TP - Segway

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```
clear vars; clc;
```

Parameters

```
g = 9.81;
l = 1;
m = 1;
M = 5;
T = 0;
F = 0;
```

Initial condition

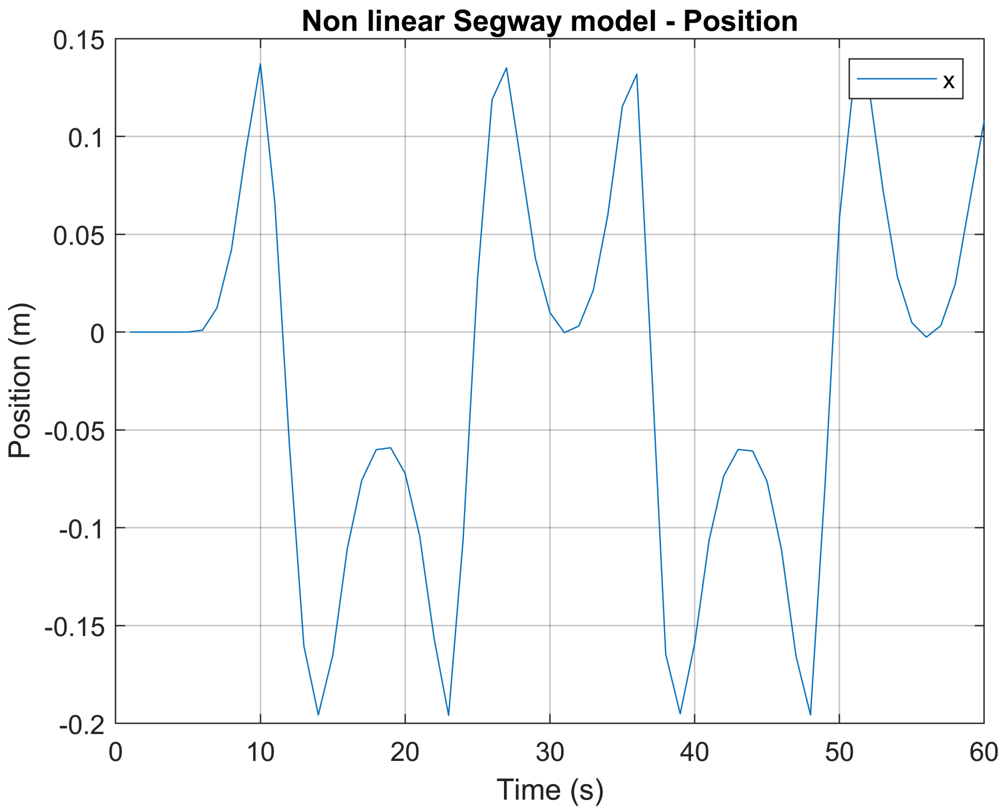
```
X0 = [0; 0; pi/18; 0]; % Non linearized model
X0lin0 = [0; 0; 5*pi/180; 0]; % Linearized around 0
X0To0 = [1; 0; 0; 0]; % First pole placement
X0ToPos = [0; 0; 0; 0]; % Second Pole placement
FromX0Spd = [0.1; 0; 0; 0]; % Third polce placement
```

Targets

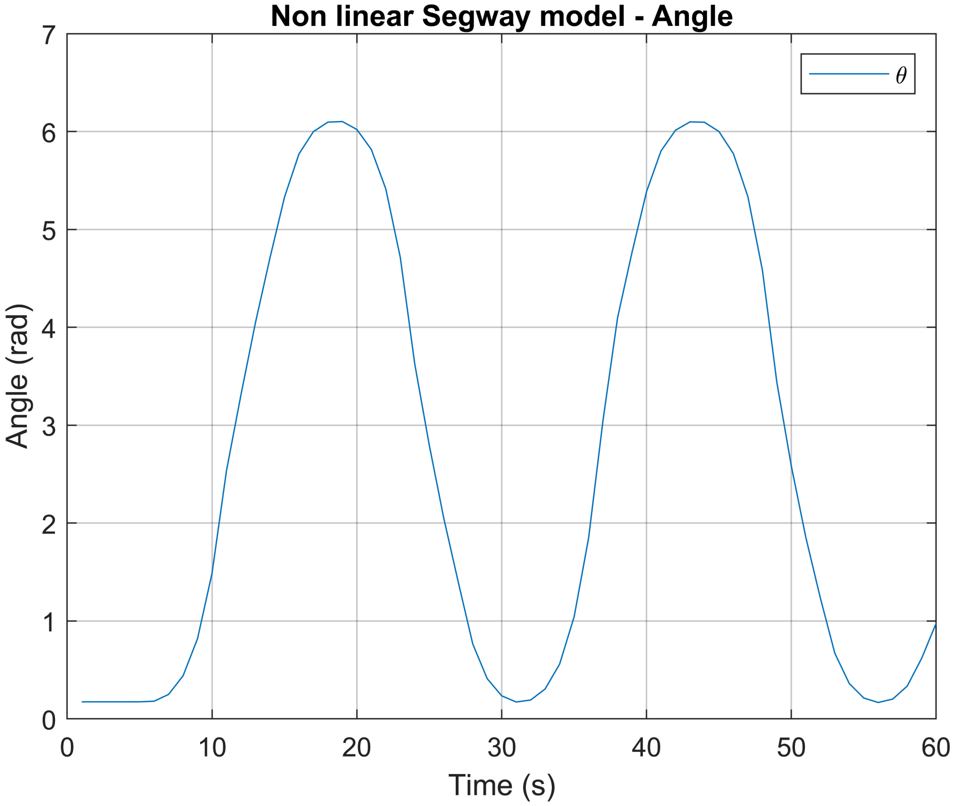
```
TargetPP1 = [0; 0; 0; 0]; % Pole placement 1, from a position to 0
TargetPP2 = [1; 0; 0; 0]; % Pole placement 2, from 0 to a position
TargetPP3 = [10; 100; 0; 0]; % Pole placement 3, from 0 to a position
```

Non linear segway

```
simu = sim("SegwayModel");
figure()
plot(simu.nonlinvalues(:, 1)); % Plot x
legend('x');
xlabel("Time (s)")
ylabel("Position (m)")
grid on;
title("Non linear Segway model - Position")
```



```
figure()
plot(simu.nonlinvalues(:, 3)); % Plot theta
xlabel("Time (s)")
ylabel("Angle (rad)")
legend('{\theta}');
grid on;
title("Non linear Segway model - Angle")
```



Linearized around $\theta = 0$

```
A = [0 1 0 0
    0 0 m*g/M 0
    0 0 0 1
    0 0 (M+m)*g/(M*l) 0]
```

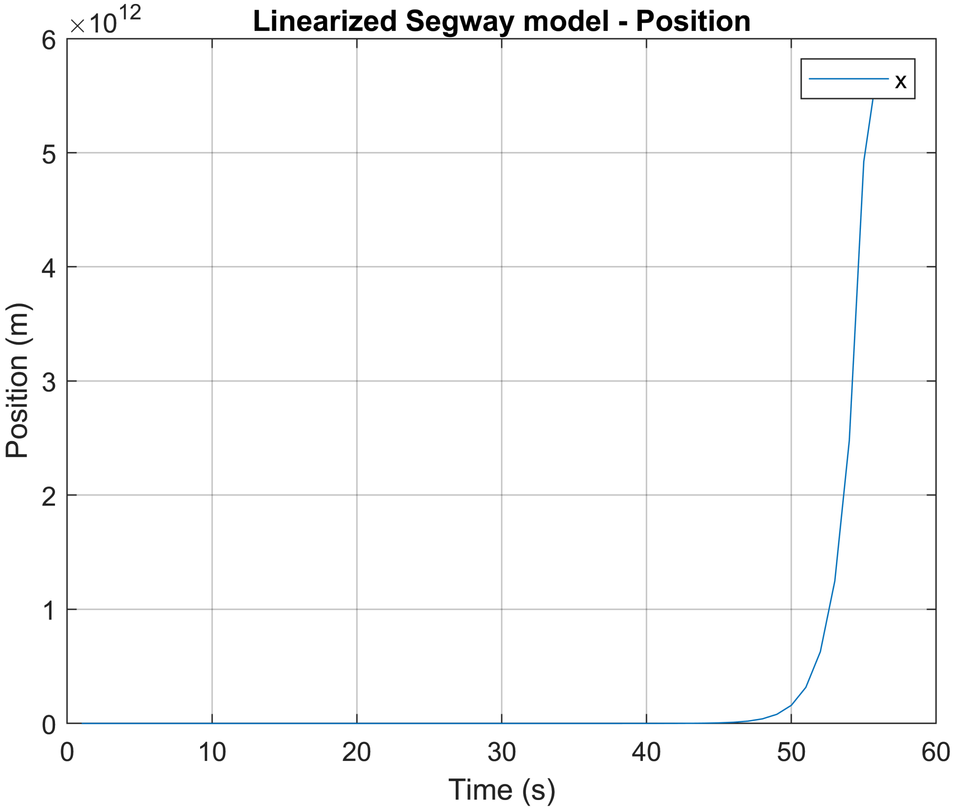
```
A = 4×4
         0    1.0000         0         0
         0         0    1.9620         0
         0         0         0    1.0000
         0         0   11.7720         0
```

```
B = [0 0
    l/m 1/M
    0 0
    (m+M)/(m*M*l^2) 1/(M*l)]
```

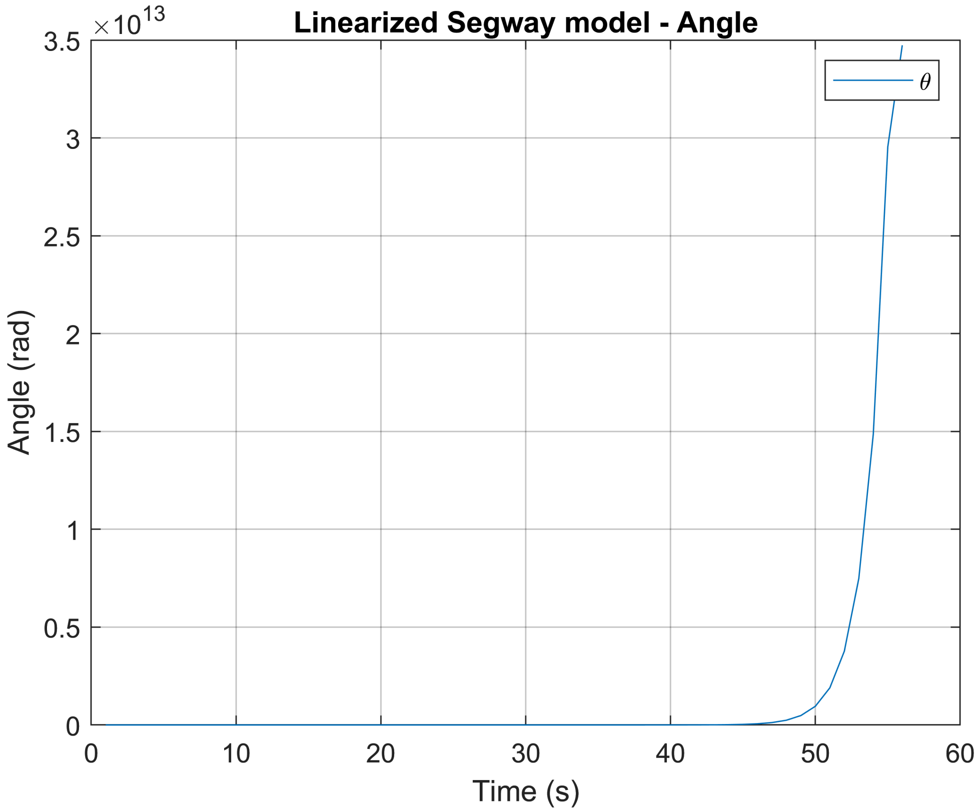
```
B = 4×2
         0         0
    1.0000    0.2000
         0         0
    1.2000    0.2000
```

```
C = [1 0 0 0
     0 0 0 0
     0 0 1 0
     0 0 0 0];
D = [0 0
    0 0
    0 0
    0 0];

simuLin0 = sim("SegwayModelLinearized0");
figure()
plot(simuLin0.lin0values(:, 1)); % Plot x
legend('x');
xlabel("Time (s)")
ylabel("Position (m)")
grid on;
title("Linearized Segway model - Position")
```



```
figure()
plot(simuLin0.lin0values(:, 3)); % Plot theta
xlabel("Time (s)")
ylabel("Angle (rad)")
legend('{\theta}');
grid on;
title("Linearized Segway model - Angle")
```



Pole placement

```
CtrSys = ctrb(A, B)
```

```
CtrSys = 4×8
         0         0    1.0000    0.2000         0         0    2.3544    0.3924
    1.0000    0.2000         0         0    2.3544    0.3924         0         0
         0         0    1.2000    0.2000         0         0   14.1264    2.3544
    1.2000    0.2000         0         0   14.1264    2.3544         0         0
```

```
[n, m] = size(CtrSys)
```

```
n = 4
m = 8
```

```
if rank(CtrSys) == min(n, m)
    fprintf('Controllable')
end
```

```
Controllable
```

```
p = [-1, -2, -3, -4];
K = place(A, B, p)
```

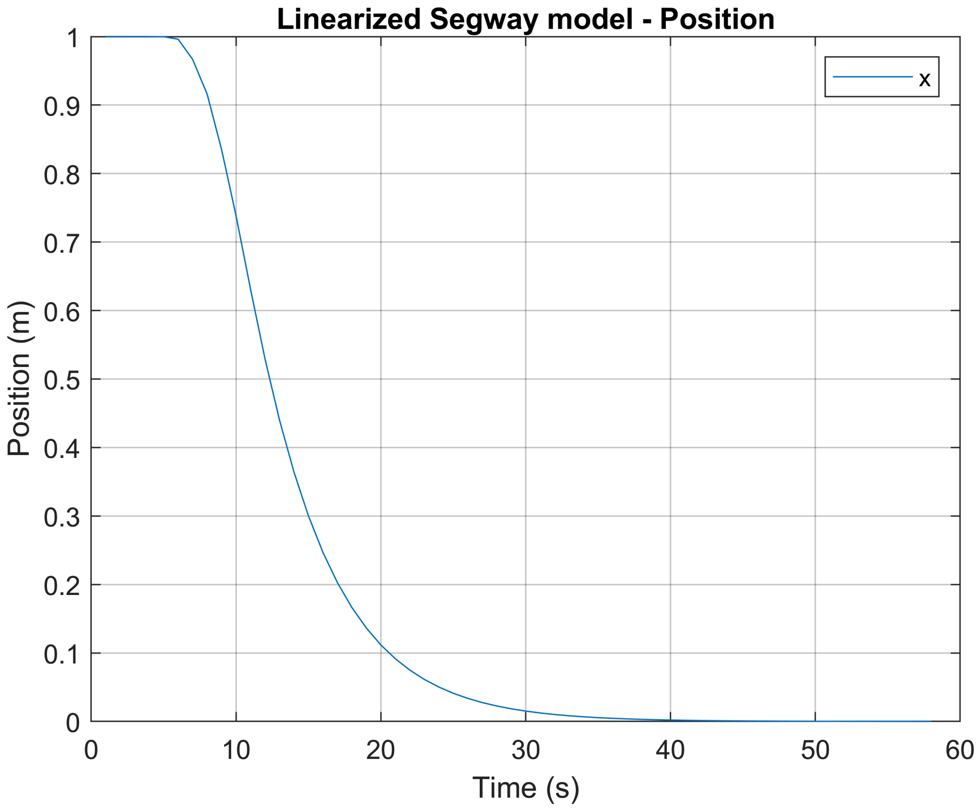
```
K = 2×4
  -14.4135  -19.7484   88.2390   29.6743
   87.0866  118.7500 -430.5934 -148.0540
```

```
Acl = A-B*K;
syscl = ss(Acl, B, C, D);
```

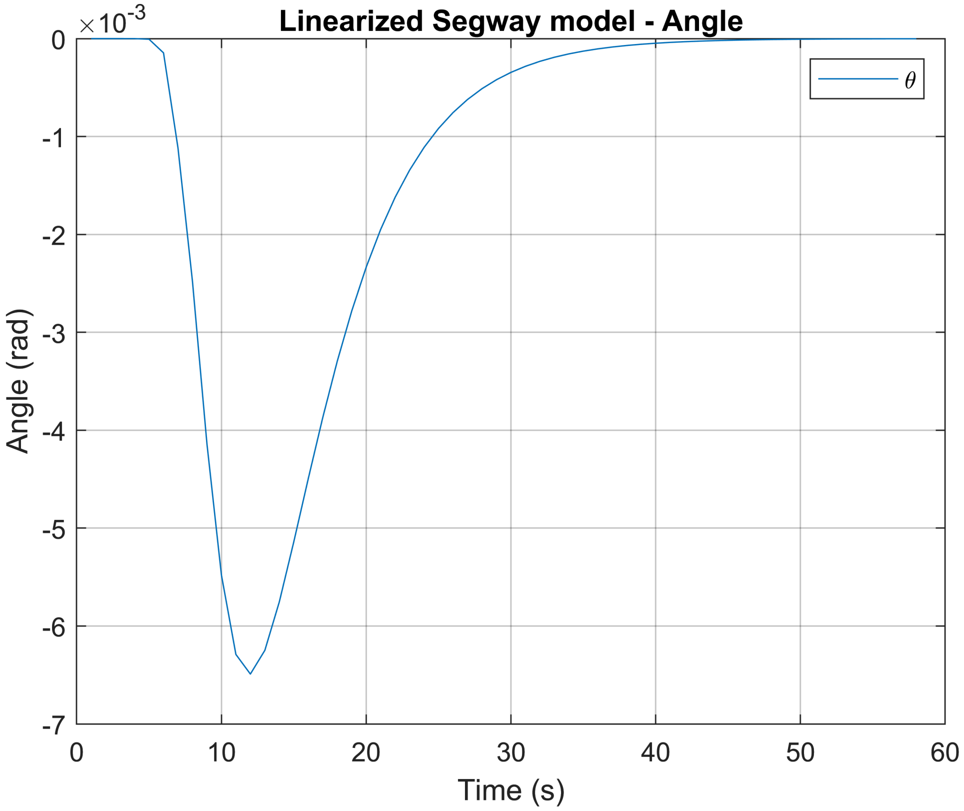
```
Kr = pinv(dcgain(syscl))
```

```
Kr = 2×4
  -14.4135         0   39.1890         0
   87.0866         0 -195.1534         0
```

```
simuLin0ctr = sim("SegwayLinearized0Controlled");
figure()
plot(simuLin0ctr.lin0ctr(:, 1)); % Plot x
legend('x');
xlabel("Time (s)")
ylabel("Position (m)")
grid on;
title("Linearized Segway model - Position")
```

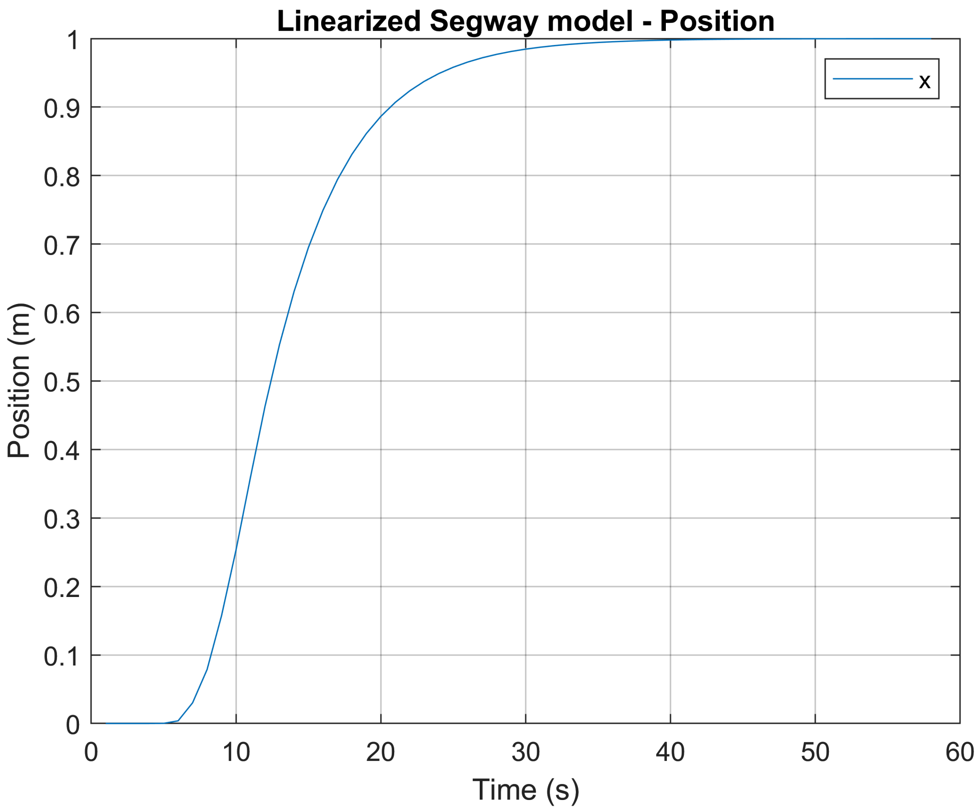


```
figure()
plot(simuLin0ctr.lin0ctr(:, 3)); % Plot theta
xlabel("Time (s)")
ylabel("Angle (rad)")
legend('{\theta}');
grid on;
title("Linearized Segway model - Angle")
```

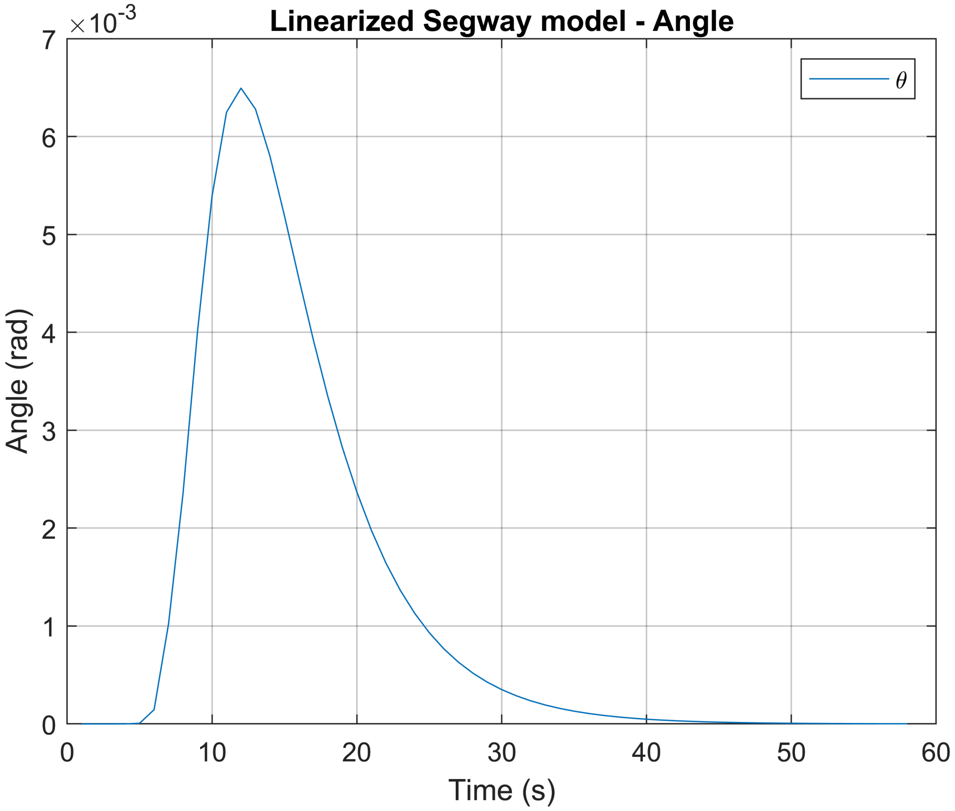


Pole placement - To another position

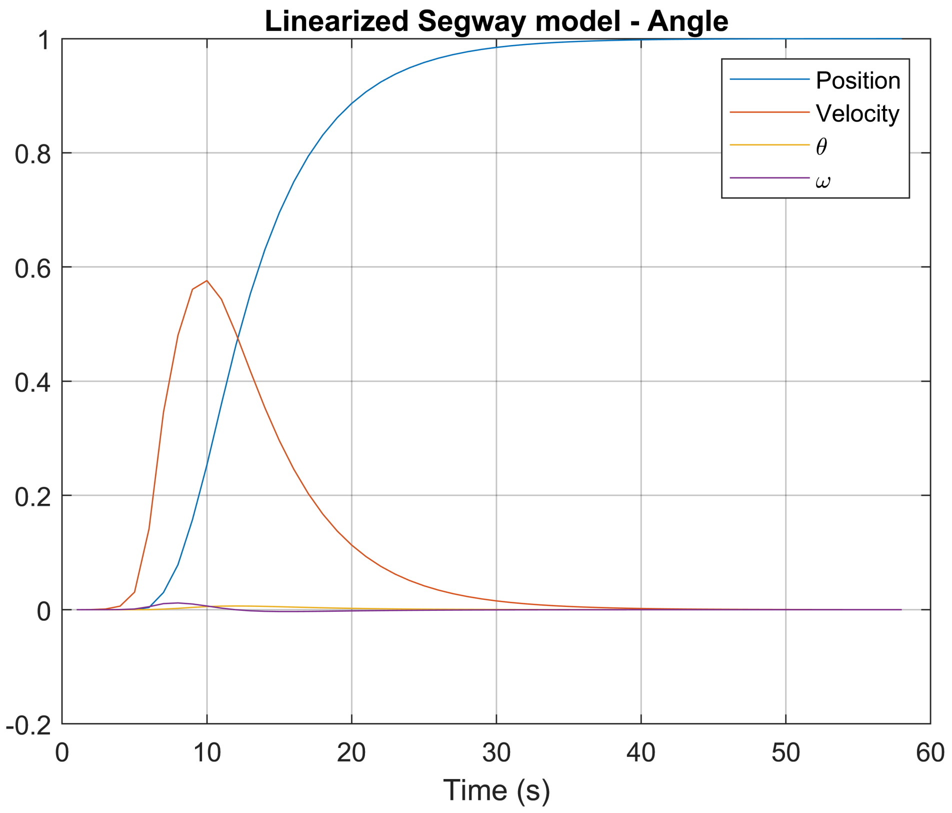
```
simuPos = sim("SegwayControlledNot0");
figure()
plot(simuPos.values(:, 1)); % Plot x
legend('x');
xlabel("Time (s)")
ylabel("Position (m)")
grid on;
title("Linearized Segway model - Position")
```



```
figure()
plot(simuPos.values(:, 3)); % Plot theta
xlabel("Time (s)")
ylabel("Angle (rad)")
legend('{\theta}');
grid on;
title("Linearized Segway model - Angle")
```



```
figure()
plot(simuPos.values(:, 1)); % Plot x
hold on;
plot(simuPos.values(:, 2)); % Plot v
plot(simuPos.values(:, 3)); % Plot theta
plot(simuPos.values(:, 4)); % Plot thetadot
hold off;
legend('{Position}', '{Velocity}','{\theta}',  '\omega')
xlabel("Time (s)")
grid on;
title("Linearized Segway model - Angle")
```



Pole placement - Constant speed

```
C = [0 0 0 0
    0 1 0 0
    0 0 0 0
     0 0 0 0];
A = linmod('SegwayModel')
```

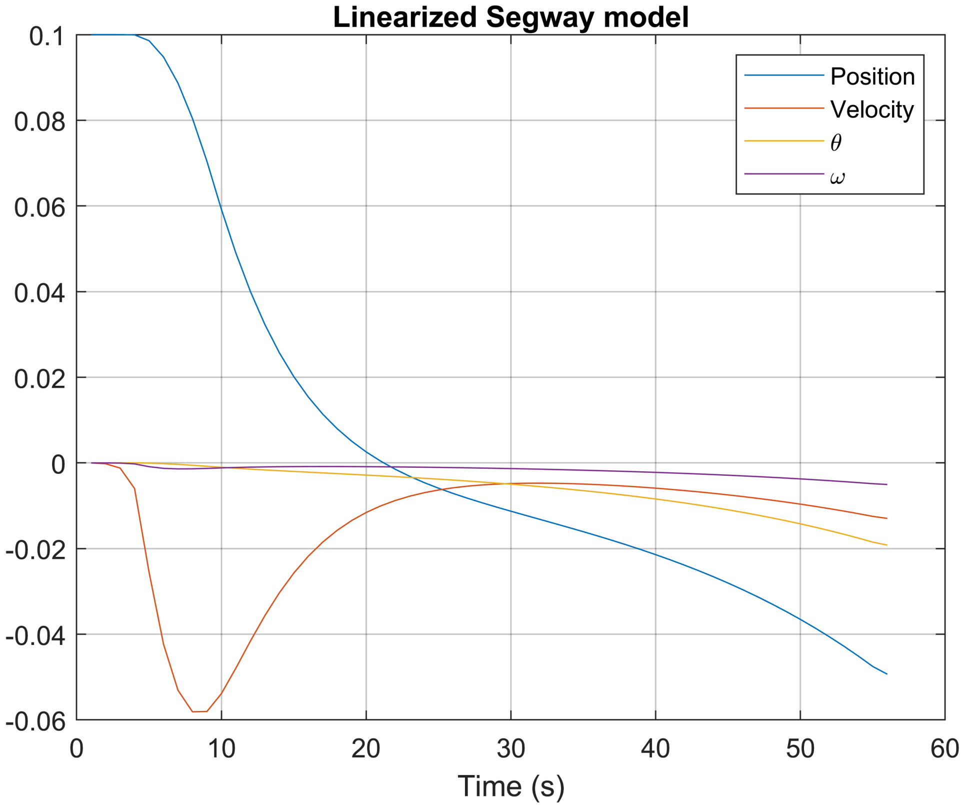
```
A = struct with fields:
                a: [4×4 double]
                b: [4×0 double]
                c: [0×4 double]
                d: []
        StateName: {4×1 cell}
       OutputName: {0×1 cell}
        InputName: {0×1 cell}
        OperPoint: [1×1 struct]
               Ts: 0
```

```
A = A.a
```

```
A = 4×4
         0    1.0000         0         0
         0         0   12.7338         0
         0         0         0    1.0000
         0         0   21.7567         0
```

```
Acl = A-B*K;
syscl = ss(Acl, B, C, D);
Kr = pinv(dcgain(syscl))
Kr = 2×4
     0     0     0     0
     0     0     0     0
```

```
simuV = sim("SegwayControlledV");
figure()
x = plot(simuV.values(:, 1)); % Plot x
hold on;
xd = plot(simuV.values(:, 2)); % Plot x dot
th = plot(simuV.values(:, 3)); % Plot theta
thd = plot(simuV.values(:, 4)); % Plot omega
xlabel("Time (s)")
hold off;
legend('{Position}', '{Velocity}','{\theta}',  '\omega')
grid on;
title("Linearized Segway model")
```


Linearized Segway model
Position
Velocity
θ
ω
Time (s)