10, 0, -0.02]
- Ts = 0.25 s
-
- external:
- [Kp, Ki, Kd] = [-0.5, 0, -0.02]
- Ts = 0.35 s



Controller 1: PID

- PID applied on non-linear model
- recovering from a distribution
-
- internal:
- Ts = 0.15 s
-
- external:
- Ts = 0.15 s

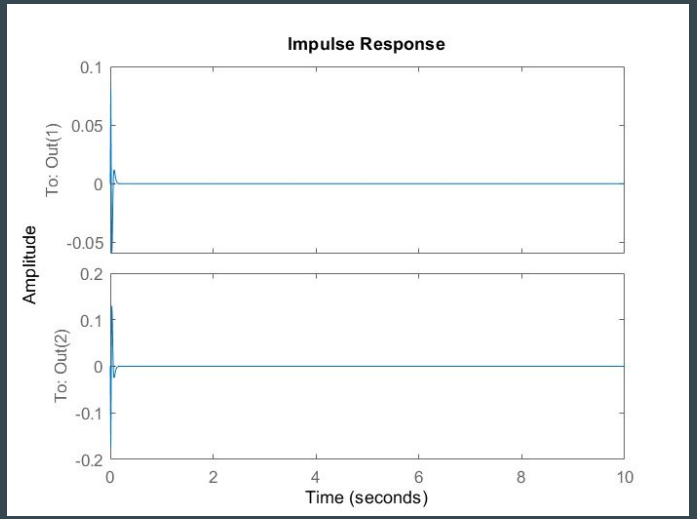


Controller 2: state feedback

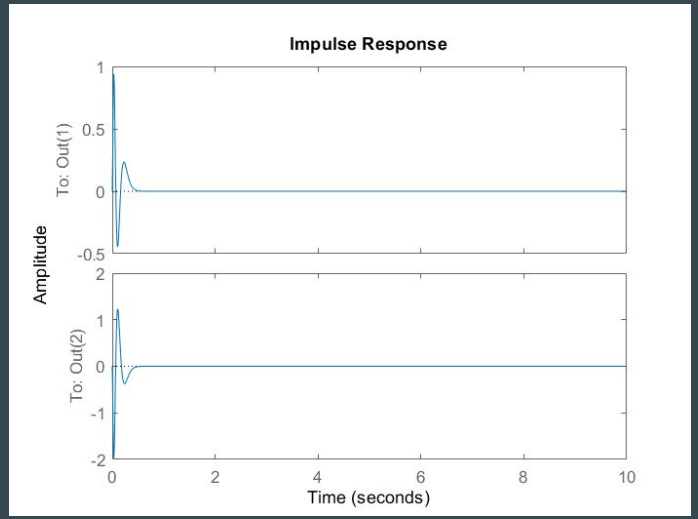
- Pole placement
- LQR

Controller 2: state feedback

- Check the impulse response of the system
- larger poles result to a decrease in rise time and overshoot



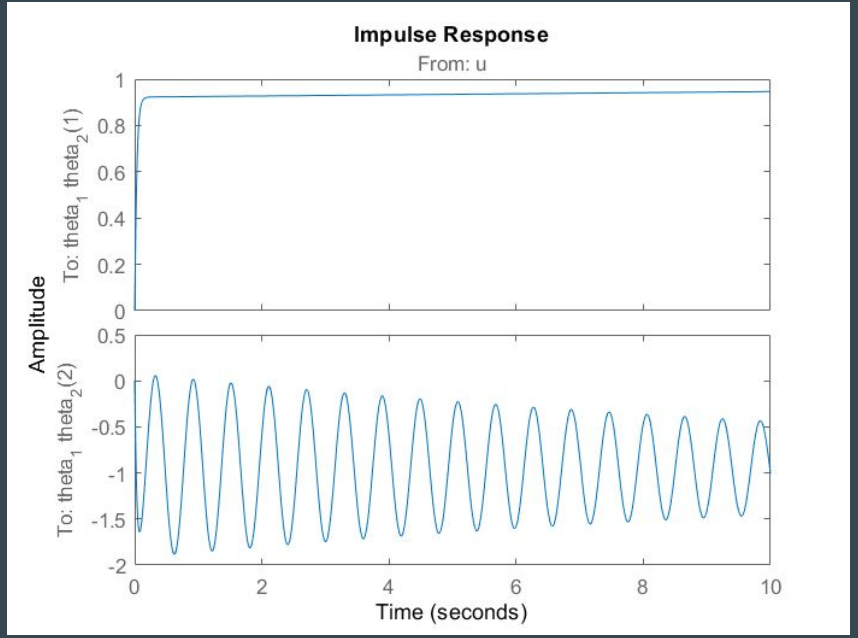
0.5*Poles



0.15*Poles

Controller 2: state feedback

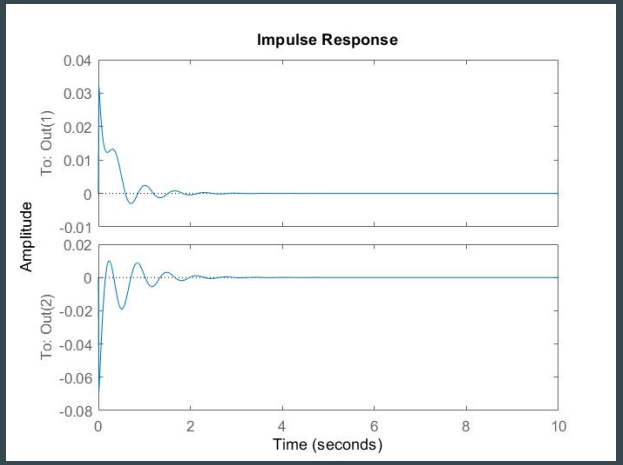
- No quite satisfying yet



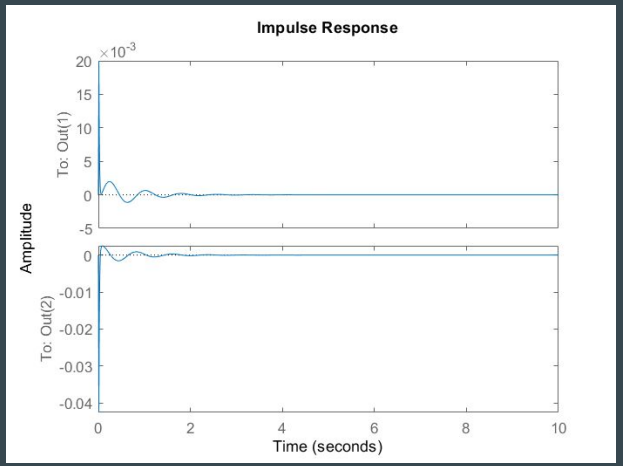
non-linear impulse response

Controller 2: state feedback

- finding a value for the cost matrix where x1 and x2 go to the reference as fast as possible.

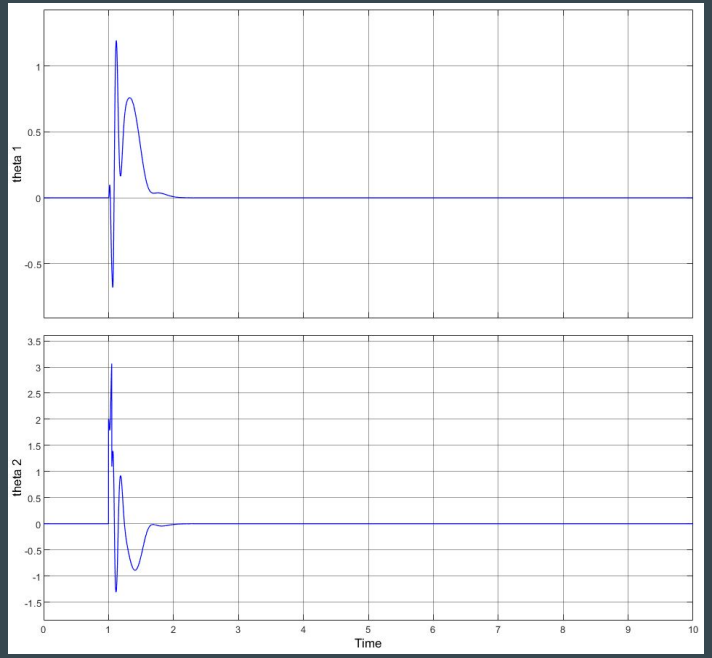


smaller Q

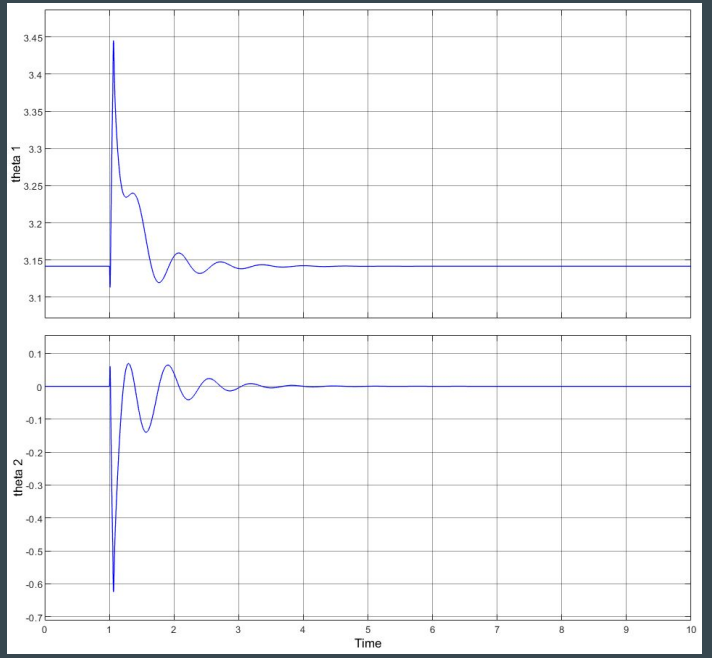


larger Q

Controller 2: state feedback

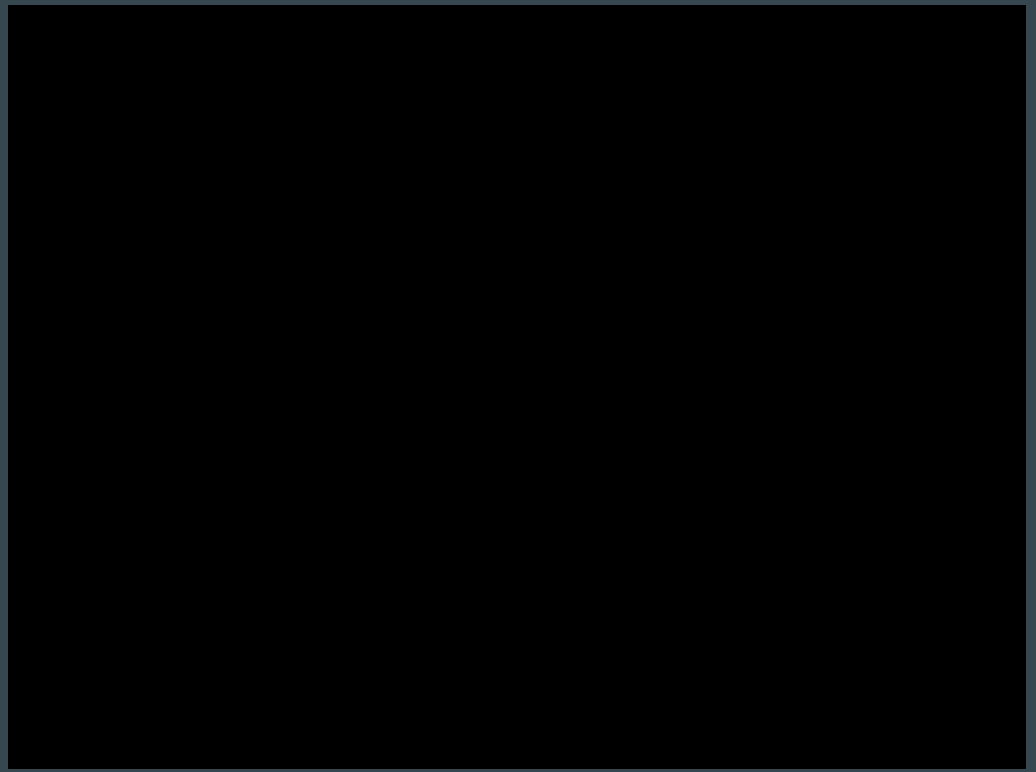


simulation output Pole placement



simulation output LQR

Remarks



Remarks

- unwrapping the signal gave some problems
- There is blind spot
- backlash

Thank you!

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Questions?