Challenging Ourselves: Three Benchmarks for Nonlinear System Identification

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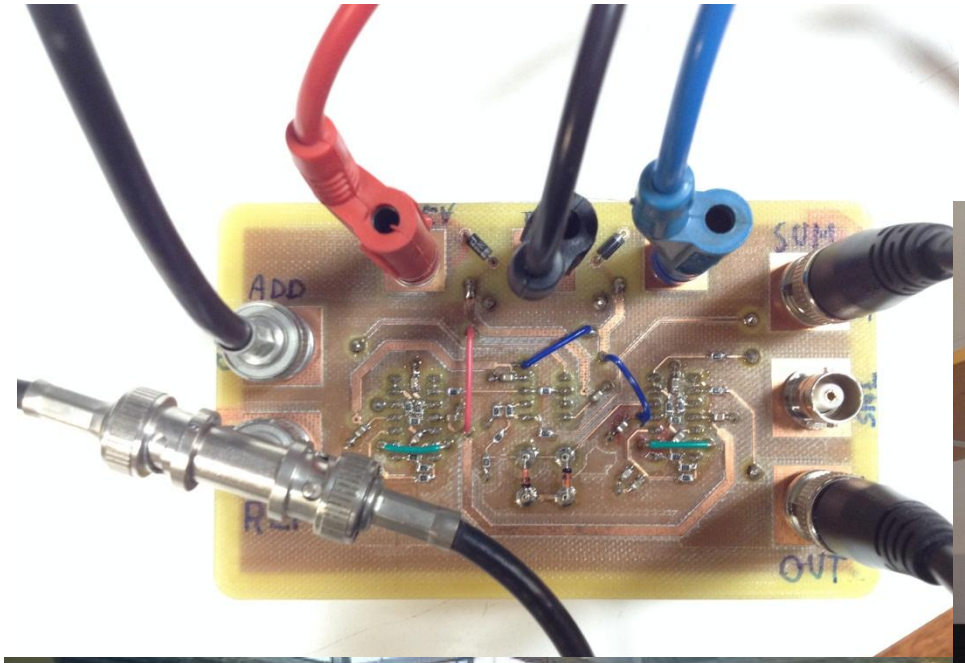
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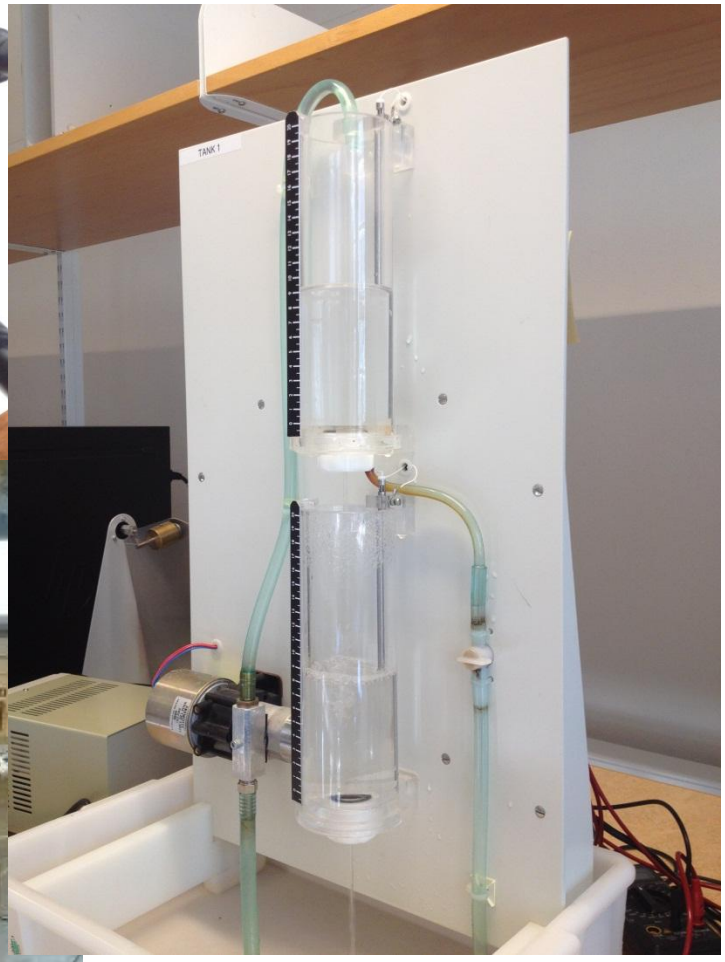

TANK 1

Benchmark on nonlinear system identification

Raise interest in selected challenges

Compare methods

Interaction between identification communities

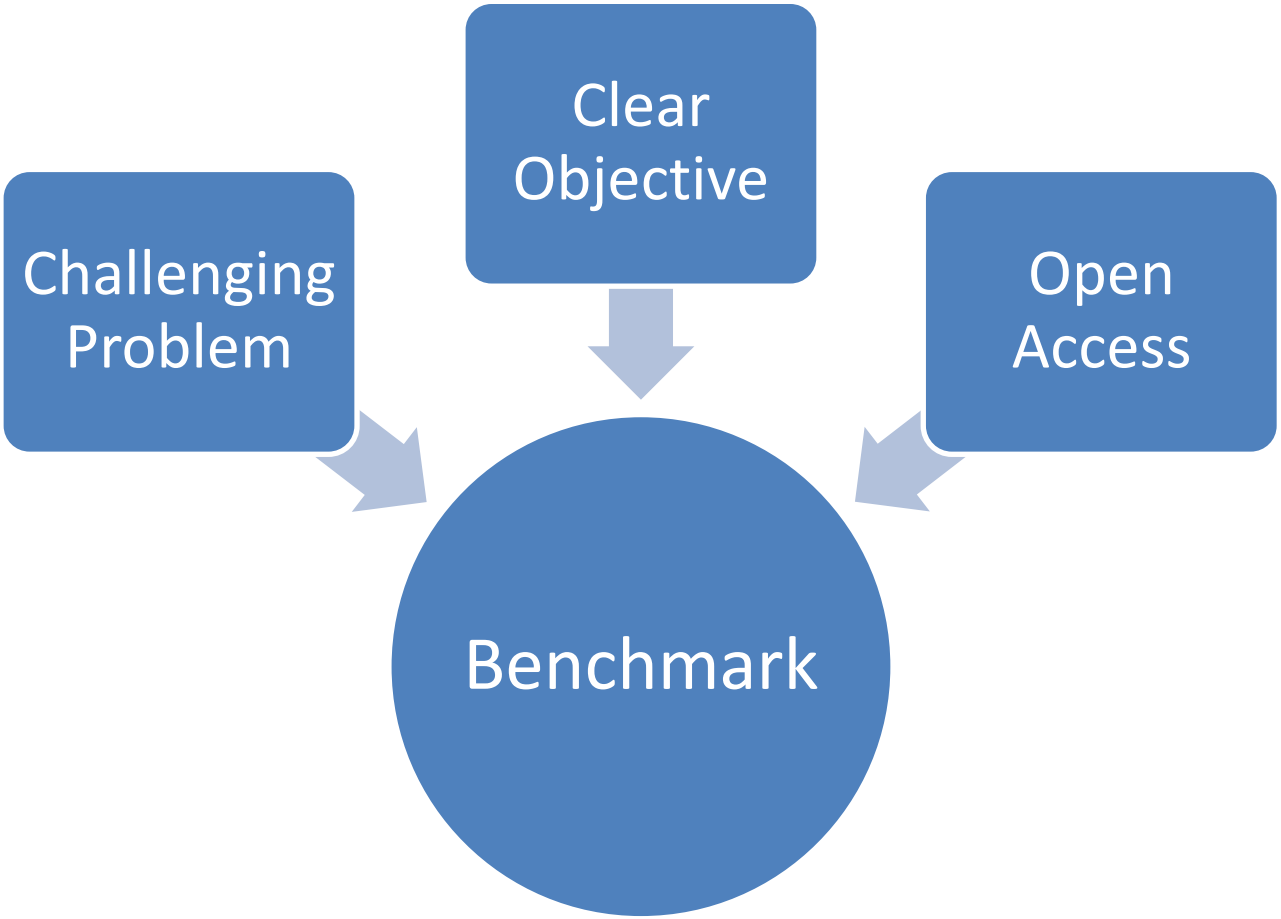
- Mechanical
- Systems & Control
- Machine Learning

Benchmark Workshop, Spring 2016

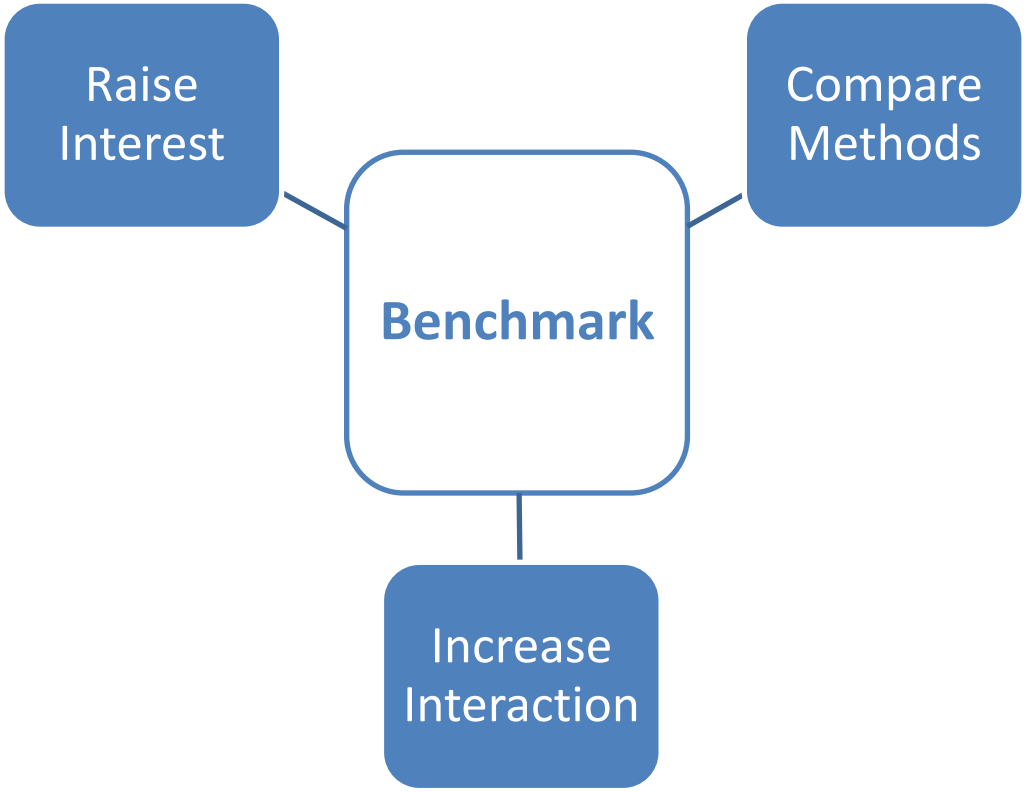
Outline

- Benchmarks
  - What? Why? How?
- Challenges in nonlinear sys. id.
- Three benchmarks
  - Bouc-Wen
  - Wiener-Hammerstein
  - Cascaded Tanks
- Benchmark meeting: practicalities

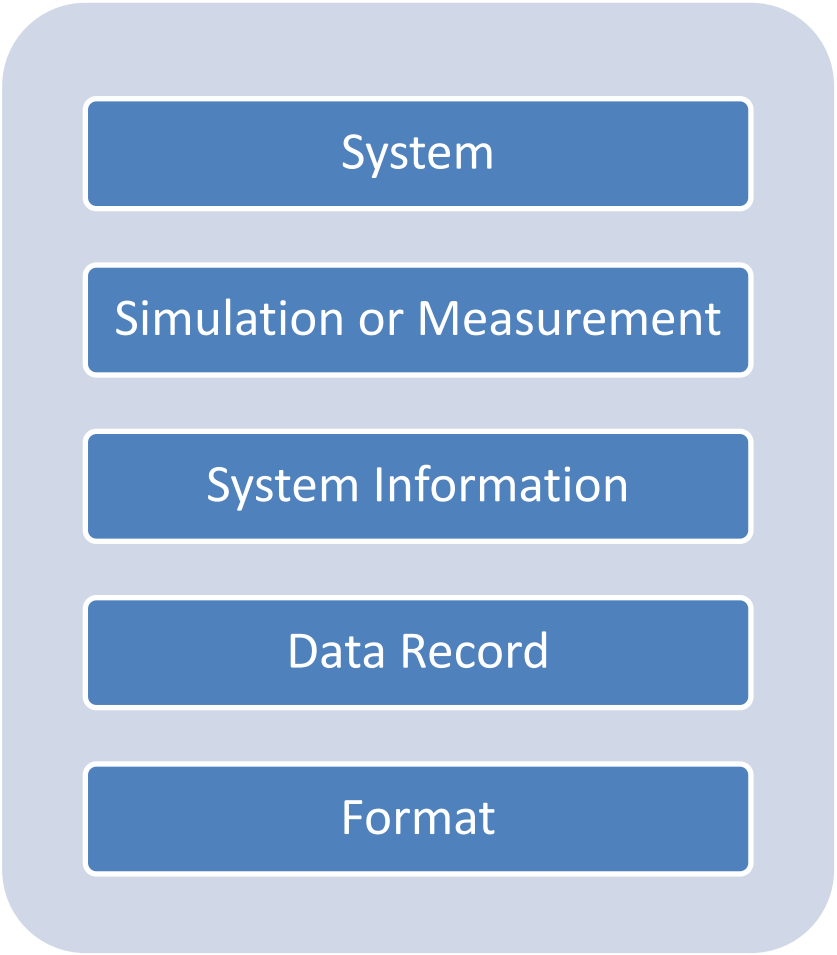
Benchmarks: What?



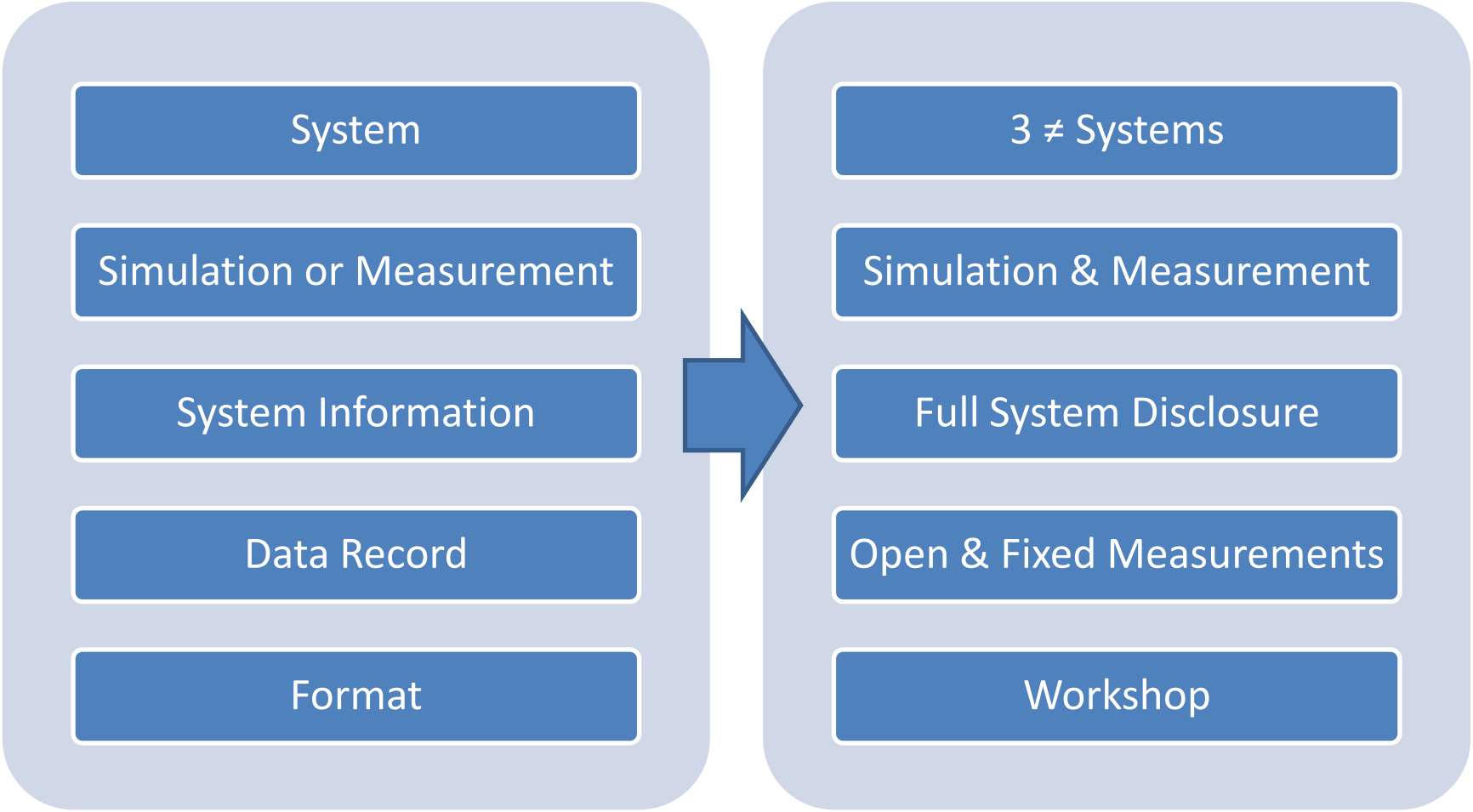
Benchmarks: Why?



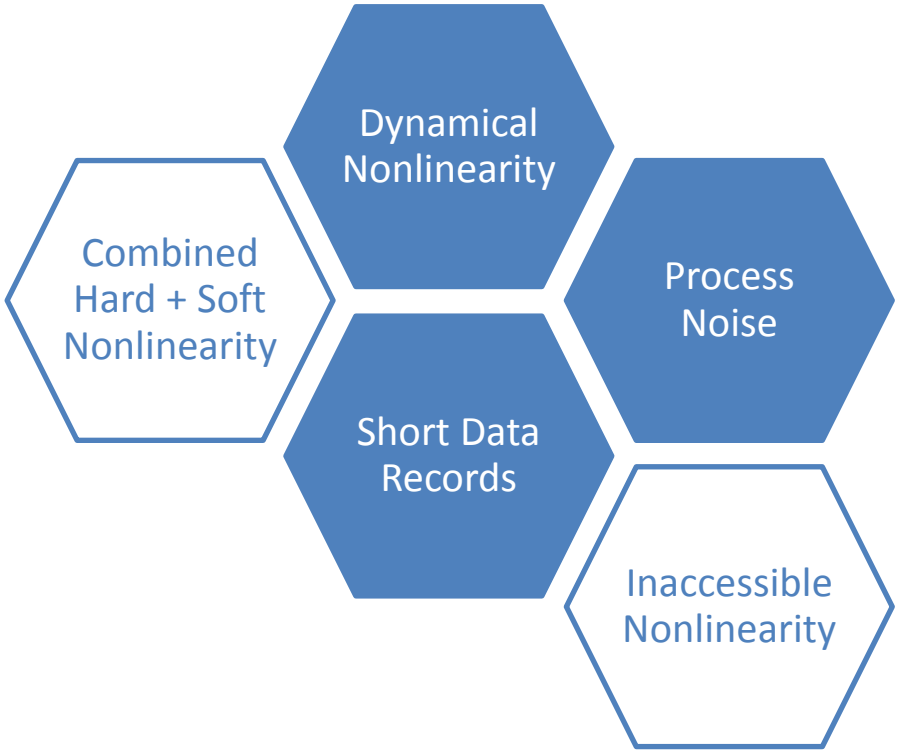
Benchmarks: How?



Benchmarks: How?



Nonlinear Sys Id: Challenges

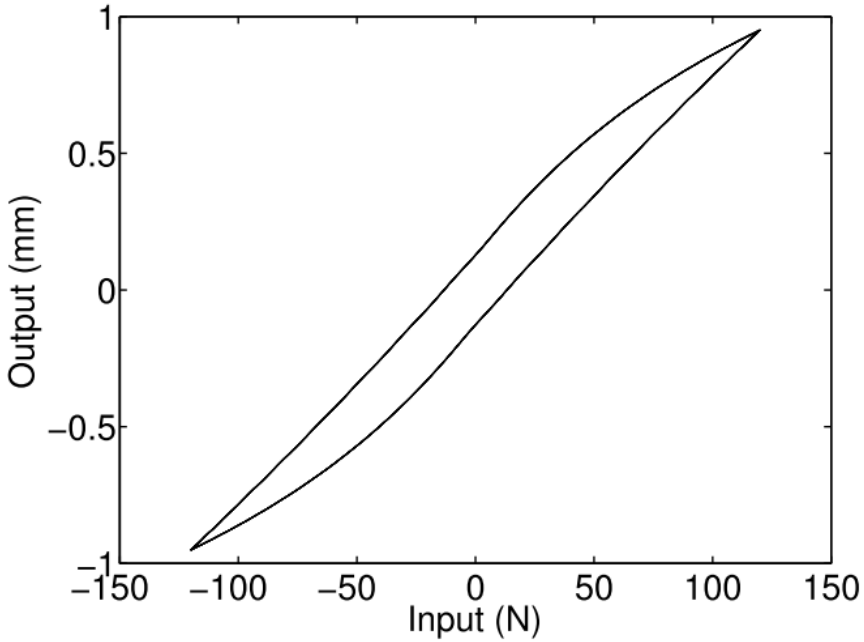


Three Benchmarks

Bouc-Wen	• Hysteresis
Wiener-Hammerstein	• Process Noise
Cascaded Tanks	• Short Data Record

Bouc-Wen Hysteretic System

Bouc-Wen Hysteretic System



Nonlinear differential equations:

$$m_L\ddot{y}(t) + r(y,\dot{y}) + z(y,\dot{y}) = u(t)$$

$$r(y,\dot{y}) = k_L y + c_L \dot{y}$$

$$\dot{z}(y,\dot{y}) = \alpha\dot{y} - \beta(\gamma|\dot{y}|z + \delta\dot{y}|z|)$$

Nonlinearity with memory

Bouc-Wen Hysteretic System

What do we provide?

Matlab simulation package

- Signal design by participants
- As much data as you want
- Available on benchmark website
- Noiseless validation

Bouc-Wen Hysteretic System

Challenges:

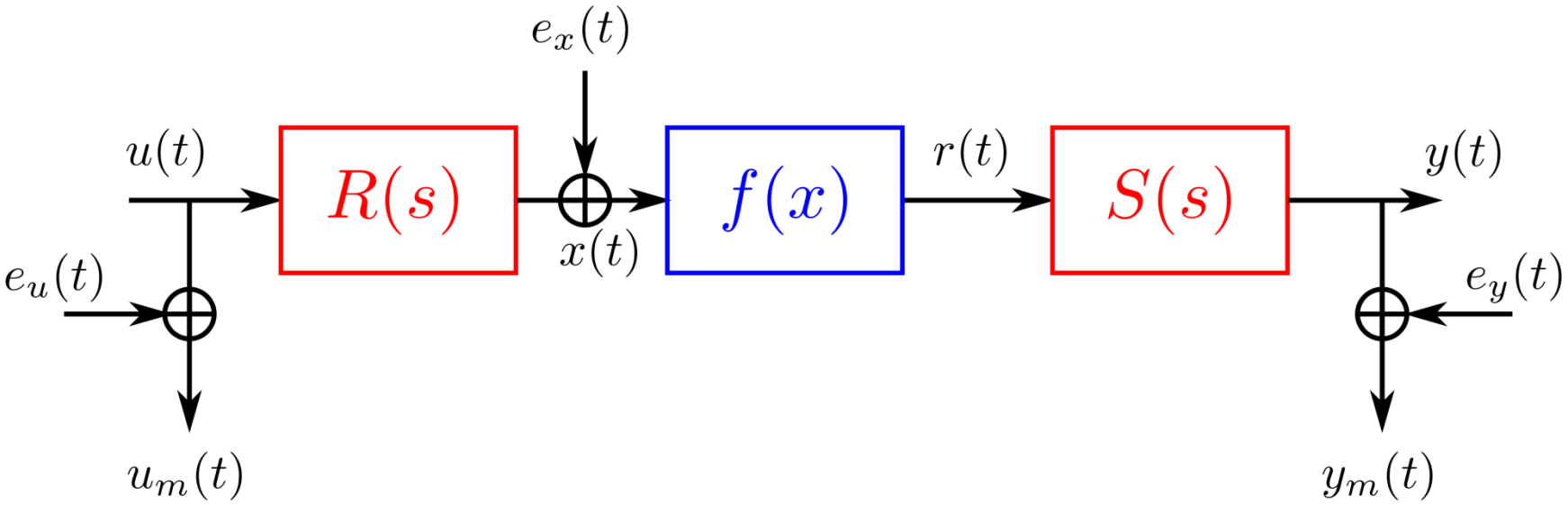
- Nonlinearity with memory
- Nonlinearity governed by internal variable
- Nonlinearity is not differentiable

$$m_L\ddot{y}(t) + r(y,\dot{y}) + z(y,\dot{y}) = u(t)$$

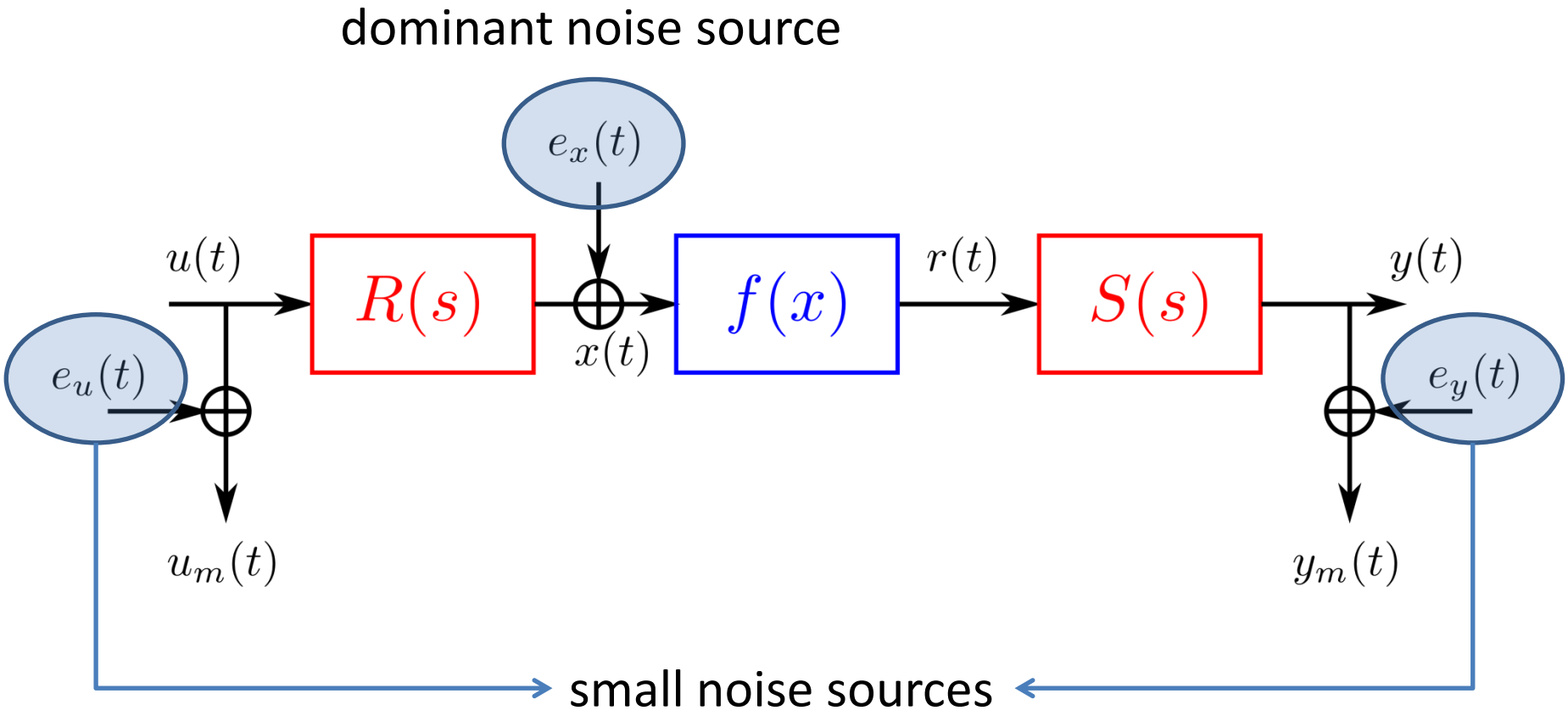
$$r(y,\dot{y}) = k_L y + c_L \dot{y}$$

$$\dot{z}(y,\dot{y}) = \alpha\dot{y} - \beta(\gamma|\dot{y}|z + \delta\dot{y}|z|)$$

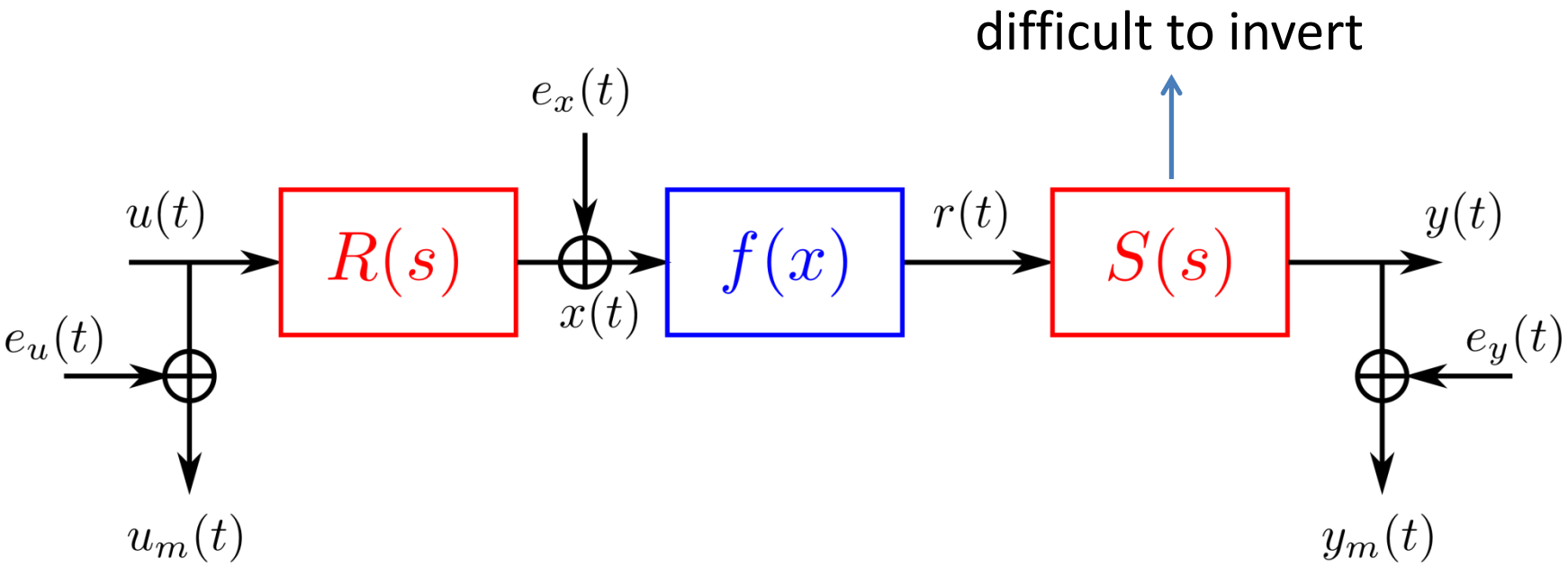
Wiener-Hammerstein + Process Noise



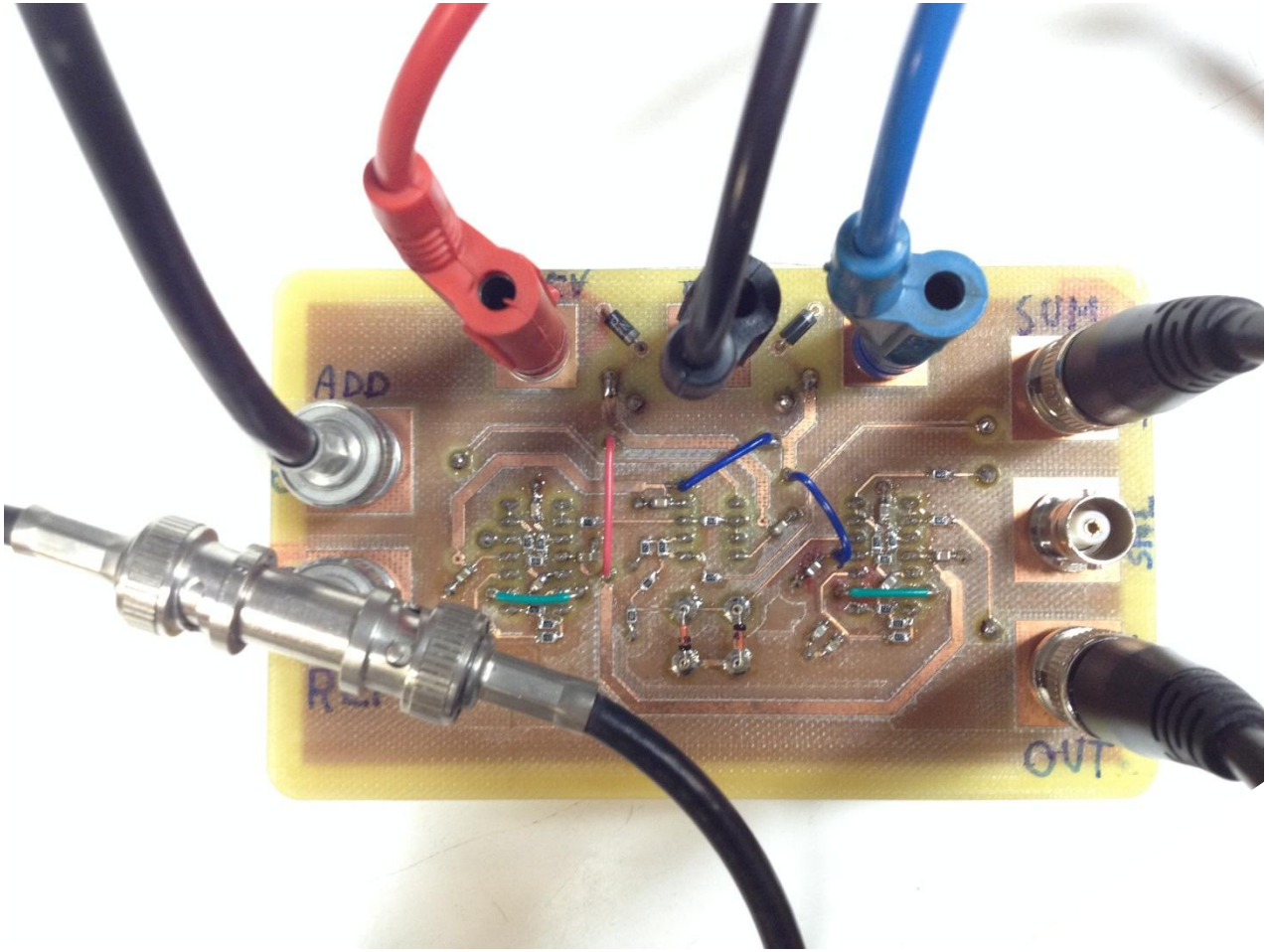
Wiener-Hammerstein + Process Noise



Wiener-Hammerstein + Process Noise



Wiener-Hammerstein + Process Noise



Wiener-Hammerstein + Process Noise

Open measurement campaigns:

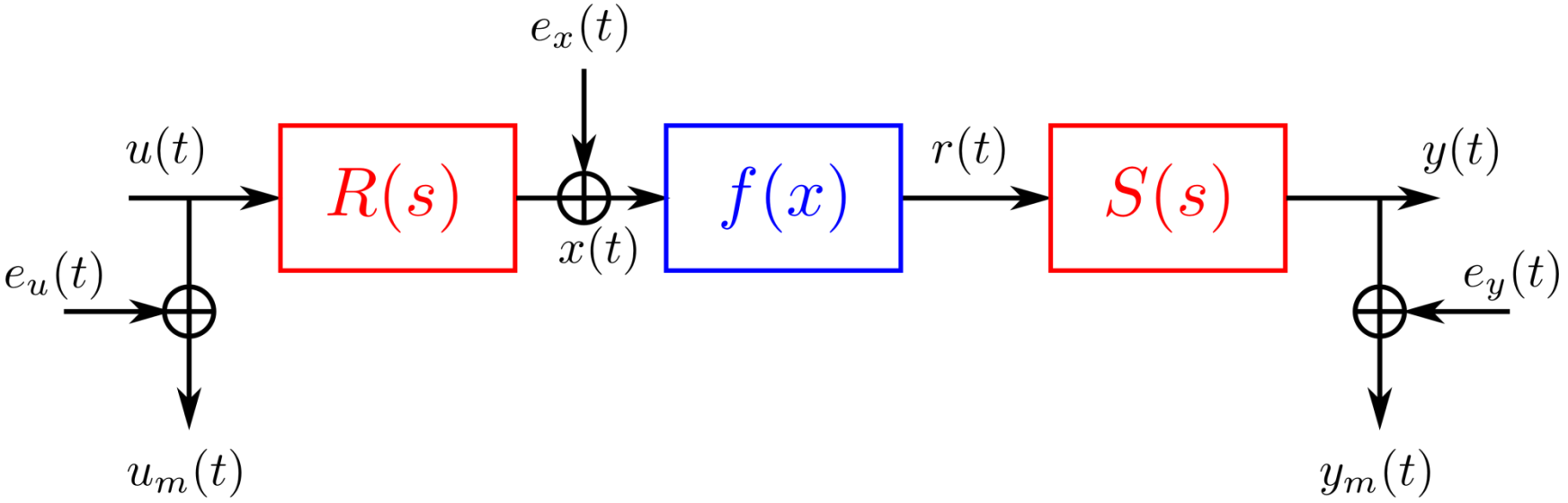
- Setup @ VUB, Brussels
- Signal design by participants
- Measurements performed by me
- As much data as you want*
- All data available to all participants
- Noiseless validation

* Terms and conditions may apply ;)

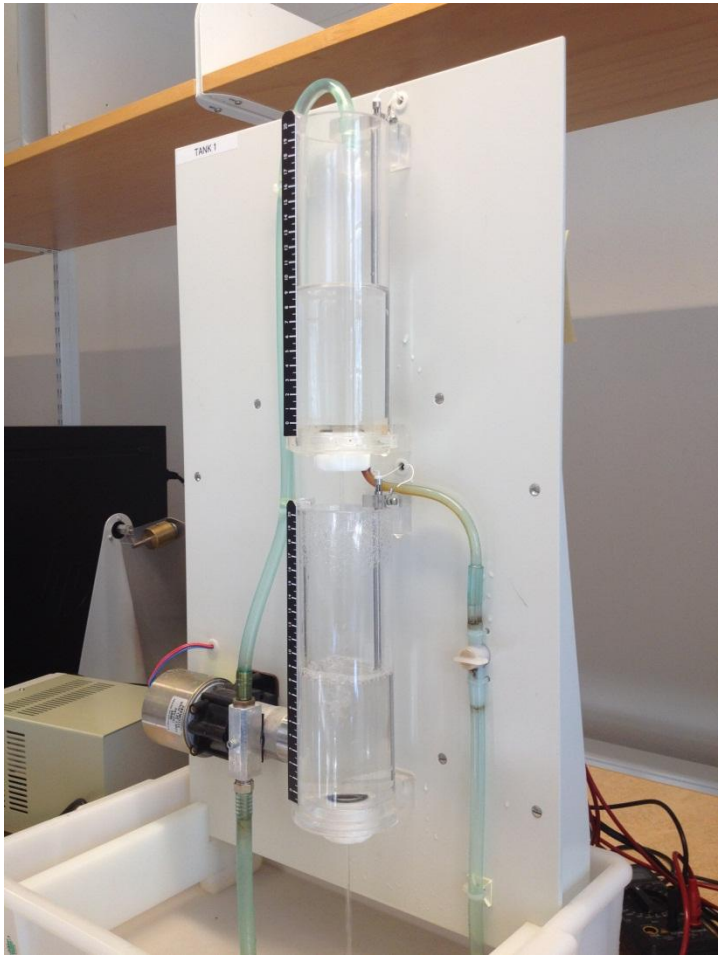
Wiener-Hammerstein + Process Noise

Challenges:

- Process noise in nonlinear system
- Nonlinearity not accessible from measurements
- Output dynamics are difficult to invert



Cascaded Tanks: Short Data Record



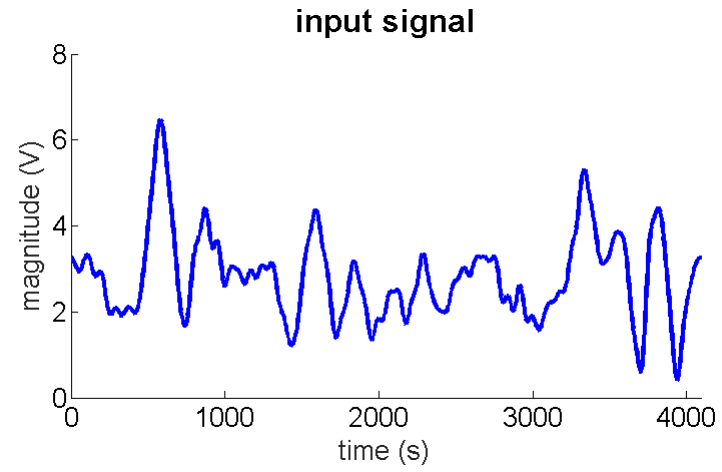
Nonlinear system dynamics:

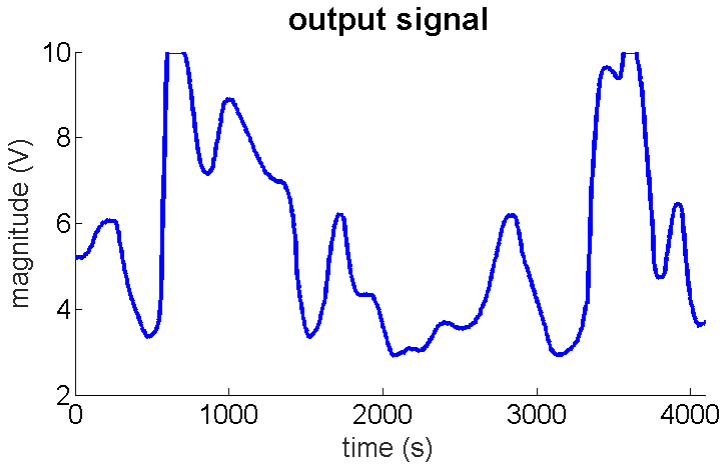
$$\dot{x}_1(t) = -k_1\sqrt{x_1(t)} + k_4 u(t) + w_1(t),$$
$$\dot{x}_2(t) = k_2\sqrt{x_1(t)} - k_3\sqrt{x_2(t)} + w_2(t),$$
$$y(t) = x_2(t) + e(t),$$

Overflow not included!

Special thanks to Torbjörn Wigren & Per Mattsson

Cascaded Tanks: Short Data Record





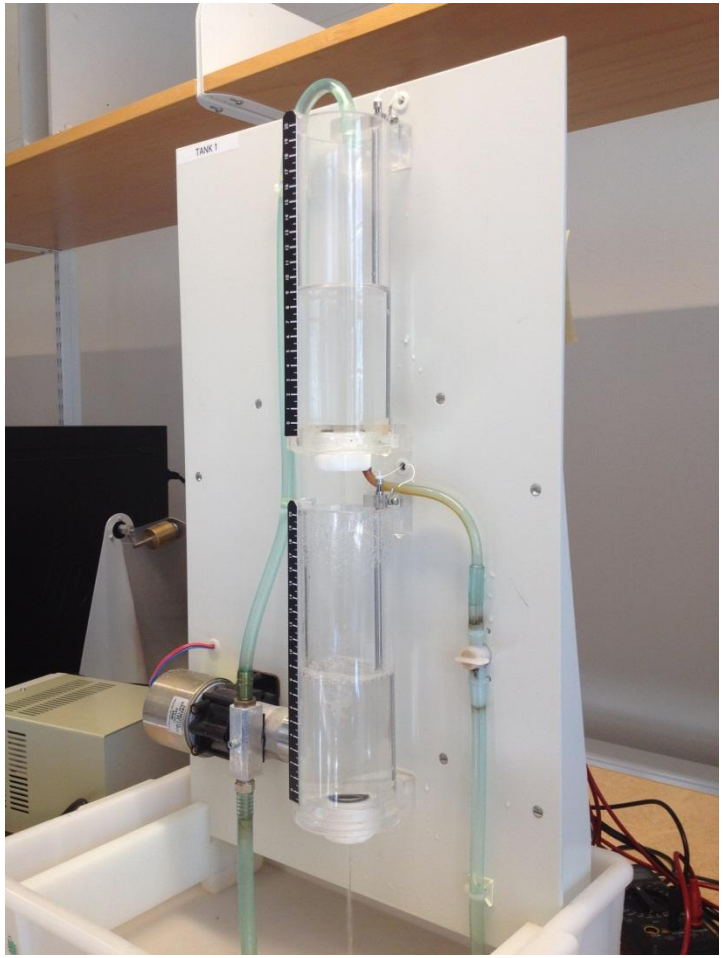
Fixed data records:

- 1024 points
- 60 frequencies excited
- Unknown initial states
- Small information content

Cascaded Tanks: Short Data Record

Challenges:

- Small information content
- Combination of soft and hard nonlinearity
- Overflow
- Unknown initial states



Benchmark on nonlinear system identification

Raise interest in selected challenges

Compare methods

Interaction between identification communities

- Mechanical
- Systems & Control
- Machine Learning

Benchmark Workshop, Spring 2016

Benchmark: Practicalities

When:	25/04/2016 – 27/04/2016
Where:	Brussels, Belgium
Who:	Mechanical, Systems & Control and Machine Learning Community
What:	Plenary sessions / discussions
Contributions:	1-page abstracts
More info:	http://homepages.vub.ac.be/~mschouke/benchmark2016.html

Benchmark on nonlinear system identification

25/04/2016 – 27/04/2016

You are all invited to participate

http://homepages.vub.ac.be/~mschouke/benchmark2016.html