EMR'22
Sion
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EMR'22 Summer School
"Energetic Macroscopic Representation"

INVERSION-BASED CONTROL DEDUCED FROM EMR

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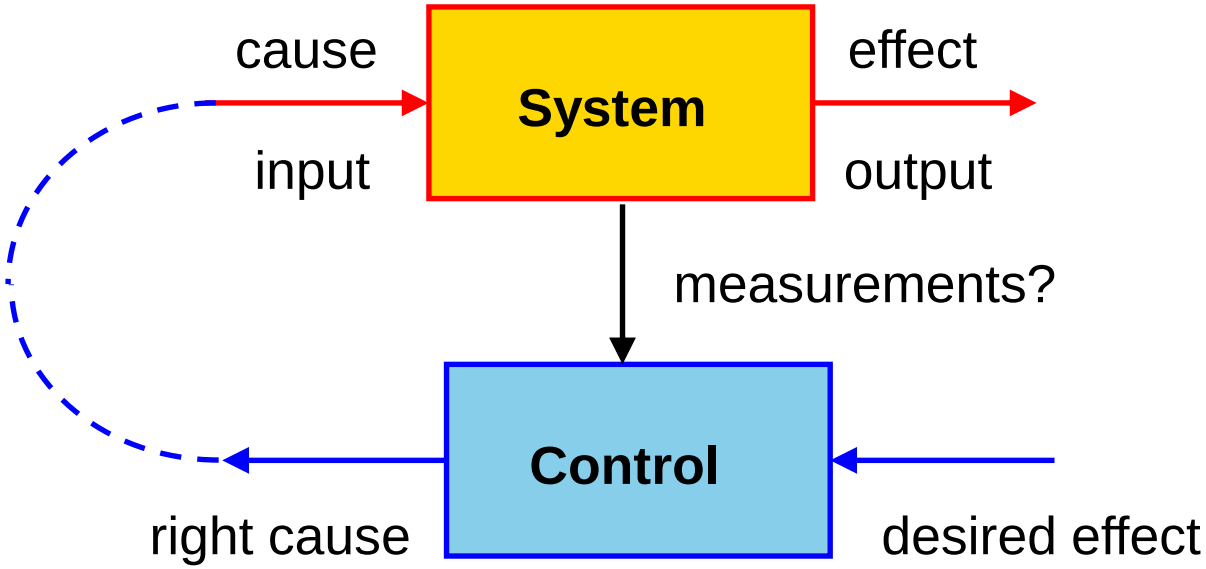
- Outline -

1. **Principle of model-based control**
2. **Inversion of EMR elements**
3. **Inversion-based control schemes**

1. Principle of model-based control

[Hautier 96]

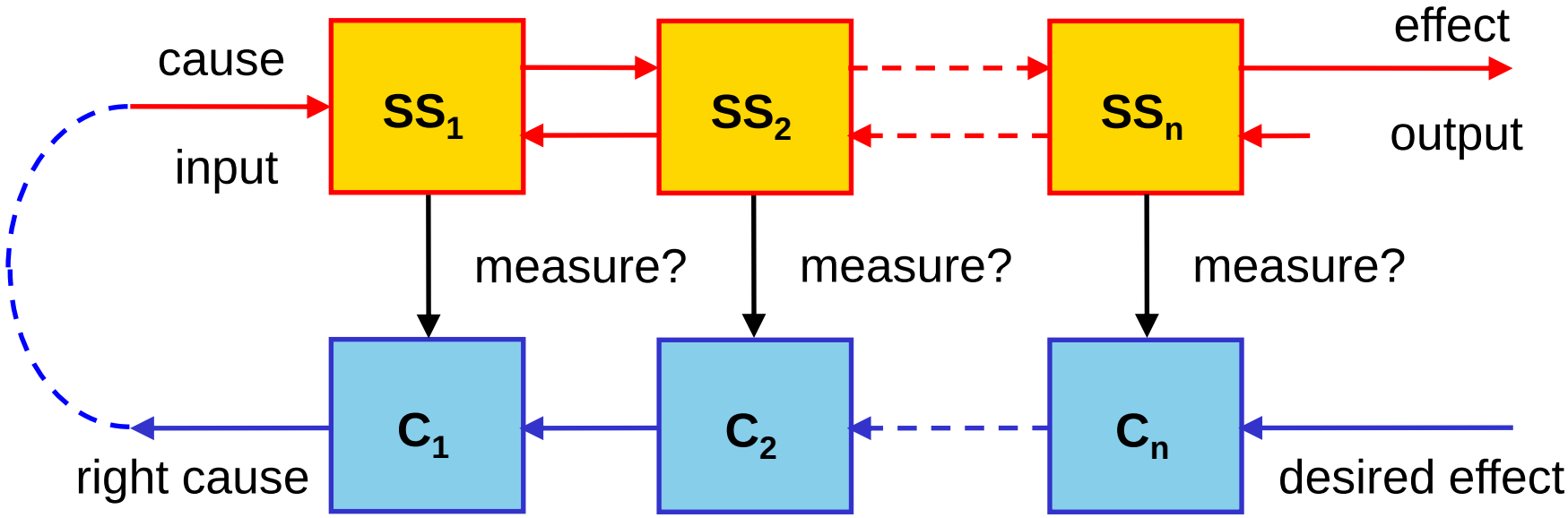


Model $out = f(in)$

$\Downarrow$

Control $in = g(out_{ref})$

control = inversion of the system functionality

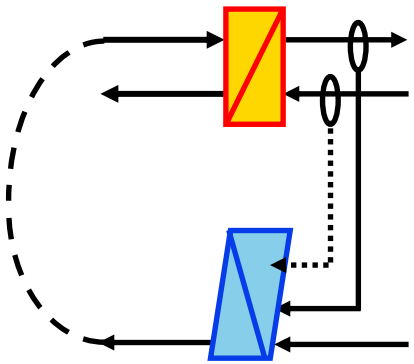


EMR = system decomposition in basic energetic subsystems (SS_n)

Remember, divide and conquer!

Inversion-based control: systematic inversion of each subsystem

2. Inversion of EMR elements



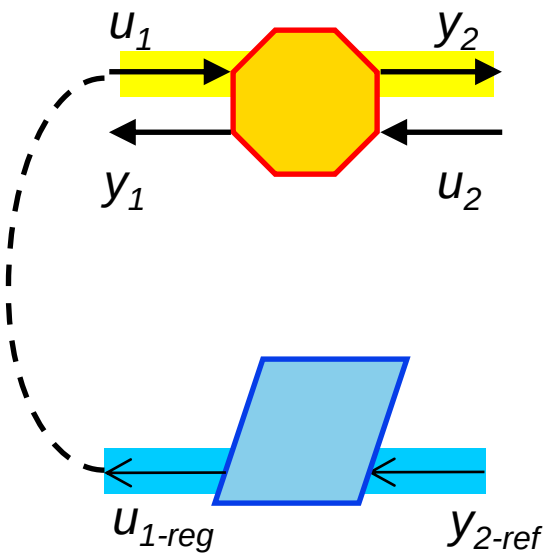
Model $out = f(in)$ ⇨ Control $in = g(out_{ref})$

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



$y_2 = f(u_1)$

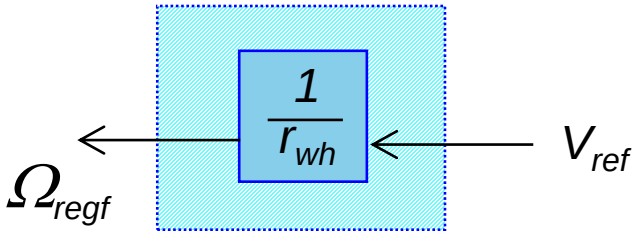
$u_{1\text{-reg}} = f^{-1}(y_{2\text{-ref}})$

Direct Inversion

Ex : wheel

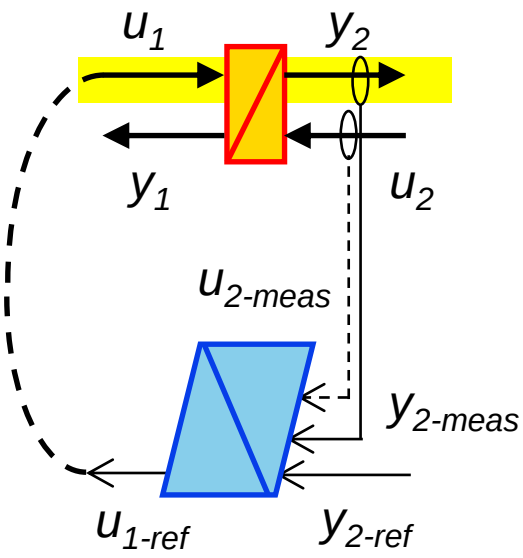
$$\begin{cases} V = r_{wh}\,\Omega \\ T = r_{wh}\,F \end{cases}$$

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



- Inversion of an accumulation element (1) -

Objective: to control y_2



$y_2=f(u_1, u_2)$

f is in integral form

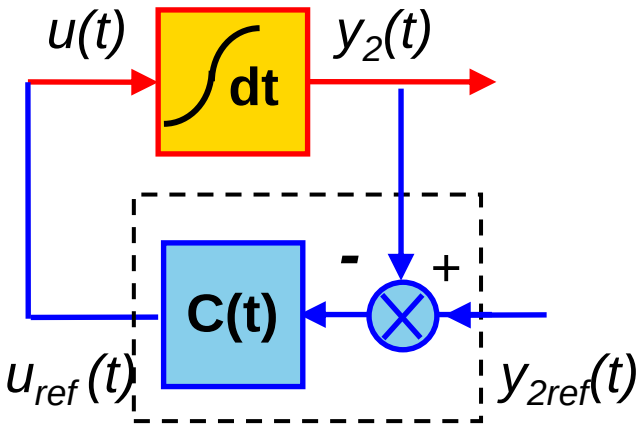
direct inversion

indirect inversion

not possible in real-time

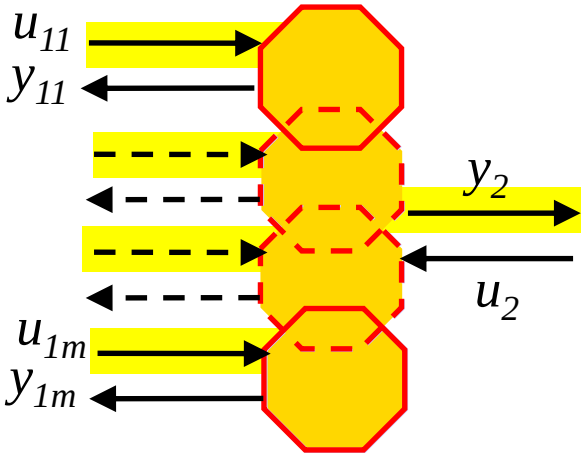
$$u_{ref}(t) = \frac{d}{dt} y_{ref}(t)$$

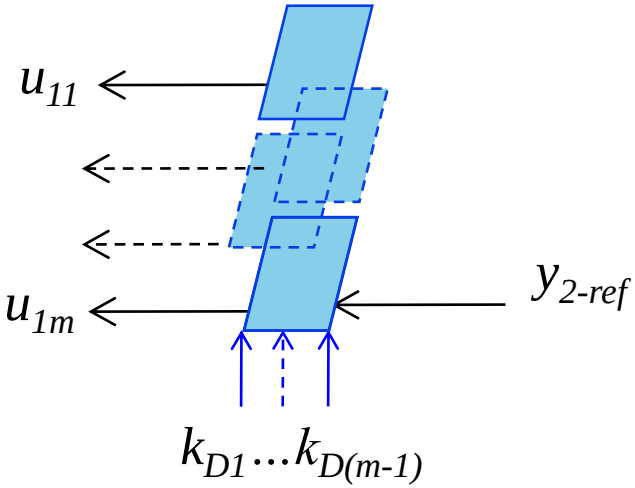
$u(t)=u_1(t)-u_2(t)$



$$u_{ref}(t)=C(t)[y_{2ref}(t)-y_{2meas}(t)]$$

closed loop controller

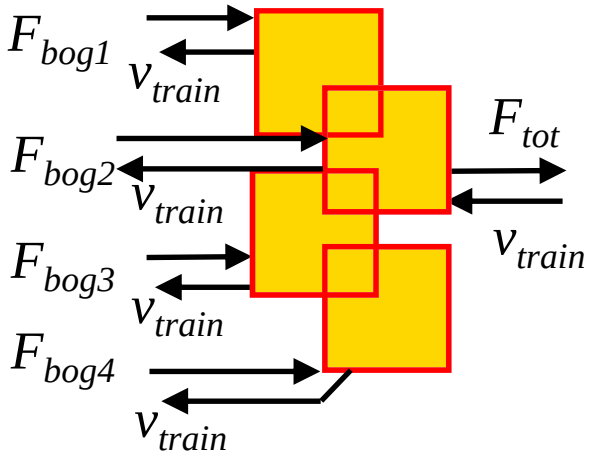


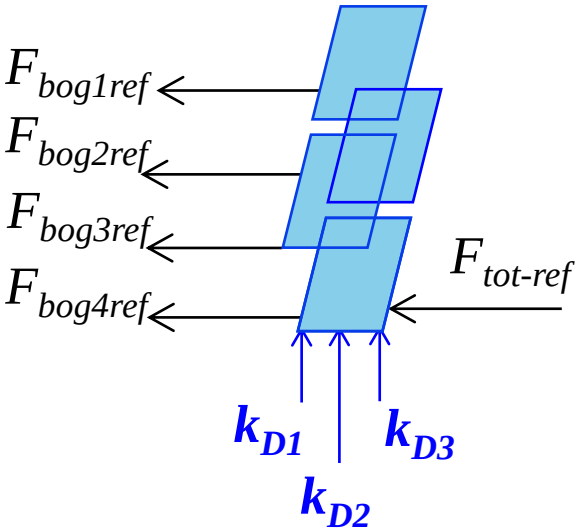


no measurement
no controller
***(m - 1)* distribution variables**

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

Example: chassis of a train





Legend

Control = light blue Parallelograms with dark blue contour

direct inversion

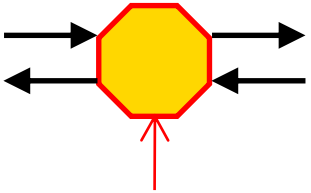
indirect inversion

sensor

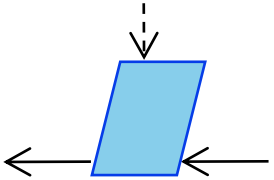
mandatory link

facultative link

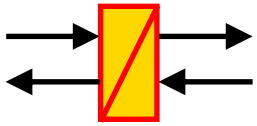
conversion element



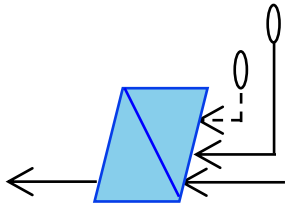
direct inversion + disturbance rejection



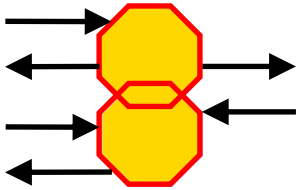
accumulation element



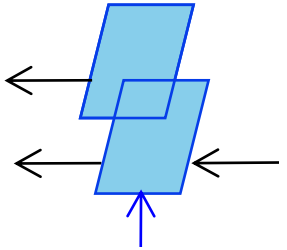
controller + disturbance rejection



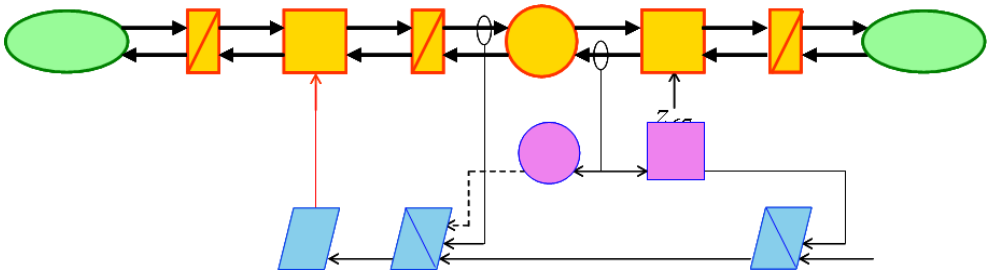
coupling element



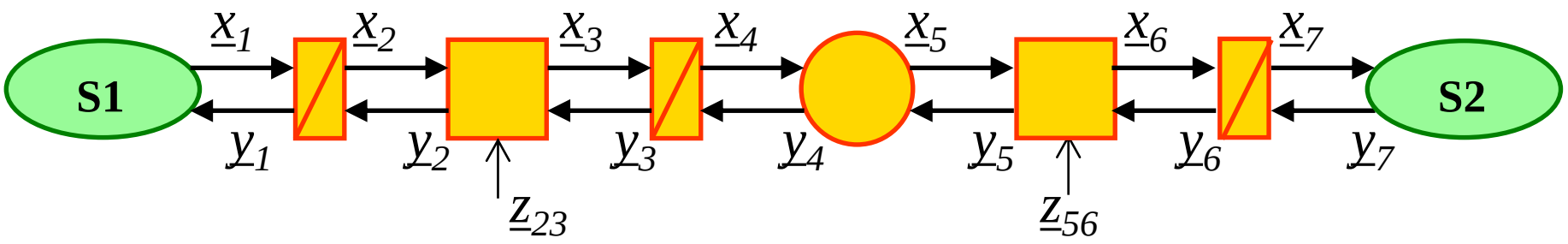
distribution criteria



3. Inversion-based control schemes



1. EMR of the system

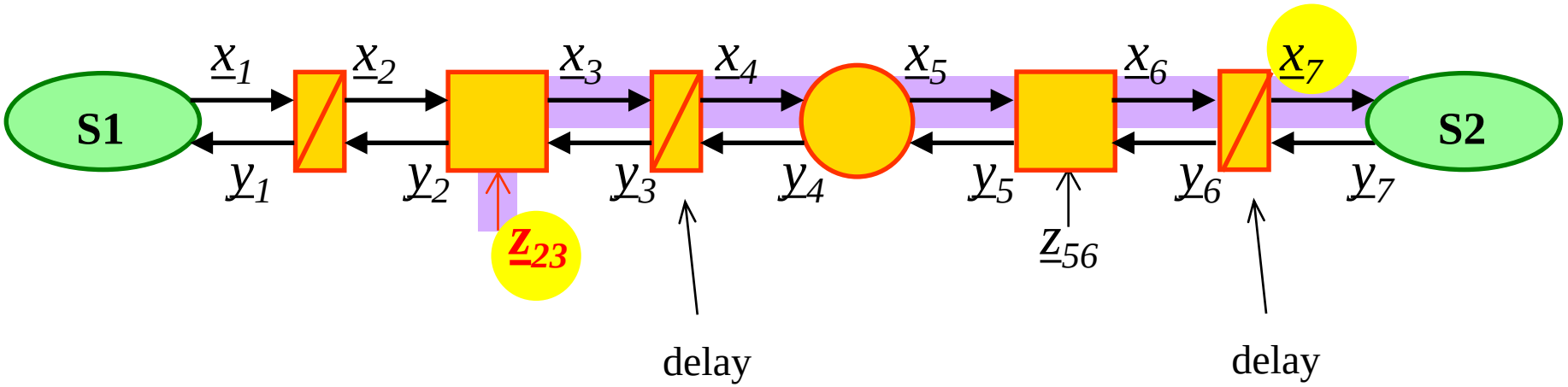


EMR depends on:

- 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

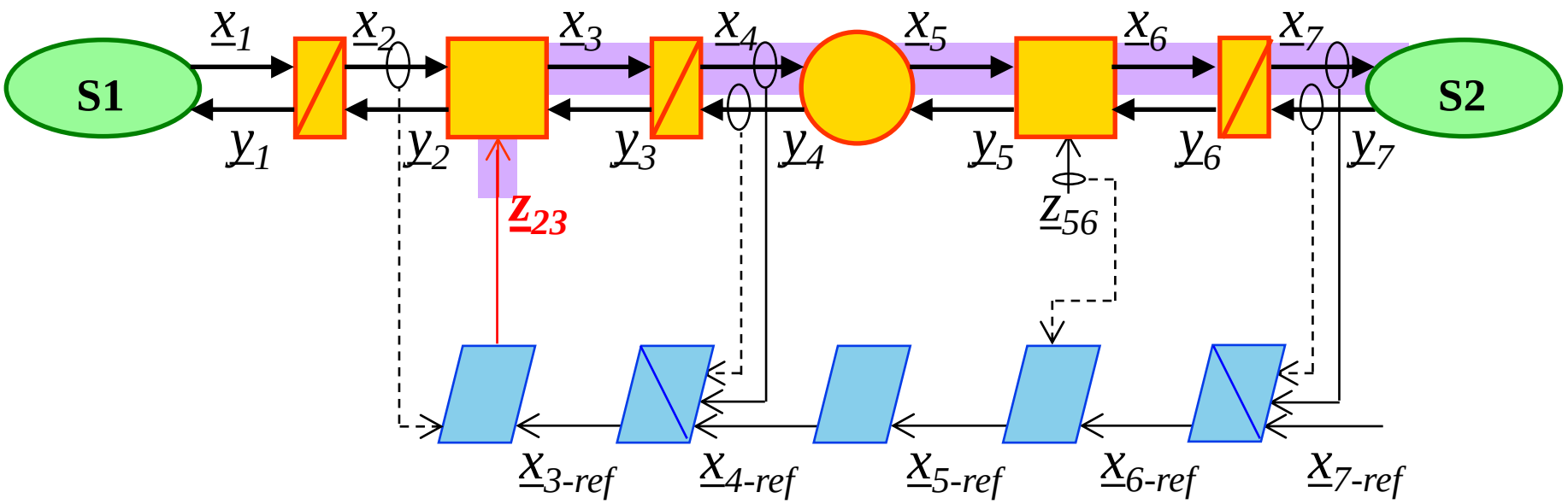


The tuning path is:

- 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

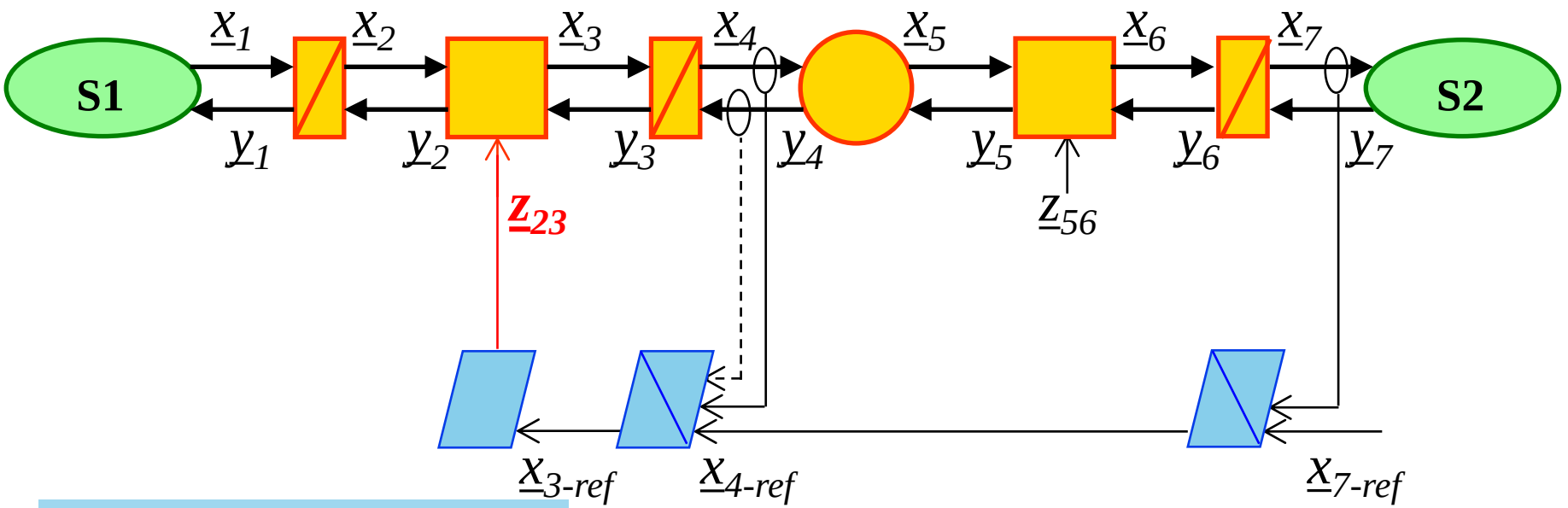
Example:
- 5 sensors
- 2 closed-loop controllers

1. EMR of the system

2. Tuning path

3. Inversion step-by-step

Strong assumption: all variables can be measured!



4. Simplification of control

Simplifications:

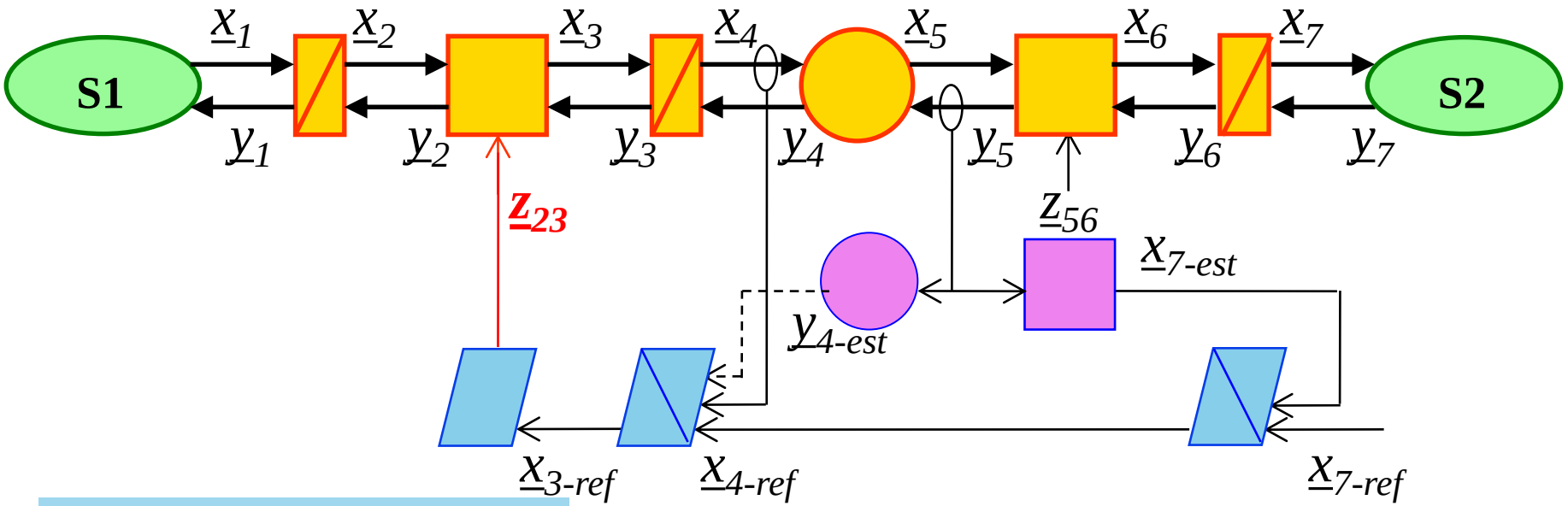
- non-consideration of disturbances ⇨ impact on the tuning and on the performances
- merging control blocks…

1. EMR of the system

2. Tuning path

3. Inversion step-by-step

Strong assumption: all variables can be measured!



4. Simplification of control

5. Estimation of non-measured variables

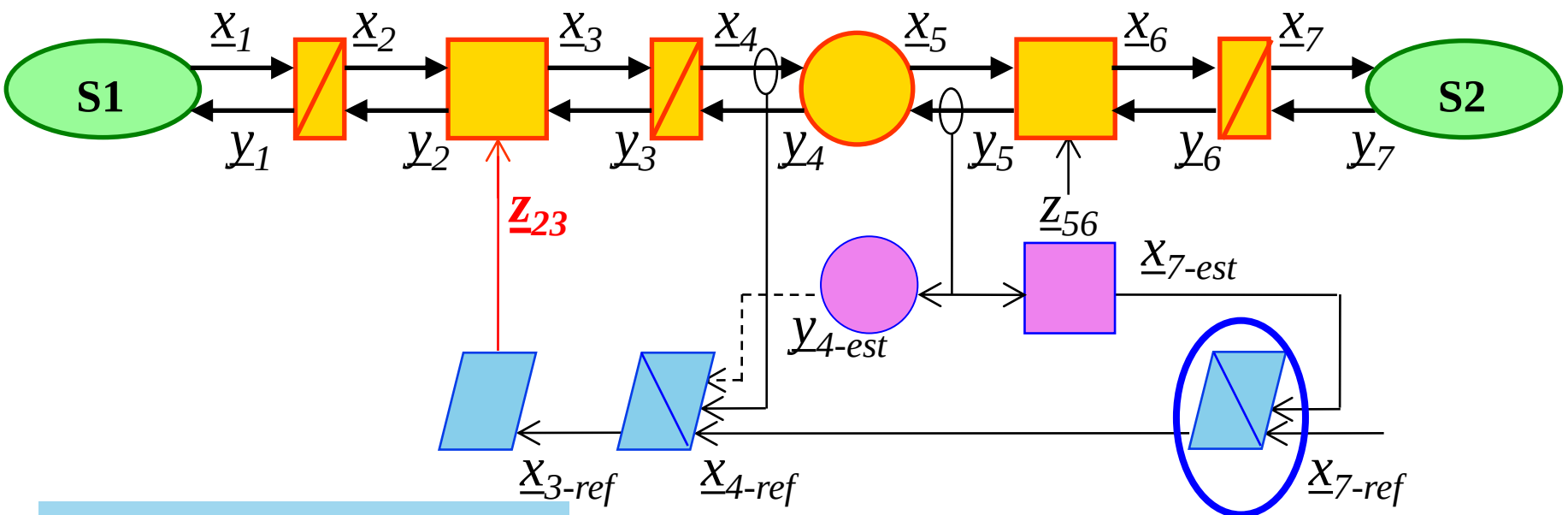
from measured variables

1. EMR of the system

2. Tuning path

3. Inversion step-by-step

Strong assumption: all variables can be measured!



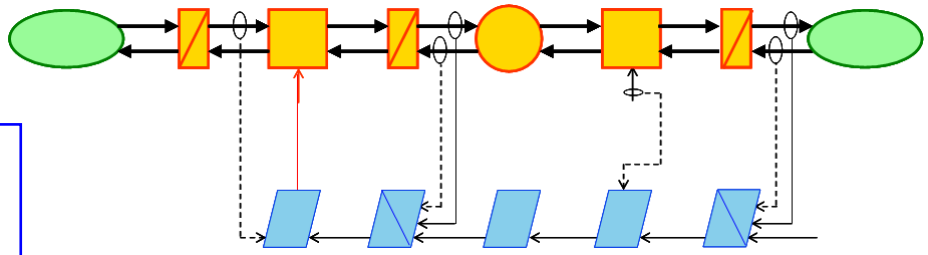
4. Simplification of control

5. Estimation of non-measured variables

6. Tuning of controllers

PI / PID / fuzzy controller?
Calculation of parameters?

1. EMR of the system
2. Tuning path
3. Inversion step-by-step



Maximal Control Scheme

- mirror of the EMR (systematic)
- unique and theoretical solution

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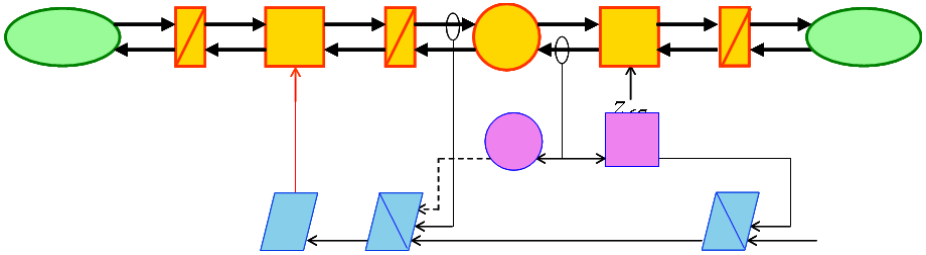
4. Simplification of control
5. Estimation of variables
6. Tuning of controllers



Practical Control Schemes

- several solutions (expertise)
- reduced performances

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, direct inversion for conversion element, degrees of freedom for coupling element

BIOGRAPHIES AND REFERENCES

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