Today (Mon 03 Sep 2012) I covered the following (partly using the board):

constraint control and backoff.

Active constraint on MV:

* Usually no backoff required

Soft active output constraint: backoff = steady-state measurement error

Hard active output constraint: backoff = steady-state measurement error + dynamic control error (Shift and squeeze rule applies)

remaining unconstrained CVs

Assume that all active constraints are controlled and consider remaining unconstrained degrees of freedom (denoted u).

What to find "self-optimizing" CVs c=Hy associated with u.

This means that when c is kept constant by using u, then u is close to uopt.

Options:

* H is selection matrix (mostly 0's with some 1's)
* H is combination matrix; we consider linear measurement combinations only

1. The ideal self-optimizing CV is the gradient, c = Ju (where Ju = dJ/du),

The problem is that Ju is generally a function of unmeasured states (x) and

disturbances (d), that is, we cannot write Ju= Hy.

1. Simple rules for selecting "self-optimizing" CVs c=Hy (especially for selecting single measurements)

Define:

F = dyopt/dd = optimal sensitivity (corresponding to uopt(d))

G^y = dy/du = steady-state gain

(i) Want small optimal sensitivity F^c = dcopt/dd (where F^c = H F).

Reason: So we can use constant setpoint when there are disturbances.

(ii) Want c to be easy and accurate to measure (and control)

Reason: Obvious

(iii) Maximum gain rule: Want large gain G = dc/du (where G = HG^y)

Reason: So we are insensitive to changes in c ("noise")

Note: Can include also disturbances in maximum gain rule by proper scali but I did not cover this in the lecture today.

We used graphics to try to understand these rules.

1. Nullspace method for case with no measurement noise is to select H such that HF=0 (which is always possible if we have enough measuments, ny >= nu+nd).

Example marathon runner

u = power

d = inclination of slope

y1 = speed [km/h]

y2 = heart rate [pr. min]

Have one unconstrained degree of freedom (u) and want to dind one CV:

c = H y = [h1 h2] y = h1\*y1 + h2\*y2

Optimal runner with d=0 (flat track)

y1opt = 10 km/h, y2opt = 180 1/s

Optimal runner with d=1 (1 degree hill)

y1opt = 9.5 km/h, y2opt = 181 1/s

Get optimal sensitivity

F = [f1; f2] where f1 = dy1opt/dd = (9.5-10)/1 = -0.5 and f2=1/1=1

Nullspace method. select H such that

HF = h1\*f1 + h2\*f2 = 0

Without loss of generality we can set h2=1. HF=0 then gives

h1 = - h2\*f2/f1 = 1/0.5 = 2

Conclusion. optimal CV as measurement combination:

c = h1\*y1 + h2\*y2 = 2y1 + y2

where we want to adjust u such that c=0 when there are changes in the slope (d).

Makes sense: Optimal pulse (y2) is lower when speed (y1) is higher.

Note: If we want to remain optimal if there is one more disturbance (d2=wind),

then we need to add one more measurement (otherwise we do not have enough degrees

of freedom in H to make HF=0).

Proof 1 of nullspace method (Alstad): Want dcopt = 0 \* dd

Here dcopt = H \* dyopt = HF \* dd

so we want to select H such that HF=0 (nullspace method)

Proof 2 of nulspace method (Jaschke): Ju = Juu (u-uopt) = Juu G^-1 (c-copt)

Constant setpoint policy and no meas. error: c=0 (steady state)

Optimal sensitivity, copt = F yopt = H F d

Also note that, G=HGy

So get: Ju = - Juu (HG^y)^-1 H F d

Ideal: Want Ju=0, which we see is achieved if we choose H such that HF=0 (nullspave method).

The advantage with the second more complicated proof is that we see that the nullspace methodactually is the same as controlling the gradient Ju to zero.

1. Exact local method for H (measurement combination). Includes noise