Disturbance Observation

also called a model regulator

a Robust Controls method applied to Mechatronic Systems

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with use of Robust Controls of Mechatronic Systems by Dr. Levent Guvenc

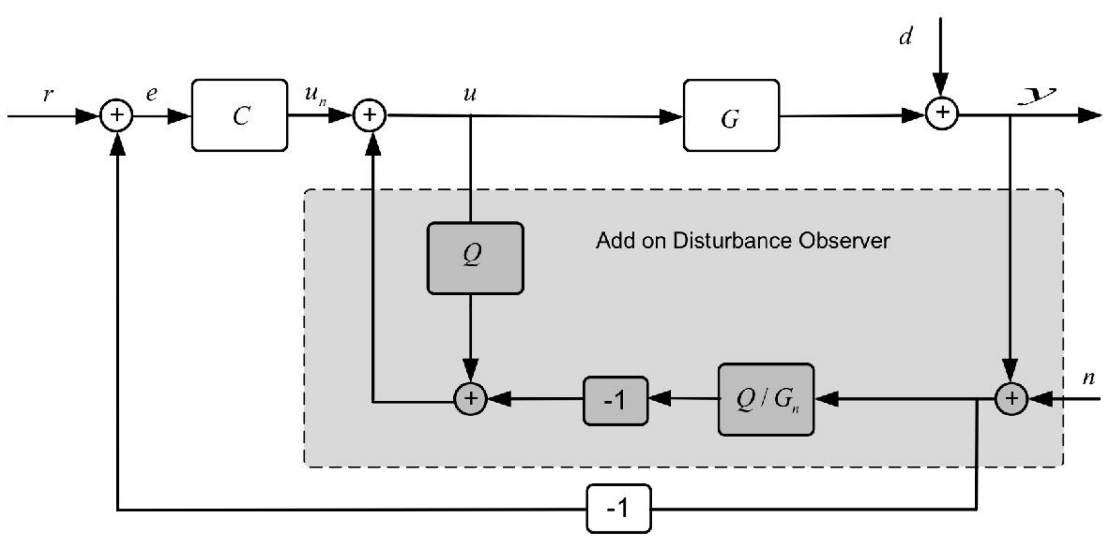
Previous work

The Qube servo plant used in this demonstrstion has been studied previously. During this previous work, time and frequency responses have been documented when implementing a variety of controller design methods. First, D-stability, margin bounds, and mixed sensitivity were used to achieve a multi-objective design by producing a controller parameter space. Next, analytical methods were used to produce a lead-lag and then PID controller - where the same procedures were repeated for numerous increases in the plant time constant.

Controls Background

Disturbance observation or Model regulation is a 2 DOF method that achieves insensitivity against modeling erros. Modeling erros are common due to order reduction, linearization, and parameter uncertainties. The disturbance observer, in addition to aiding modeling error, rejects disturbances within its bandwidth of operation.

Disturbance Observer




```
%The Nominal Plant
s = tf('s'); tau_n = 0.1; K_n = 28;
```

```
Gn = K_n / (tau_n*s + 1) % / s for the angular position plant
```

```
Gn =

     28
  ---------
  0.1 s + 1

Continuous-time transfer function.
```

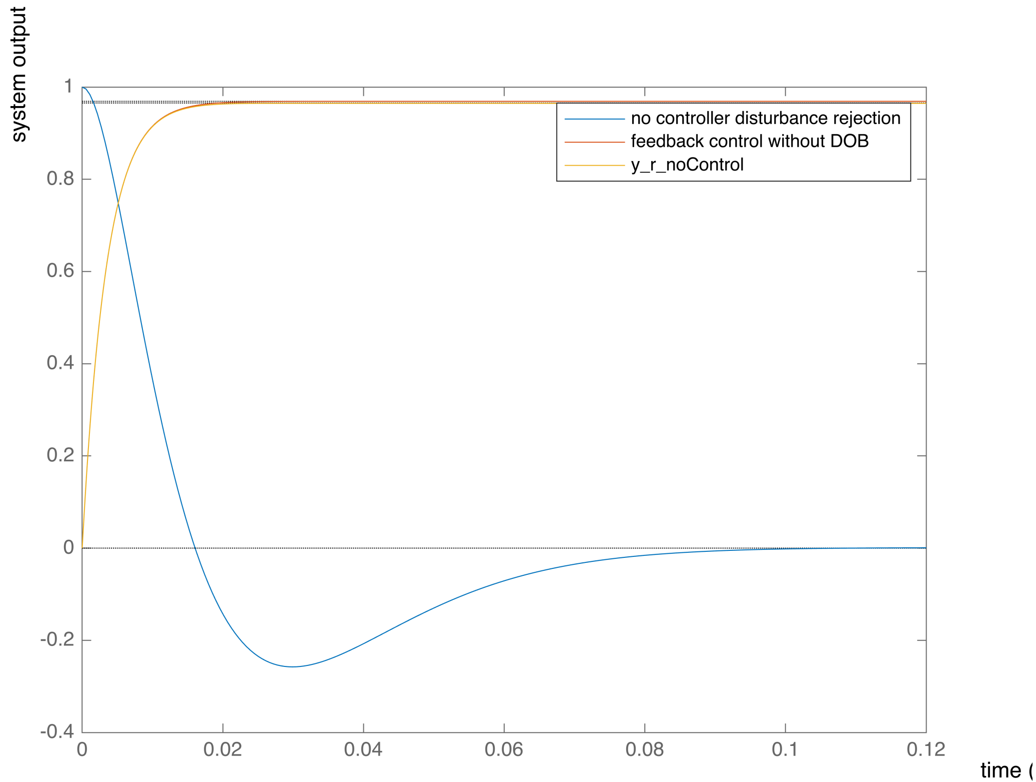
```
% 25% increase in parameters, "Unexpected" Actual Plant
increase = 1.12;
K = K_n * increase;
tau = tau_n * increase;
tau_d = 0;
G = K / (tau*s + 1) * exp(tau_d * s); %%%
uncertainty_bound = Gn/(G-Gn);

% Low pass unity gain
Qnum = 0.03 * s + 1; Qden = (0.01)^3*s^3 + 3*(0.01)^2*s^2 + 0.03*s + 1;
Q = Qnum / Qden;

% Controller
C = (1.122*s + 1)/(9.238*10^-5 + 1); % A Lead Controller from Previous Work
```

Disturbance Rejection

```
y_d = Gn*(1-Q)/(Gn*(1-Q)+G*Q); % disturbance rejection, no controller
disturbanceRejection(y_d,G)
```

Command Following

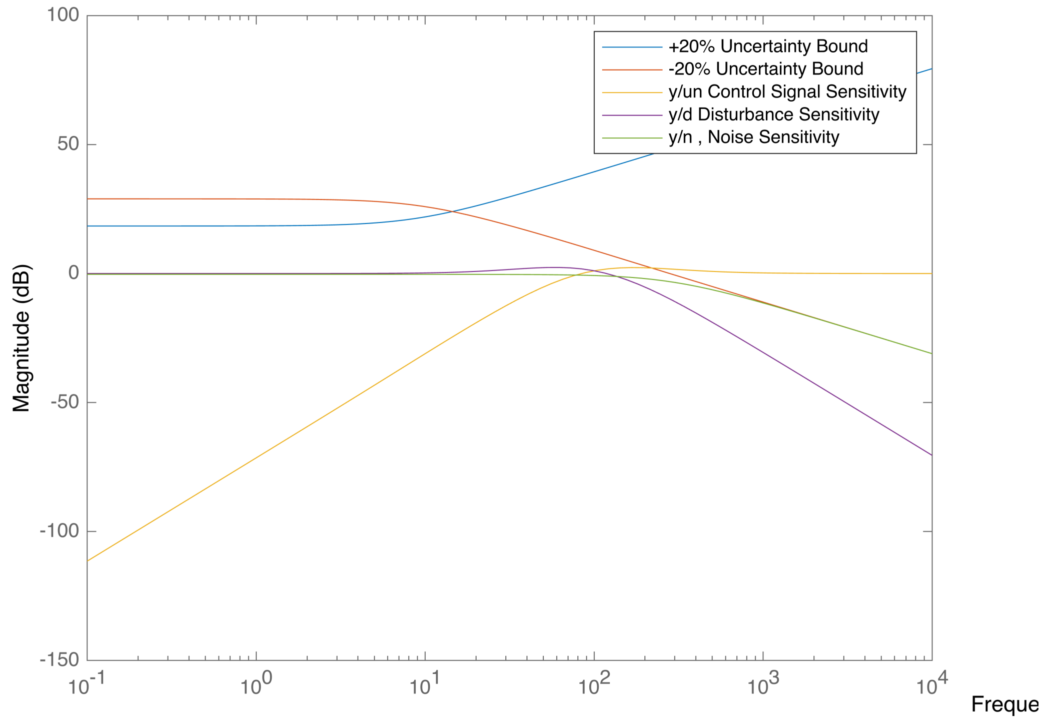
```
C=1; y_r_noControl = C*Gn*G/(Gn*(1-Q)+G*(C*Gn+Q));
step(y_r_noControl)
```



Frequency Domain Magnitude Responses

```
magResponse(G,Gn,Q,C)
```

```
Warning: Ignoring extra legend entries.
```



Functions

```
function magResponse(G,Gn,Q,C)
    uncertainty_bound = Gn/(G-Gn);
    %Sensitivity Responses
    y_un = Gn*G / (Gn*(1-Q)+G*Q); % model regulation - un is the control signal
    y_d = Gn*(1-Q)/(Gn*(1-Q)+G*Q); % disturbance rejection
    y_n = -G*Q/(Gn*(1-Q)+G*Q); % sensor noise rejection
    y_r = C*Gn*G/(Gn*(1-Q)+G*(C*Gn+Q)); %input output sensitivty
    y_un = minreal(y_un);
    y_d = minreal(y_d);
    y_n = minreal(y_n);

    figure()
    hold on
    bodemag(uncertainty_bound); bodemag(y_un); bodemag(y_d); bodemag(y_n); bodemag(y_r
    legend('+20% Uncertainty Bound','-20% Uncertainty Bound','y/un Control Signal Sens
    hold off
end

function disturbanceRejection(y_d,G)
    figure()
    hold on
    step(y_d)
    step(G*(1-feedback(G,1))) % No disturbance observer with feedback control
```

```
    legend('no controller disturbance rejection','feedback control without DOB')
    title('Disturbance observer performance with and without a controller')
    xlabel('time'), ylabel('system output')
end
```