Resolving actuator redundancy – Control allocation vs. LQ control

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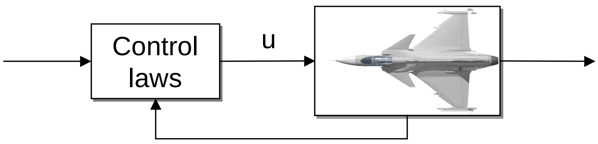
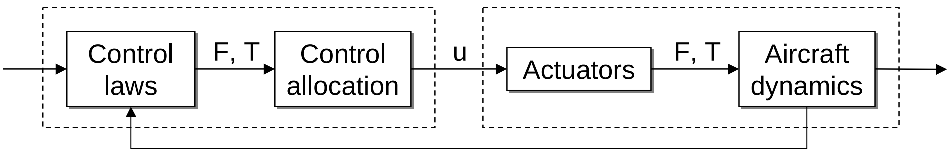
Can being greedy be optimal in the long run?

Motivation

- Regular control design:



- Modular control design:

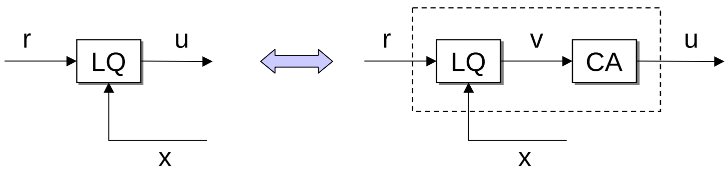


? How are the two strategies related?

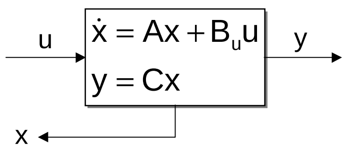
Main message

- Linear dynamics
- LQ control laws
- Quadratic control allocation

Control design strategies **equivalent**



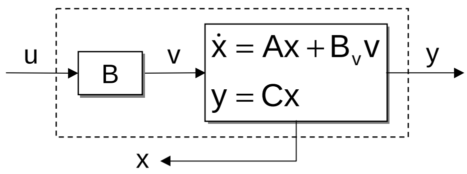
System class



Input redundancy:

$\text{rank}(B_u) < \dim(u)$

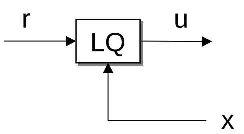
$\Rightarrow B_u = B_v B$



Example:

$$\dot{x} = u_1 + u_2 \quad \Leftrightarrow \quad \begin{array}{l} \dot{x} = v \\ v = u_1 + u_2 \end{array}$$

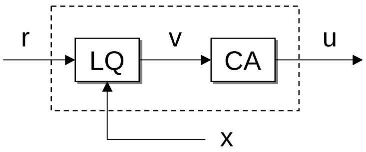
Control design alternatives



$$\dot{x} = Ax + B_u u$$

$$\min_u \int_0^\infty x^T Q_1 x + u^T R_1 u \, dt$$

$$u = -L_1 x$$



$$\begin{cases} \dot{x} = Ax + B_v v \\ v = Bu \end{cases}$$

$$\min_v \int_0^\infty x^T Q_2 x + v^T R_2 v \, dt \qquad v = -L_2 x$$

$$\min_u \|Wu\|_2 \quad \text{subj. to} \quad Bu = v \qquad u = L_3 v = -L_3 L_2 x$$

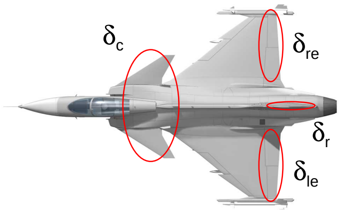
Q_1, R_1 ⟺ Q_2, R_2, W

Why use control allocation?

- Can include input constraints
  - Control redistribution
  - Command limiting
- Easy to reconfigure
- Facilitates tuning

Example

- Admire (FOI)
  - Mach 0.22, 3000 m
  - $\dot{x} = (\alpha \quad \beta \quad p \quad q \quad r)$



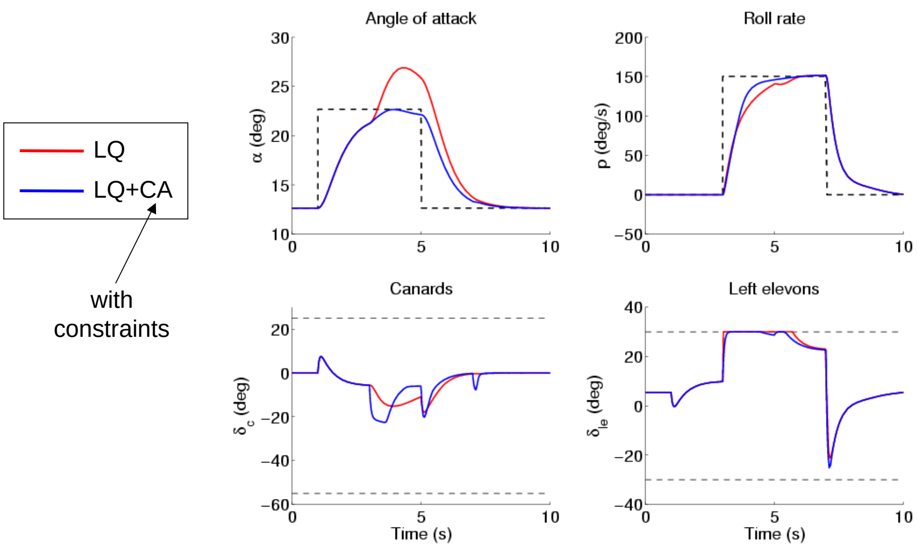
- Approximations:
  - Ignore actuator dynamics
  - View control surfaces as moment generators

- Model (for control): $\dot{x} = Ax + B_v v$

$$v = B\delta$$

angular acc. control surfaces

Simulation results



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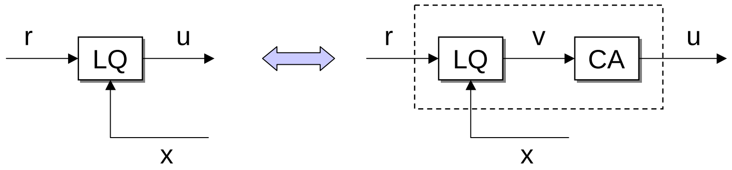
Summary

- For linear systems,



- Input constraints can be considered in control allocation.

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