Parameterized modeling and model order reduction for large electrical systems

Dr Elizabeth Rita Samuel

UNIVERSITEIT GENT

SUMO

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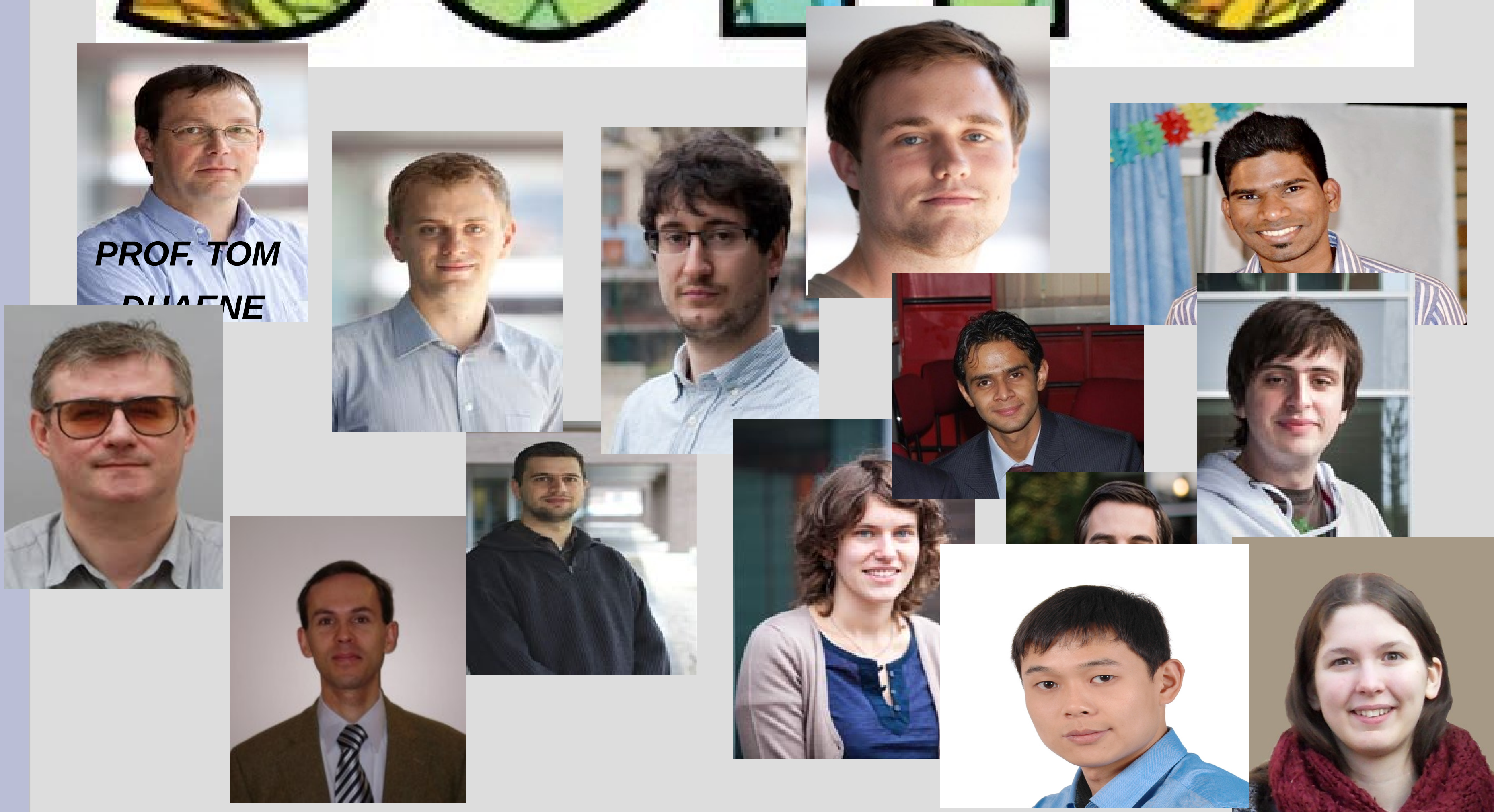
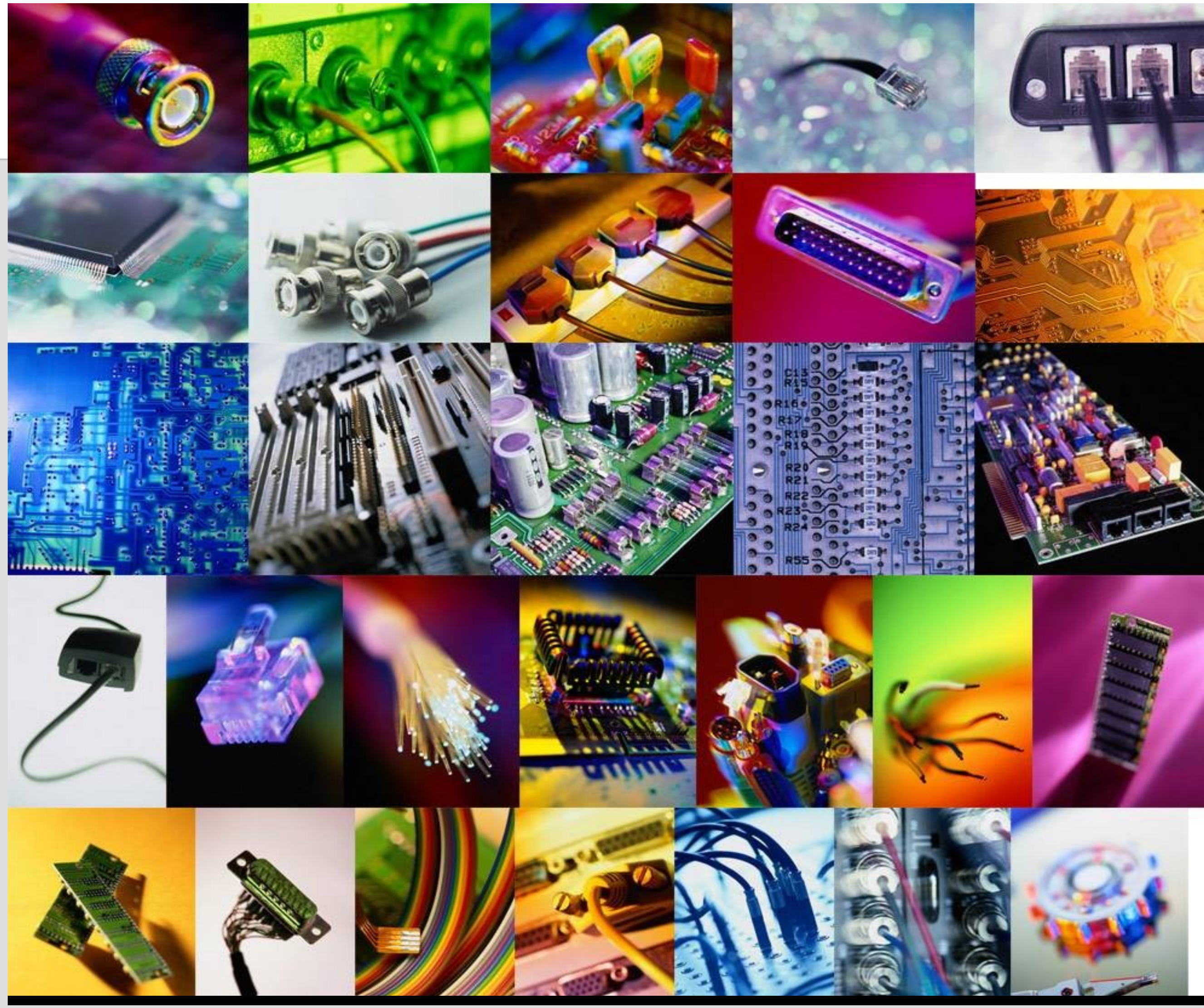


Parametric modeling
Parametric model order reduction
Supervised machine learning
Bioinformatics
High performance computing

Parameterized modeling and model order reduction for large electrical systems

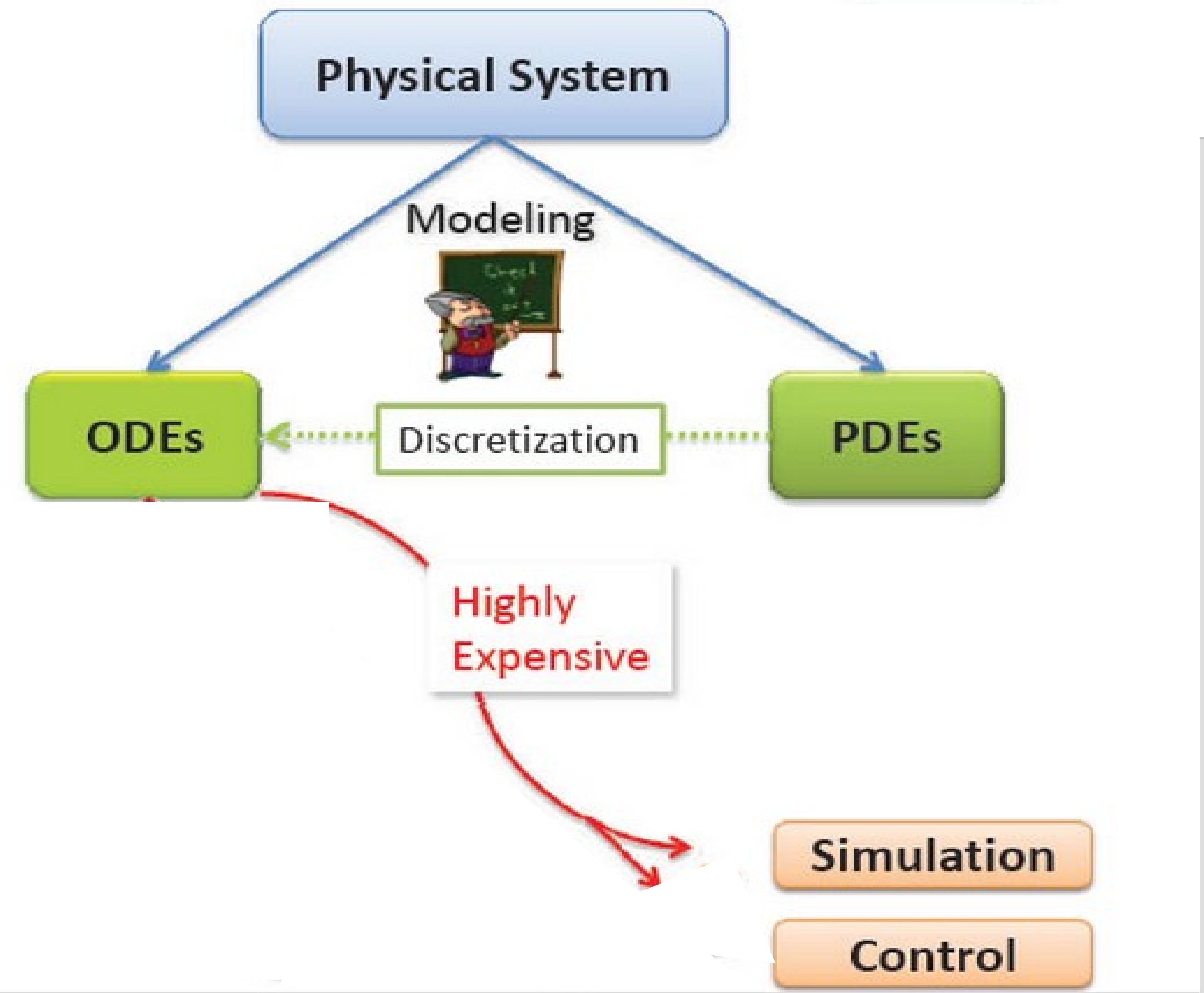
Dr Elizabeth Rita Samuel



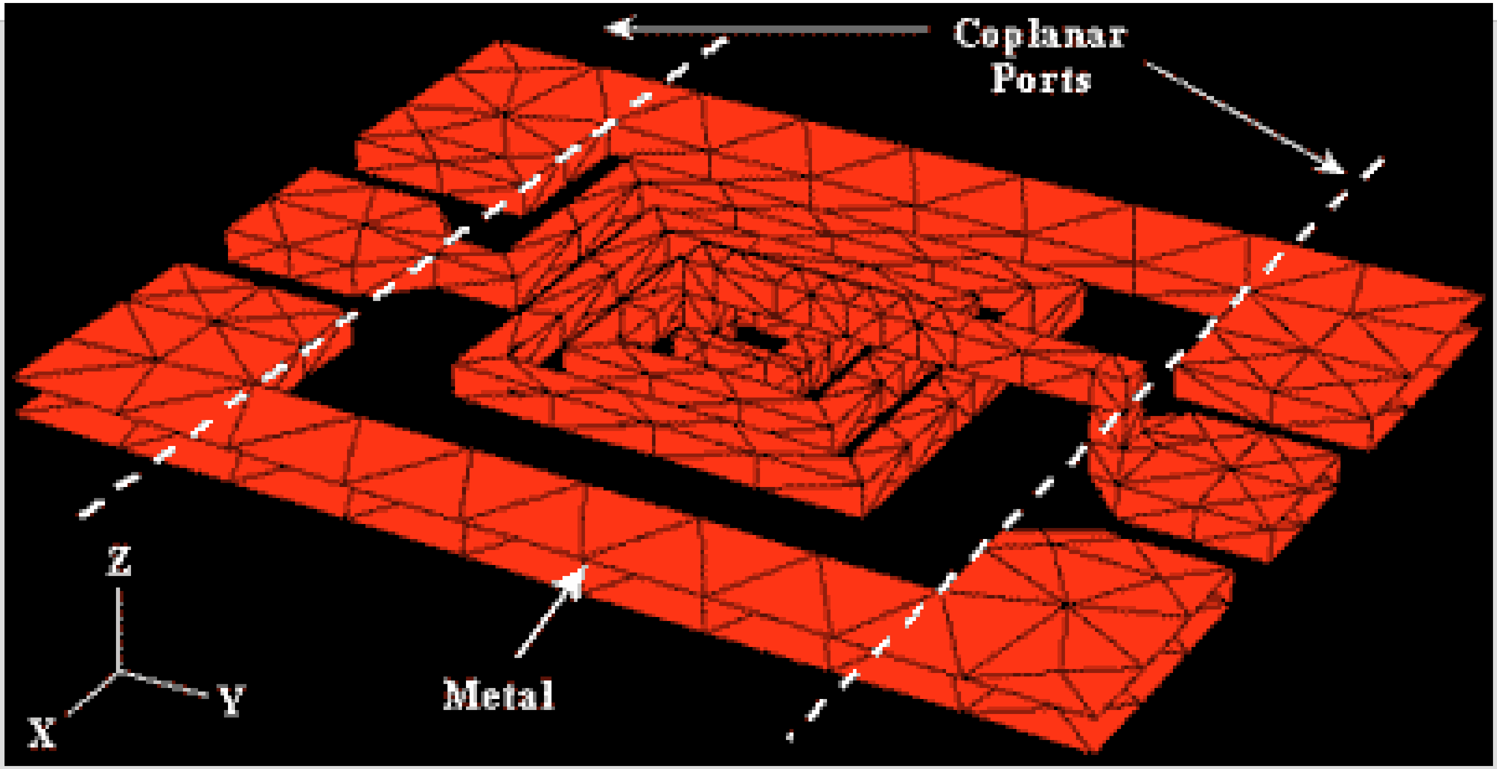
OVERVIEW

- **Model Order Reduction**
- Multipoint expansion
- Parameterized modeling

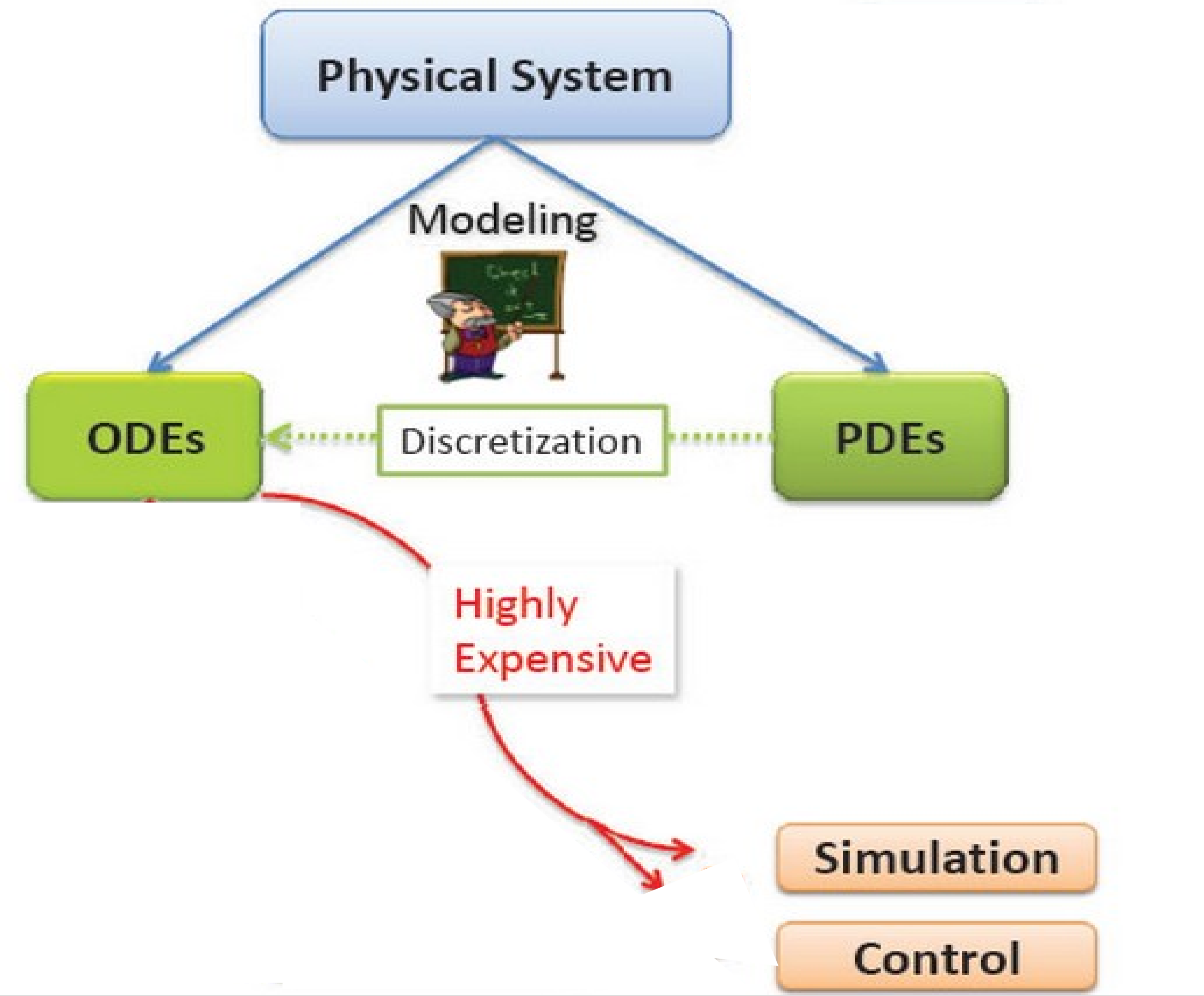
MODEL ORDER REDUCTION



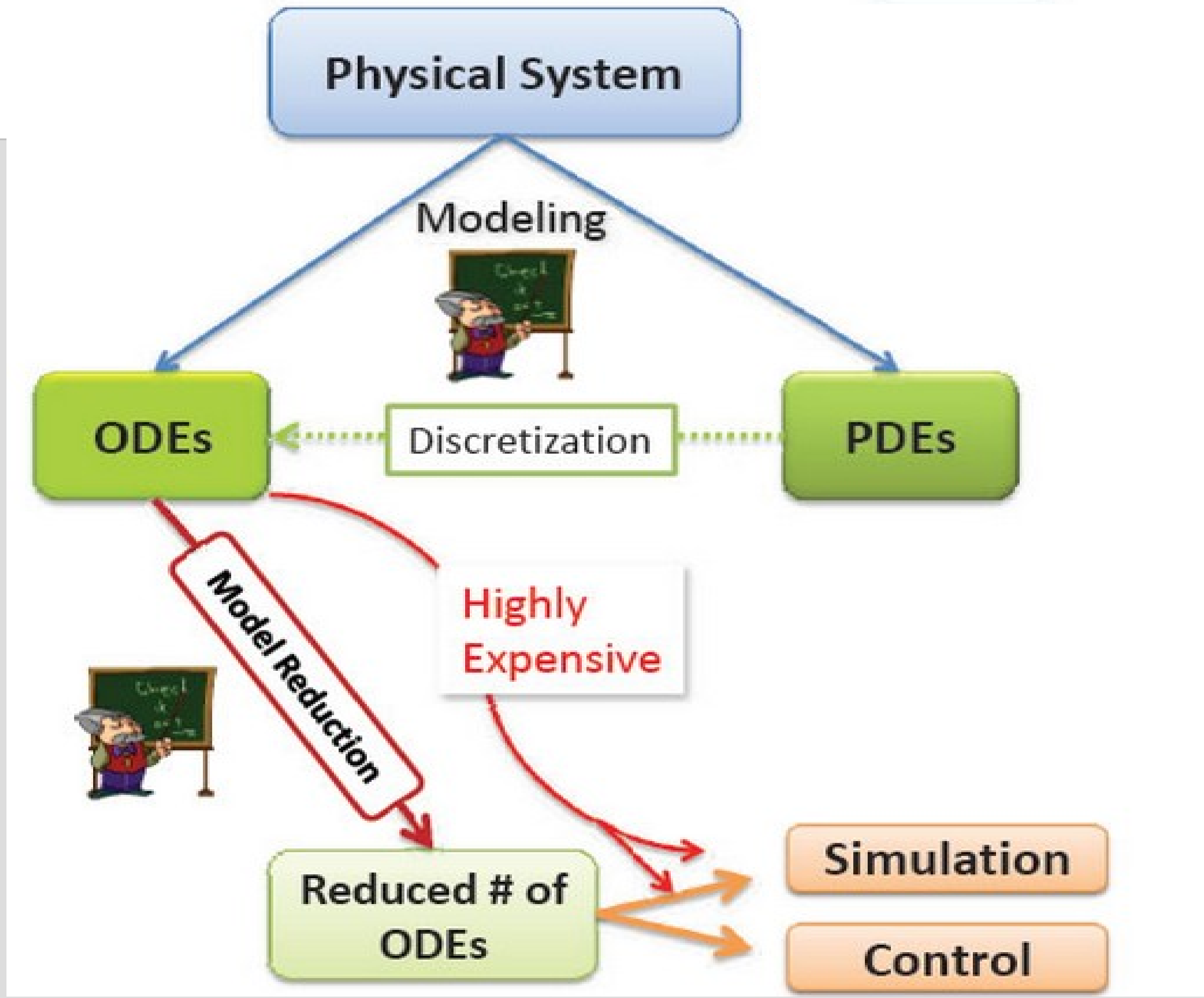
DISCRETIZATION



MODEL ORDER REDUCTION



MODEL ORDER REDUCTION



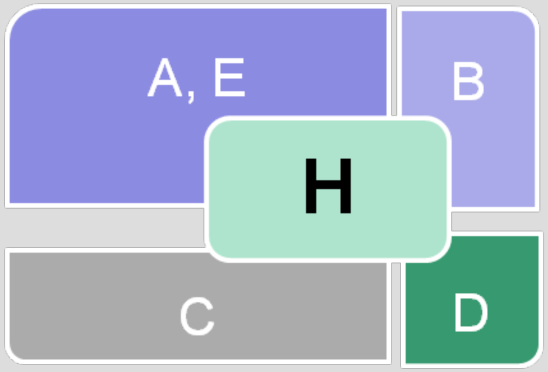
STATE SPACE

$$E\dot{x} = Ax + Bu$$

MODEL ORDER REDUCTION

$$E\dot{x} = Ax + Bu$$

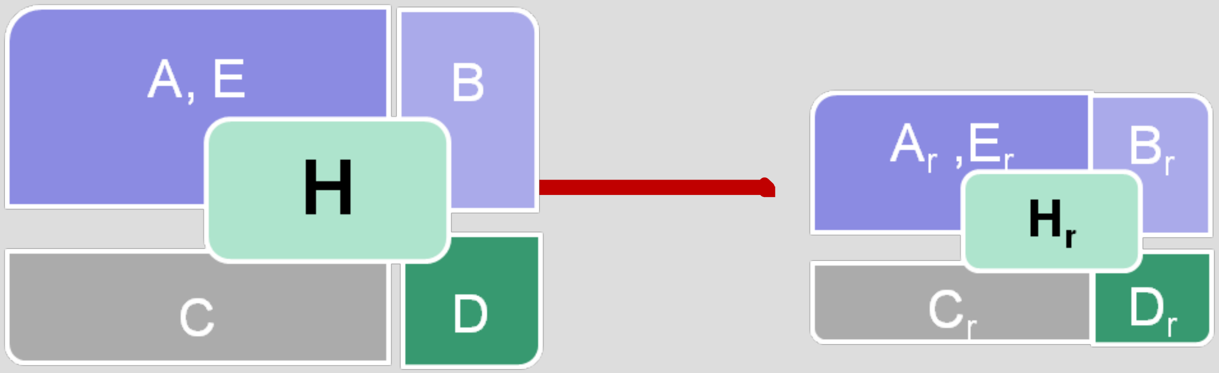
$$y = Cx$$



MODEL ORDER REDUCTION

$$E\dot{x} = Ax + Bu$$

$$y = Cx$$



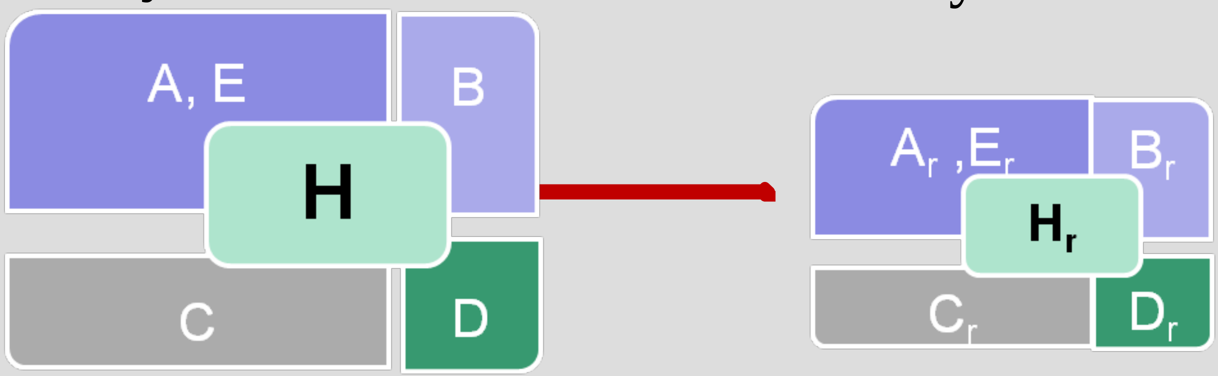
MODEL ORDER REDUCTION

$$E\dot{x} = Ax + Bu$$

$$y = Cx$$

$$V^T E V \dot{z} = V^T A V z + V^T B u$$

$$y = CVz$$



MODEL ORDER REDUCTION

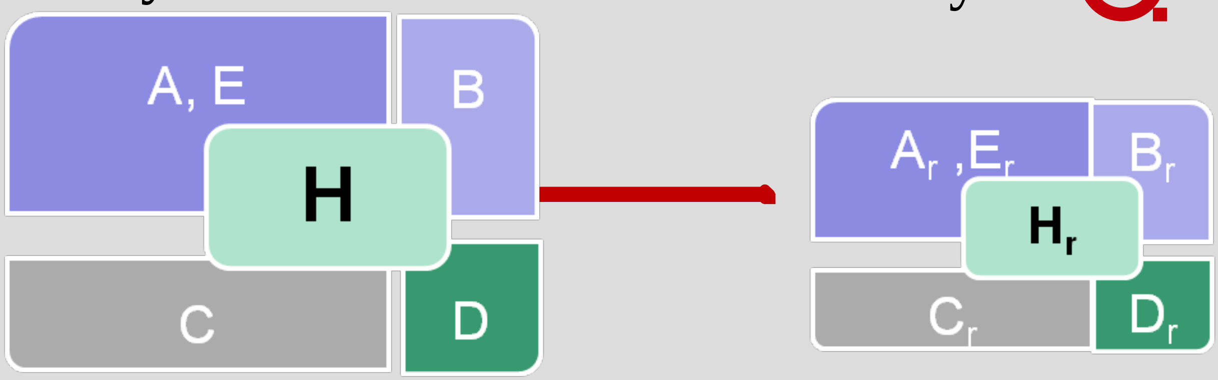
M O R

$$E\dot{x} = Ax + Bu$$

$$y = Cx$$

$$V^T E V \dot{z} = V^T A V z + V^T B u$$

$$y = CVz$$



MODEL ORDER REDUCTION

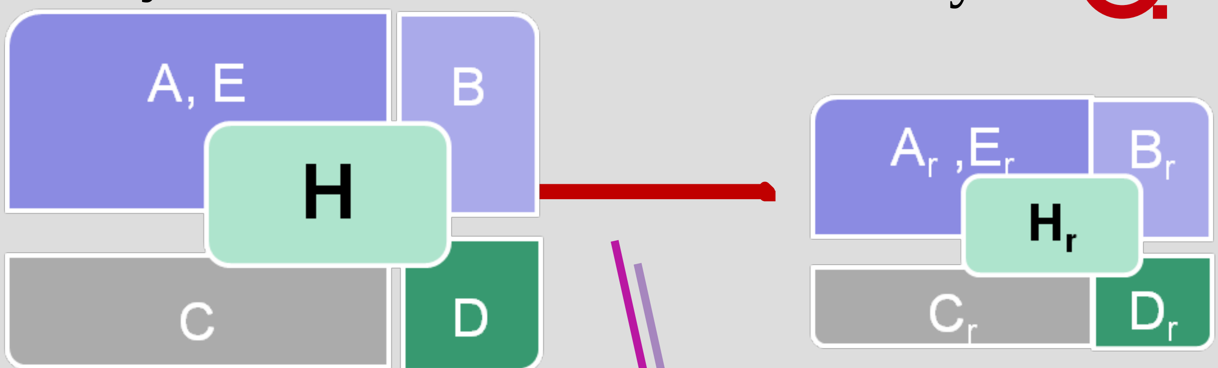
M O R

$$E\dot{x} = Ax + Bu$$

$$y = Cx$$

$$V^T E V \dot{z} = V^T A V z + V^T B u$$

$$y = CVz$$

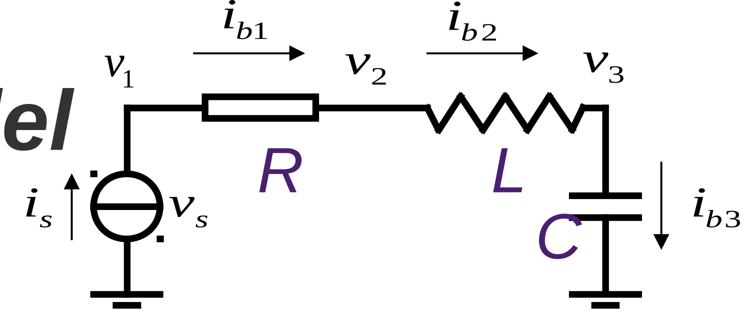


Approximation error small

Preservation of system properties

Computationally stable and efficient.

RLC circuit model

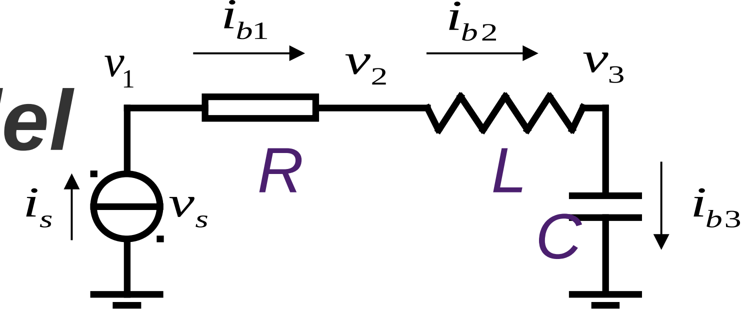


State-space model (MNA)

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & C & 0 \\ 0 & 0 & 0 & L \end{bmatrix} \begin{pmatrix} \dot{V}_1 \\ \dot{V}_2 \\ \dot{V}_3 \\ \dot{i}_L \end{pmatrix} = \begin{bmatrix} 1/R & -1/R & 0 & 0 \\ -1/R & 1/R & 0 & 1 \\ 0 & 0 & 0 & -1 \\ 0 & -1 & 1 & 0 \end{bmatrix} \begin{pmatrix} V_1 \\ V_2 \\ V_3 \\ i_L \end{pmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} i_s$$

$$y = \begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix} \begin{pmatrix} V_1 \\ V_2 \\ V_3 \\ i_L \end{pmatrix}$$

RLC circuit model



State-space model (MNA)

E A B

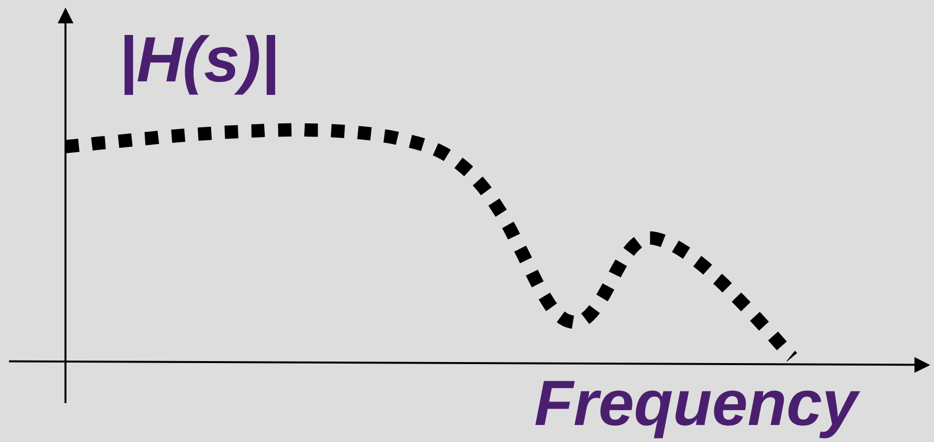
$$\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&C&0\\0&0&0&L\end{bmatrix}\begin{pmatrix}\dot V_1\\ \dot V_2\\ \dot V_3\\ \dot i_L\end{pmatrix} = \begin{bmatrix}1/R&-1/R&0&0\\-1/R&1/R&0&1\\0&0&0&-1\\0&-1&1&0\end{bmatrix}\begin{pmatrix}V_1\\V_2\\V_3\\i_L\end{pmatrix} + B\, i_s$$

C

$$y = C\begin{pmatrix}V_1\\V_2\\V_3\\i_L\end{pmatrix}$$

TRANSFER FUNCTION

$$Y(s) = C\,(E\,s - A)^{-1}\,B\,U(s)$$



MOMENT MATCHING

Taylor expansion:

$$H(s) = C\,(M_0 + M_1 s + M_2 s^2 \ldots)$$

Moment-matching

Taylor expansion:

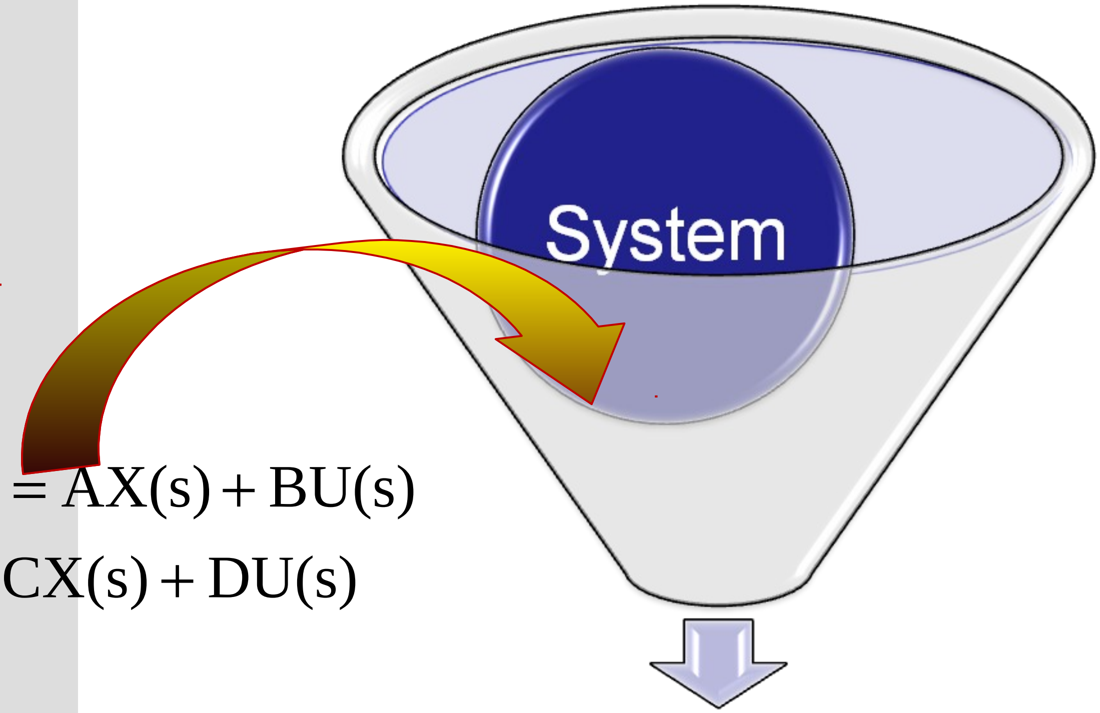
$$H(s) = C\,(M_0 + M_1 s + M_2 s^2 \ldots)$$

$$V = \begin{bmatrix} M_0 & M_1 & M_2 \end{bmatrix}$$

OVERVIEW

* Model Order Reduction
* **Multipoint expansion**
* Parameterized modeling

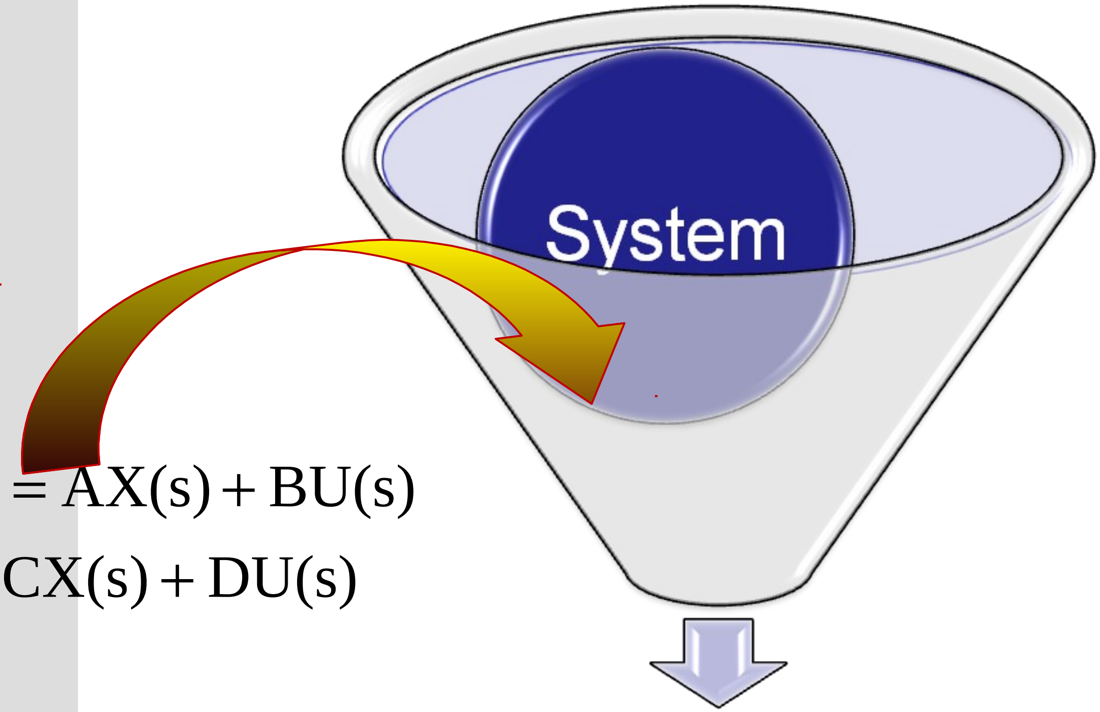
EXPANSION POINT



$$sEX(s) = AX(s) + BU(s)$$

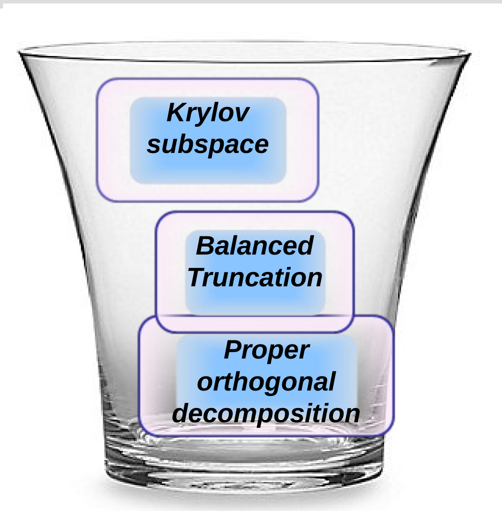
$$Y(s) = CX(s) + DU(s)$$

EXPANSION POINT



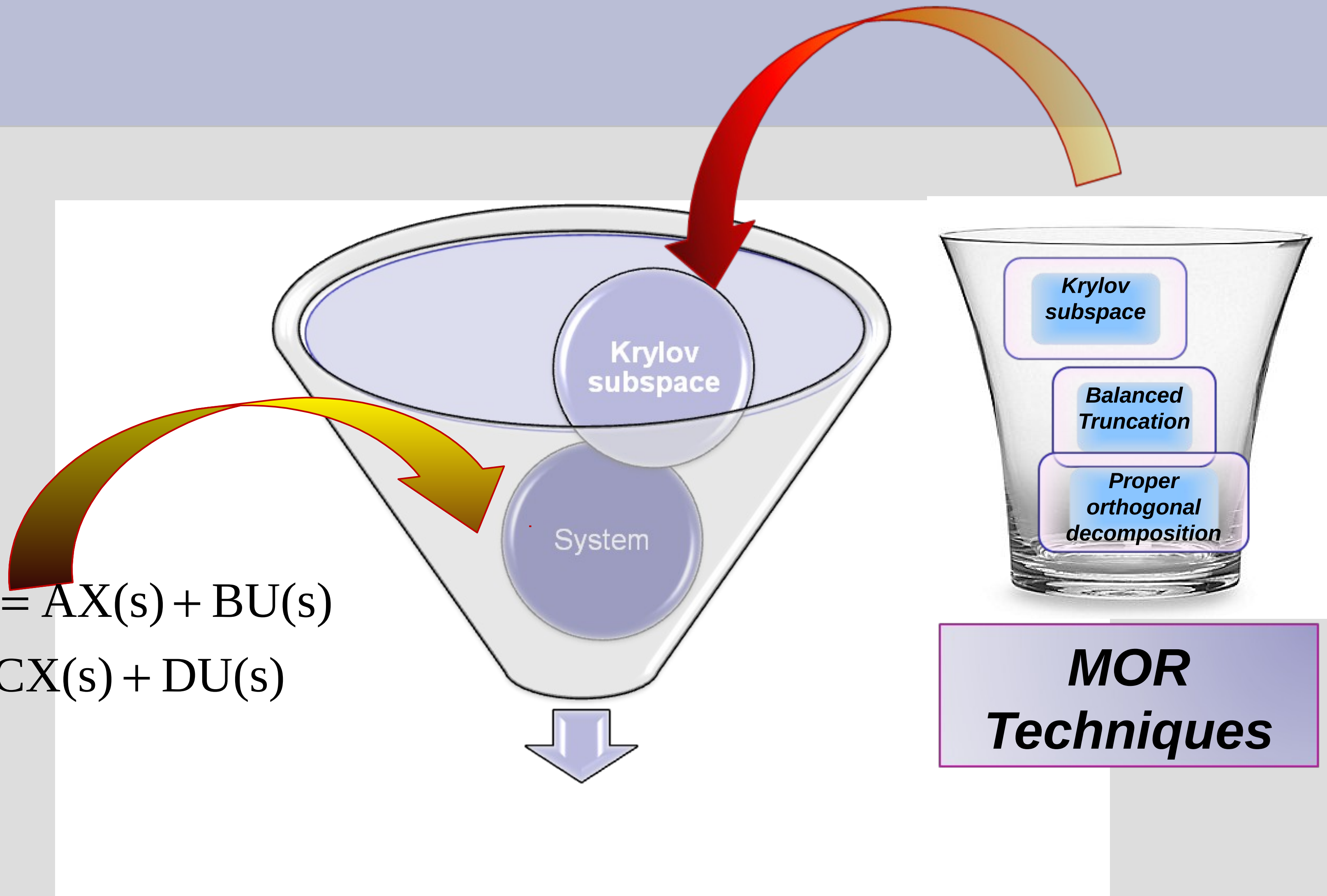
$$sEX(s) = AX(s) + BU(s)$$

$$Y(s) = CX(s) + DU(s)$$



MOR Techniques

EXPANSION POINT

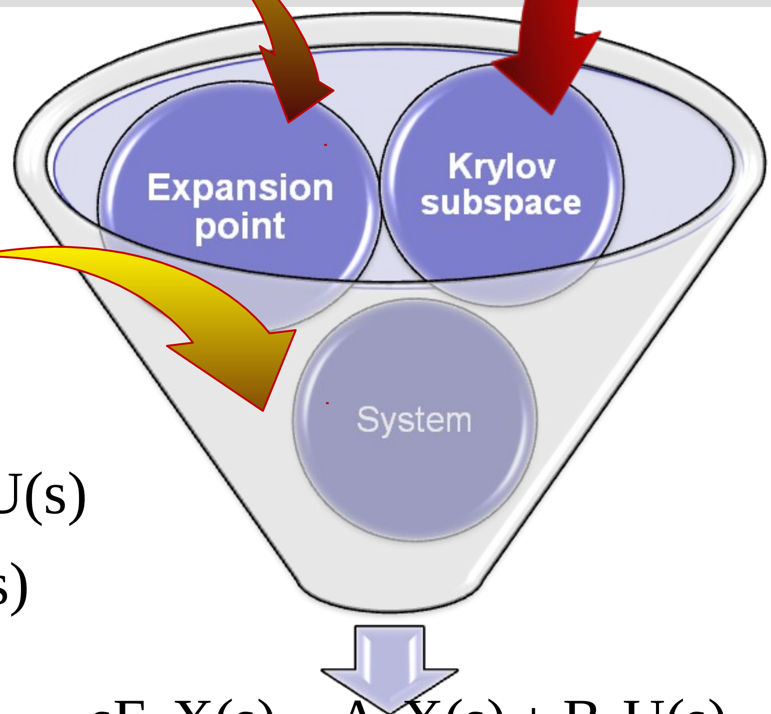


$$sEX(s) = AX(s) + BU(s)$$

$$Y(s) = CX(s) + DU(s)$$

EXPANSION POINT

$$H(s) = m_0 + m_1(s - s_0) + \cdots + m_i(s - s_0)^i - \ldots$$

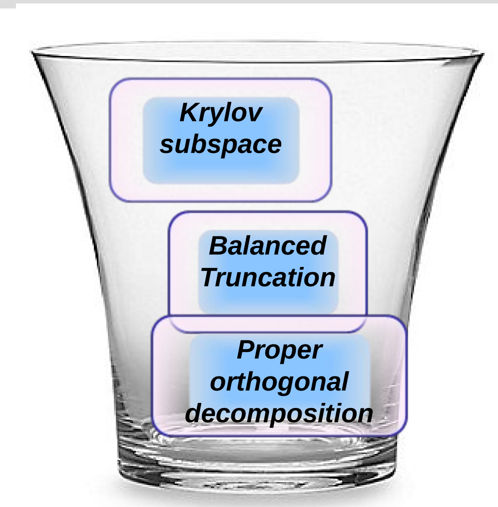


$$sEX(s) = AX(s) + BU(s)$$

$$Y(s) = CX(s) + DU(s)$$

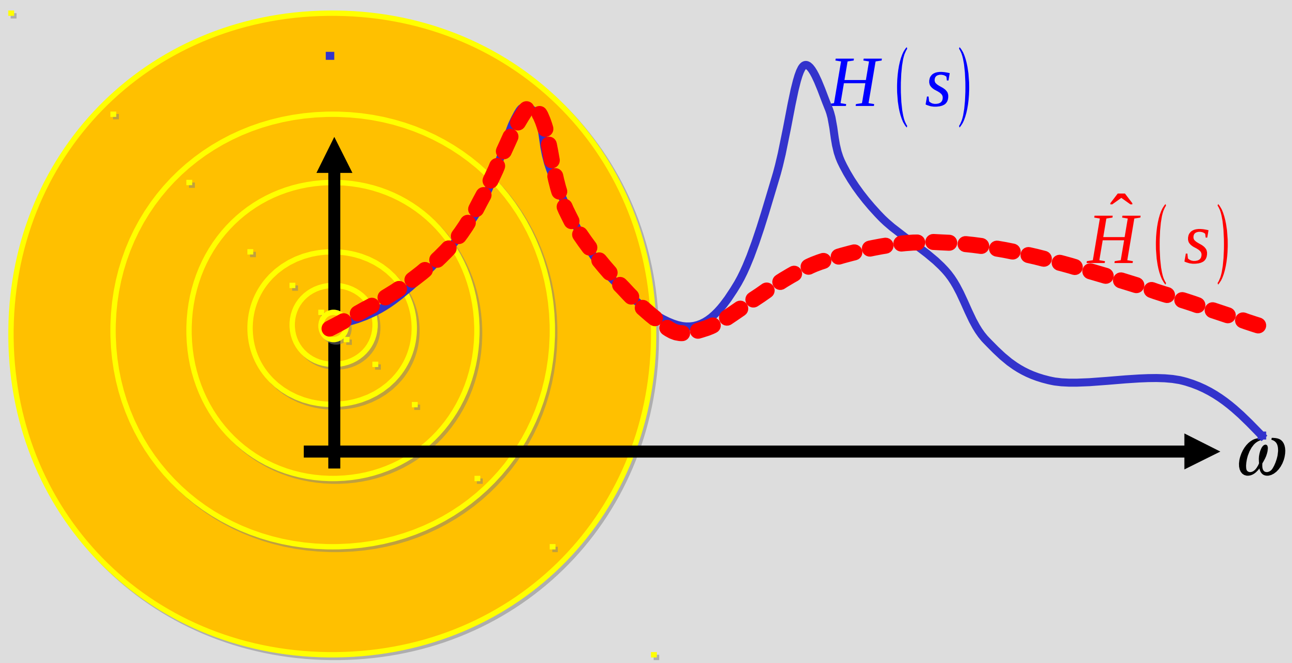
$$sE_rX(s) = A_rX(s) + B_rU(s)$$

$$Y(s) = C_rX(s) + D_rU(s)$$



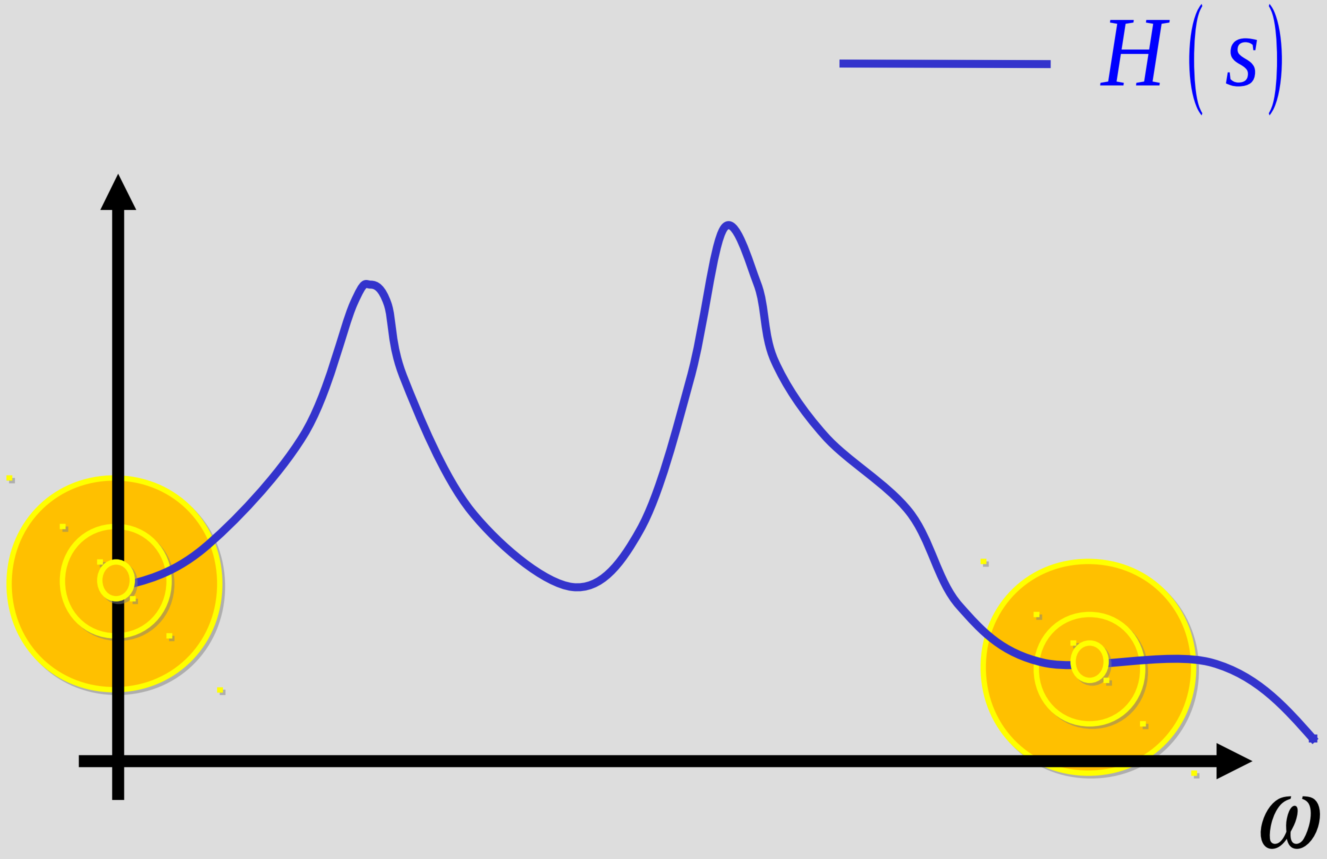
MOR Techniques

EXPANSION POINT



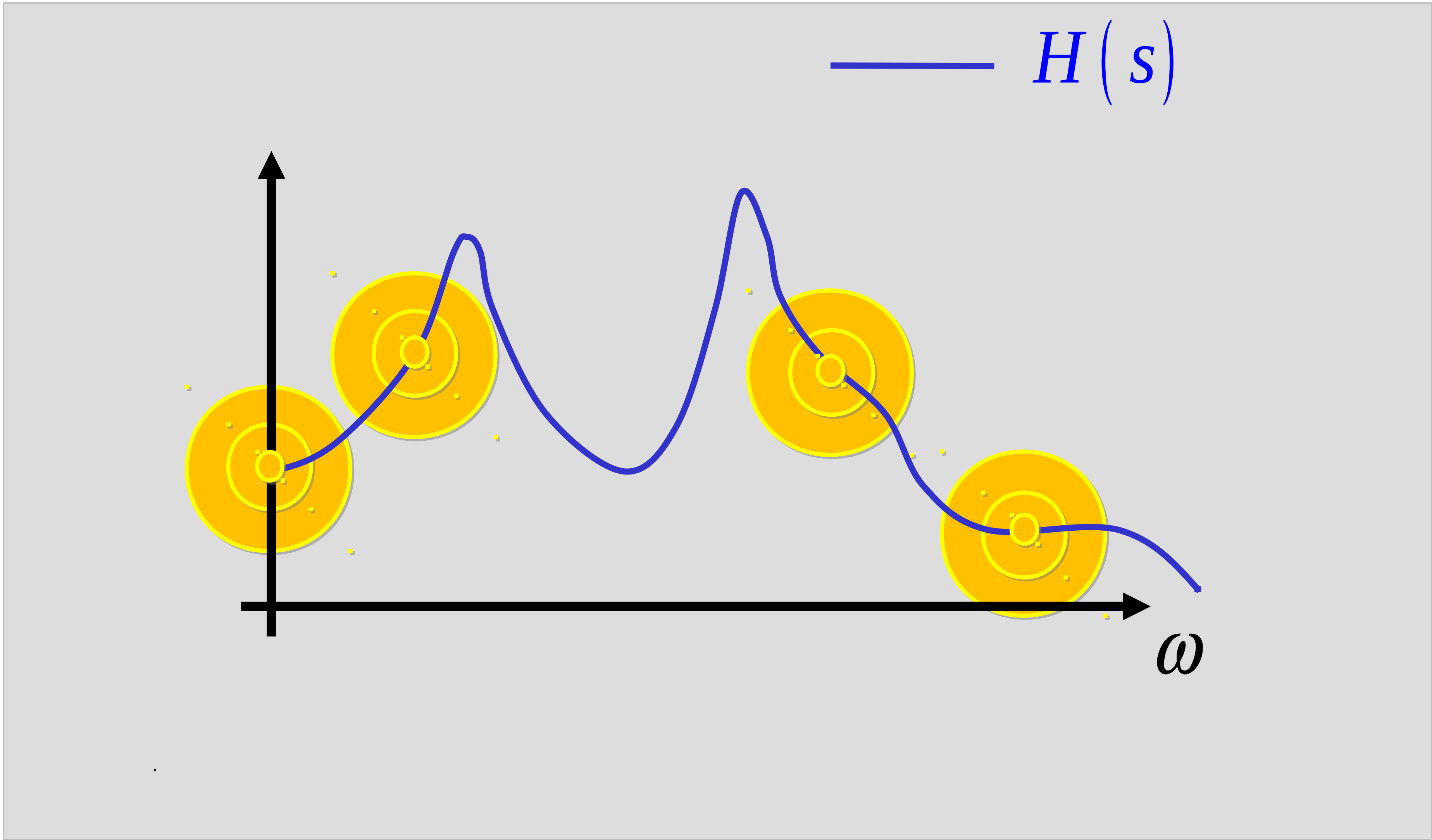
EXPANSION POINT

For multiple expansion point



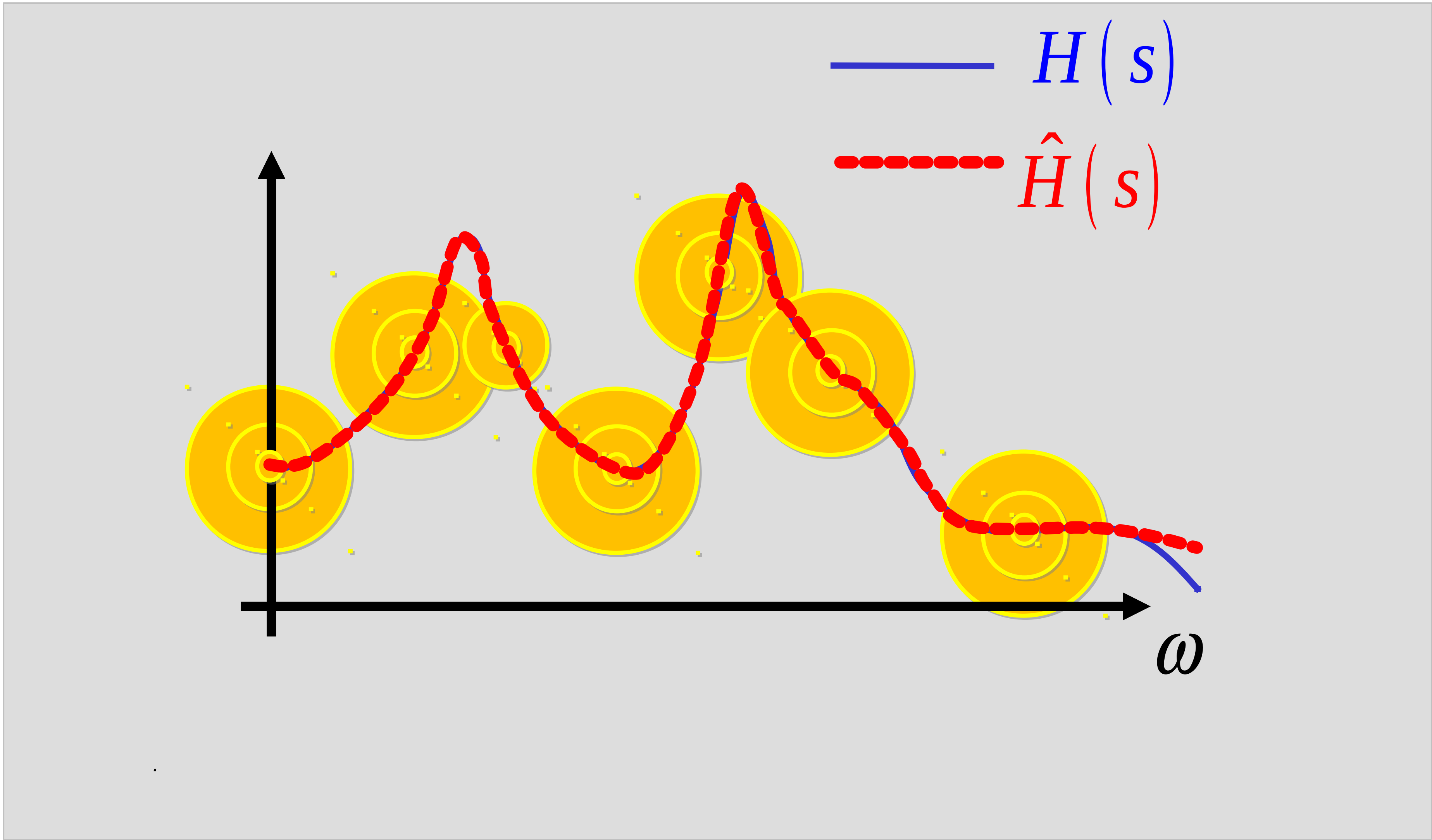
EXPANSION POINT

For multiple expansion point



EXPANSION POINT

For multiple expansion point



OVERVIEW

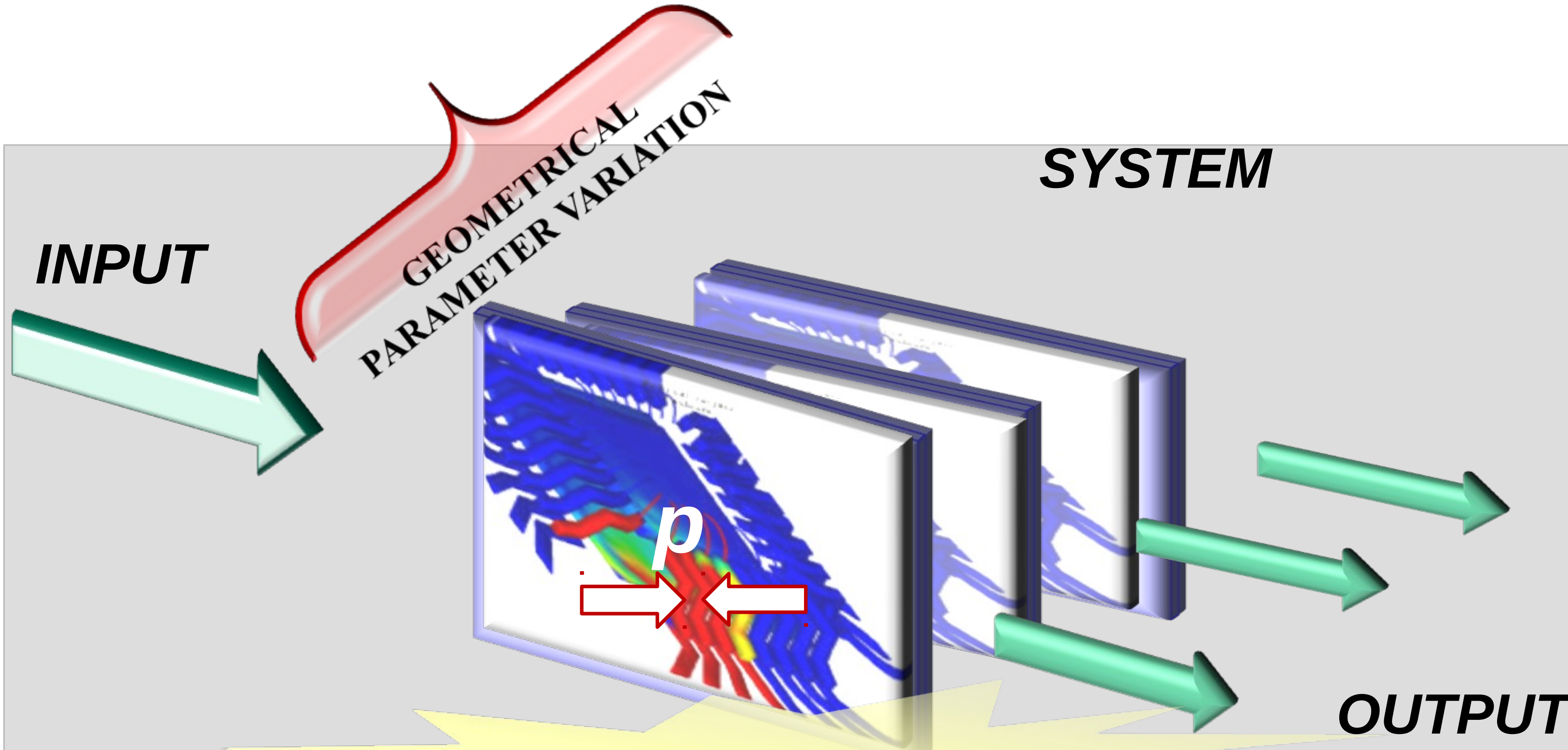
- Model Order Reduction
- Multipoint expansion
- **Parameterized modeling**

PARAMETERIZED MODELING

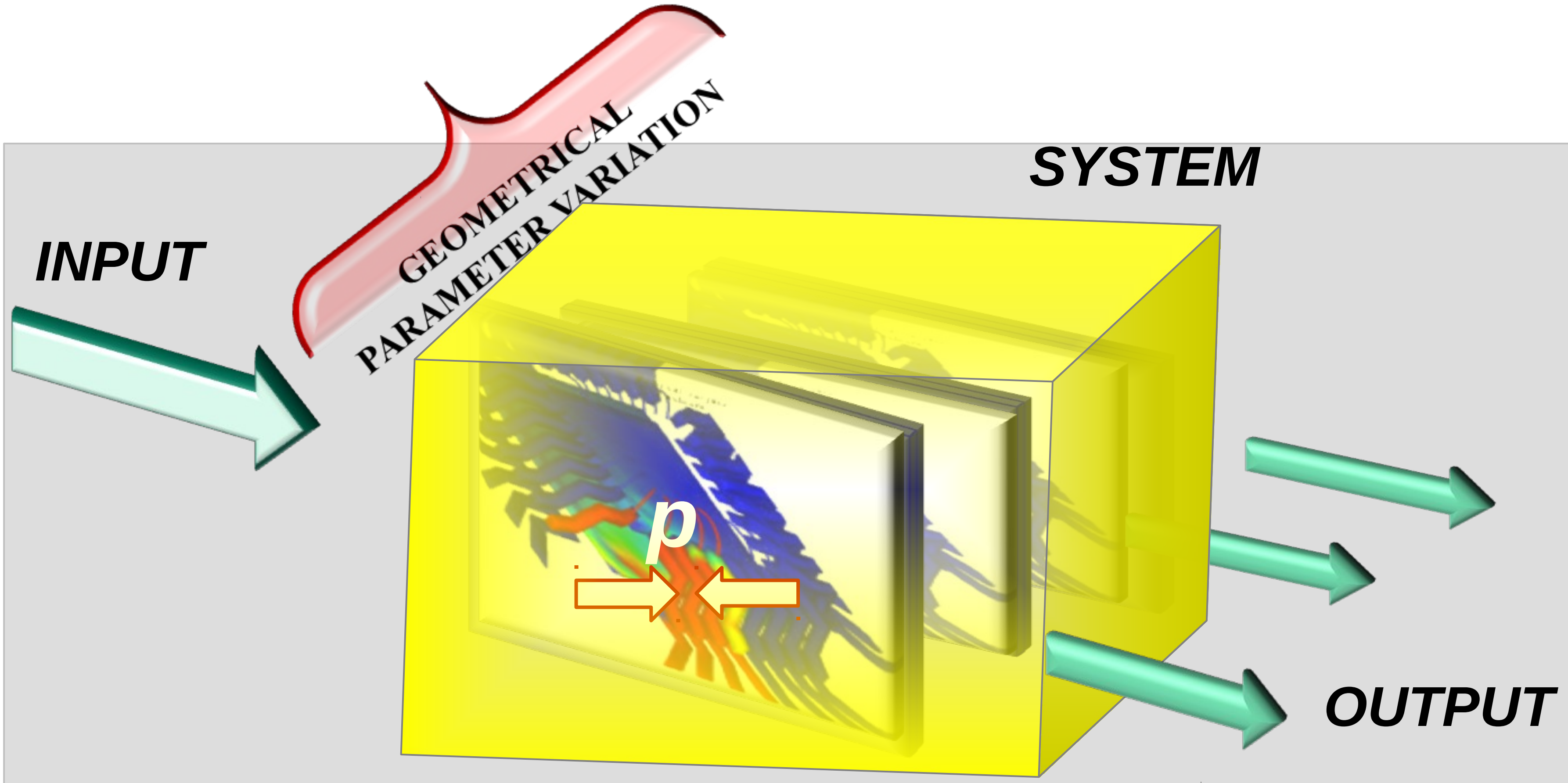
Let us make a cake

PARAMETERIZED MODELING

PARAMETERIZED MODELING



***Parameterized modeling** and model order reduction for large electrical systems*



INPUT
GEOMETRICAL
PARAMETER VARIATION
SYSTEM
p
OUTPUT

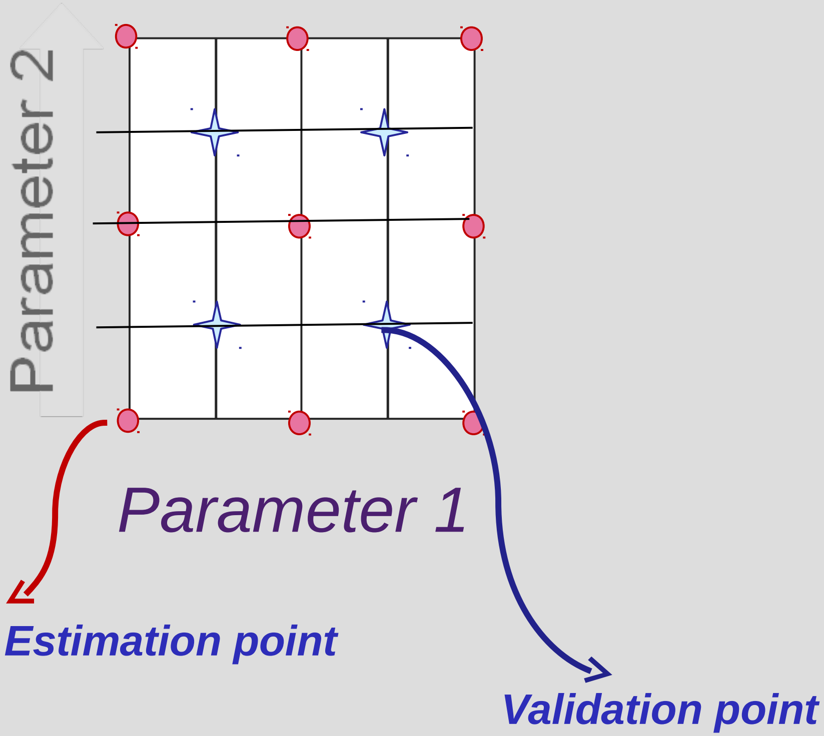
RESEARCH CONTRIBUTION

- Model order reduction – Systems with delay
- Multipoint expansion – Adaptive frequency sampling algorithm
- Parameterized modeling – Sylvester realization
- Parameterized model order reduction using a common projection matrix with state space interpolation

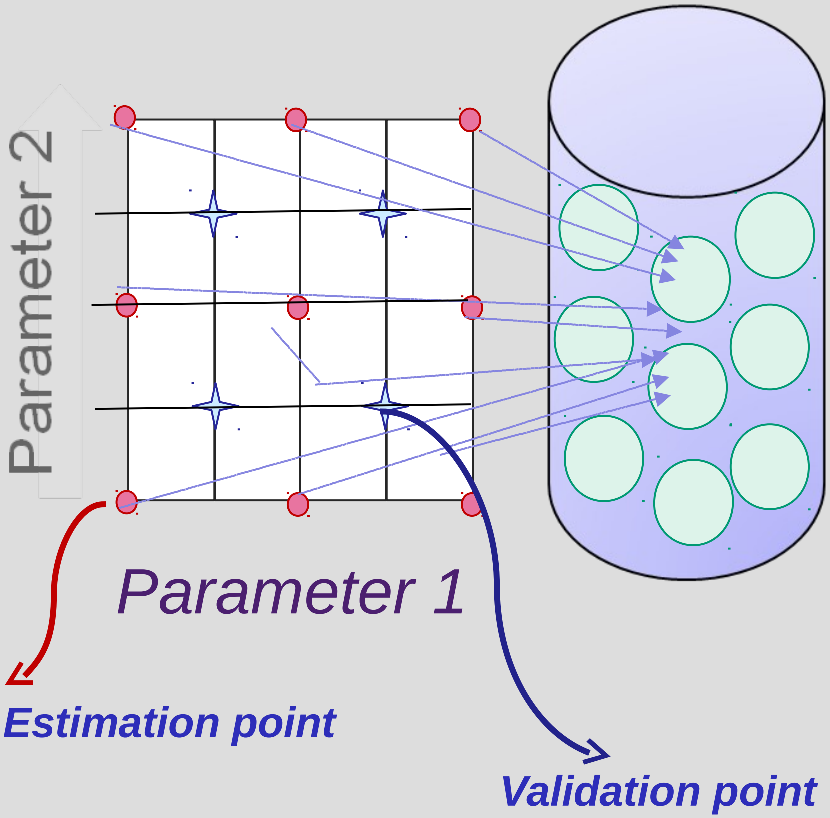
RESEARCH CONTRIBUTION

- Model order reduction – Systems with delay
- Multipoint expansion – Adaptive frequency sampling algorithm
- Parameterized modeling – Sylvester realization
- **Parameterized model order reduction using a common projection matrix with state space interpolation**

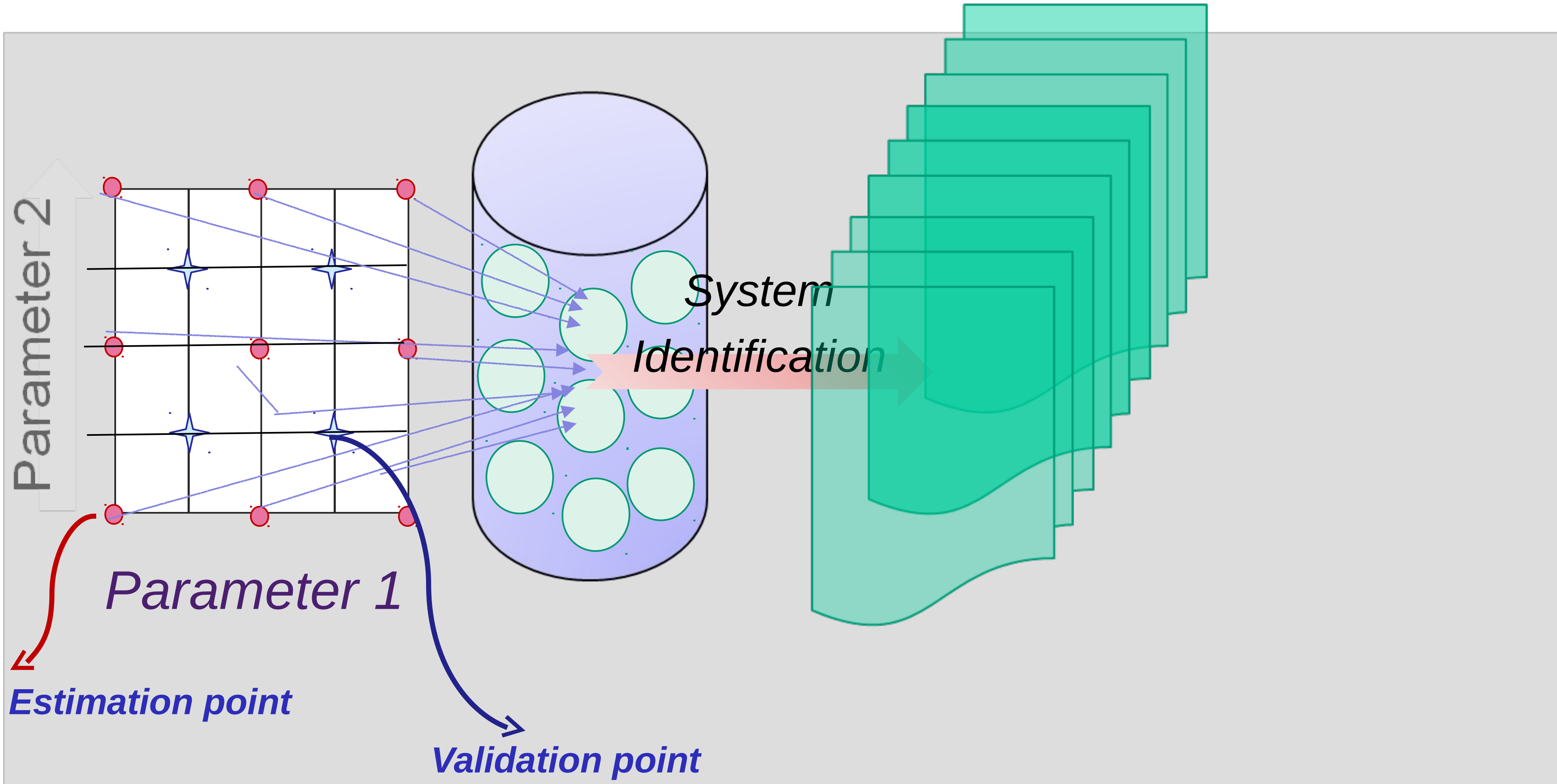
DESIGN SPACE

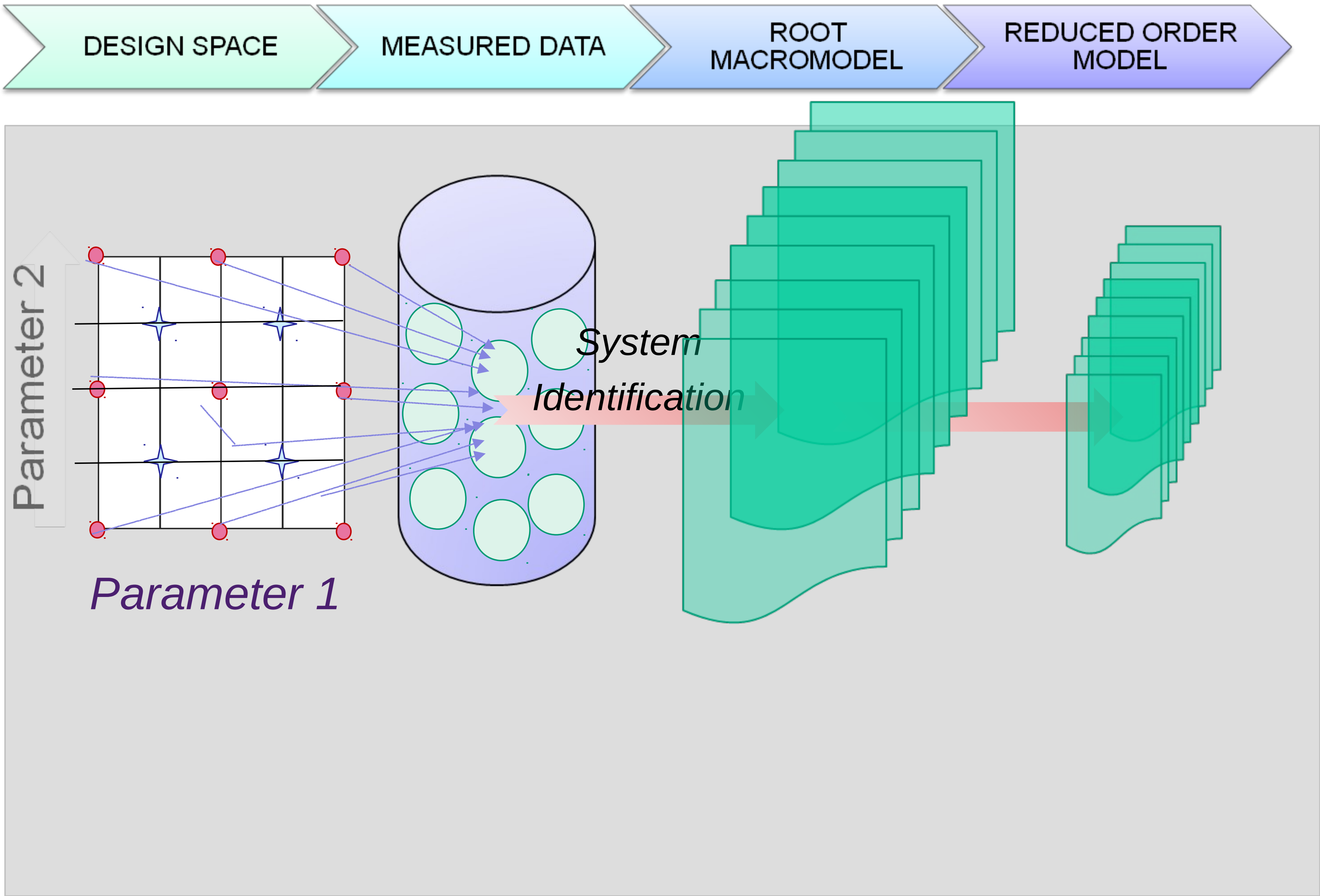


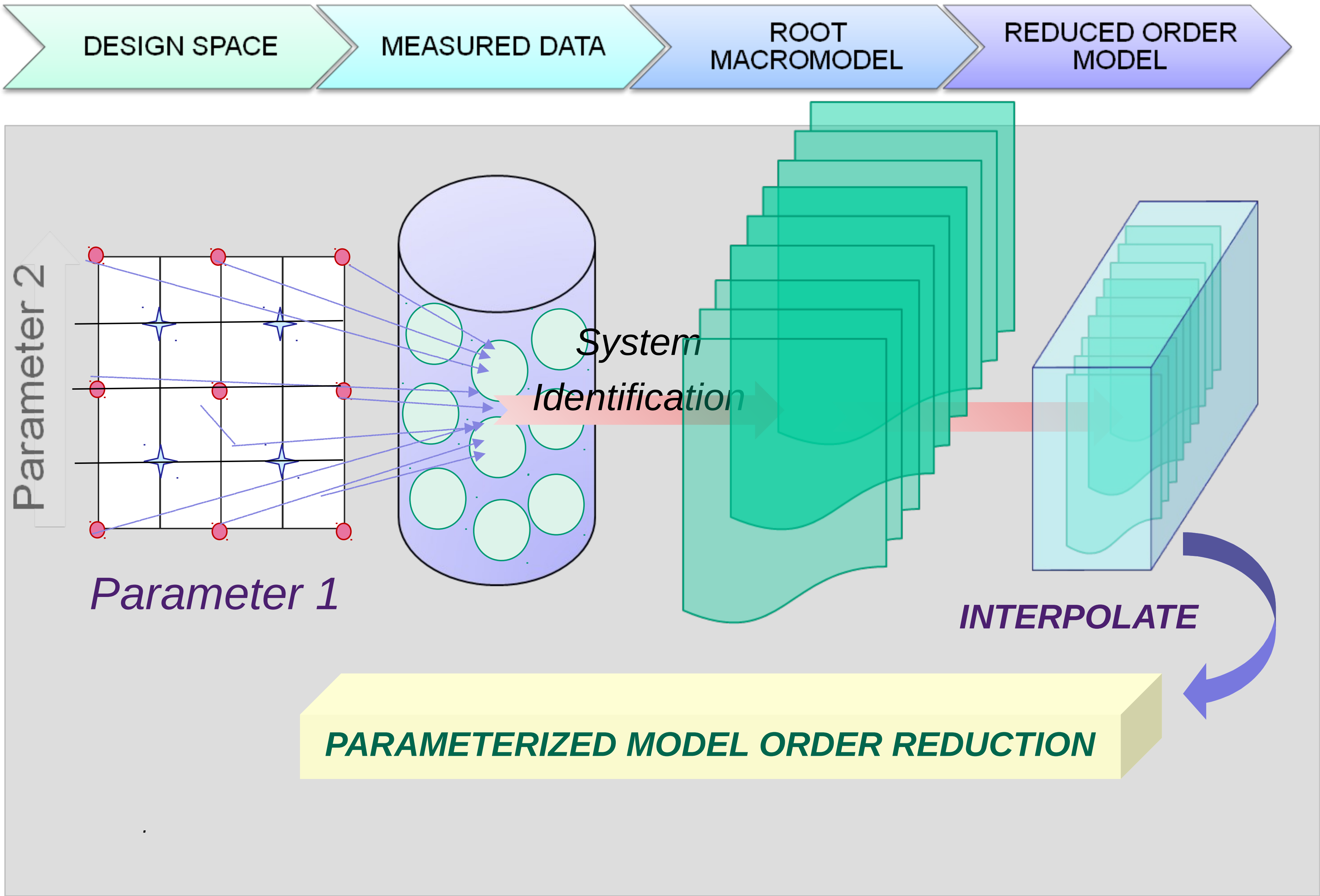
DESIGN SPACE | MEASURED DATA



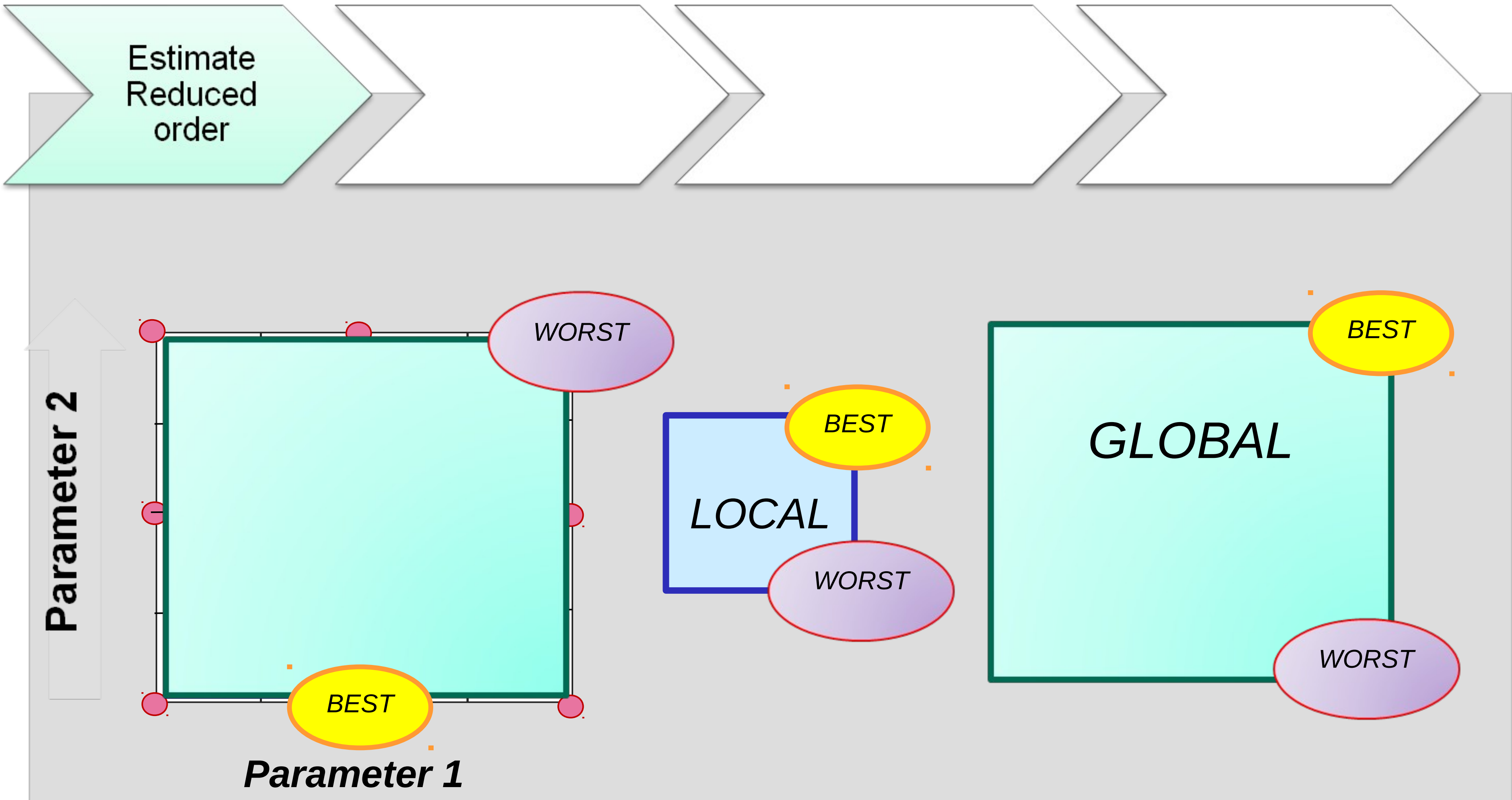
DESIGN SPACE → MEASURED DATA → ROOT MACROMODEL →




DESIGN SPACE
MEASURED DATA
ROOT MACROMODEL
REDUCED ORDER MODEL
Parameter 2
Parameter 1
System Identification



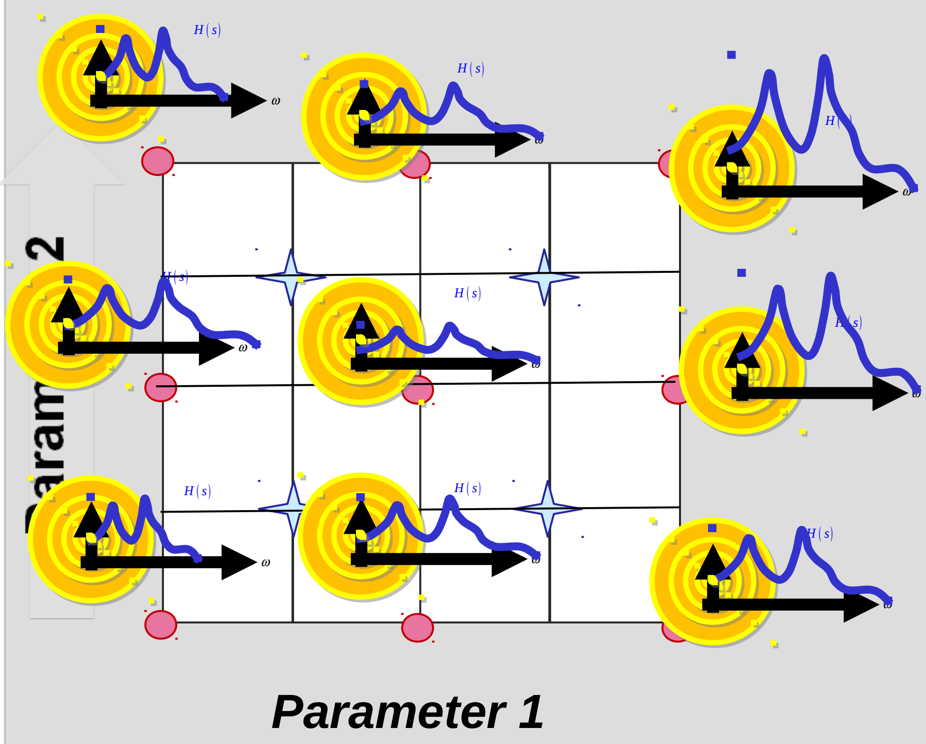
DESIGN SPACE
MEASURED DATA
ROOT MACROMODEL
REDUCED ORDER MODEL
Parameter 2
Parameter 1
System Identification
INTERPOLATE
PARAMETERIZED MODEL ORDER REDUCTION



Estimate Reduced order
WORST
BEST
Parameter 2
Parameter 1
BEST
LOCAL
WORST
BEST
GLOBAL
WORST

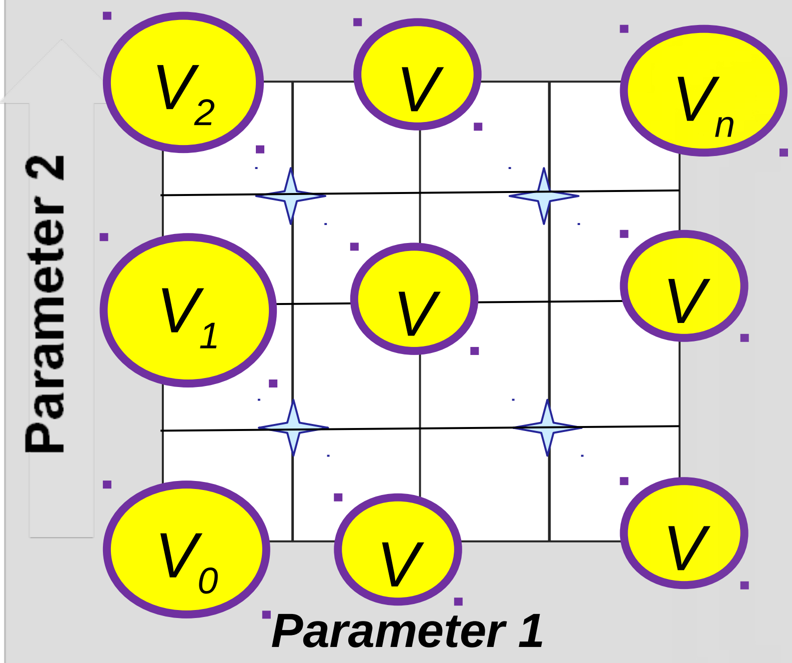
Estimate Reduced order

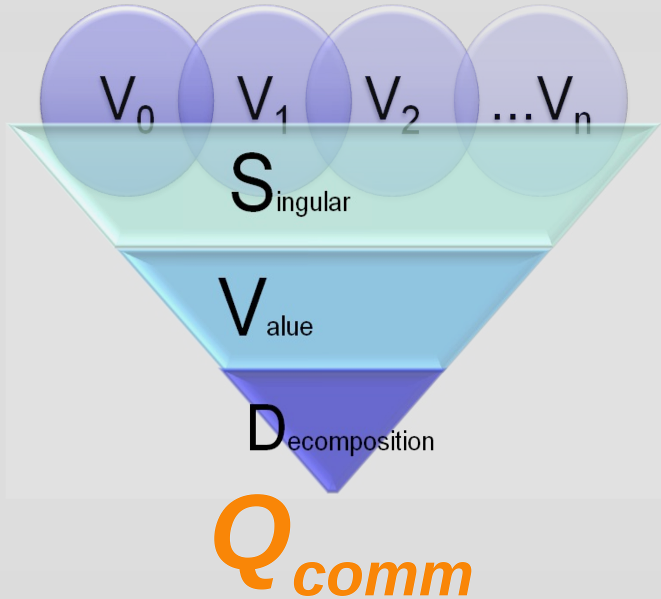
Common projection matrix



Estimate Reduced order

Common projection matrix

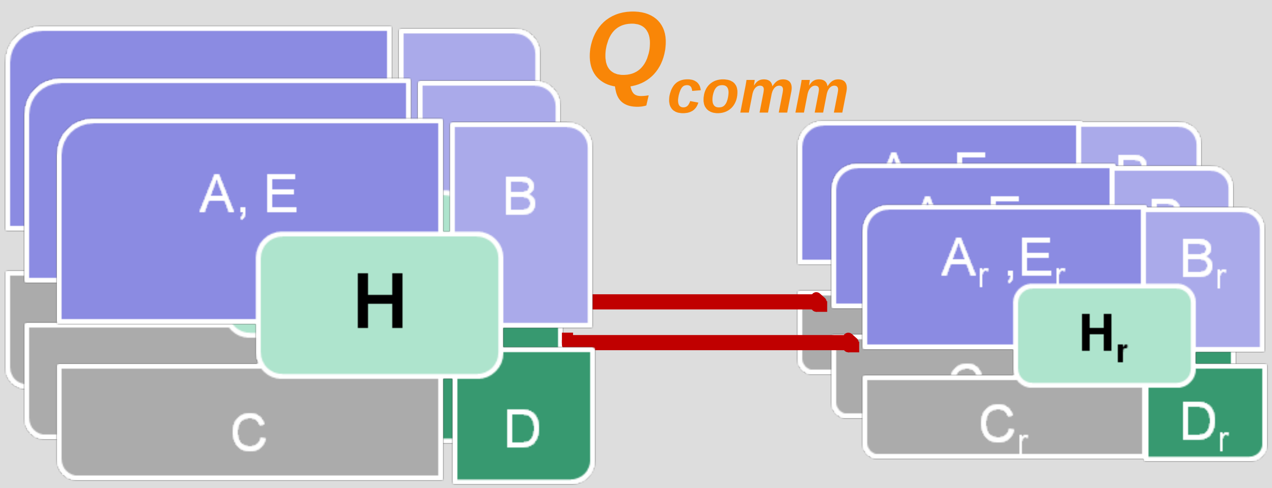




Estimate Reduced order

Common projection matrix

Congruence transformation

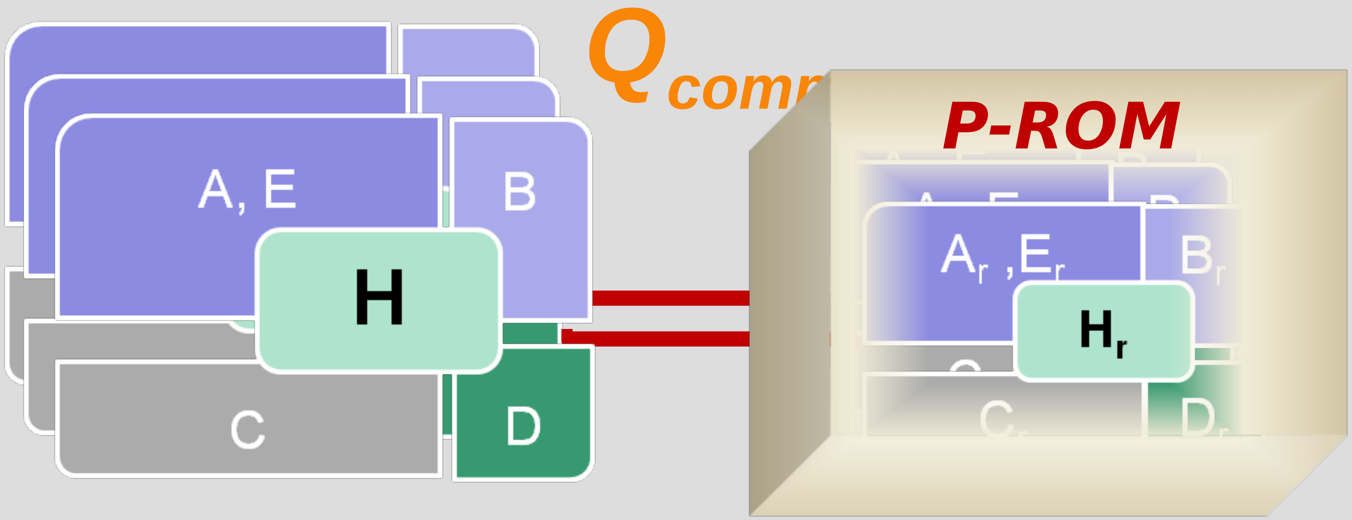


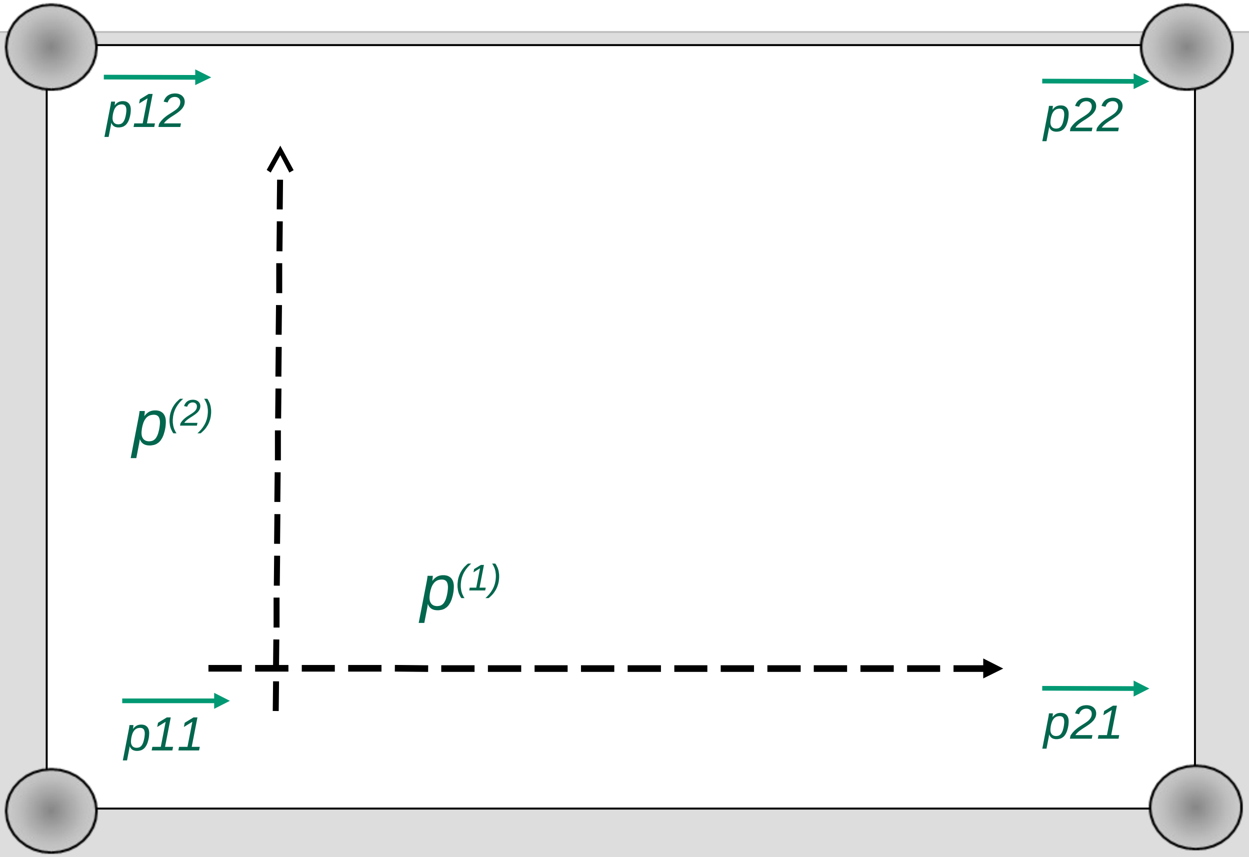
Estimate Reduced order

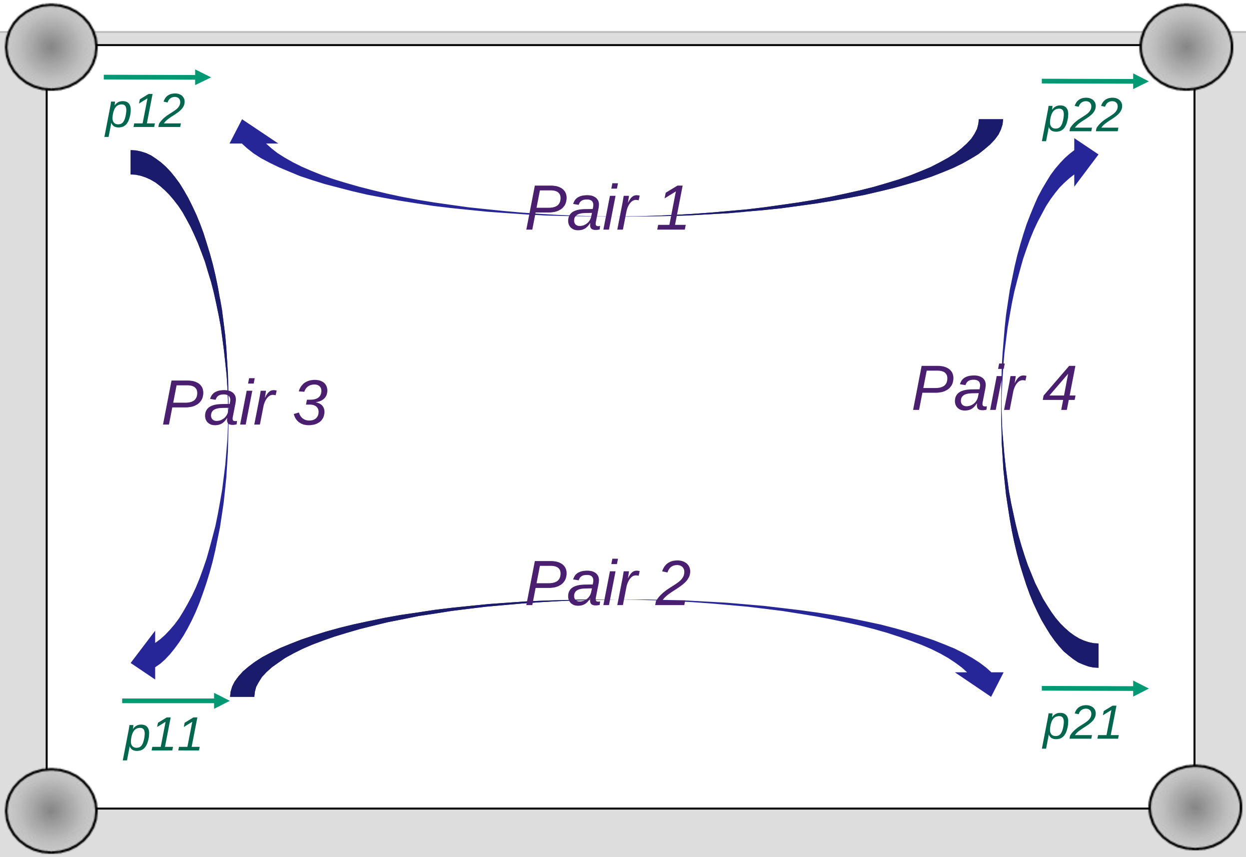
Common projection matrix

Congruence transformation

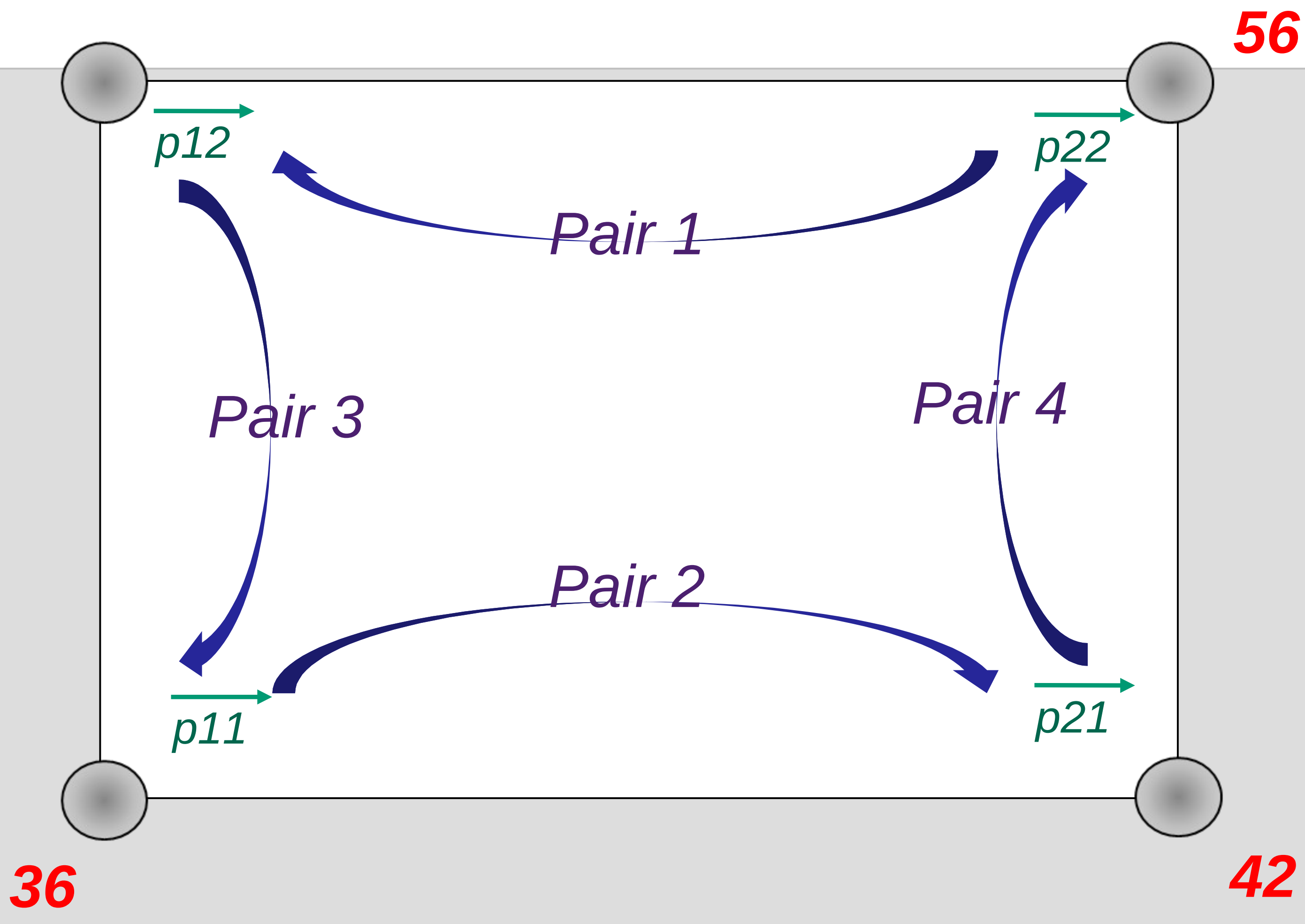
Interpolation



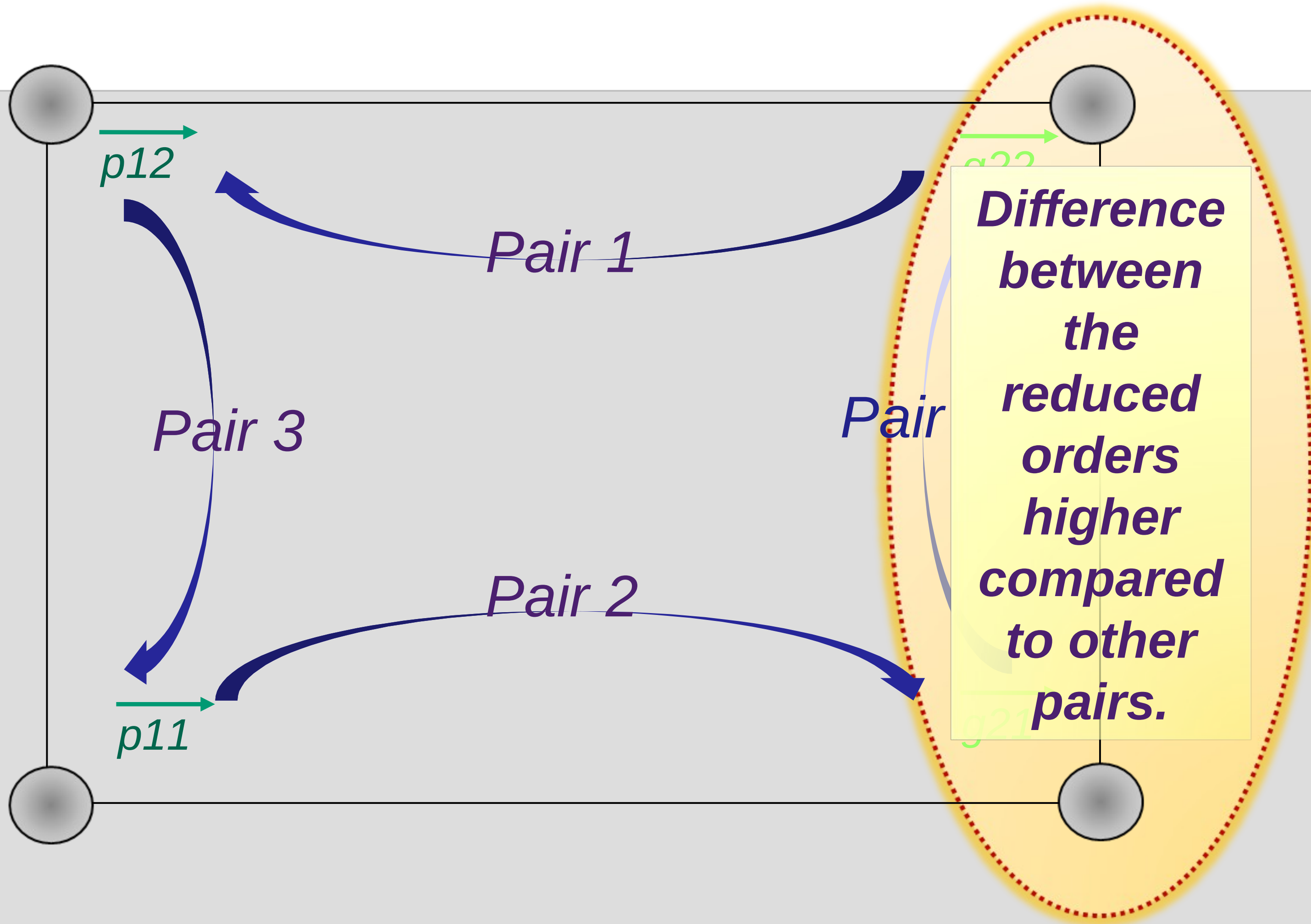

p12
p22
$p^{(2)}$
$p^{(1)}$
p11
p21



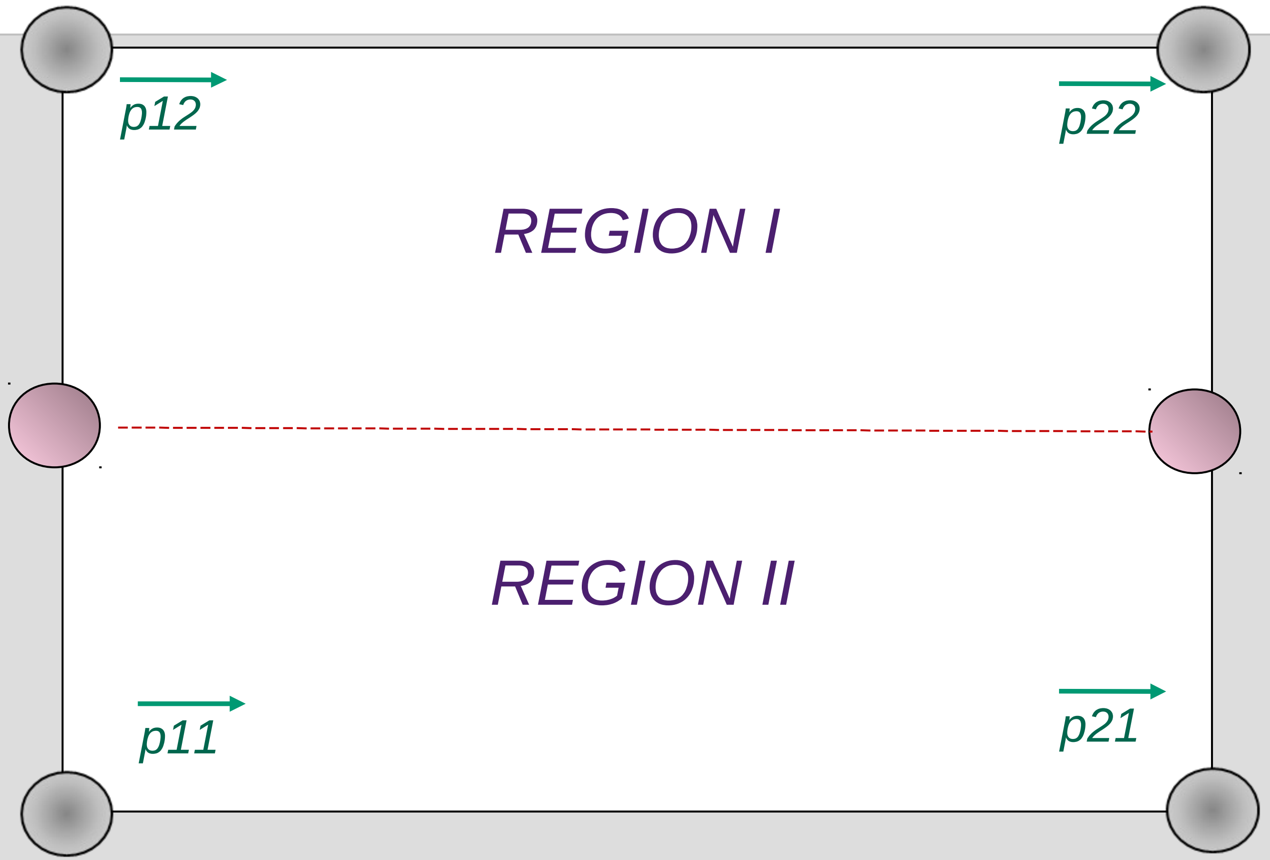
p12
p22
Pair 1
Pair 3
Pair 4
Pair 2
p11
p21



56
p12
p22
Pair 1
Pair 3
Pair 4
Pair 2
p11
p21
36
42

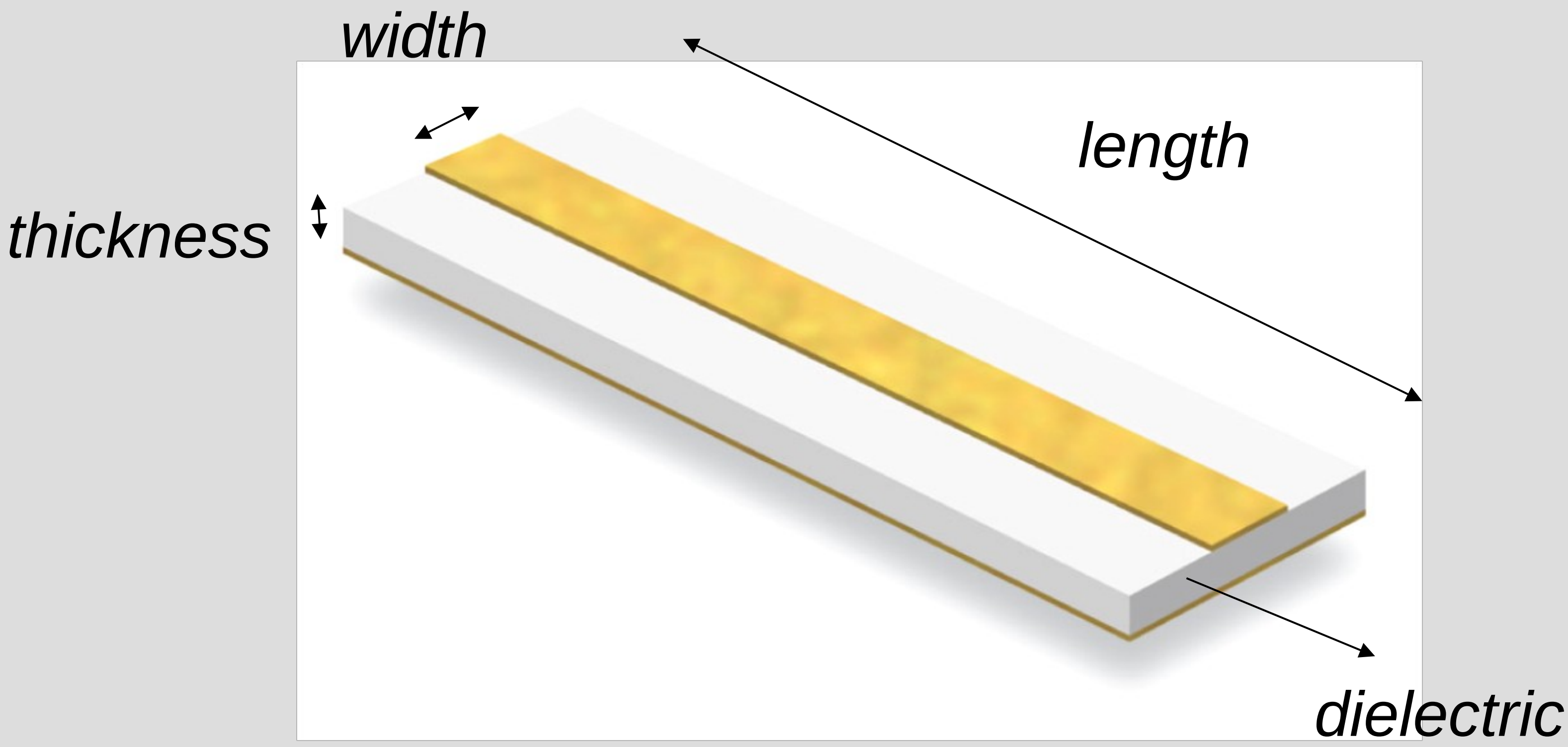


p12
Pair 1
Pair 3
Pair
Pair 2
p11
Difference between the reduced orders higher compared to other pairs.

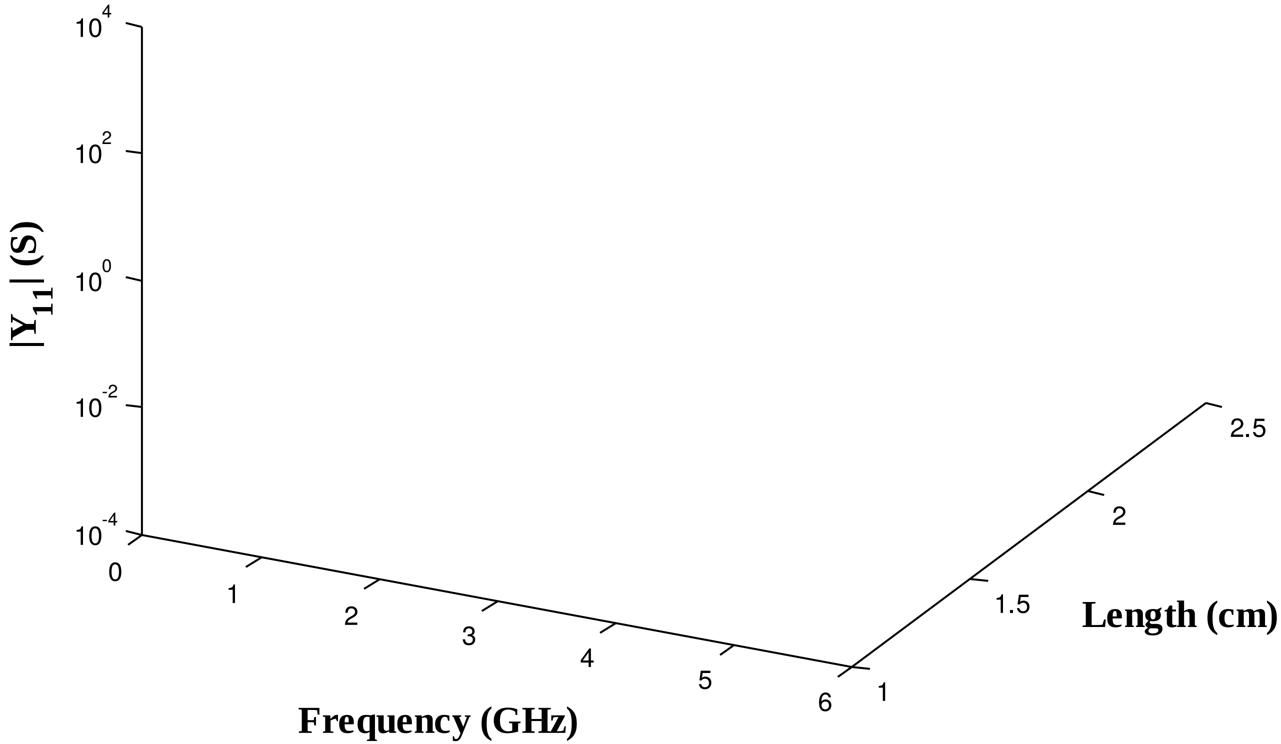

p12
p22
REGION I
REGION II
p11
p21


11:25


LG Display

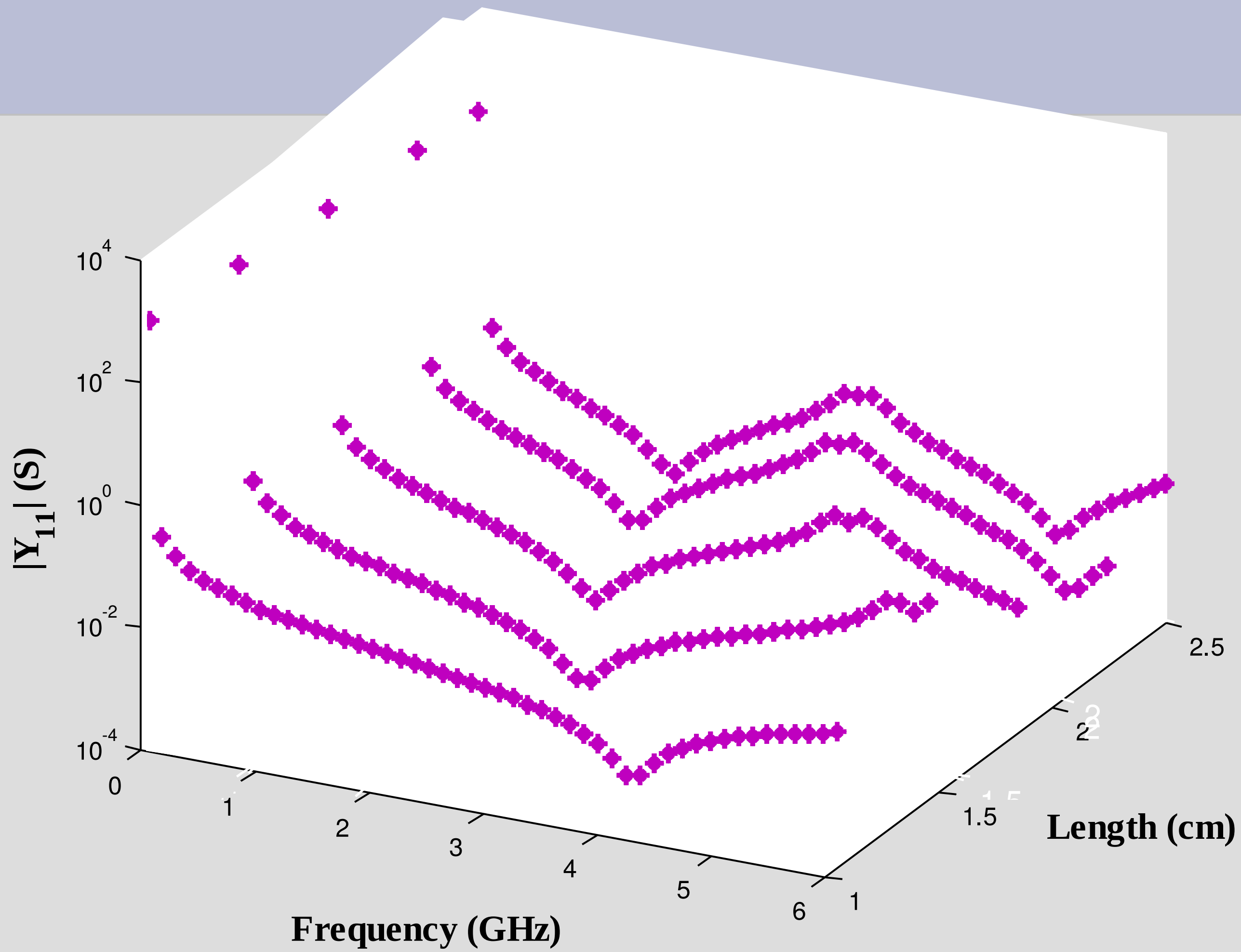

width
length
thickness
dielectric

MICROSTRIP

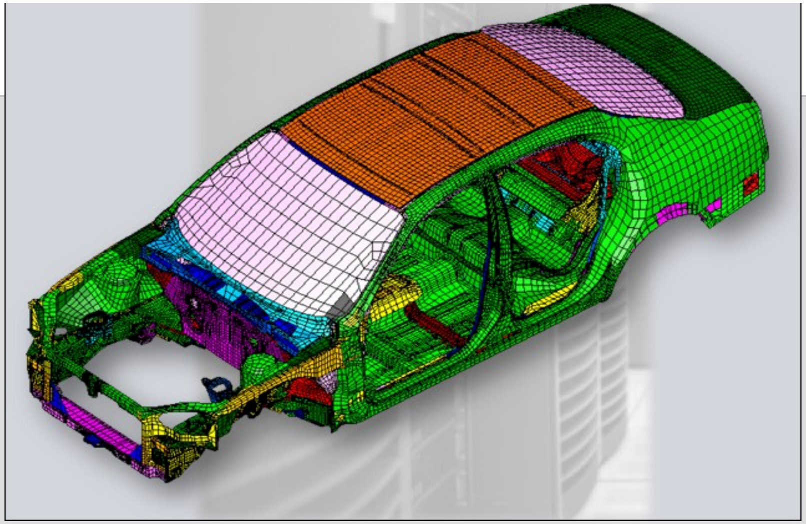


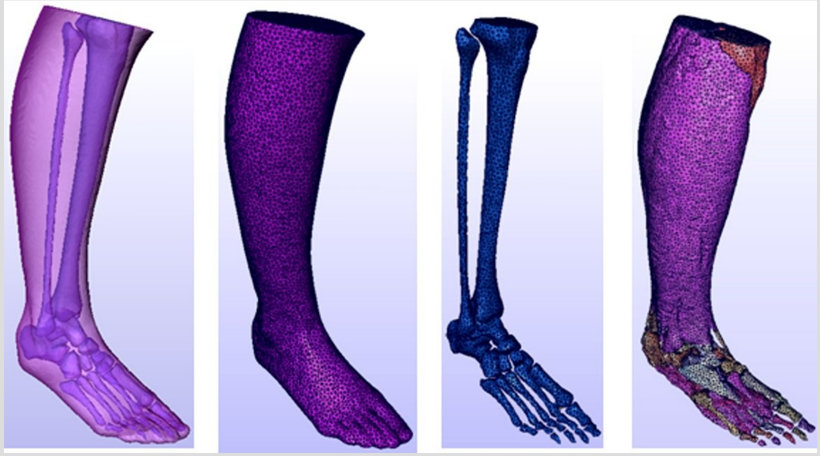
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
$|Y_{11}|$ (S)
0
1
2
3
4
5
6
Frequency (GHz)
1
1.5
2
2.5
Length (cm)

MICROSTRIP



10^4
10^2
10^0
10^{-2}
10^{-4}
$|Y_{11}|$ (S)
0
1
2
3
4
5
6
Frequency (GHz)
1
1.5
2
2.5
Length (cm)






41.97
18.64
32.84
81.11
45.87
51.42
35.21
22.11
76.61
62.54
33.48
54.32
51.67
72.28

Thank you

Elizabeth Rita Samuel
lizita3@gmail.com