Delft University of Technology

Biomedical Engineering
BM41040

Neuromechanics & Motor Control Assignment 5

Authors:

Janneke Blok 4300408
Jessie van Dam 4395832

June 5, 2020

Question 1

A

B

C

Question 2

B

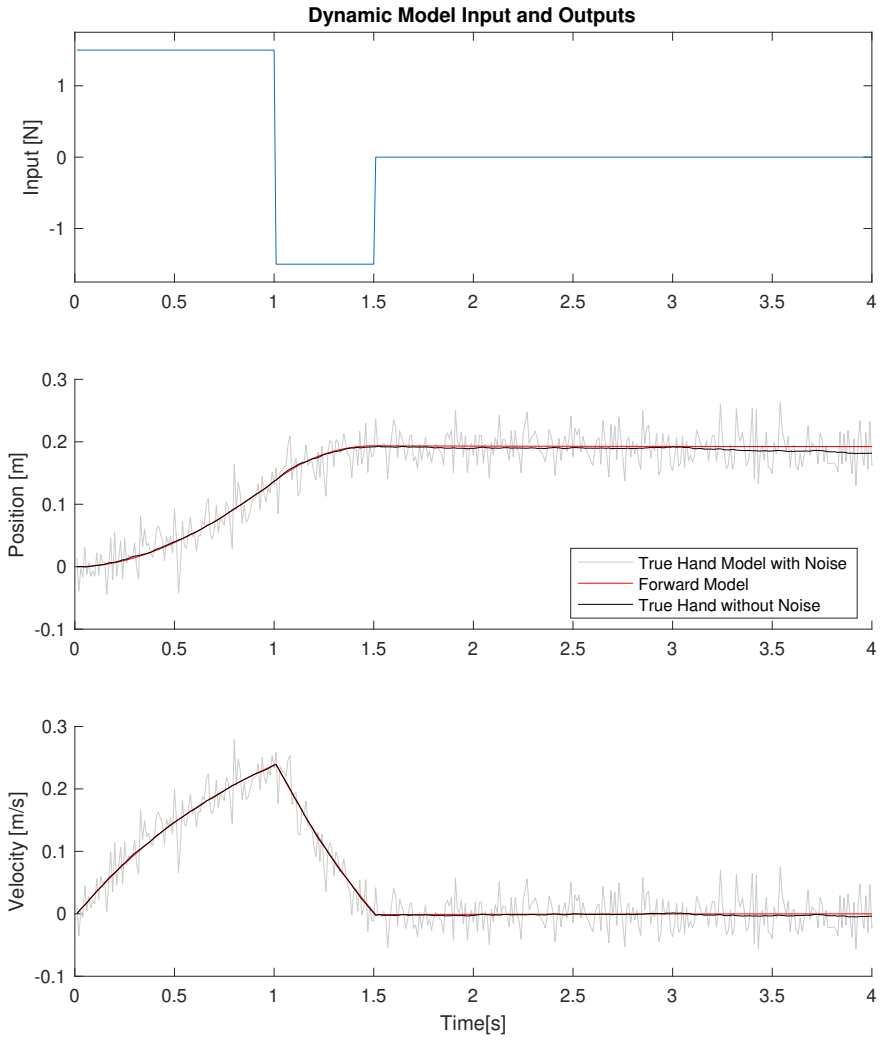

Figure 1: Input force F and the resulting movement

Question 3

A

```
1 %% 3) Initialize Covariance and State Estimates
2
```

```
xPrioriArray(1,:) = A*x0+B*u0;
pPriori = A*P0*A.'+Q;
pPrioriArray(1,:,:) = pPriori;

%% 4) Run the Kalman Filter


for i = 1:(length(u)-1)
    M = pPriori*C.'/(C*pPriori*C.'+R);
    MArray(i,:,:) = M;
    xPosterioArray(i,:) = xPrioriArray(i,:)+(M*(Z(i,:).'-C*xPrioriArray(i,:).')).';
    pPosterio = pPriori-M*C*pPriori;
    pPosterioArray(i,:,:) = pPosterio;

    xPrioriArray(i+1,:) = (A*xPosterioArray(i,:).').'+B.'*u(i,:);
    pPriori = A*pPosterio*A.'+Q;
    pPrioriArray(i+1,:,:) = pPriori;
end
```

B

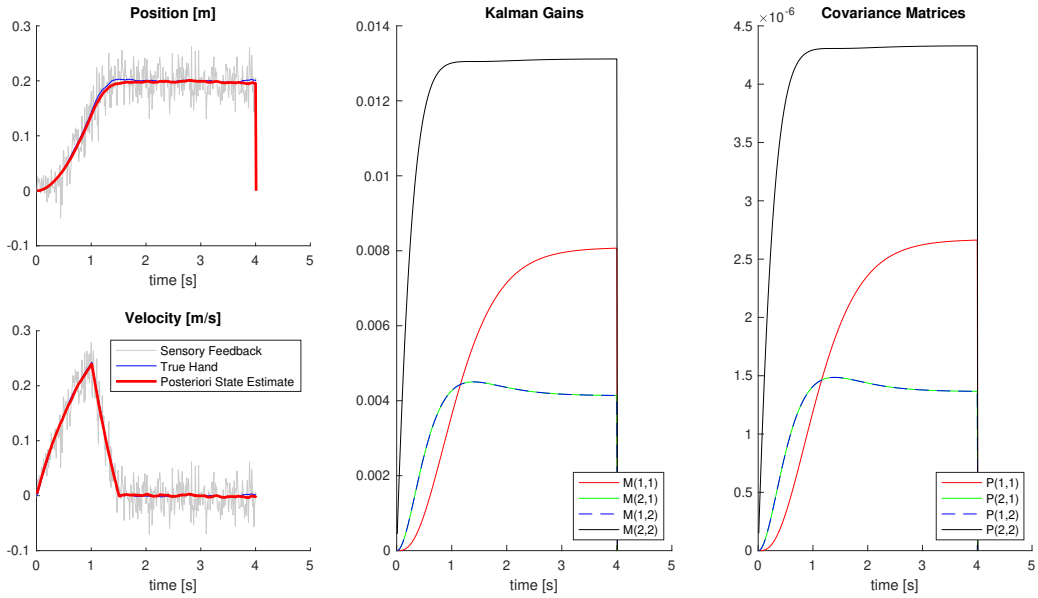

Figure 2: Simulation of movement with Kalman filter to estimate hand position

Question 4

A

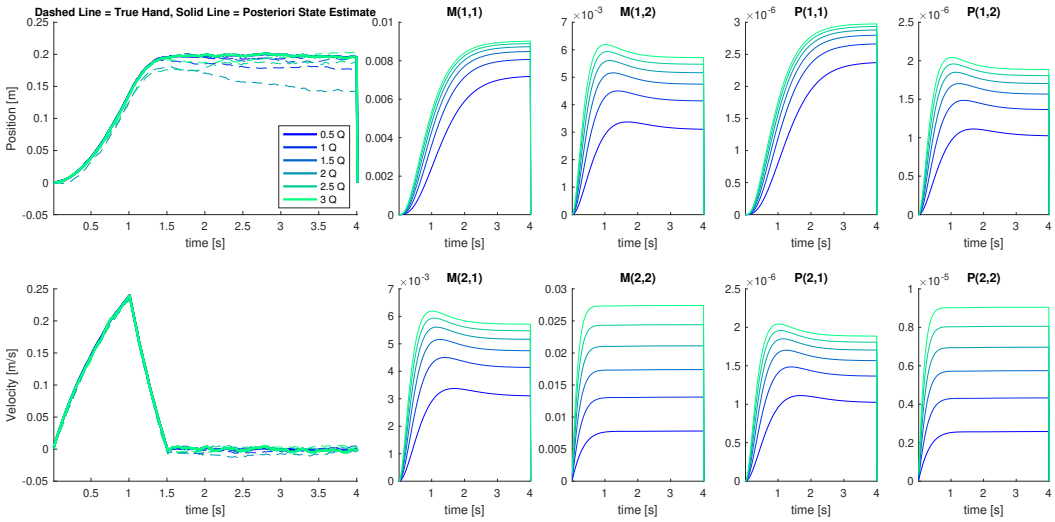

Figure 3: Investigation of the effect of different levels of Q by running the Kalman filter for a range between 0% and 300% of the initial value of Q

B

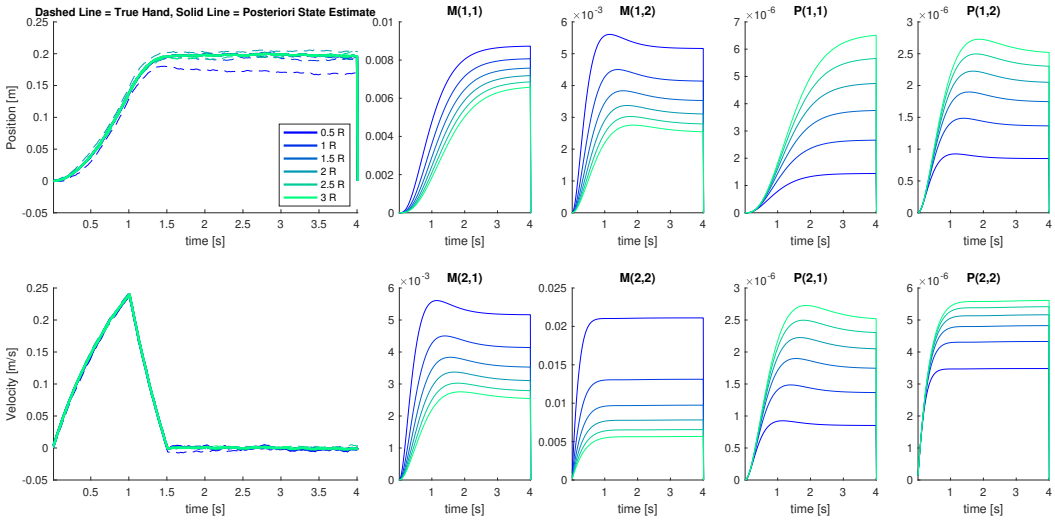

Figure 4: Investigation of the effect of different levels of R by running the Kalman filter for a range between 0% and 300% of the initial value of R

Question 5

A

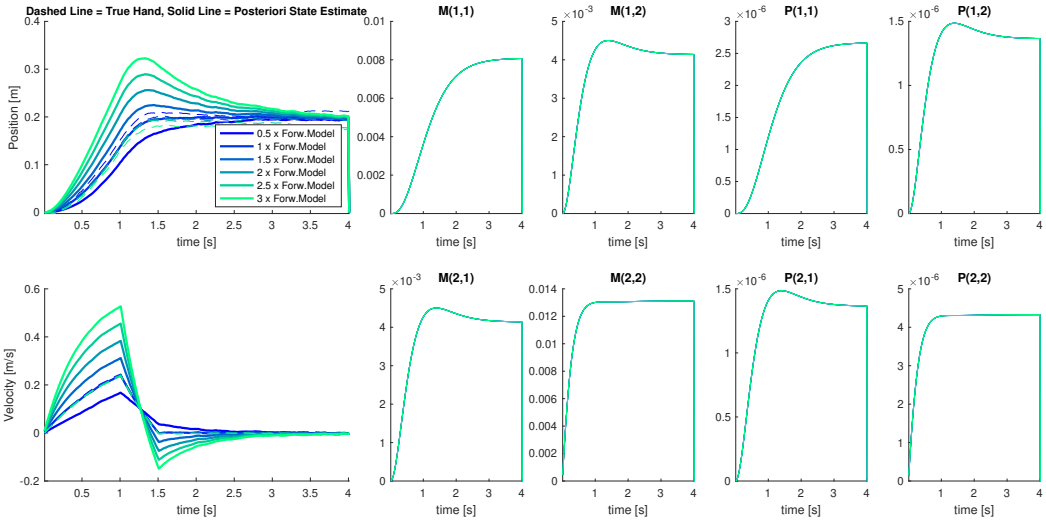

Figure 5: Investigation of the effect of different settings for the forward model gain factor g: position and velocity profiles

Question 6

A

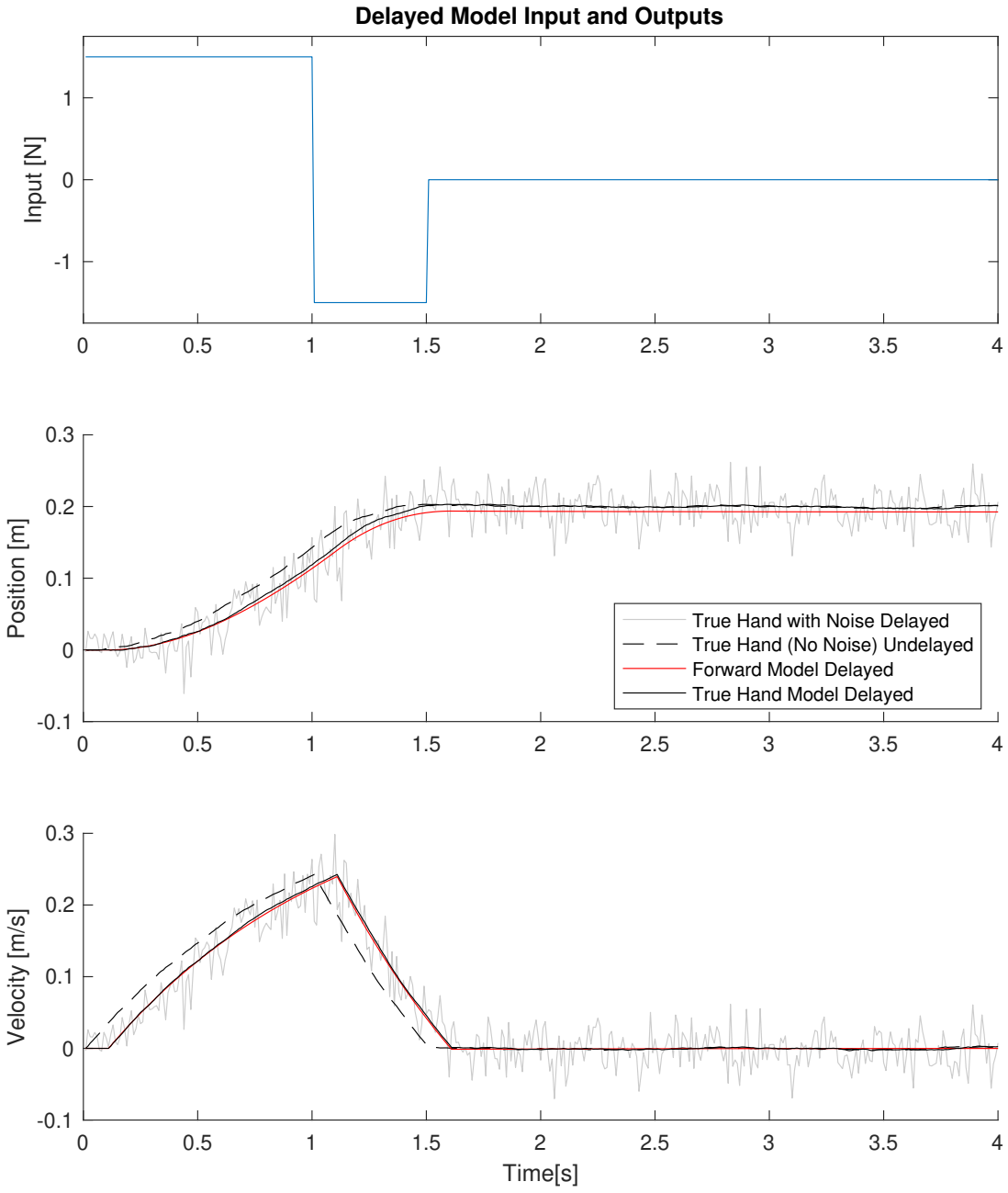

Figure 6: The delayed movement, with d the delay in number of time steps

B

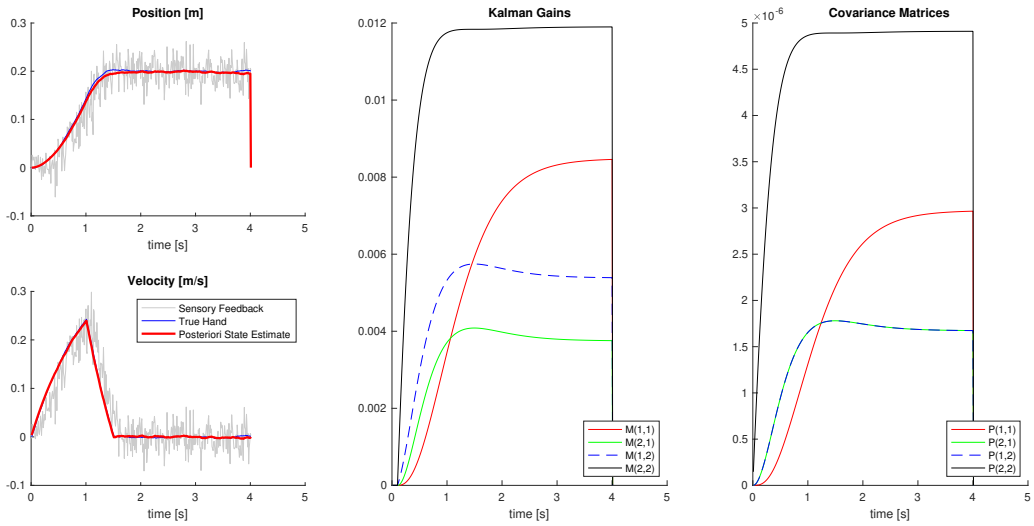

Figure 7: The Kalman filter with the delayed model

C

To design an experiment with delayed feedback of body state, either the visual, proprioceptive or sensory feedback must be removed. It is chosen to remove visual feedback by doing an experiment where the subject must move a certain object from point A to point B, without actually seeing the movements he makes with his hand. The results of the experiments in terms of hand position measured are compared with the estimation of the hand position computed with the a-posteriori state estimates with the Kalman filter.