POLITECNICO DI TORINO

Dipartimento di Automatica e Informatica

PhD in Computer and Control Engineering

XXXI cycle

Supervisor

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Experiment design in nonlinear system identification with application to automotive problems

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1. Introduction

- Accurate **modeling of dynamic systems** is a fundamental step in many engineering fields for simulation, prediction, decision making, fault detection, control design, etc.
- Consider a nonlinear dynamic system in regression form:

$$y^{t+1} = f_o(w^t)\,,\; w^t = [y^t ... y^{t-n_y} u^t ... u^{t-n_u}]$$

Suppose that the function f_o is not known but a set of measurement data is available

$$\mathcal{M} \doteq \{\widetilde{y}^{t+1}, \widetilde{w}^t\}_{t=1}^{T-1}$$

- The goal of **system identification** is to build a mathematical model of a dynamic system using some prior information and measurement data.
- The first element that influences the accuracy of a model is the quality of the collected data.

2. Objective

Synthesize an input sequence to apply to the plant to maximize the information extracted from the collected data and thus minimizing the uncertainty of the estimated model.

3. Set Membership Design of Experiments (SM-DoE)

The proposed Design of Experiments (SM-DoE) algorithm for nonlinear systems is based on the Set Membership framework that minimizes the worst-case model error.

Algorithm Dynamic Set-Membership DoE

1) select a reference regressor w^r to be visited which has a high uncertainty and it's equivalent pseudo-state is close to estimated state.

$$w^r, x^r = \arg \min_{w^r \in \mathcal{W}, x^r \in \mathcal{X}} (\left\| \widehat{x}^{t+1} - x^r \right\|_2 + \frac{\delta}{f_e(w^r)})$$

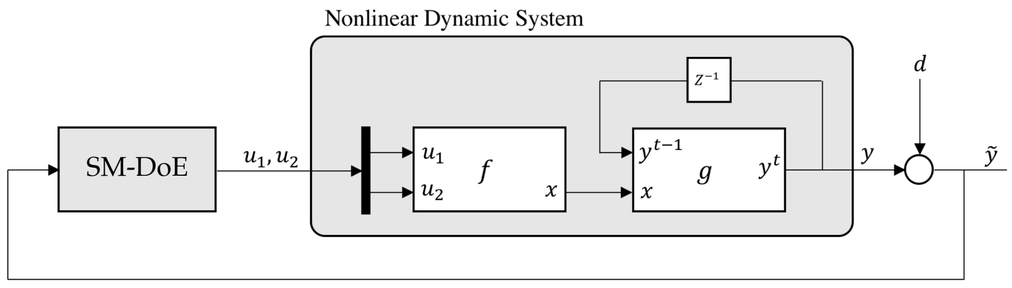
2) compute $\mathcal{X}_r$ with a suitable λ.
3)

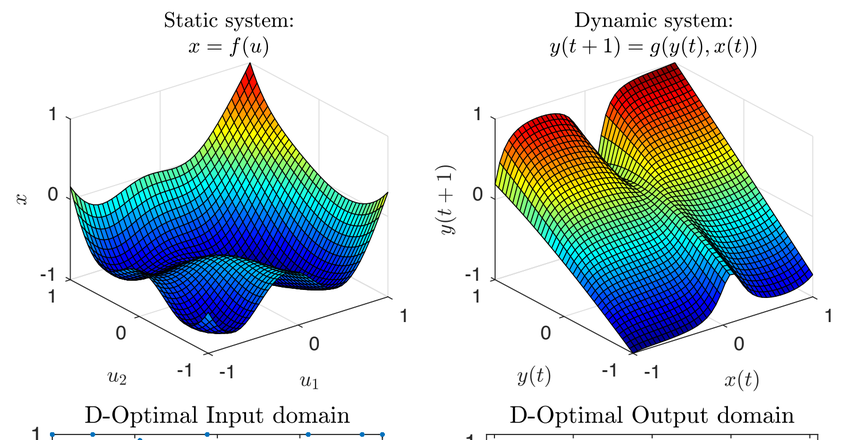
$$\begin{aligned} &\text{if} && \widehat{x}^{t+1} \in \mathcal{X}_r \\ &\text{then} && u^t = u^r \in w^r \\ &\text{else} && u^t = \mathcal{K}(x^r, x^t) \end{aligned}$$

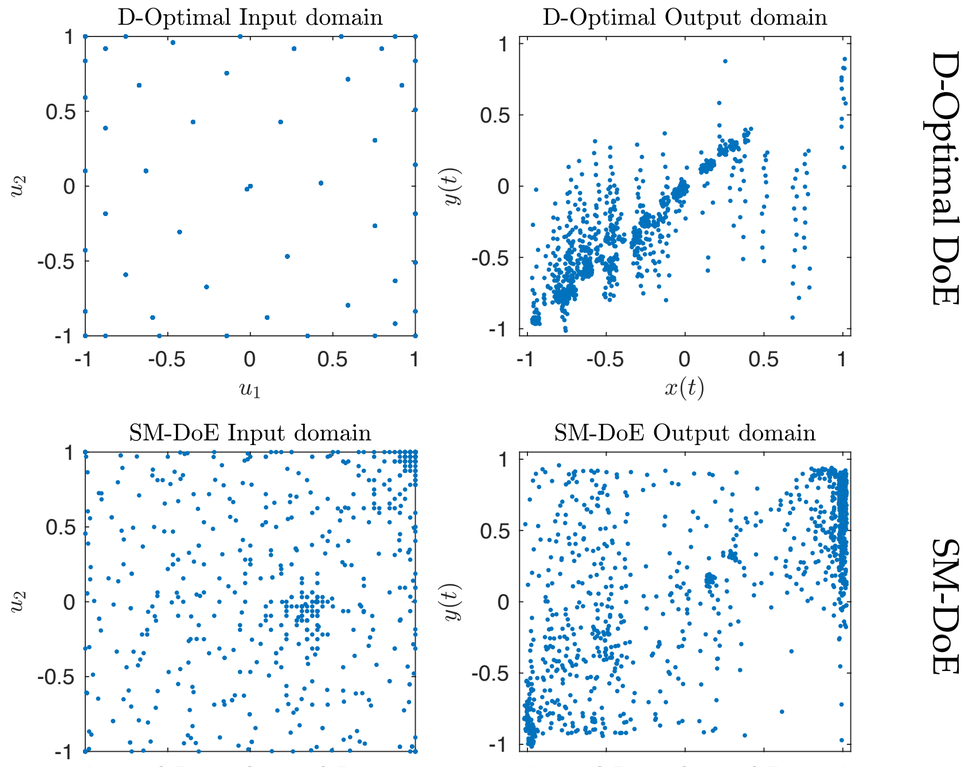
4) evaluate the function $\widetilde{y}^{t+1} = f_o(\widetilde{w}^t) = f_o(x^t, u^t)$
5) add $\widetilde{y}^{t+1}$ and $\widetilde{w}^t$ to the set $\mathcal{M}$
6) update γ and Γ according to algorithm 2
7) set $t = t + 1$ and go to step (1)

4. Results

Different DoE methods are compared in a simulation study on the following dynamic nonlinear system which is relevant to the behavior of a combustion engine







Identified Model Accuracy (Neural Network model)

Inputs	FIT	RMSE
Random	0.69 ± 0.03	0.149 ± 0.017
LHC	0.68 ± 0.04	0.155 ± 0.022
D-Optimal	0.76 ± 0.01	0.115 ± 0.008
SM-DoE	0.91	0.043

5. Conclusion

We propose a novel set membership design of experiments (SM-DoE) approach for nonlinear systems, aimed at minimizing the radius of information. The algorithm is able to guarantee a desired model accuracy