Challenge Deliverable 2
Answer form

4DB00 Dynamics and Control of mechanical systems
2019-2020

Name:	Jelle Langedijk
Student number:	1315358

Be aware of the TU/e Code of Scientific conduct. See: https://www.tue.nl/en/our-university/about-the-university/organization/integrity/scientific-integrity/.

Question a):

Identify all equilibrium positions in the domain $0 \leq x_1 \leq L_1, -\pi \leq \varphi_2 \leq \pi$ for the input $\vec{F}_A = 0$ and the prescribed displacements $s_{pd}(t) = \dot{s}_{pd}(t) = \ddot{s}_{pd}(t) = 0$.

$$V = \frac{1}{2}k_h\left(x_1 - \frac{1}{2}L_1\right)^2 + \frac{1}{2}m_0 g L_0 + m_1 g\left(L_0 + \frac{1}{2}L_1 sin(\varphi_1)\right) + m_2 g(L_0 + x_1 sin(\varphi_1)) + m_3 g(L_0 + x_1 sin(\varphi_1) - L_2 sin(\varphi_2))$$

Then

$$\underline{V_q} = \begin{bmatrix} m_2 g(sin(\varphi_1)) + m_3 g(sin(\varphi_1)) + k_h x_1 - \frac{1}{2}k_h L_1 \\ -m_3 g(L_2 sin(\varphi_2)) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Gives

$$q_0^1 = \begin{bmatrix} \frac{1}{2}L_1 \\ \frac{-\pi}{2} \end{bmatrix} ;\; q_0^2 = \begin{bmatrix} \frac{1}{2}L_1 \\ \frac{\pi}{2} \end{bmatrix}$$

With

Question b):

For each equilibrium position, determine whether or not it is stable.

q_0^1 is unstable, since det($\underline{K_0}$) evaluated at q_0^1 is smaller than 0.
q_0^2 is stable, since det($\underline{K_0}$) evaluated at q_0^2 is bigger than 0.

Where $\underline{K_0} = \left(\underline{V_q}\right)_{\underline{q}} = \begin{bmatrix} k_h & 0 \\ 0 & m_3 g(L_2 sin(\varphi_2)) \end{bmatrix}$, evaluated at q_0^i, with $i \in \{1,2\}$

Question c):

Linearize the equations of motion, that are computed in question e of deliverable 1, around one stable and (if it exists) one unstable equilibrium position. This, by utilizing the “Linearize” request within the

For q_0^2 (stable):

$$M = \begin{bmatrix} 4000 & 20000 \\ 20000 & 200000 \end{bmatrix}$$

```
[           m2 + m3, L2*m3*cos(phi1)]
[ L2*m3*cos(phi1),          L2^2*m3]
```

$$D = \begin{bmatrix} 200 & 0 \\ 0 & 20000 \end{bmatrix}$$

```
[ dh,        0]
[  0, L2^2*dW]
```

$$K = \begin{bmatrix} 8000 & 0 \\ 0 & 196200 \end{bmatrix}$$

```
[ kh,        0]
[  0, L2*g*m3]
```

For q_0^1 (unstable):

$$M = \begin{bmatrix} 4000 & -20000 \\ -20000 & 200000 \end{bmatrix}$$

```
[            m2 + m3, -L2*m3*cos(phi1)]
[ -L2*m3*cos(phi1),          L2^2*m3]
```

$$D = \begin{bmatrix} 200 & 0 \\ 0 & 20000 \end{bmatrix}$$

```
[ dh,        0]
[  0, L2^2*dW]
```

$$K = \begin{bmatrix} 8000 & 0 \\ 0 & -196200 \end{bmatrix}$$

```
[ kh,         0]
[  0, -L2*g*m3]
```

DOMS toolbox. For each equilibrium position, add the symbolic expressions for M, D and K to this document. You may copy and paste the expressions from Matlab.

Question d):

Generate a time trajectory for each set of linear equations that are computed in question c, by utilizing the “Sim_Linear” request within the DOMS toolbox. Use the simulation conditions as described in the deliverable and add the requested plots here.

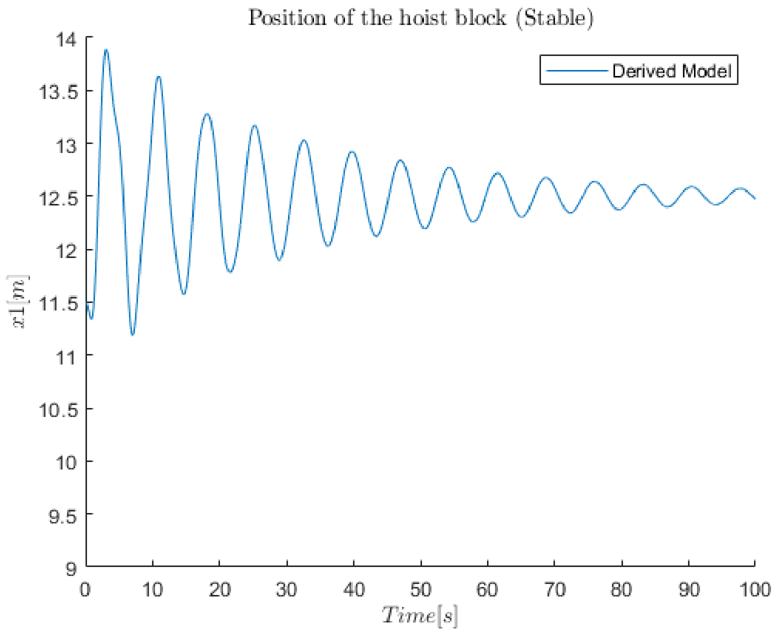

Figure 1: Position of the hoist block (linearized, stable)

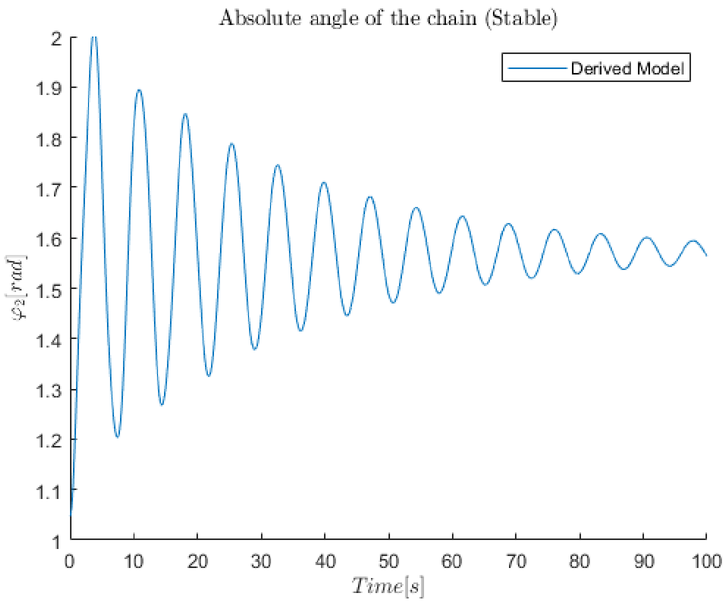

Figure 2: Absolute angle of the chain (linearized, stable)

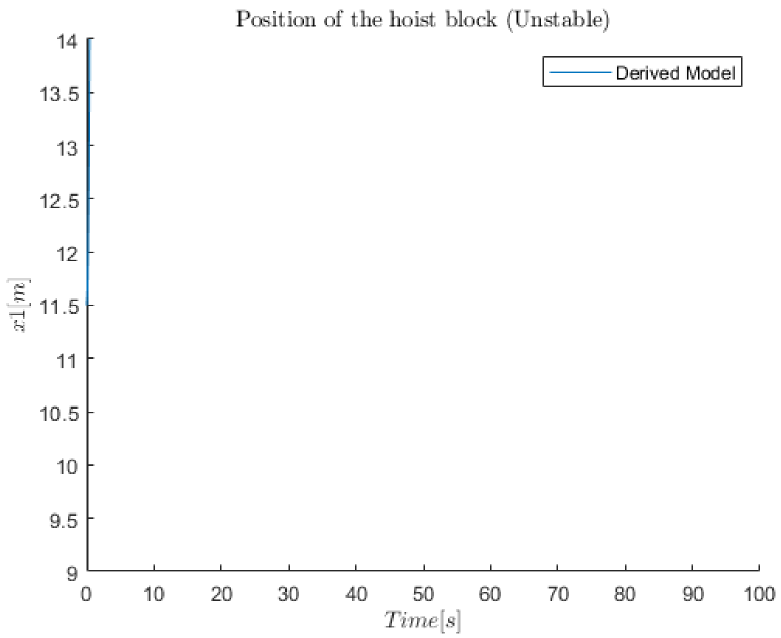

Figure 3: Position of the hoist block (linearized, unstable)

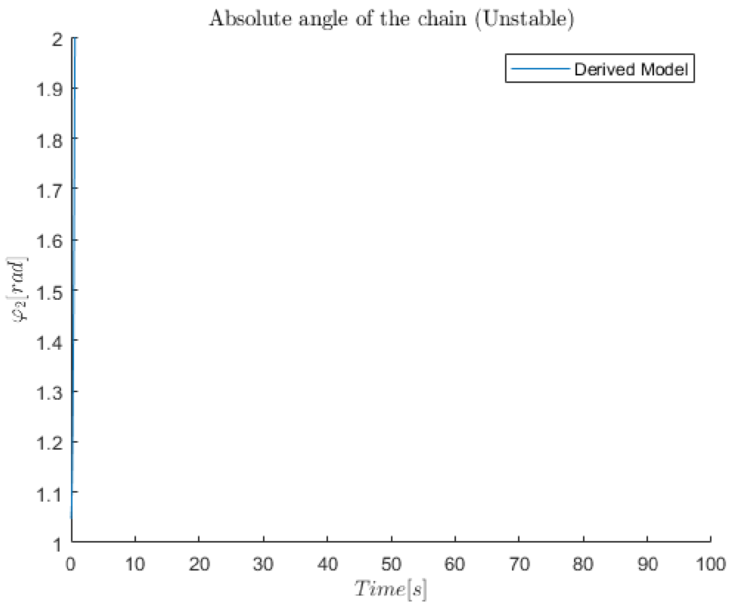

Figure 4: Absolute angle of the chain (linearized, unstable)

Question e):

How does each trajectory compare to the response of the "virtual test setup" and what conclusions can be drawn from this?

The figures below are the same as figure 1 till 4, but also show the trajectory of the virtual test setup ("Simulation" in the legend). (**NOTE: The s_{pd} of the virtual test setup also equals zero in these plots, which was not the case in deliverable 1)**

STABLE:

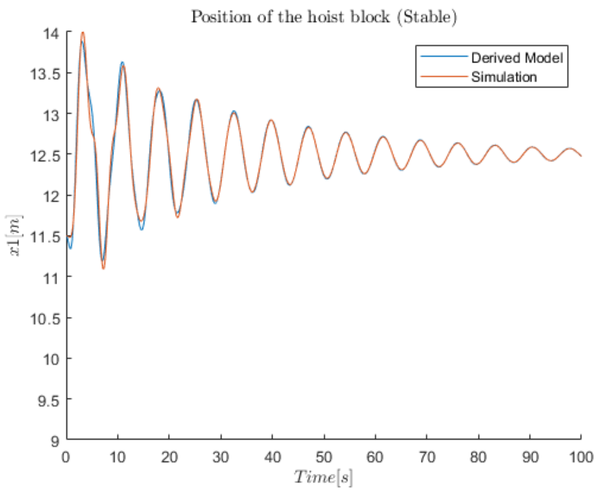

Figure 5: Figure 1 with nonlinear trajectory of Simulation

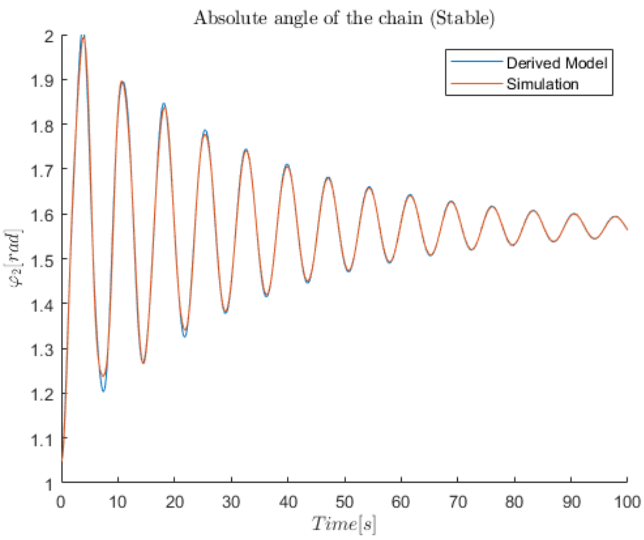

Figure 6: Figure 2 with nonlinear trajectory of Simulation

Concluded from figures 5 and 6 can be, that the EOM linearized around a stable EP is an quite accurate, but visibily not perfect, representation of the actual dynamic system we are describing.

UNSTABLE:

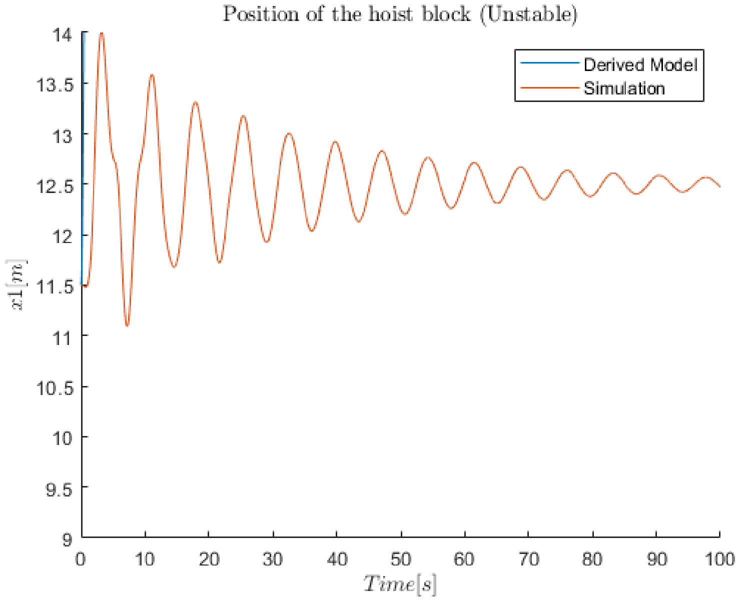

Figure 7: Figure 3 with nonlinear trajectory of Simulation

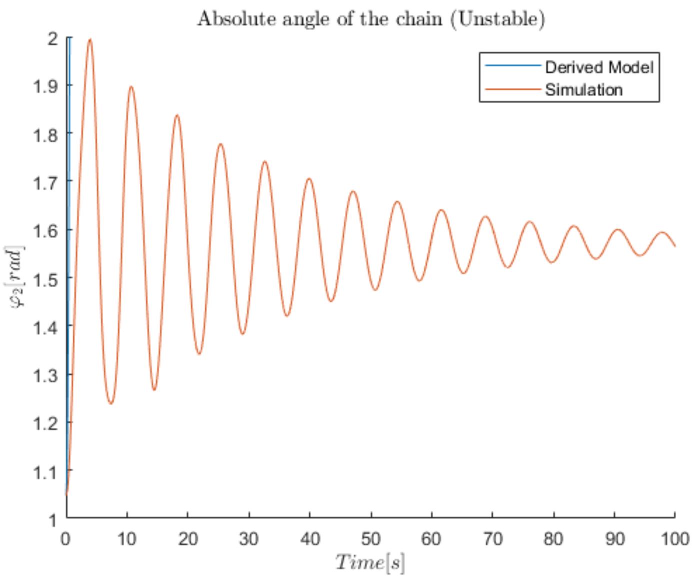

Figure 8: Figure 4 with nonlinear trajectory of Simulation

What is immediately noticeable, is that the trajectories are entirely different. The time trajectory of the derived model is a line with a very high slope. This can easily be explained by the fact that both EP's are unstable. We can draw here the conclusion that using unstable EP's for linearization gives us a bad linearization (it does not represent the nonlinear EOM anymore).