« Inversion-based control deduced from EMR »

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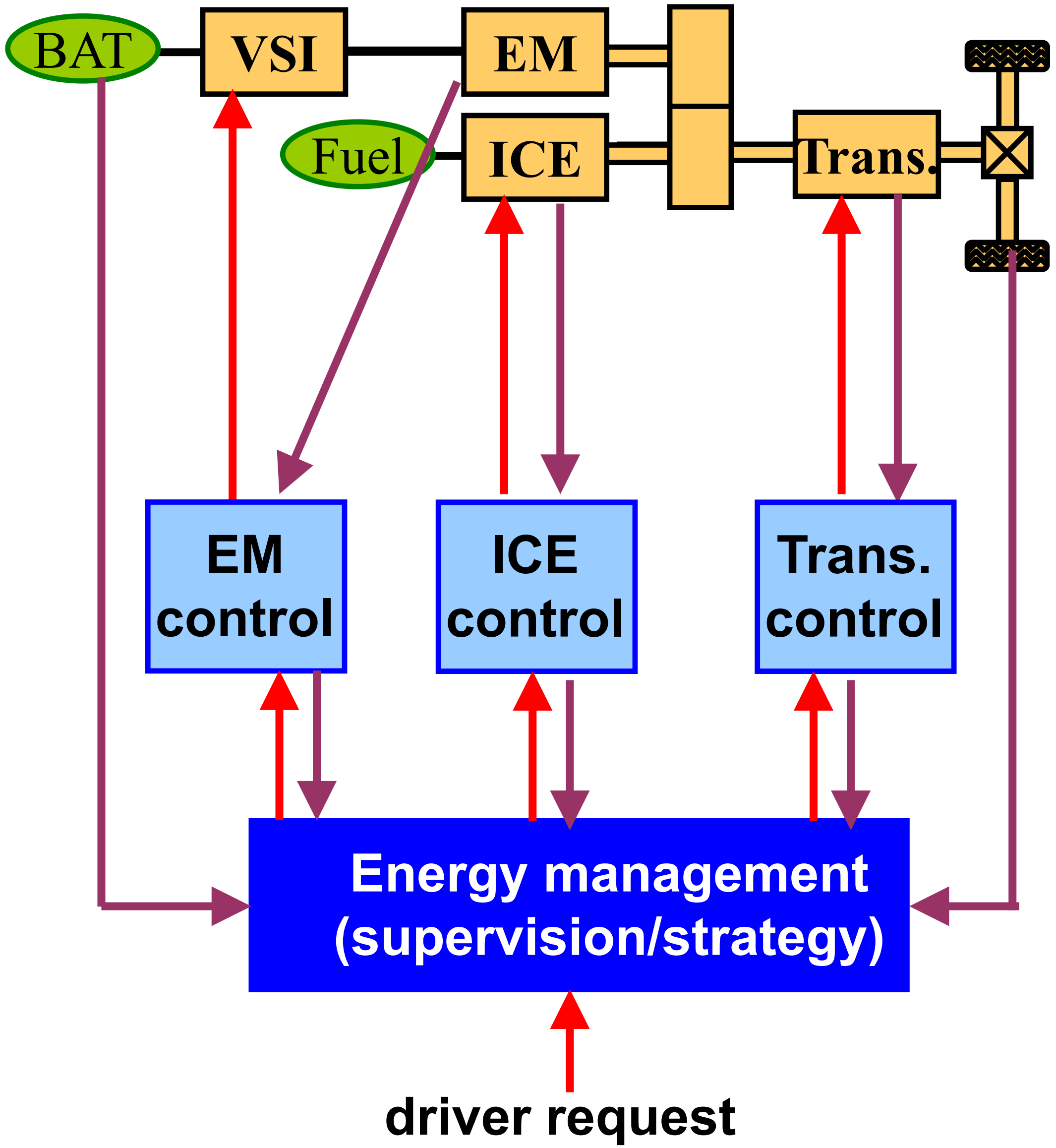
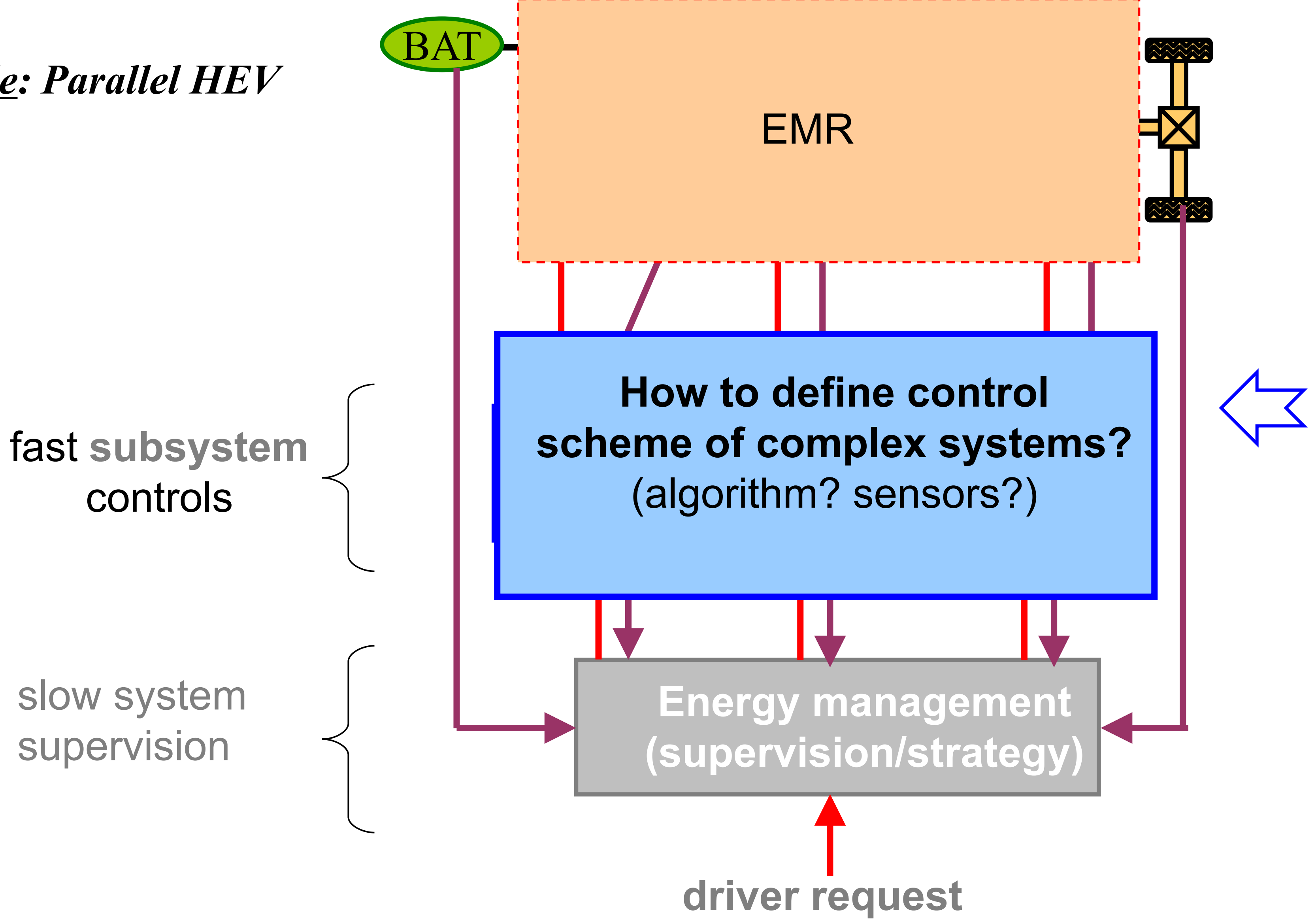
***Example*: Parallel HEV**

fast subsystem controls

slow system supervision



***Example*: Parallel HEV**

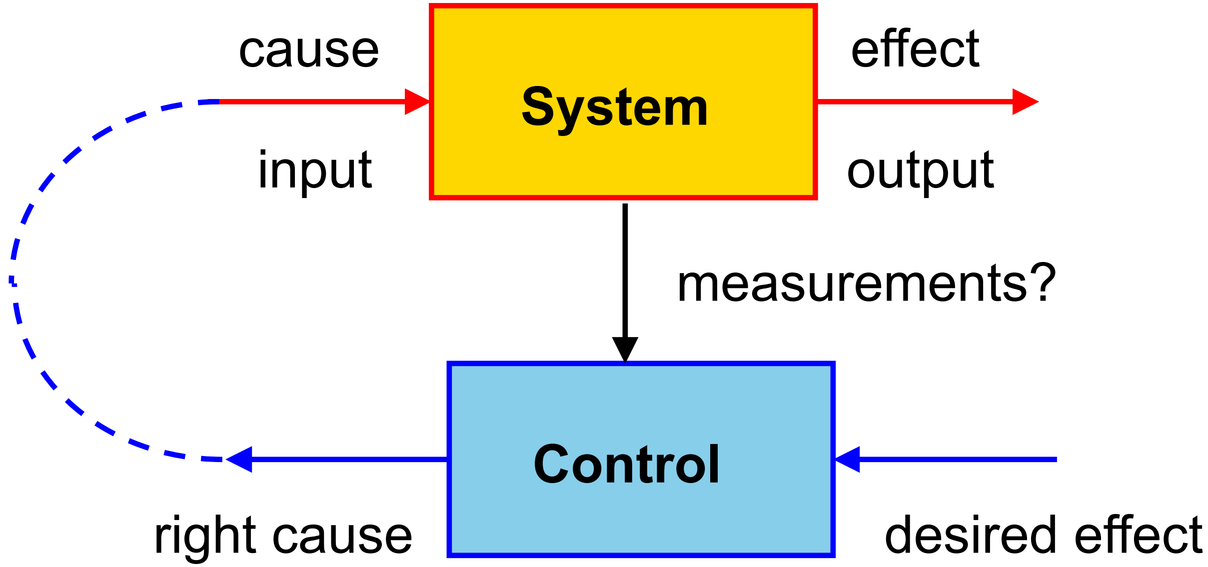


Objective of this section

1. Principle of Model-Based Control
2. Inversion of EMR Elements
3. Inversion-Based Control Scheme

« Principle of Model-based Control »

[Hautier 96]



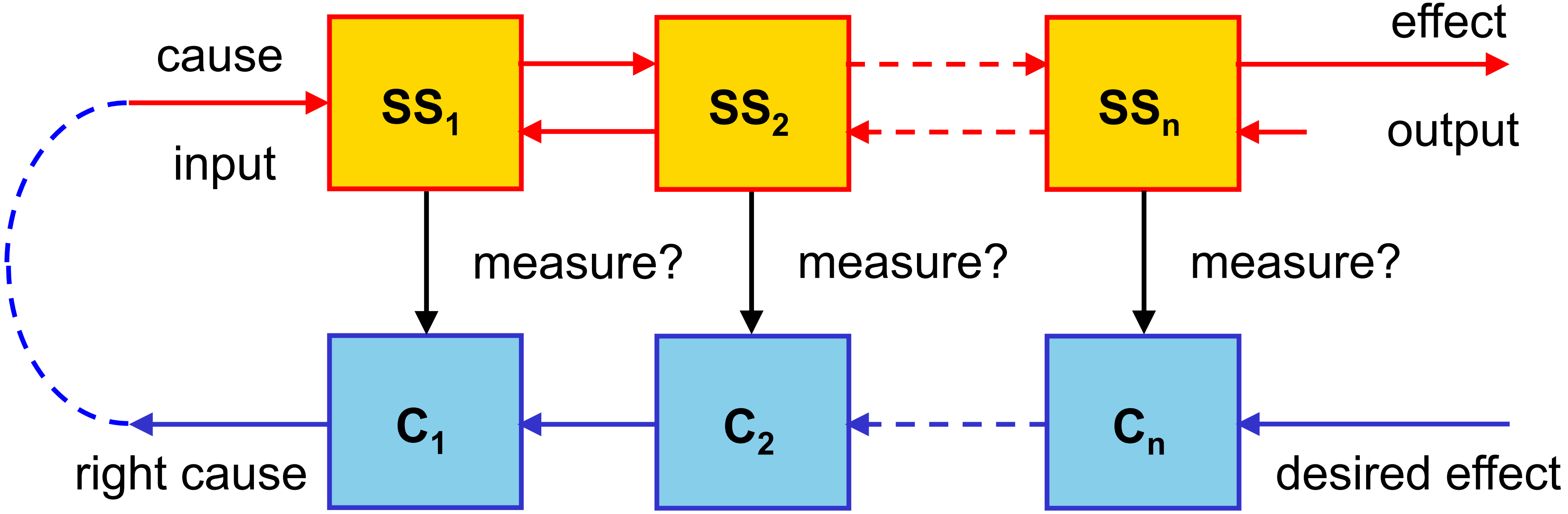
Model $out = \mathrm{f}\,(in)$

$\Downarrow$

Control $in = \mathrm{g}\,(out_{ref})$

control = inversion of the system functionality

- Principle of Model-based Control -



EMR = system decomposition in basic energetic subsystems (SS_n)

Remember,
divide and conquer!

Inversion-based control: systematic inversion of each subsystem

« Inversion of EMR elements »

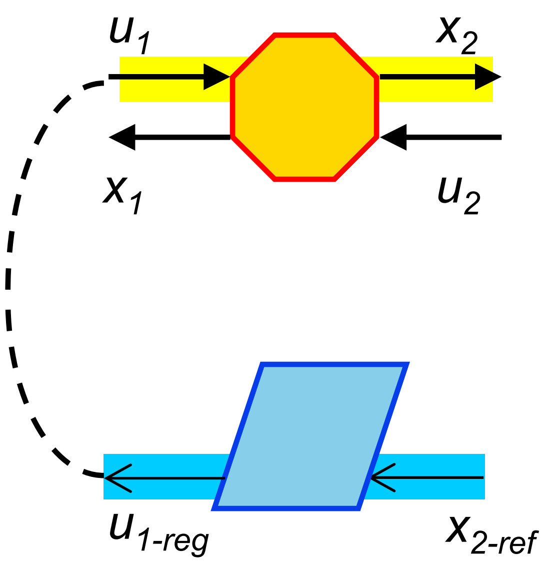
Model $out = f\,(in)$ ⇨ Control $in = g\,(out_{ref})$

I/O relation without delay → direct inversion

I/O relation with delay → Indirect inversion (closed-loop control)

I/O relation with multiple Inputs → Multiple solutions

Objective: to control y_2



$x_2 = f(u_1)$

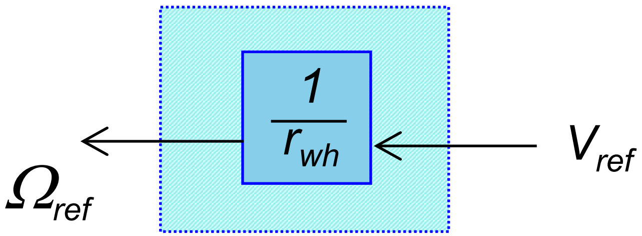
$u_{1\text{-reg}} = f^{-1}(X_{2\text{-ref}})$

Direct Inversion

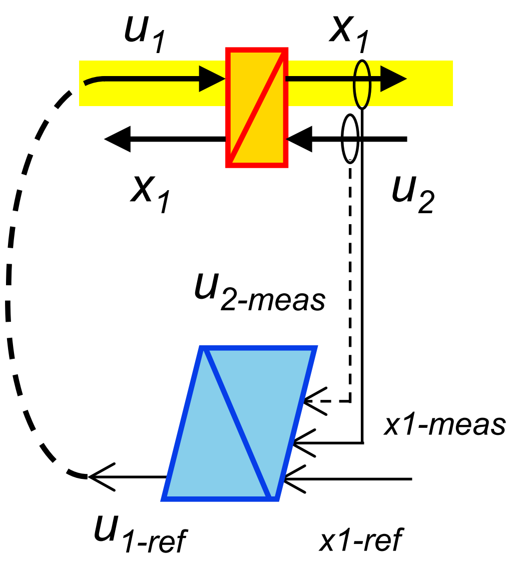
Ex : wheel

$$\begin{cases} V = r_{wh}\,\Omega \\ T = r_{wh}\,F \end{cases}$$

$$\Omega_{ref} = V_{ref} / r_{wh}$$



Objective: to control y_2



$x_1=f(u_1, u_2)$

f is in integral form

direct inversion

indirect inversion

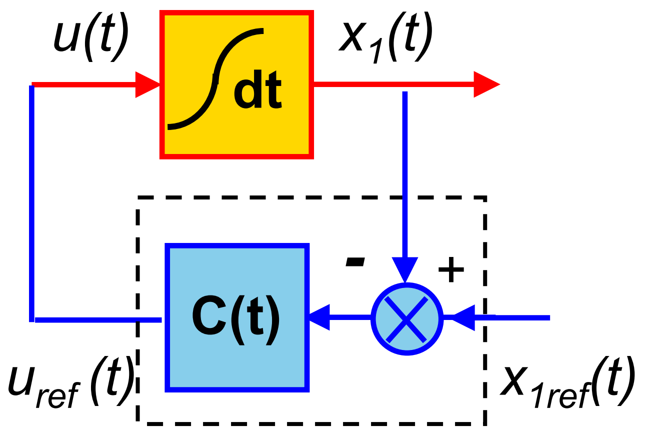
not possible in real-time

$$u_{ref}(t) = \frac{d}{dt}x_{1ref}(t)$$

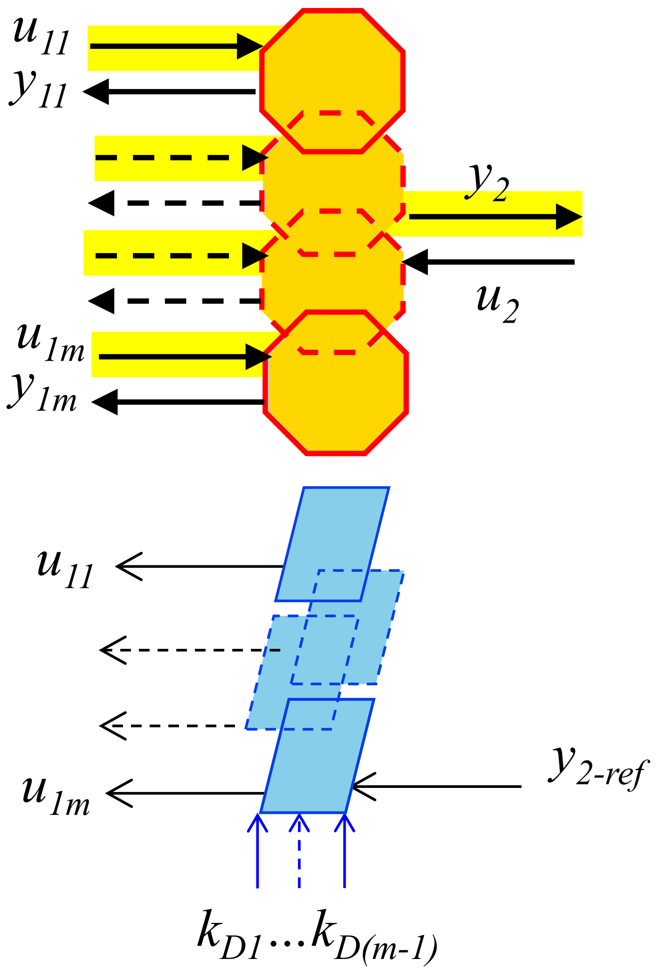
$$u_{ref}(t)=C(t)[x_{1ref}(t)-x_{1meas}(t)]$$

closed loop controller

$u(t)=u_1(t)-u_2(t)$



- Inversion of a coupling element -



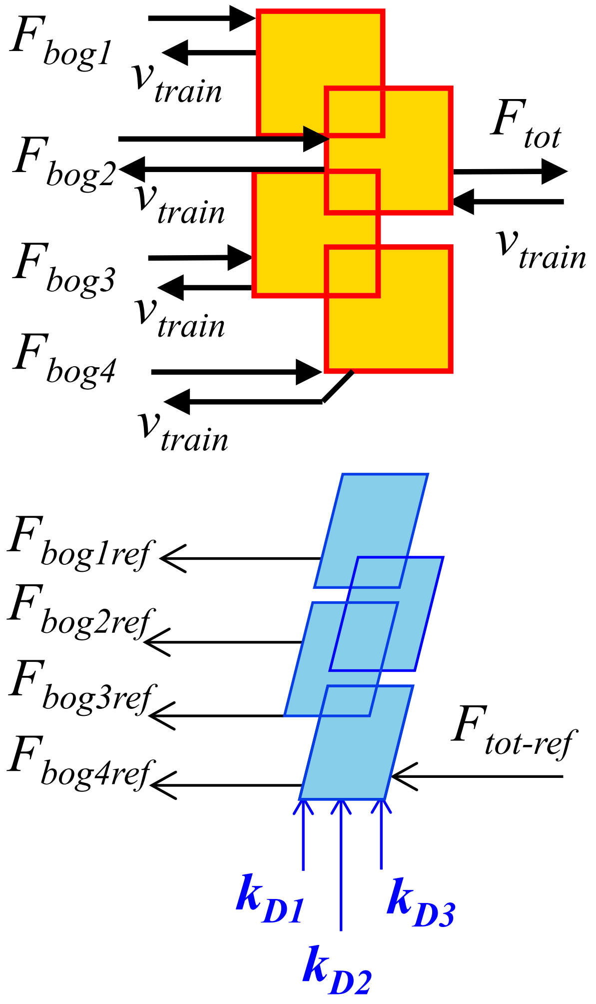
no measurement

no controller

***(m - 1)* distribution variables**

$$\begin{cases} u_{11} = k_{D1} y_{2ref} \\ \dots \\ u_{1(m-1)} = k_{D(m-1)} y_{2ref} \\ u_{1m} = (1 - \sum k_{Di}) y_{2ref} \end{cases}$$

Example: chassis of a train



Inversion-based control

- Inversion of EMR elements -

Legend

Control = light blue Parallelograms with dark blue contour

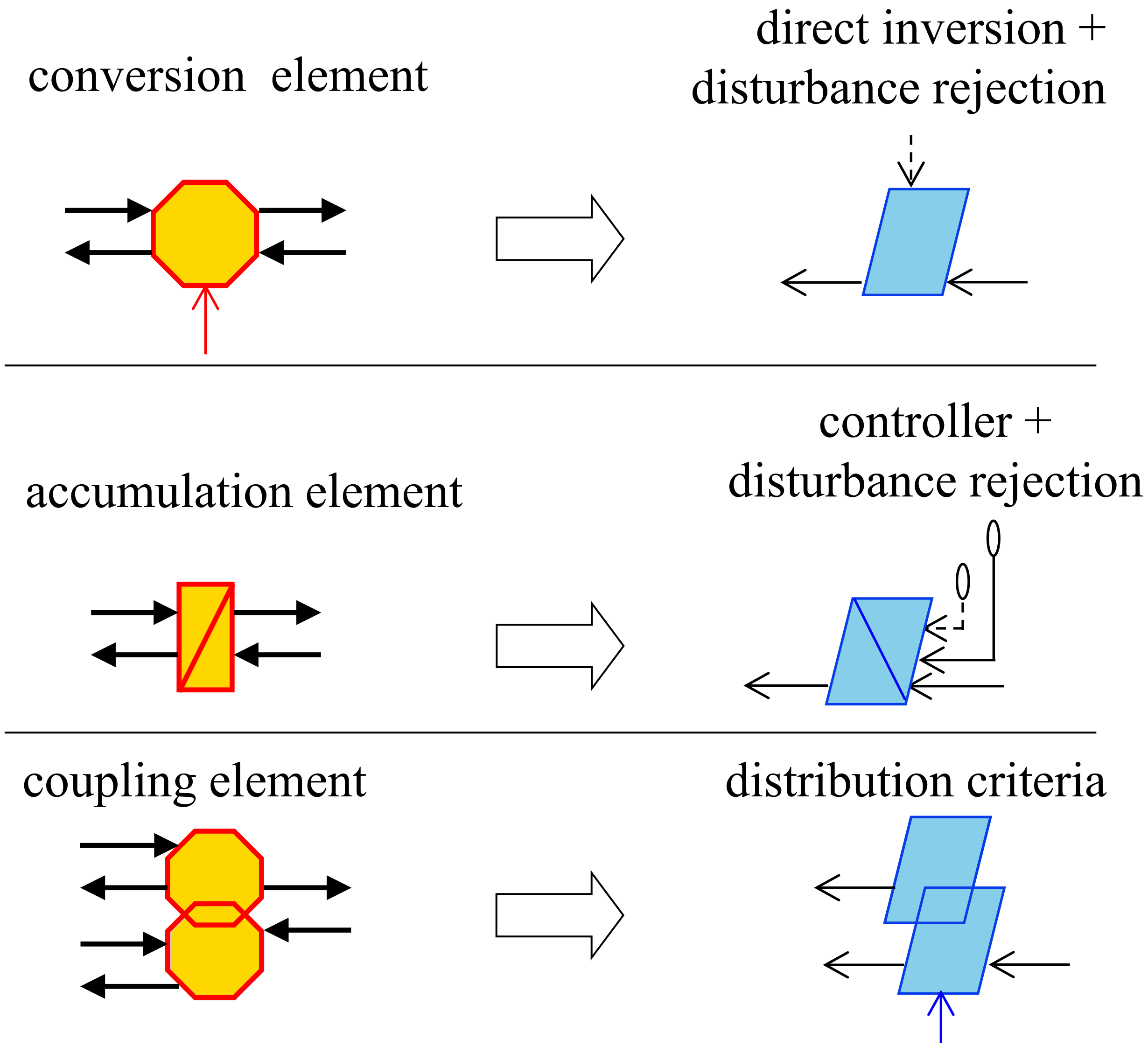
direct inversion

indirect inversion

sensor

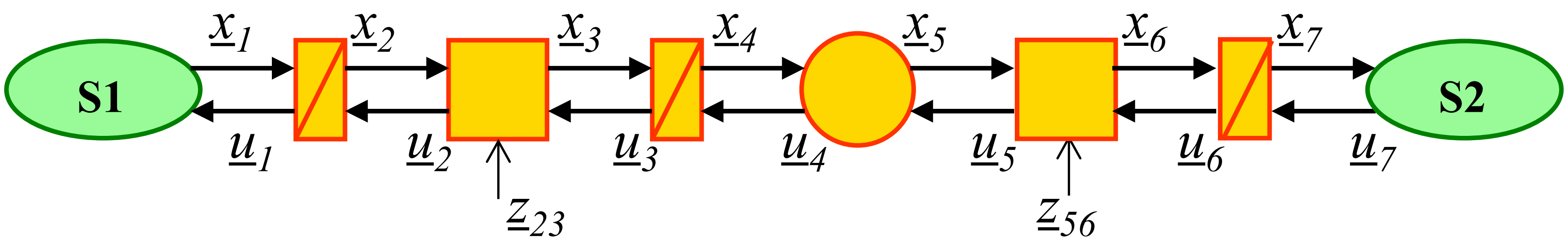
mandatory link

facultative link



«Inversion-Based Control Scheme »

1. EMR of the system

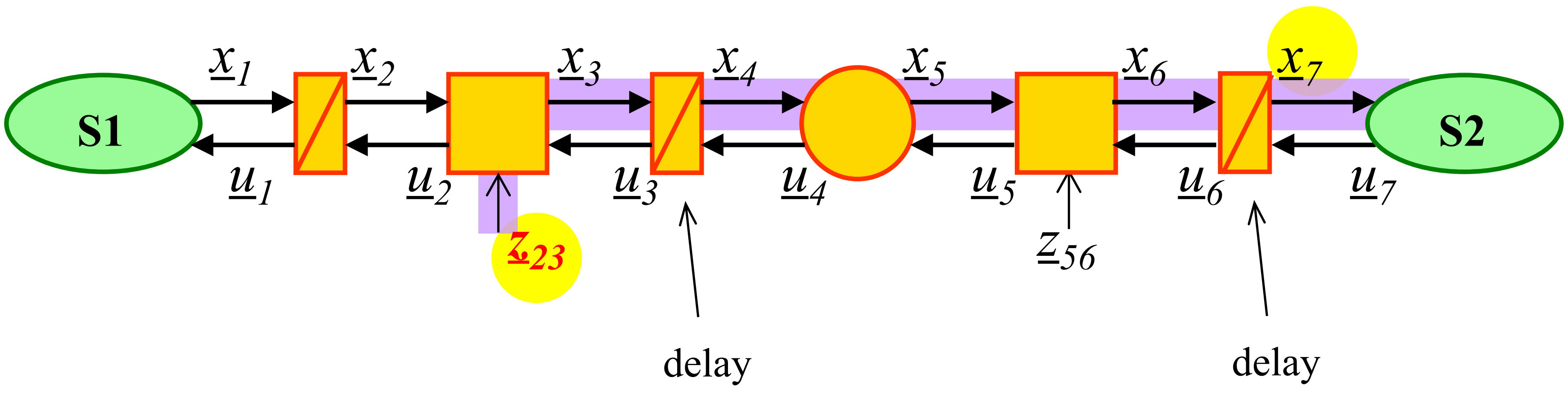


EMR depends on:

- the study objective (limits between system and sources)
- the physical laws of subsystems (physical causality)
- the association of subsystems (systemic approach)

1. EMR of the system

2. Tuning path



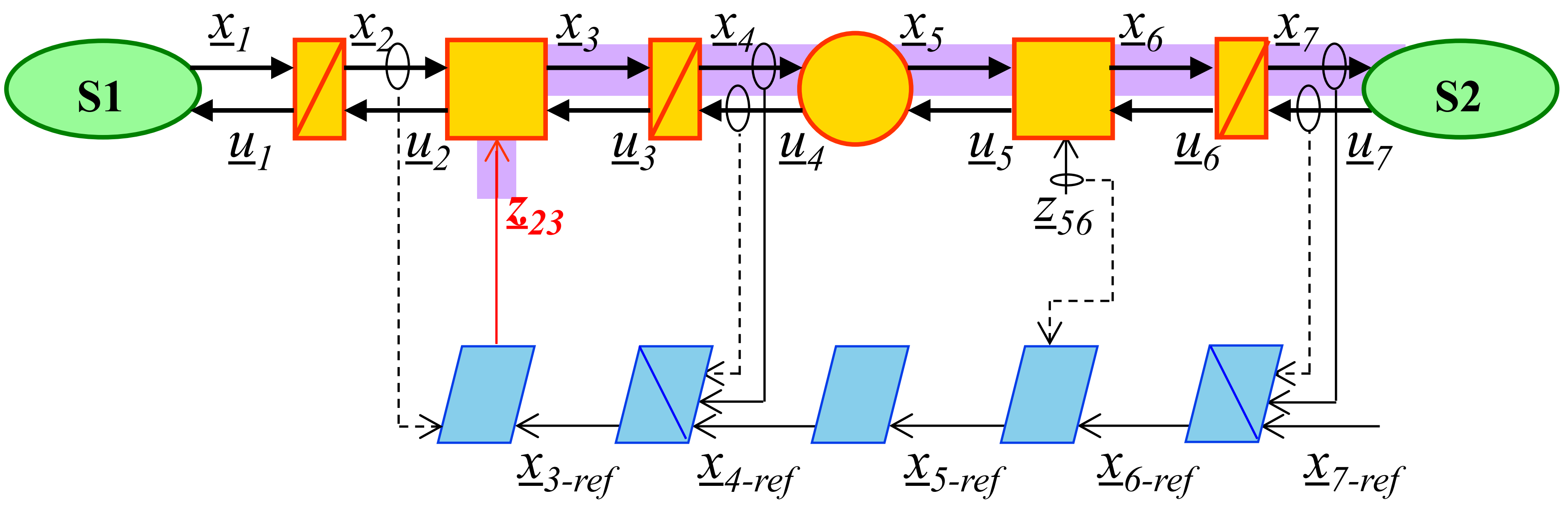
The tuning path is:
- dependant on the technical requirements (chosen tuning input / output to control)
- **independent of the power flow direction**

1. EMR of the system

2. Tuning path

3. Inversion step-by-step

Strong assumption: all variables can be measured!



Maximal Control Structure (or scheme):
- maximum of sensors
- maximum of operations

Example:
- 6 sensors
- 2 closed-loop controllers

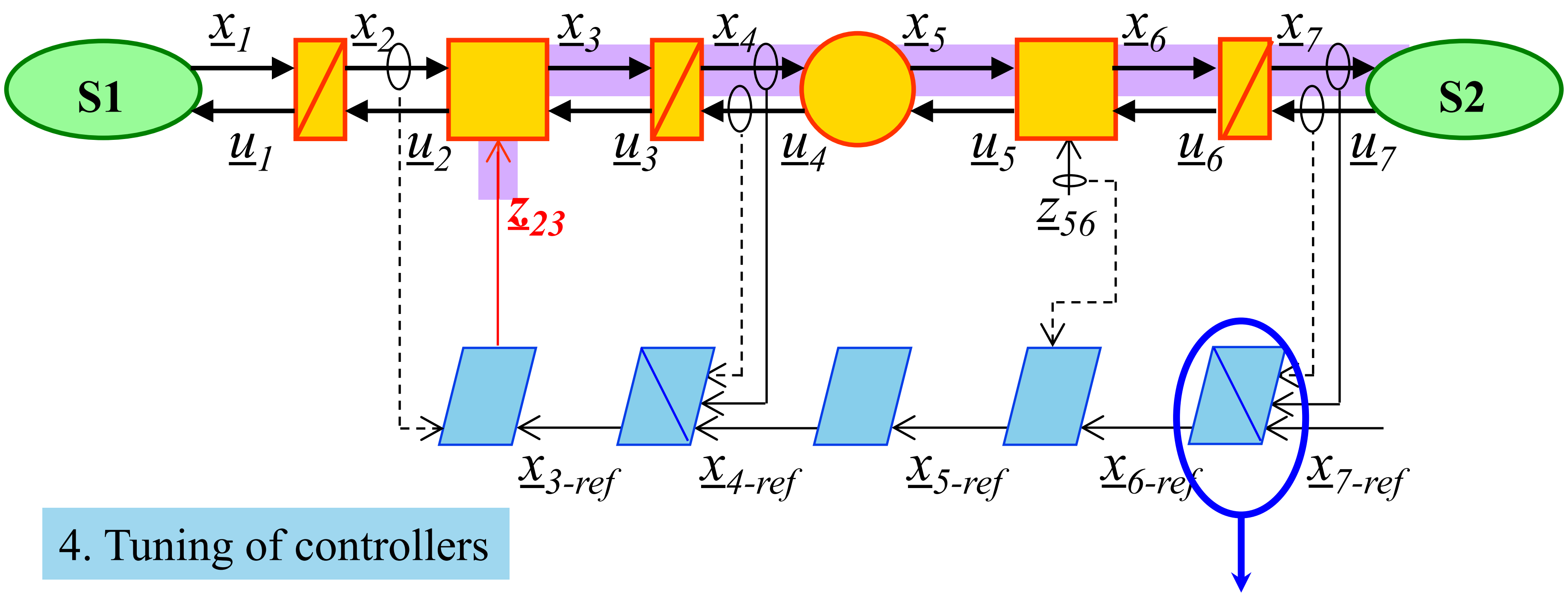
- Maximum Control Scheme -

1. EMR of the system

2. Tuning path

3. Inversion step-by-step

Strong assumption: all variables can be measured!



4. Tuning of controllers

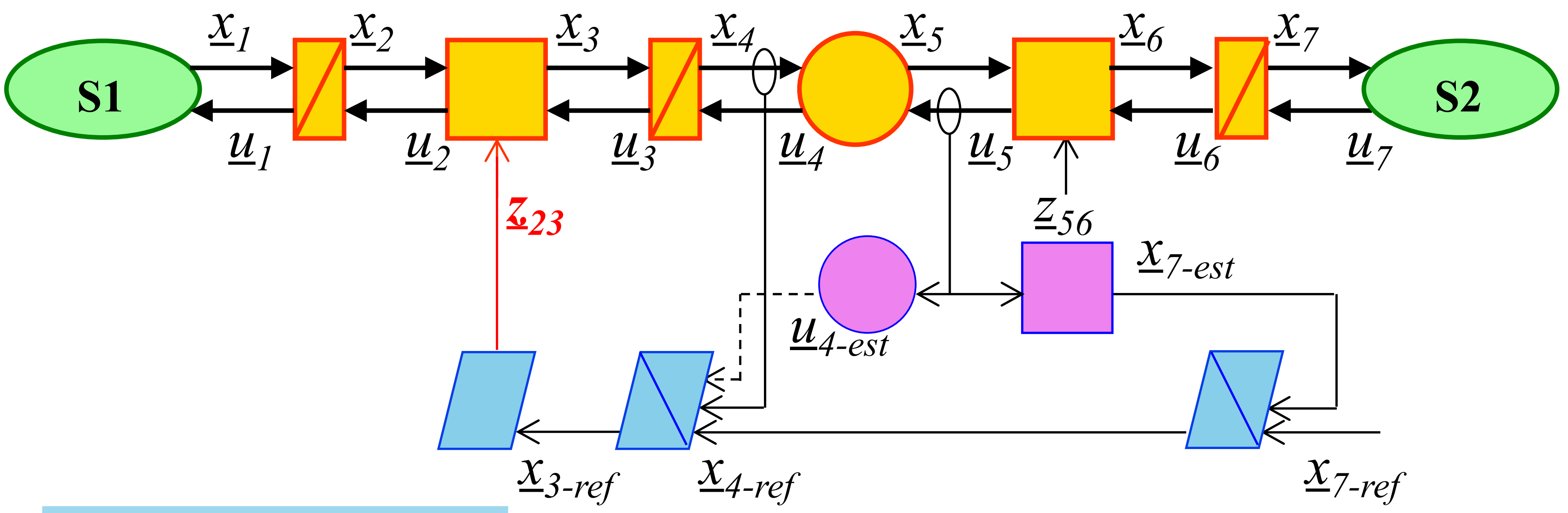
PI / PID / fuzzy controller?
Calculation of parameters?

1. EMR of the system

2. Tuning path

3. Inversion step-by-step

Strong assumption: all variables can be measured!



4. Tuning of controllers

5. Simplification and estimation

« Conclusion »

Inversion based control = inversion of EMR

-based on the cognitive systemic

-and the causality principle (energy)

Inversion rule for control scheme

-closed-loop control to invert accumulation element,

-direct inversion for conversion element,

-degrees of freedom for coupling element

« Biographies and references »

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Thanks for your attention !