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Laboratory Exercise 3
Learning Quadcopter Flight Dynamics

Answer to Task 1: Estimating k

Selecting a sine wave signal as input, tests were conducted on three systems, and the results are as follows.

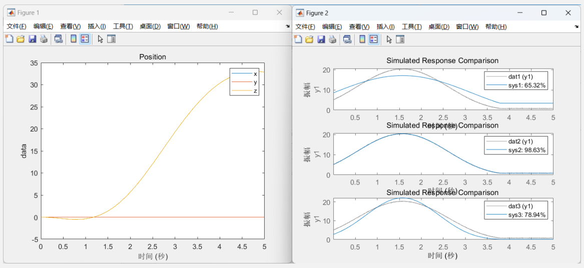


Figure 1: Task1 plot

Estimate k based on the simulation results, and the results are as follows.

```
k_est =

   2.2004e-08


k =

   2.2000e-08
```

Figure 2: Task1 result

```
%%
Omega_in.time = (0:inner_h:10)';
% 500 < Omega_in.signals.values < 2500
%Omega_in.signals.values = 1000*ones(length(Omega_in.time),1)*ones(1,4) %You will ...
    need to change ones to something better, HINT linspace
Omega_in.signals.values = 1250*(sin(Omega_in.time)+1)*ones(1,4)
%Omega_in.signals.values = zeros(length(Omega_in.time),1)*ones(1,4)


k_est = sys2.kp * m
```

Answer to Task 2: Estimating I3 and b

It's not possible to solve for both b and I3 simultaneously because if both b and i3 are unknowns, the system of equations has no solution.

Use I(3) and the result of simulation to estimate b , the plots are shown as follows.

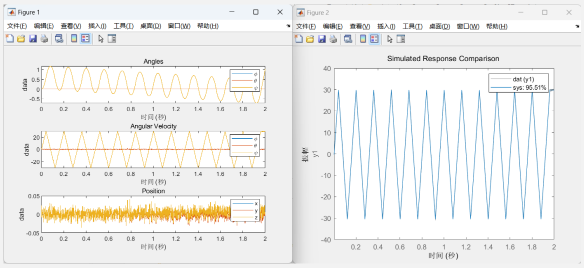
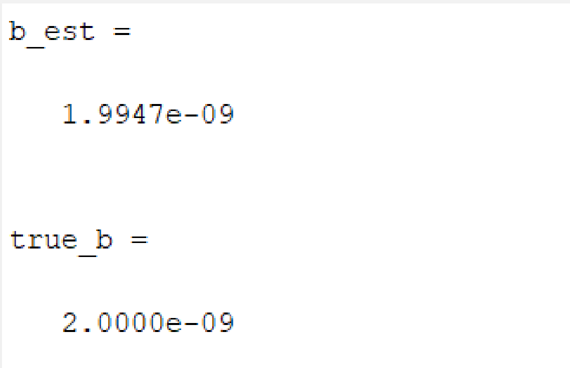


Figure 3: Task2 plot

The estimation of b is shown as follow.



```
b_est =

   1.9947e-09


true_b =

   2.0000e-09
```

Figure 4: Task2 b result

```
%%
c = 5 %TODO change
%Omega1 = TODO, calculate as a function of c
Omega1 = sqrt((m*g)/(2*k*(c^2+1)));
Omega2 = c*Omega1;
Omega = [Omega1 Omega2 Omega1 Omega2];
Omega_in.time = (0:inner_h:2)';
nbr_samples = length(Omega_in.time);
Omega_in.signals.values = zeros(nbr_samples,4);
segments = 25; %TODO change to something better
segment_size = floor(nbr_samples/segments)
switch_time = [floor(segment_size/2):segment_size:nbr_samples, nbr_samples]

u=-2*Omega1^2+2*Omega2^2;
% b_est = abs((max(Psidot)-min(Psidot))/(2/segments)/u*I(3))
b_est =sys.kp *I(3)
```

Answer to Task 3: Estimating I1 and I2

Construct a suitable iddata object and choose a suitable model structure. The simulation results are shown as follows.

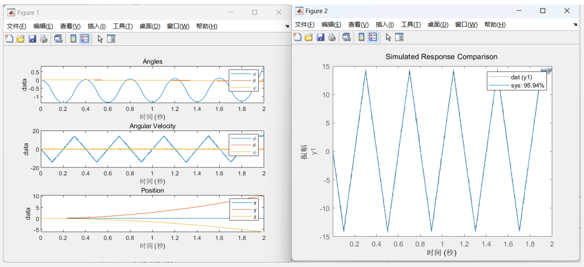
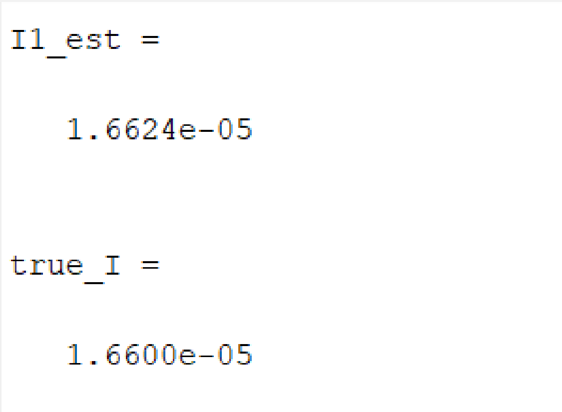


Figure 5: Task3 plot

Estimate I1(=I2) based on the simulation results, and the results are as follows.


I1_est =

1.6624e-05

true_I =

1.6600e-05

Figure 6: Task3 I1/I2 result

```
Omega_H = sqrt((m*g)/(4*k)); %TODO
c = 1.5; %TODO
Omega2 = sqrt((2*(Omega_H^2))/(1+c^2)); %TODO
Omega4 = c*Omega2;
Omega_in.time = (0:inner_h:2)';
nbr_samples = length(Omega_in.time);
Omega_in.signals.values = zeros(nbr_samples,4);
segments = 10; %TODO
segment_size = floor(nbr_samples/segments)
switch_time = [floor(segment_size/2):segment_size:nbr_samples, nbr_samples]

u=-Omega2^2+Omega4^2;
I1_est = (k*l)/sys.kp
```

Answer to Task 4: Closing the Loop

Set y_ref = 0.1, the simulation results are shown as follows.

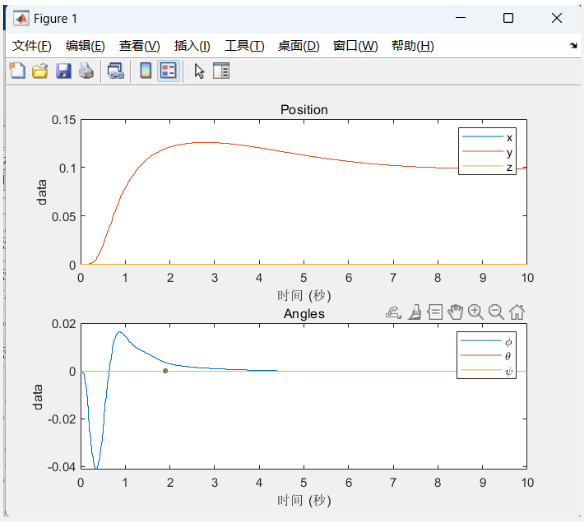


Figure 7: Task4 result

Answer to Task 5: Estimating a Disturbance Model

Set R = 10,put [2,1] into the model structure, the coefficient of the denominator of the simulation result is most approach the 'wind.denum',which is [1,0.05708,0.9511]

```
%% From wind
 R = 10;%TODO might be needed to change
% R = 3;
y_acc = out.acc.data(:,2);
Ft = out.T.data.*sin(out.eta.data(:,1));
wind_force_est = m*y_acc-Ft;
dat = iddata(wind_force_est(1:R:end),[],sample_time*R);
opts = armaxOptions;
armax2 = armax(dat,[2 1]) %TODO select suitable model structre
figure(1)
clf
compare(dat,armax2,3)
```

Figure 8: Task5 code

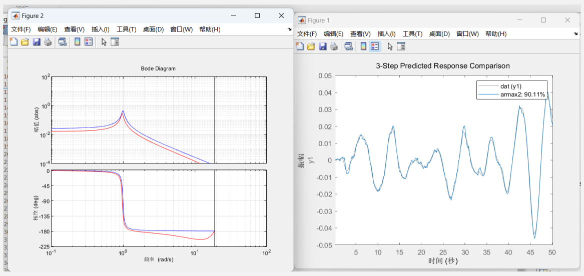


Figure 9: Task5 R=10

```
ans =

     1.716 s + 51.88
  -----------------------
  s^2 + 0.05708 s + 0.9511

Continuous-time transfer function.
```

Figure 10: Task5 transfer function

But then I notice that the Bode plot obtained from the simulation is not similar to the original system, especially in the high-frequency region. And the highest degree of the polynomials in the numerator is different. So I set R = 3, and get a better result.

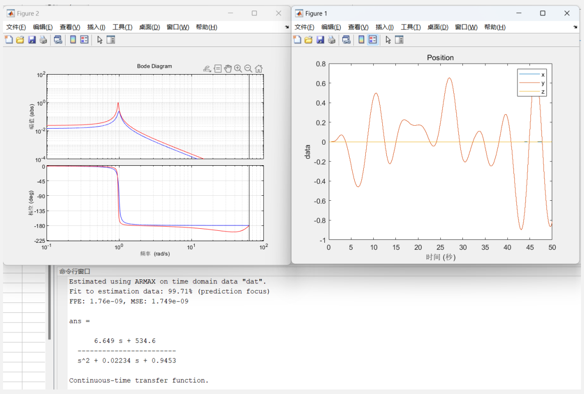


Figure 11: Task5 R=3

Answer to Task 6: Using the Disturbance Model in a control design

Since the structure of the transfer function is $\frac{\omega_0^2}{x^2+2\epsilon\omega_0+\omega_0^2}$,use [1,0.05708,0.9511] to calculate ω_0 and ϵ Insert $\omega_0 = 0.9752$ and $\epsilon = 0.0293$ into design_LQG.m, run the control synthesis and run the simulation.

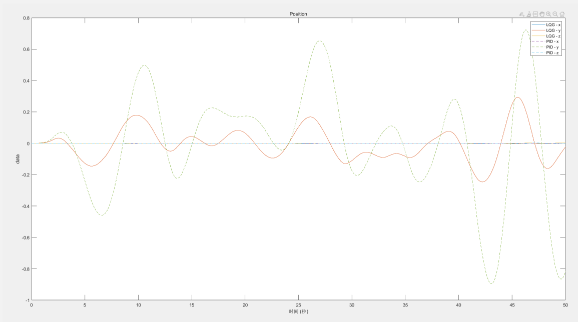


Figure 12: Task6