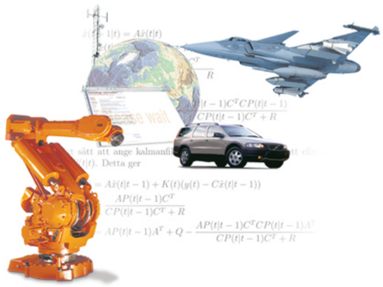
Efficient Active Set Algorithms for Solving Constrained LS Problems in Aircraft Control Allocation



Ola Härkegård
Linköpings universitet, Sweden

Main Message

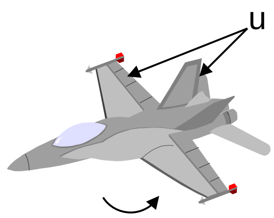
Today: Efficient but approximate methods

? Can standard QP methods be used efficiently?

! Yes, complexity ≈ pseudoinverse methods

What is Control Allocation?

- Control design $\rightarrow$ $M(u) = Bu = v$
- Actuator constraints
  - Position: $u_{min} \leq u \leq u_{max}$
  - Rate: $r_{min} \leq \dot{u} \leq r_{max}$



$$\dot{u}(t) \approx \frac{u(t) - u(t-T)}{T} \quad \rightarrow \quad \begin{array}{c} Bu(t) = v(t) \\ \underline{u}(t) \leq u(t) \leq \overline{u}(t) \end{array}$$

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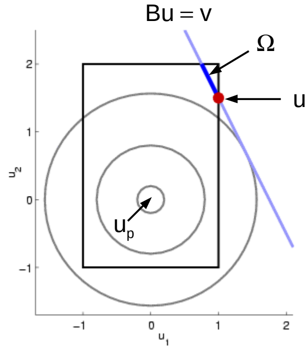
Least Squares Formulation

- Sequential least squares:

$$\Omega = \arg \min_{\underline{u} \leq u \leq \overline{u}} \left\| W_v (Bu - v) \right\|_2$$

$$u = \arg \min_{u \in \Omega} \left\| W_u (u - u_p) \right\|_2$$



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Numerical Methods

- Active set methods **(this paper)**
- Pseudoinverse methods **(dominate)**
- ...

Active Set

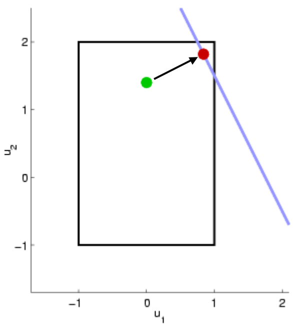
① $\min \|Bu - v\|_2$

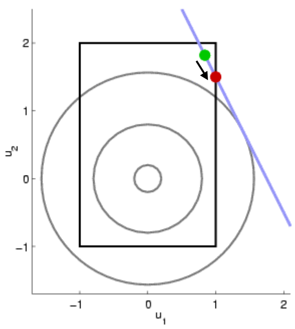
$\underline{u} \le u \le \overline{u}$

② $\min \|u\|_2$

$Bu = v$

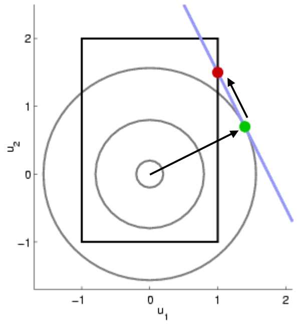
$\underline{u} \le u \le \overline{u}$



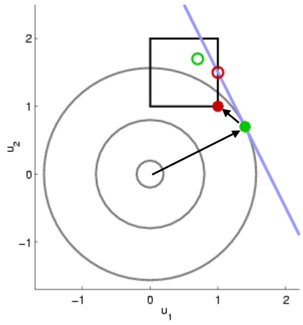


Pseudoinverse

- Successful case



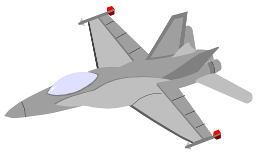
- Failing case



Why Active Set?

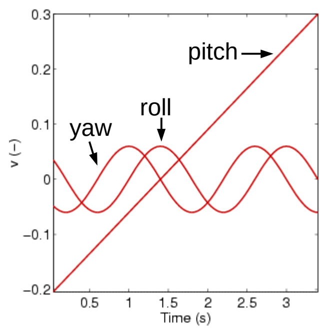
- Always finds optimal solution
- Can reuse previous solution
- All iterates are feasible

Example (Durham and Bordignon, 1996)



- 8 actuators, 3 moments
- Position and rate limits

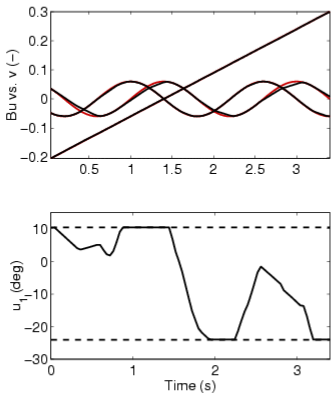
- Aerodynamic coefficients



Simulations

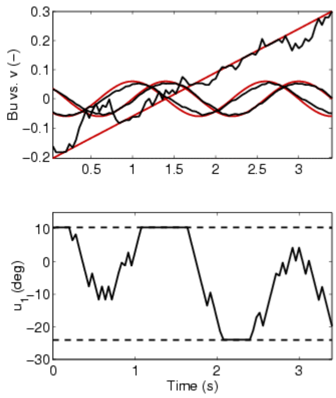
Active set

Mean: **0.9 ms** Max: **2.5 ms**



Pseudoinverse

Mean: **0.9 ms** Max: **1.5 ms**



Conclusions

Active set methods are well suited for control allocation

- Find optimal control input
- Complexity ≈ pseudoinverse methods