Data-Driven Feedforward Tuning based on Closed-Loop Identification Techniques

**Feedforward tuning**

Feedforward control is key for control performance

![Diagram of Feedforward Tuning]

Earlier tuning approaches:
- Batchwise approach
- resembles IFT
- either biased or inefficient

Estimation of $\theta$ directly linked with control performance

**Identification perspective**

Pre-existing approaches:

$$V(\theta^{i+1}) = \frac{1}{N} \sum_{t=1}^{N} \hat{e}^{i+1}(t, \theta^{i+1})^2$$

with $\hat{e}^{i+1} = e^i - (C_{fb} + C_{ff}^{-1}(\theta^{i+1})y^i$

Either biased or inefficient?
- One experiment $\Rightarrow w^i$ leads to biased $\theta^{i+1}$
- Two experiments $\Rightarrow$ inefficient use of measured data

Reason: Closed-loop identification problem

Solution: Instrumental variable approach $\Rightarrow$ with $r$ as instrument

**Optimal IV**

Eliminate bias by IV approach $\Rightarrow$ variance?

Typical IV criterion:

$$V(\theta^{i+1}) = \frac{1}{N} \sum_{t=1}^{N} Z(t)L(q)\hat{e}^{i+1}(t, \theta^{i+1})^2_w$$

Design of $Z(t)$ and $L(q)$ for optimal accuracy of $\theta$ [2,3]?

Approximate implementation of optimal IV method:
- Set $\theta_0^{i+1} = \theta^i$ and repeat for $i \geq 1, 2, ... M$
  - Construct instruments $z(t, \theta_0^{i+1})$
  - Solve for $\hat{\theta}_0^{i+1}$, set $i \rightarrow i + 1$ and repeat

Parameters $\theta$ as a function of iteration for $m = 200$ realizations

Result: optimal accuracy in terms of variance $\Rightarrow$ Enhanced control performance

**Ongoing Research**

- value of iterations/optimal input design [5]
- connections to inverse model identification [6]
- extensions to complex systems

**References**