PARAMETER IDENTIFICATION METHODS IN A MODEL OF THE CARDIOVASCULAR SYSTEM

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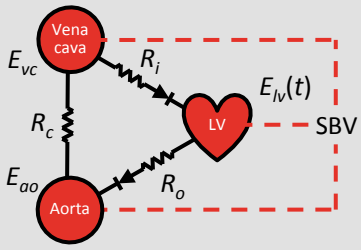
Introduction

- To be clinically relevant, the parameters **p** of a model have to be identified from patient data **y**.
- To achieve real-time monitoring, it is important to select the best parameter identification method, in terms of speed, efficiency and reliability.
- This work compares seven parameter identification methods applied to a cardiovascular system (CVS) model.

Methods

Three-chamber CVS model:



p = (E_{lv} E_{ao} E_{vc} R_i R_o SBV)

The seven methods are tested using *in silico* and animal experimental reference data.

Output vector (available in the ICU):

y = (Aortic pulse pressure,
venous pulse pressure,
stroke volume,
mean aortic pressure,
mean venous pressure,
mean left ventricular (LV) volume,
peak 1st derivative of aortic pressure)

- Residual vector: $r_i = \dfrac{y_i^{ref} - \hat{y}_i(\mathbf{p})}{y_i^{ref}}$
- Objective: minimise $\|\mathbf{r}\|_1 = \sum_{i=1}^{7} |r_i|$
- For *in silico* reference data: error w.r.t. the true parameters $e_j = \dfrac{p_j^{ref} - p_j}{p_j^{ref}}$

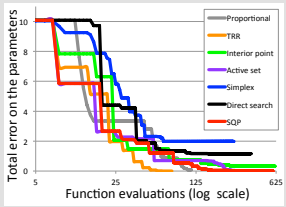
Results

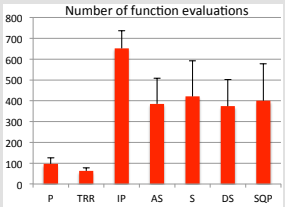
Proportional (P)
Trust-region reflective (TRR)
Interior point (IP)
Active set (AS)
Simplex (S)
Direct search (DS)
Sequential quadratic programming (SQP)

- P and TRR work on **r**; the others work on $\|\mathbf{r}\|_1$.
- P, S and DS are derivative free; the others are gradient-based.

In silico reference datasets

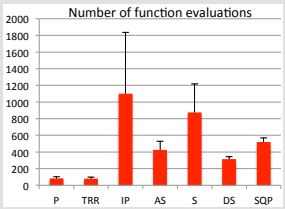
Final $\lvert e_j \rvert < 0.05$ V j				Minimum $\|\mathbf{r}\|_1$			
A	B	C	D	A	B	C	D
N	Y	N	N	0.08	0.04	0.05	0.82
Y	Y	N	Y	0.00	0.00	0.40	0.00
N	Y	N	N	0.08	0.00	0.14	0.10
Y	Y	N	N	0.00	0.00	1.59	0.12
N	N	N	N	0.32	0.09	0.57	0.39
N	Y	N	N	0.80	0.05	0.32	1.24
Y	Y	N	N	0.00	0.00	0.57	0.22





Experimental reference datasets

Minimum $\|\mathbf{r}\|_1$			
E	F	G	H
0.04	0.29	2.05	0.03
0.02	0.23	1.65	0.00
0.14	0.65	1.48	0.00
0.02	0.19	1.44	0.00
0.42	0.64	2.51	0.00
0.69	1.44	2.67	0.75
0.02	0.19	1.45	0.00



Conclusions

- The best methods are the TRR, SQP and AS. AS and SQP are based on similar principles.
- These best methods are all gradient-based, indicating that the residual **r** is smooth.
- The P method, designed for identification of CVS models by Hann *et al*. (2010), is the second fastest.
- Parameter identification in this lumped CVS model can be performed in 2 to 3 minutes.

Acknowledgments

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