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FACULTY OF ENGINEERING

Parameterized Model Order Reduction of Delayed Systems using an Interpolation Approach with Amplitude and Frequency Scaling Coefficients

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Outline

Introduction

PMOR for delayed systems

Numerical results

Conclusions

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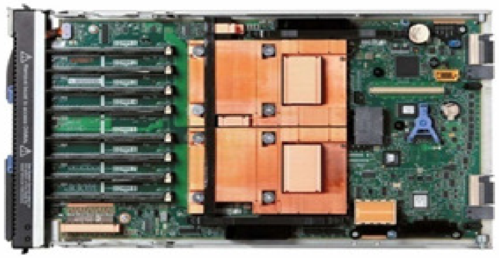
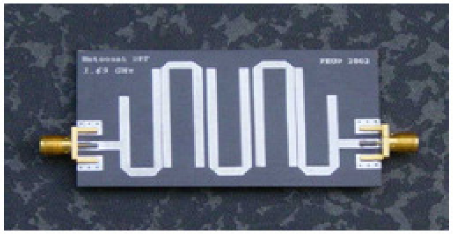
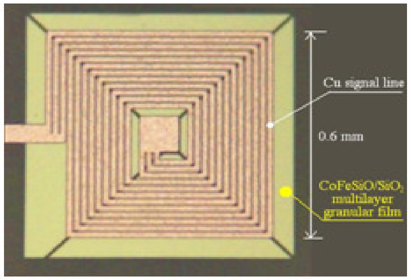
SONY
Cyber-shot

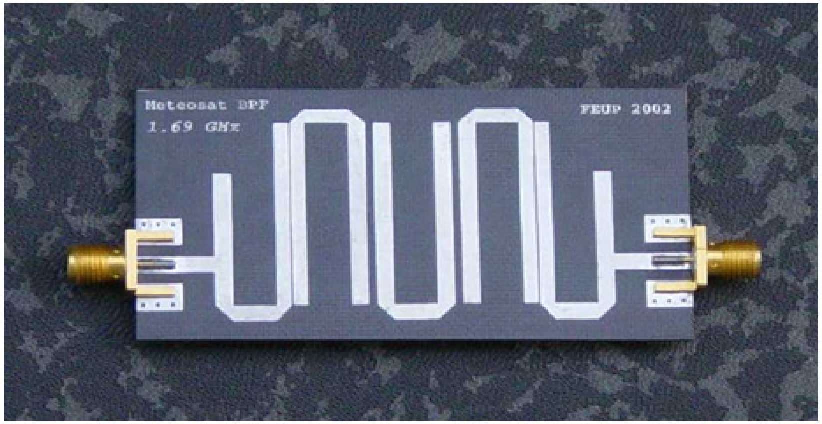

DELL





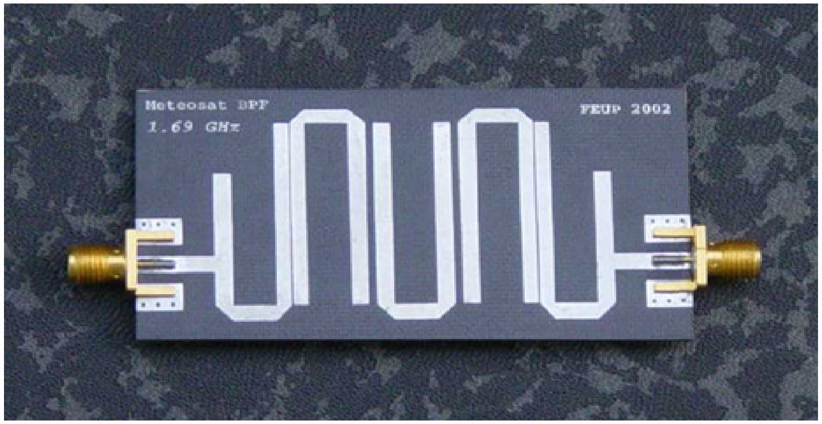

Cu signal line
0.6 mm
CoFeSiO/SiO2 multilayer granular film

A typical design process requires



A typical design process requires

- design space optimization
- design space exploration
- sensitivity analysis
  - multiple simulations (measurements)
  - different design parameters values (e.g. layout features)



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    - computationally expensive (time and memory)

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- Can we do better?

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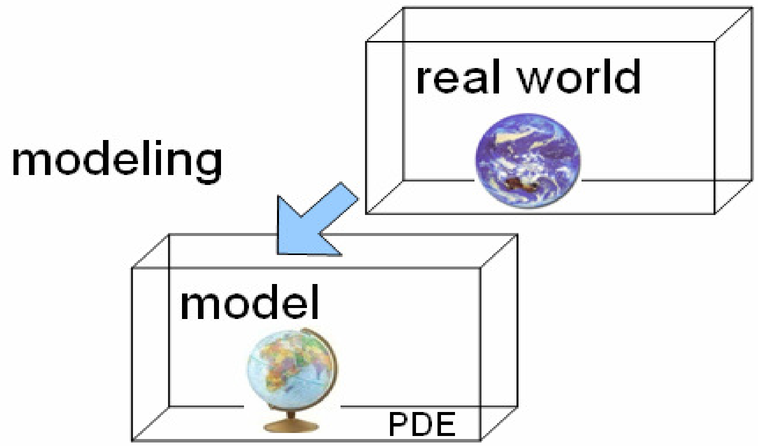
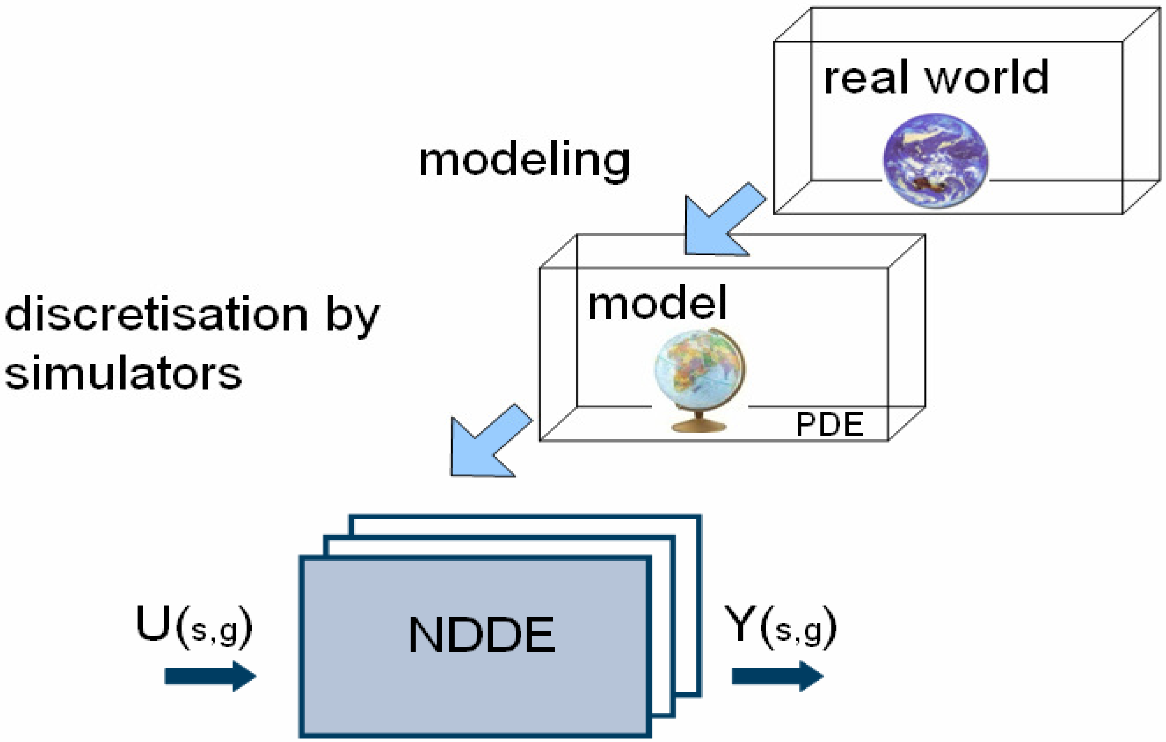
- Multiple simulations (measurements)
  - computationally expensive (time and memory)

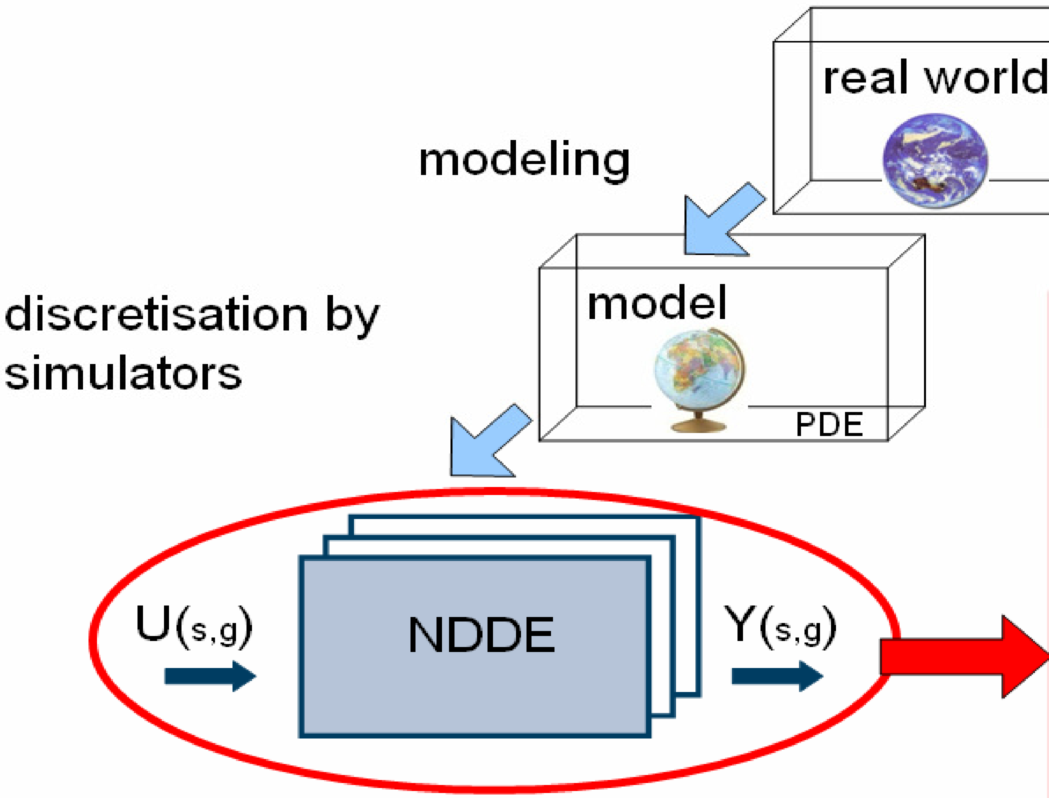
- Can we do better?

- Yes
  - By parameterized reduced order models


real world


real world
modeling
model
PDE

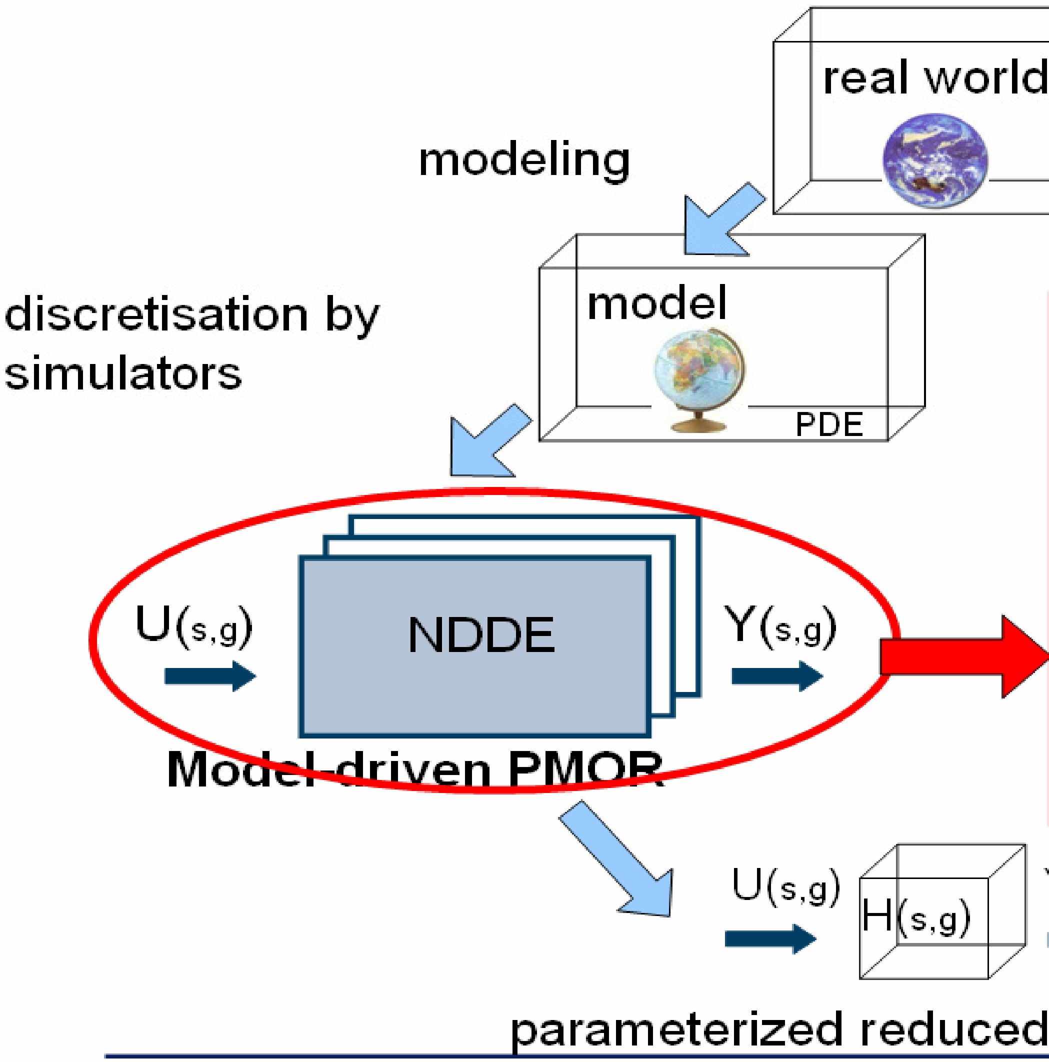

real world
modeling
model
PDE
discretisation by
simulators
U(s,g)
NDDE
Y(s,g)



$$
\begin{aligned}
s\mathbf{C}(s,\boldsymbol{g})\mathbf{X}(s,\boldsymbol{g}) &= -\mathbf{G}(s,\boldsymbol{g})\mathbf{X}(s,\boldsymbol{g}) + \mathbf{B}\mathbf{U}(s) \\
\mathbf{Y}(s,\boldsymbol{g}) &= \mathbf{L}^T\mathbf{X}(s,\boldsymbol{g}) \\
\mathbf{C}(s,\boldsymbol{g}) &= \mathbf{C}_0(\boldsymbol{g}) + \sum_{k=1}^{n_\tau(\boldsymbol{g})} \mathbf{C}_k(\boldsymbol{g})e^{-s\tau_k(\boldsymbol{g})} \\
\mathbf{G}(s,\boldsymbol{g}) &= \mathbf{G}_0(\boldsymbol{g}) + \sum_{k=1}^{n_\tau(\boldsymbol{g})} \mathbf{G}_k(\boldsymbol{g})e^{-s\tau_k(\boldsymbol{g})}
\end{aligned}
$$

Electrically long/large systems

Delays



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\end{aligned}
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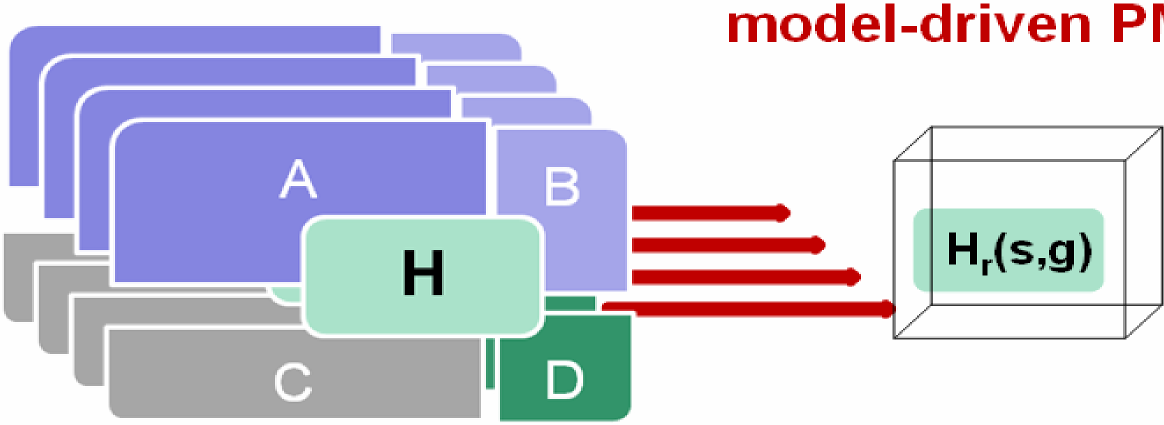
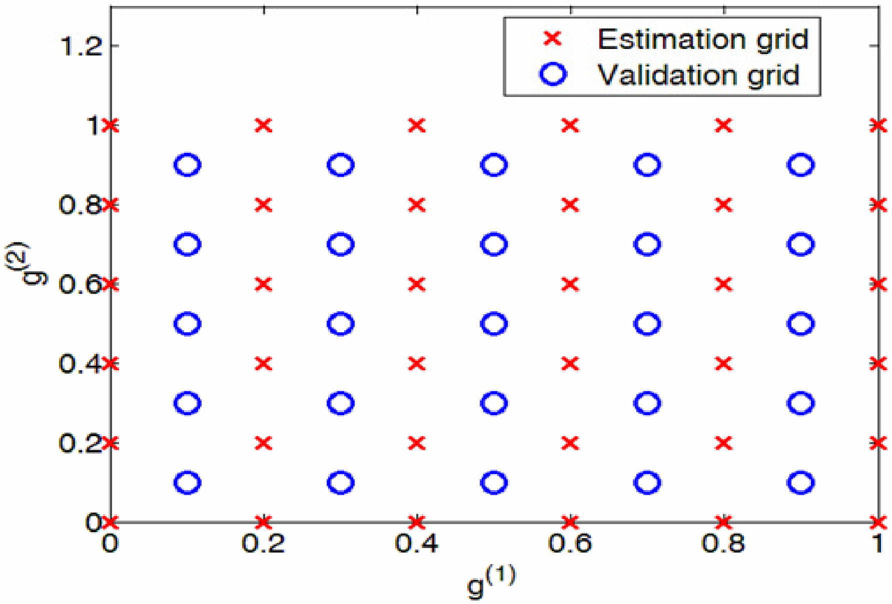
model-driven PMOR



- accuracy
- efficiency
- stability guaranteed
- passivity guaranteed

Design space $g = (g^{(n)})_{n=1}^{N}$



Compute τROMs $\mathbf{R}(s, \mathbf{g}_k^{\Omega_i})$ in the estimation design space grid

↓

Compute scaling and frequency shifting coefficients $\alpha_{1,k}(\mathbf{g}_j^{\Omega_i}), \alpha_{2,k}(\mathbf{g}_j^{\Omega_i})$ in the estimation design space grid

↓

Multivariate interpolation of scaling and frequency shifting coefficients $\alpha_1(\mathbf{g}), \alpha_2(\mathbf{g})$

↓

Multivariate interpolation of scaled and shifted τROMs $\alpha_1(\mathbf{g})\mathbf{R}(s\alpha_2(\mathbf{g}), \mathbf{g})$

Features

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- each design space cell has its own model

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- local approach

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- suitable to robust adaptive sampling

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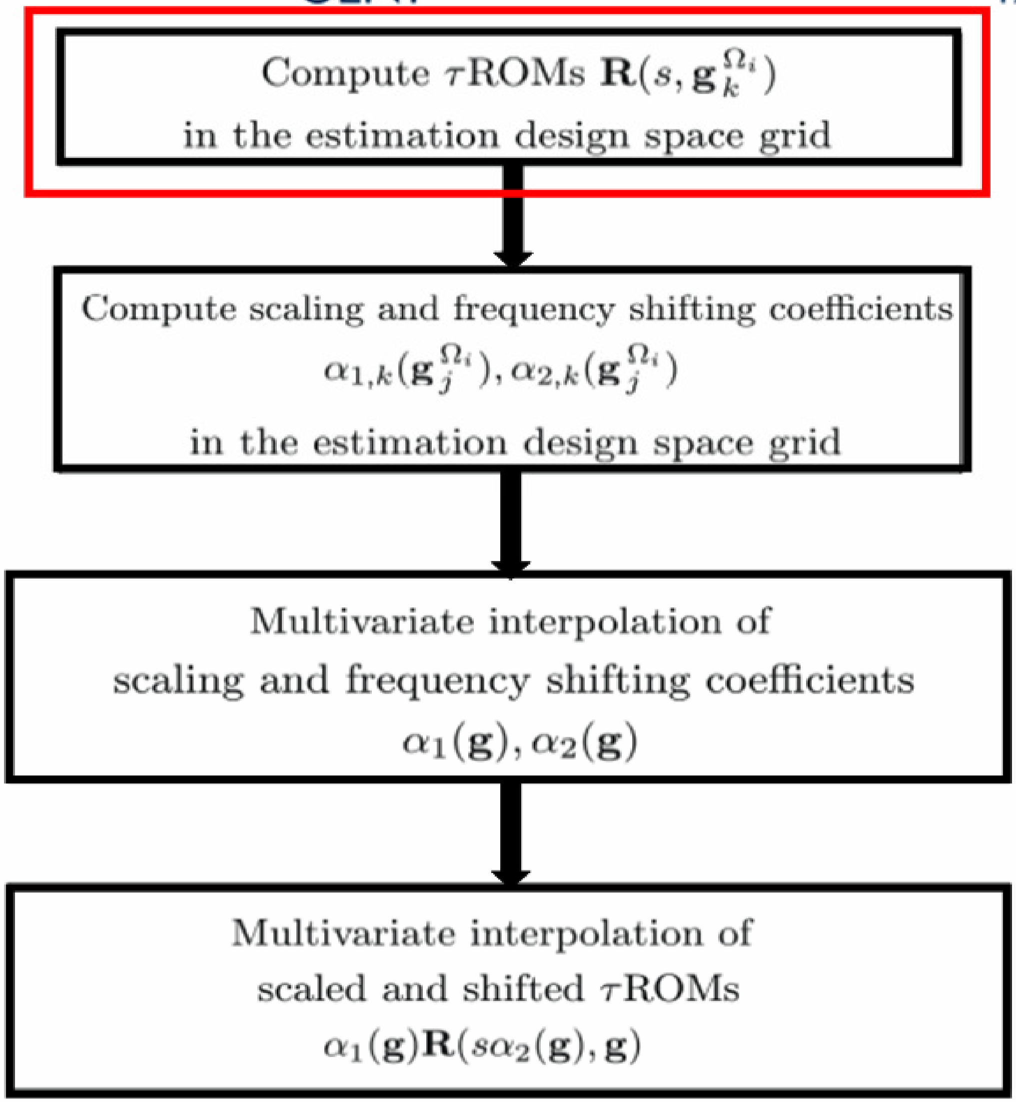
- each design space cell has its own model
- local approach
- independent from a specific MOR method
- stability and passivity guaranteed over the design space
- suitable to robust adaptive sampling
- different flavours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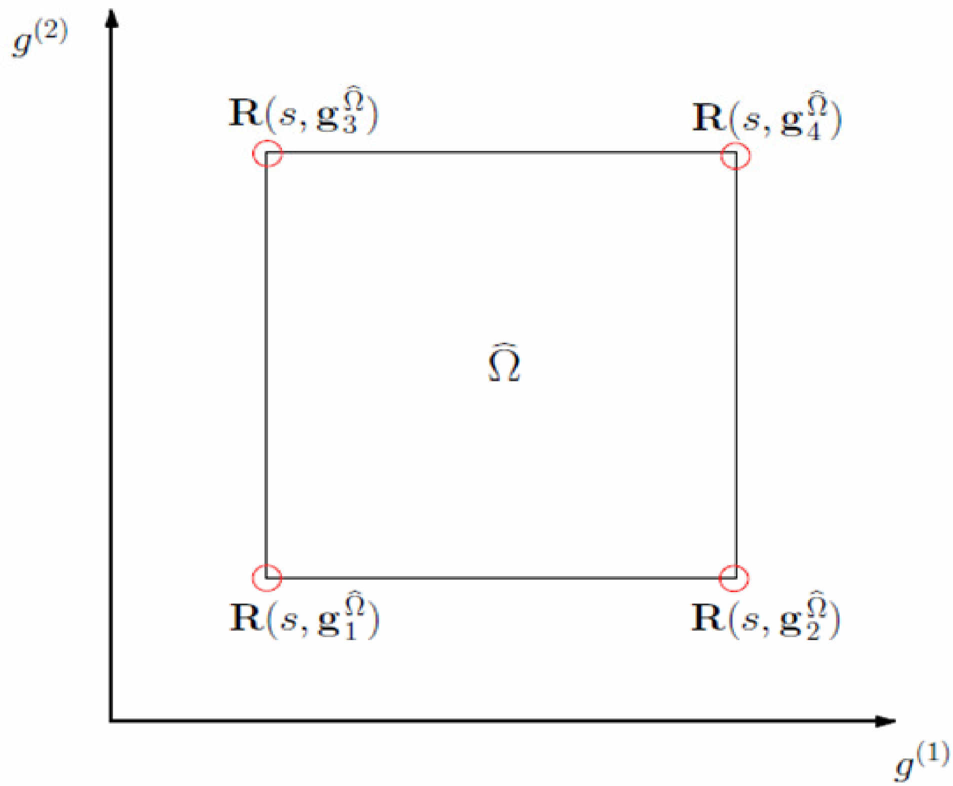
τROMs at the cell vertices



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↓

Multivariate interpolation of
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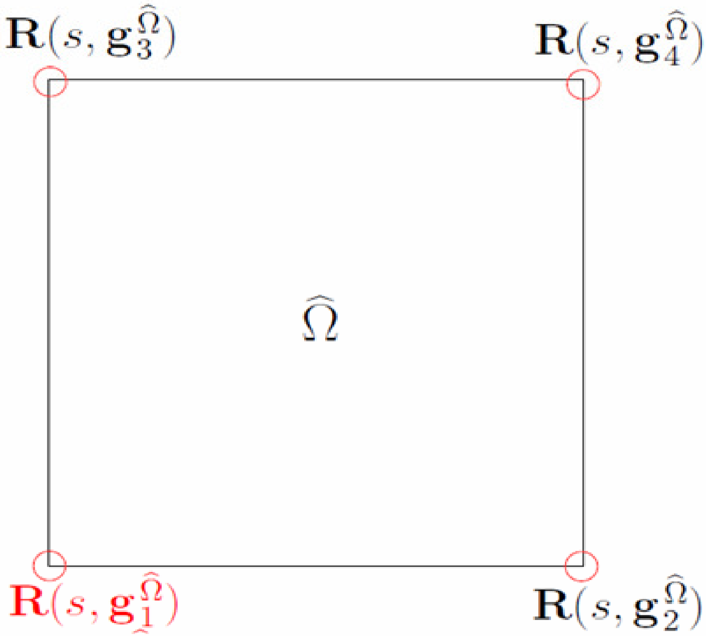
$\alpha_1(\mathbf{g})\mathbf{R}(s\alpha_2(\mathbf{g}), \mathbf{g})$

$$\min_{\alpha_{1,k}(\mathbf{g}_j^{\widehat{\Omega}}),\alpha_{2,k}(\mathbf{g}_j^{\widehat{\Omega}})} Err(\widetilde{\mathbf{R}}(s,\boldsymbol{g}_k^{\widehat{\Omega}}),\mathbf{R}(s,\boldsymbol{g}_j^{\widehat{\Omega}}))$$

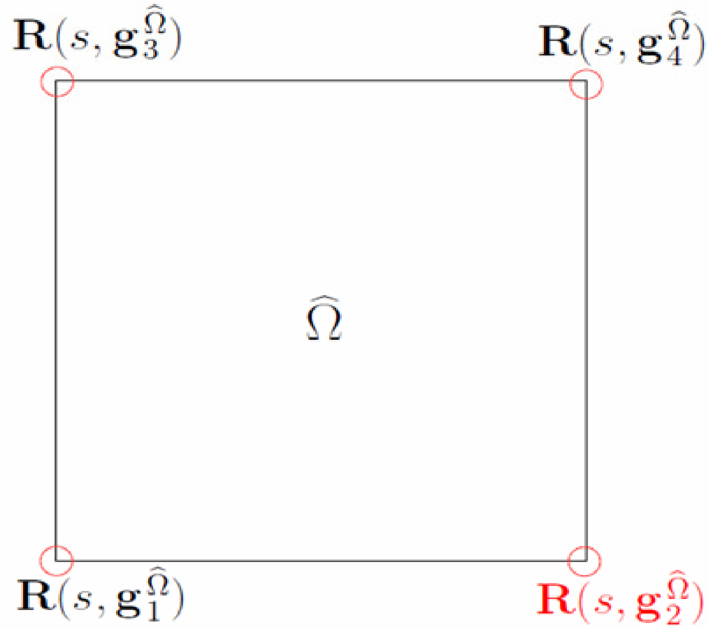
$$\widetilde{\mathbf{R}}(s,\boldsymbol{g}_k^{\widehat{\Omega}}) = \alpha_{1,k}(\boldsymbol{g}_j^{\widehat{\Omega}})\mathbf{R}(s\alpha_{2,k}(\boldsymbol{g}_j^{\widehat{\Omega}}),\boldsymbol{g}_k^{\widehat{\Omega}})$$

$$\alpha_{1,k}(\boldsymbol{g}_j^{\widehat{\Omega}}) = \alpha_{2,k}(\boldsymbol{g}_j^{\widehat{\Omega}}) = 1, \;\; j = k$$



$\alpha_{1,1}(\mathbf{g}_j^{\widehat{\Omega}}), j = 1, ..., 4$

$\alpha_{2,1}(\mathbf{g}_j^{\widehat{\Omega}}), j = 1, ..., 4$



$\alpha_{1,2}(\mathbf{g}_j^{\widehat{\Omega}}), j = 1, ..., 4$

$\alpha_{2,2}(\mathbf{g}_j^{\widehat{\Omega}}), j = 1, ..., 4$

$$\min_{\alpha_{1,k}(\mathbf{g}_j^{\widehat{\Omega}}),\alpha_{2,k}(\mathbf{g}_j^{\widehat{\Omega}})} Err(\widetilde{\mathbf{R}}(s,\boldsymbol{g}_k^{\widehat{\Omega}}),\mathbf{R}(s,\boldsymbol{g}_j^{\widehat{\Omega}}))$$

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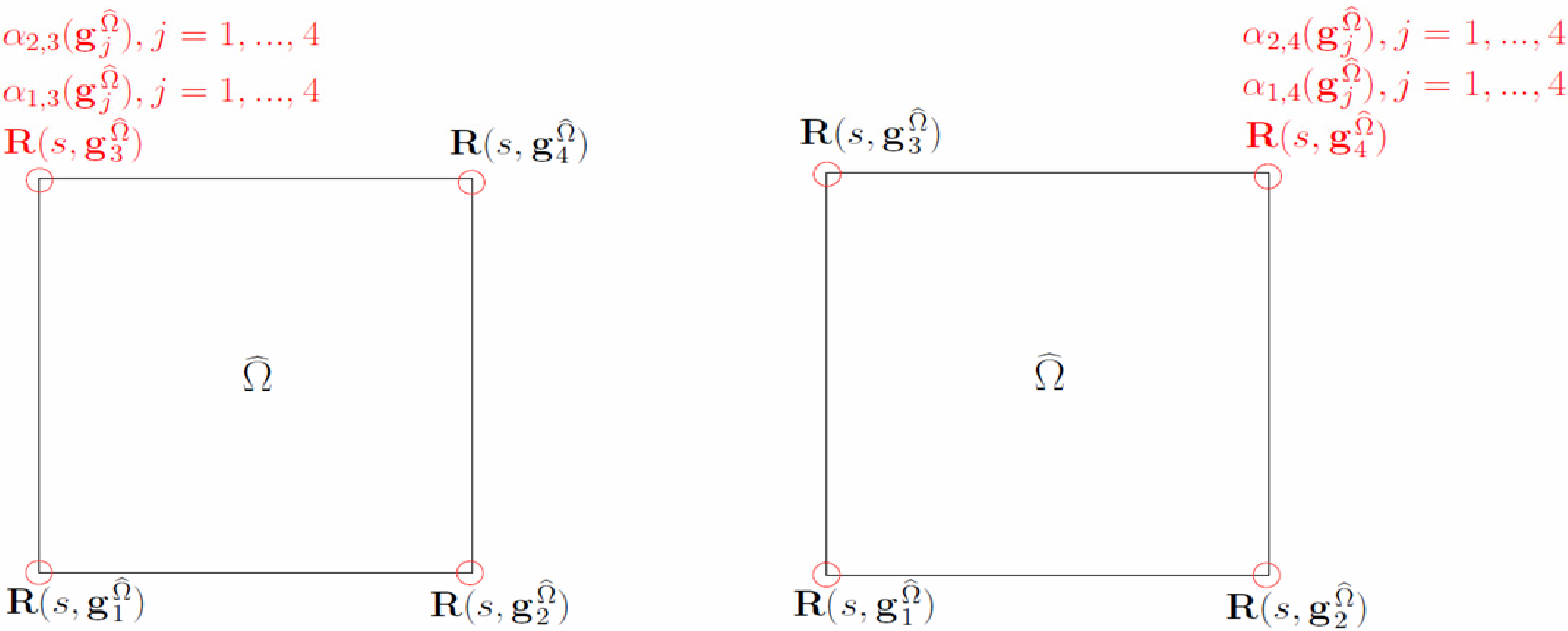

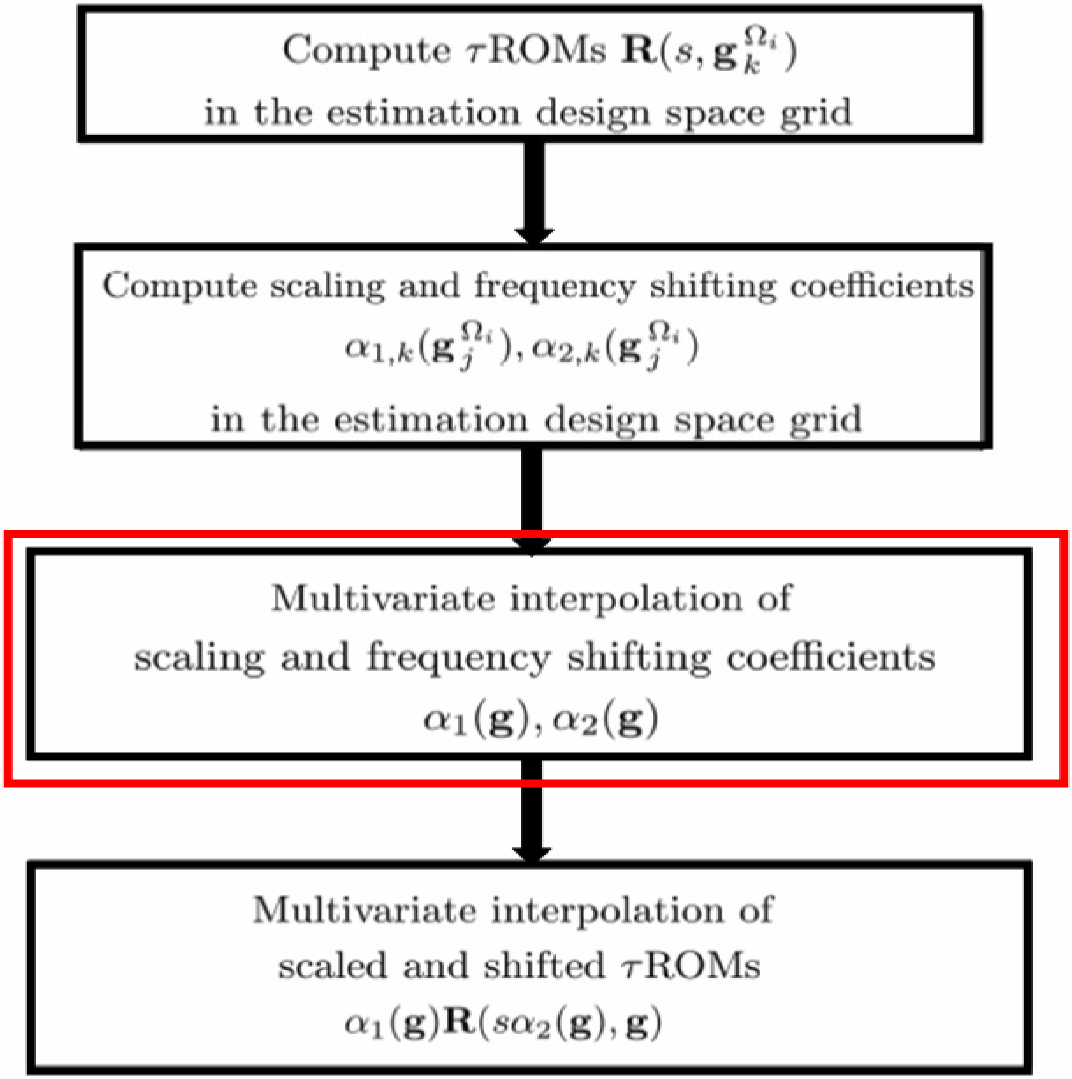
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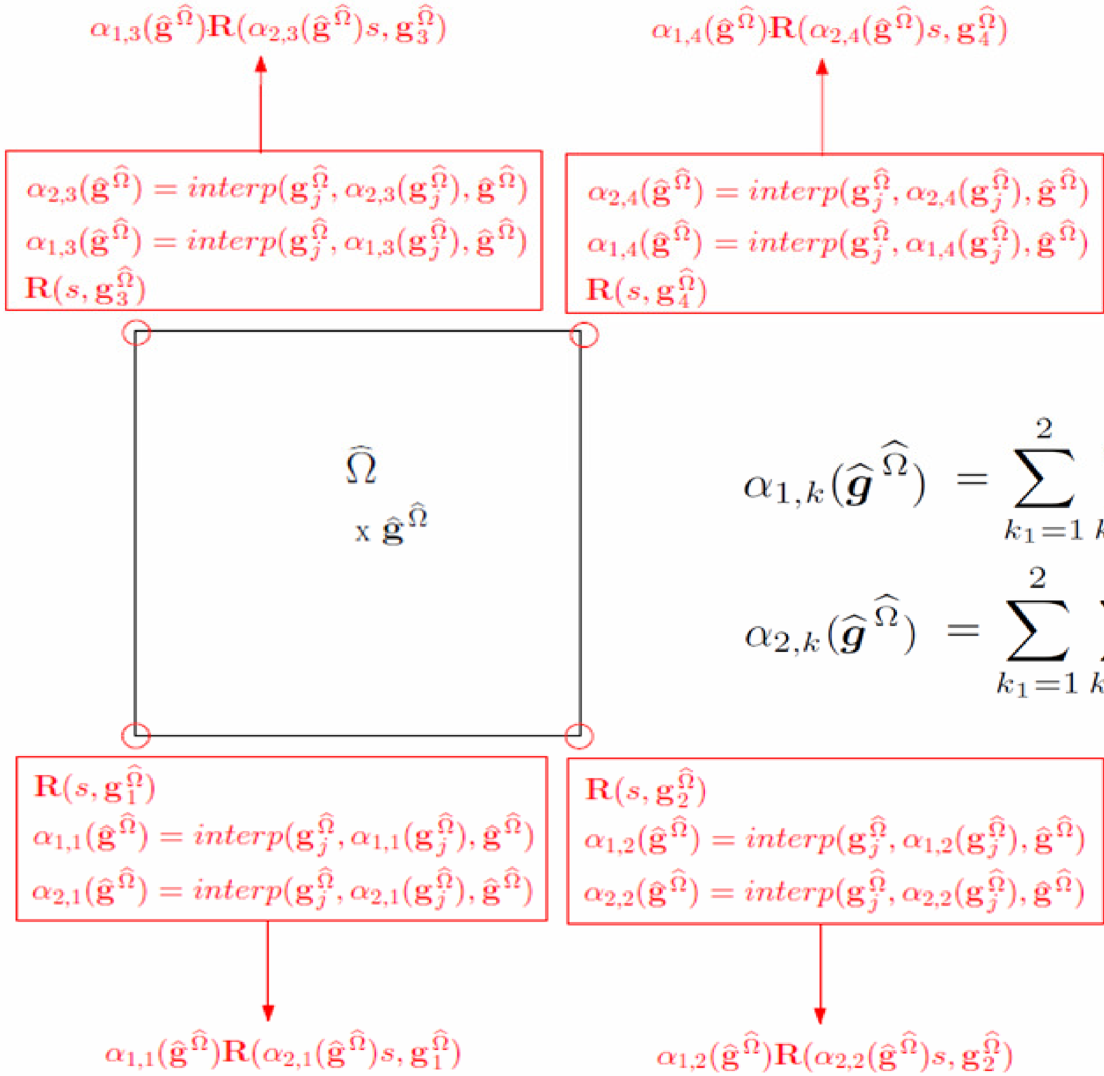
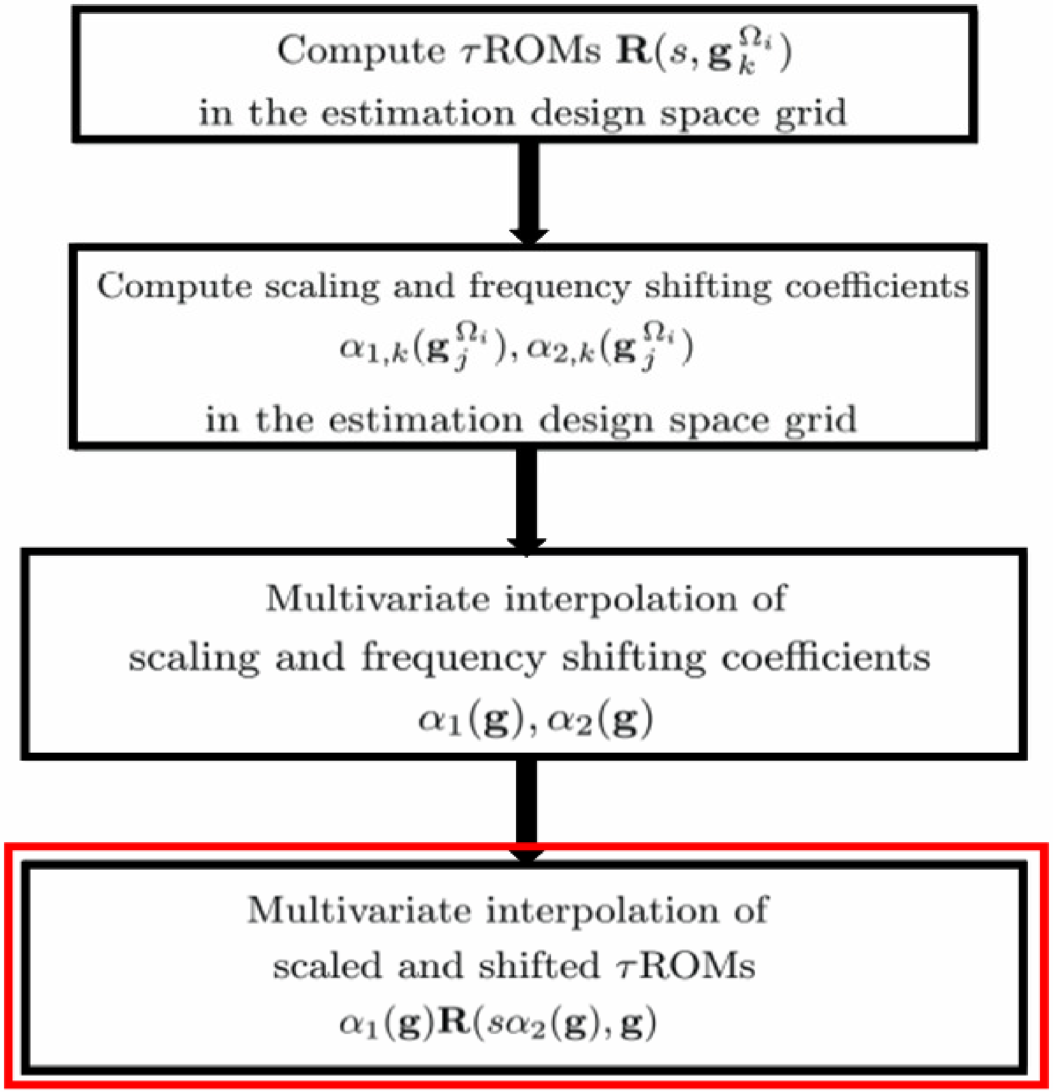


$$\alpha_{1,k}(\hat{\boldsymbol{g}}^{\hat{\Omega}}) = \sum_{k_1=1}^{2}\sum_{k_2=1}^{2} \alpha_{1,k}((g_{k_1}^{(1)}, g_{k_2}^{(2)})^{\hat{\Omega}})\ell_{k_1}(g^{(1)})\ell_{k_2}(g^{(2)})$$

$$\alpha_{2,k}(\hat{\boldsymbol{g}}^{\hat{\Omega}}) = \sum_{k_1=1}^{2}\sum_{k_2=1}^{2} \alpha_{2,k}((g_{k_1}^{(1)}, g_{k_2}^{(2)})^{\hat{\Omega}})\ell_{k_1}(g^{(1)})\ell_{k_2}(g^{(2)})$$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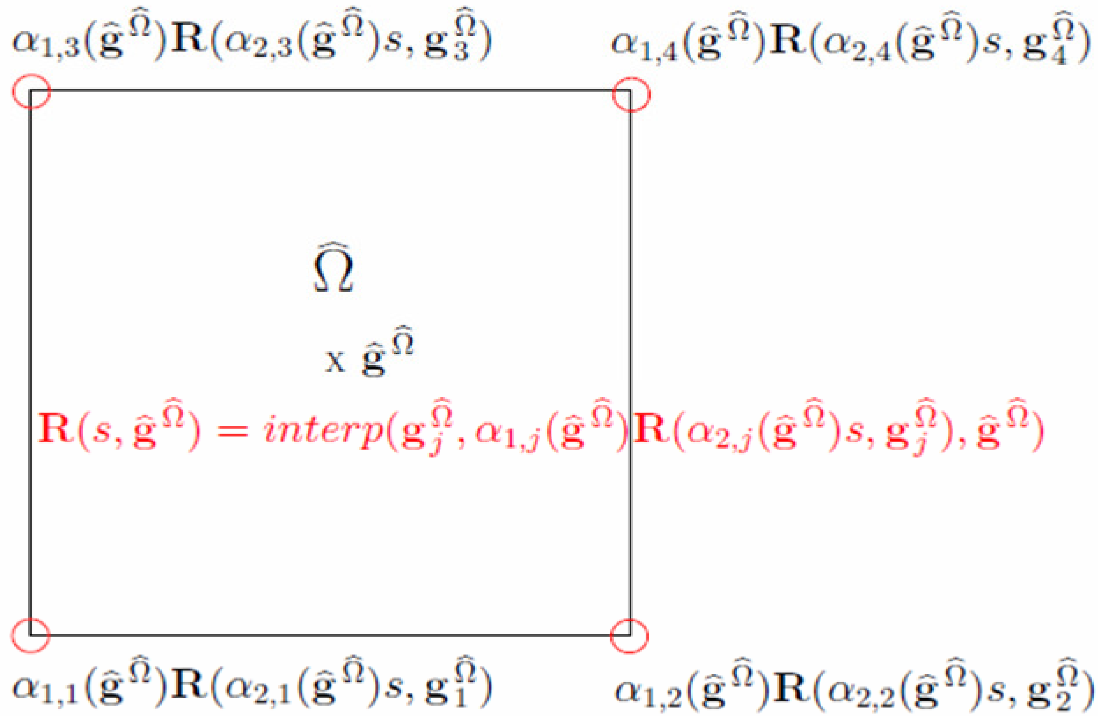

$$\mathbf{R}(s, \widehat{g}^{\widehat{\Omega}}) = \sum_{k_1=1}^{2} \sum_{k_2=1}^{2} \widetilde{\mathbf{R}}(s, (g_{k_1}^{(1)}, g_{k_2}^{(2)})^{\widehat{\Omega}}) \ell_{k_1}(g^{(1)}) \ell_{k_2}(g^{(2)})$$

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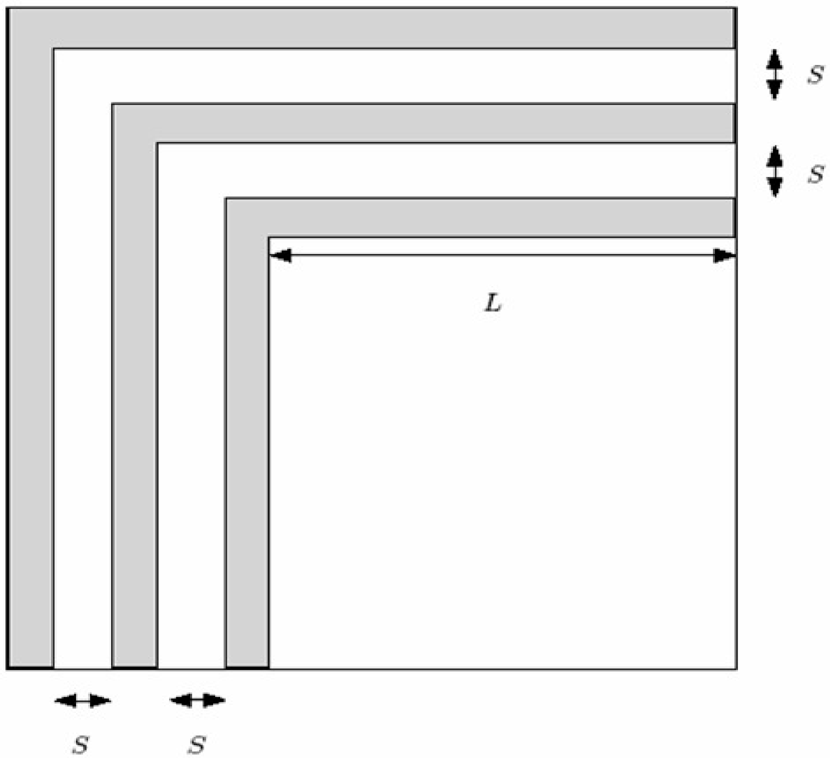
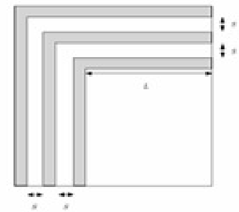
3D example: Bends

Parameter	Min	Max
Frequency ($freq$)	100 kHz	10 GHz
Length (L)	1 cm	1.3 cm
Spacing (S)	2.5 mm	3 mm

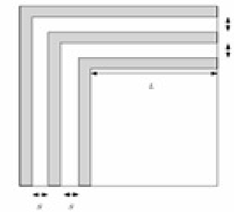
Estimation grid by solver (6 × 5) (L,S)
Validation grid by solver (5 × 4) (L,S)





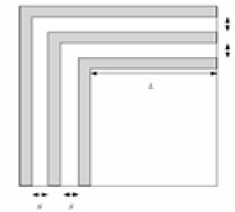
(ORDER,DELAYS) OF τPEEC MODELS AND τROMS.

	τPEEC models	τROMs
(L_1, S_1)	(2124,510)	(64,510)
(L_2, S_1)	(2124,508)	(64,508)
(L_3, S_1)	(2124,510)	(64,510)
(L_4, S_1)	(2124,511)	(64,511)
(L_5, S_1)	(2124,517)	(64,517)
(L_6, S_1)	(2124,519)	(64,519)
(L_1, S_2)	(2124,509)	(64,509)
(L_2, S_2)	(2124,511)	(64,511)
(L_3, S_2)	(2124,513)	(64,513)
(L_4, S_2)	(2124,512)	(64,512)
(L_5, S_2)	(2124,519)	(64,519)
(L_6, S_2)	(2124,520)	(80,520)
(L_1, S_3)	(2124,511)	(64,511)
(L_2, S_3)	(2124,514)	(64,514)
(L_3, S_3)	(2124,518)	(64,518)
(L_4, S_3)	(2124,515)	(64,515)
(L_5, S_3)	(2124,518)	(64,518)
(L_6, S_3)	(2124,522)	(64,522)
(L_1, S_4)	(2124,511)	(64,511)
(L_2, S_4)	(2124,512)	(64,512)
(L_3, S_4)	(2124,519)	(64,519)
(L_4, S_4)	(2124,519)	(64,519)
(L_5, S_4)	(2124,519)	(64,519)
(L_6, S_4)	(2124,527)	(64,527)
(L_1, S_5)	(2124,510)	(64,510)
(L_2, S_5)	(2124,513)	(64,513)
(L_3, S_5)	(2124,518)	(64,518)
(L_4, S_5)	(2124,520)	(64,520)
(L_5, S_5)	(2124,519)	(80,519)
(L_6, S_5)	(2124,524)	(64,524)



Original order	2124
Reduced order	64-272

Step	CPU time
Evaluating solver (one frequency response - 1 sample)	15 s
Evaluating model (one frequency response - 1 sample)	0.24 s



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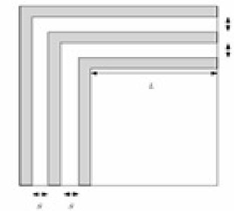
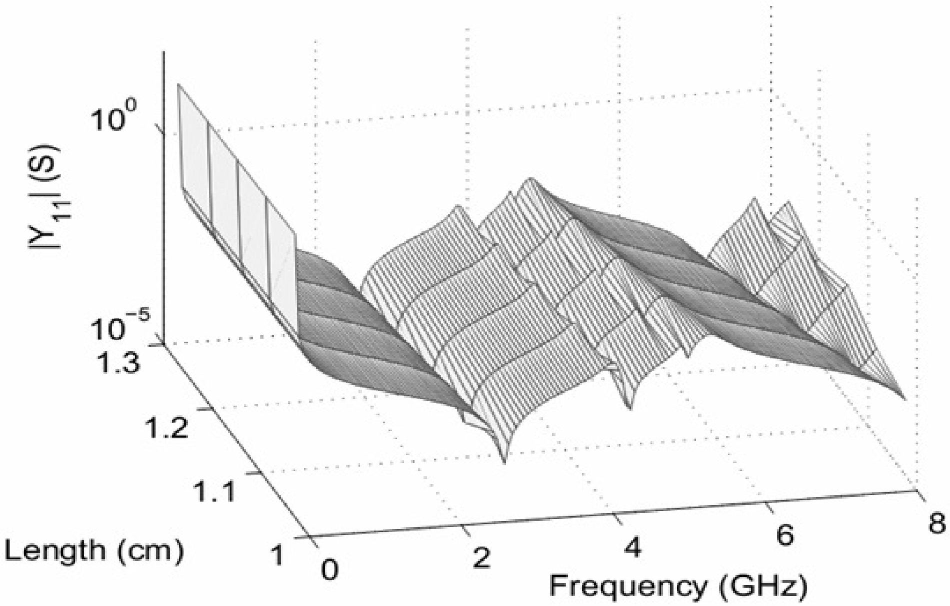
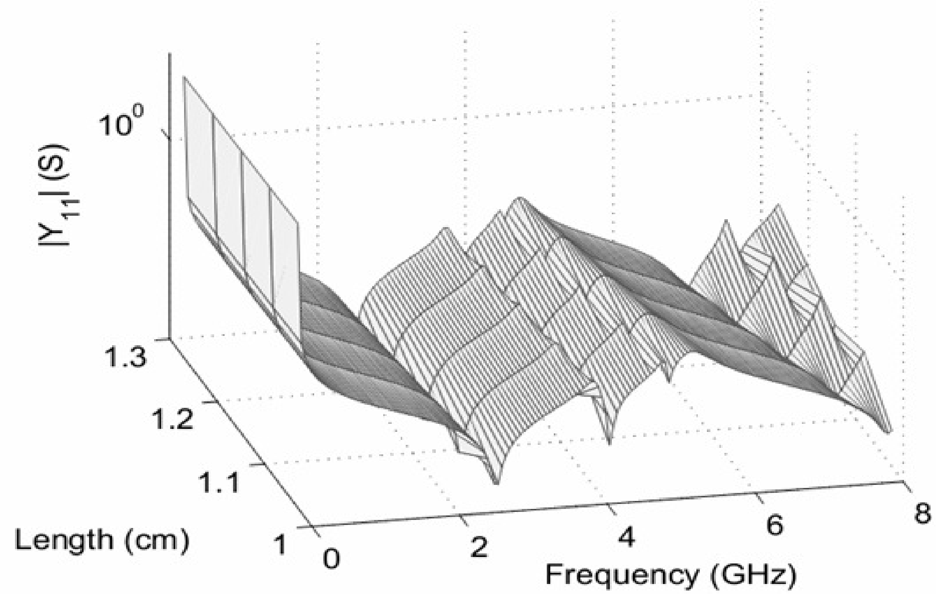
Speed-up 62.5 x

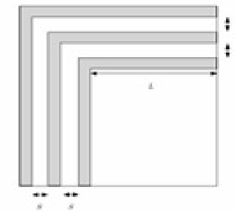


S=2.56 mm

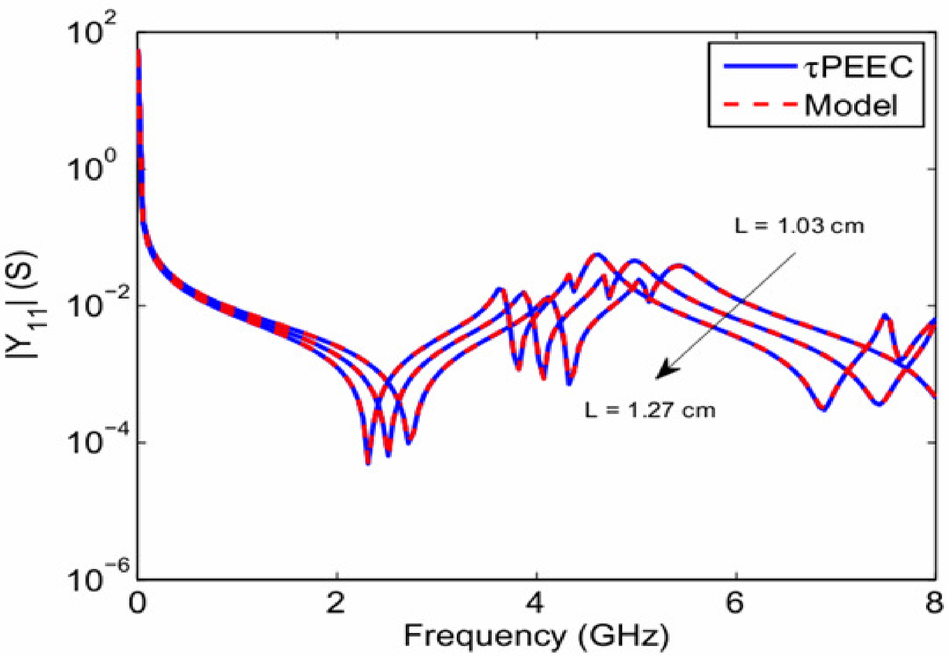


S=2.94 mm

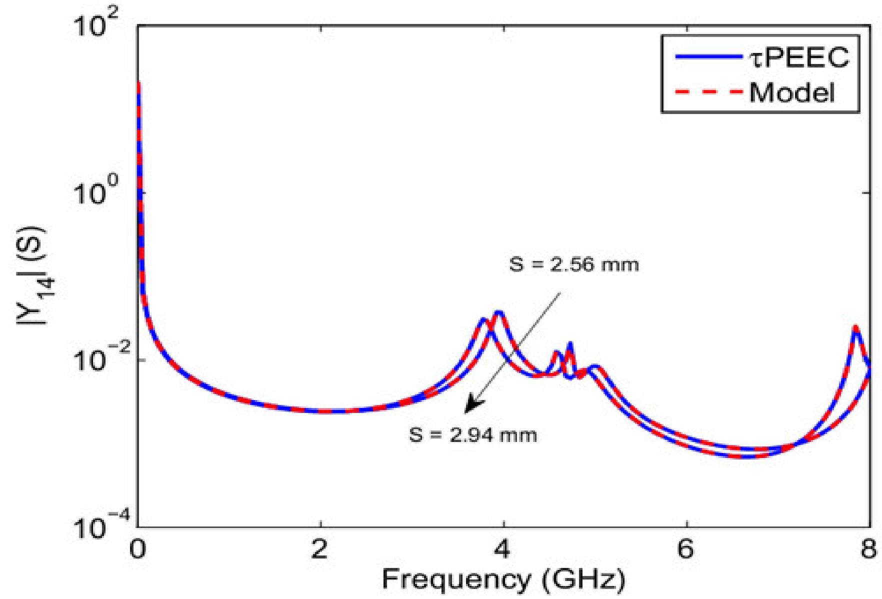




S=2.69 mm



L=1.15 mm



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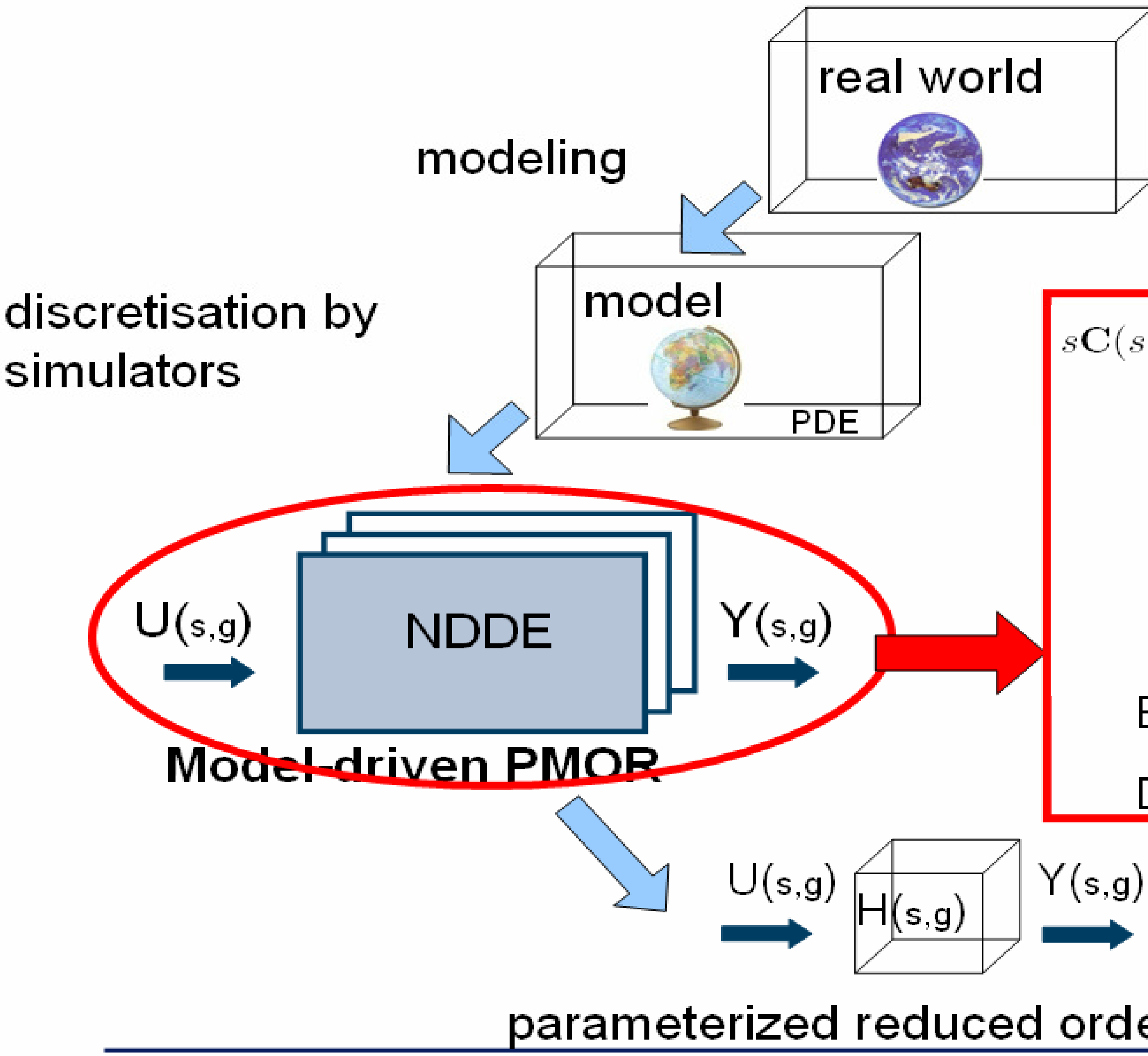

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- independent from a specific MOR method
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- suitable to robust adaptive sampling
- different flavours

Questions

Contact info: francesco.ferranti@ugent.be

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Recent publications

F. Ferranti, M. Nakhla, G. Antonini, T. Dhaene, L. Knockaert, A. Ruehli, "Multipoint Full-Wave Model Order Reduction for Delayed PEEC Models with Large Delays", IEEE Transactions on Electromagnetic Compatibility, vol. 53, no. 4, pp. 959-967, November 2011

F. Ferranti, M. Nakhla, G. Antonini, T. Dhaene, L. Knockaert, A. E. Ruehli, "Interpolation-based Parameterized Model Order Reduction of Delayed Systems", IEEE Trans. on Microwave Theory and Techniques, vol. 60, no. 3, pp. 431-440, March 2012.

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