DIRECT PARAMETER IDENTIFICATION IN A MODEL OF THE CARDIOVASCULAR SYSTEM

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Abstract

Equations of a simple lumped model of the cardiovascular system are used to express model parameters as functions of model outputs. The one-to-one relations obtained guarantee model identifiability and provide useful bounds on physiological parameters.

Keyword: modeling of physiological systems

1 Introduction

Parameter identification is crucial if developed models are meant to be used to track a specific patient's condition. In cardiovascular system modeling, iterative model-dependent identification methods have gained interest, as they can allow finding the best set of parameters, whereas nonlinear regression methods cannot [1]. In this work, a model-dependent method is developed which allows computing model parameters without requiring any model simulation.

2 Methods

The electrical analog model of the cardiovascular system used is presented in Figure 1. This model only represents the left ventricle and systemic part of the cardiovascular system [1]. An equivalent version can be derived for the right ventricle and pulmonary circulation.

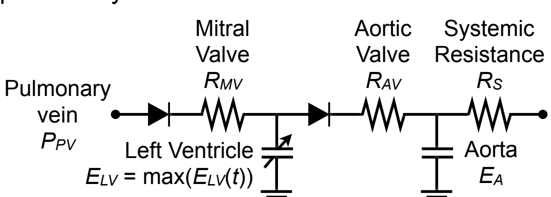

Fig. 1 – Electrical scheme of the systemic circulation submodel. The seven model parameters are indicated.

The model is governed by simple algebraic and differential equations. In particular, ventricular pressure $P_{LV}(t)$ and volume $V_{LV}(t)$ are linked by a time-varying elastance $E_{LV}(t)$:

$$P_{LV}(t) = E_{LV}(t)\cdot V_{LV}(t) = e(t)\cdot E_{LV}\cdot V_{LV}(t)$$

where $e(t)$ is the model input. The mitral and aortic valves are supposed to behave as ideal flow diodes.

The model equations have been used to derive equations expressing model parameters in terms of model outputs (arterial pressure $P_A(t)$, ventricular volume $V_{LV}(t)$ and pressure $P_{LV}(t)$). For example, resistances R can be computed from

$$R\cdot(\max[V_{LV}(t)] - \min[V_{LV}(t)]) = \int_+ P_{up}(t) - P_{down}(t)\,\mathrm{d}t$$

where $P_{up}(t)$ and $P_{down}(t)$ respectively denote up and downstream pressures and the "+" symbol means that the integral is computed only for $P_{up}(t) > P_{down}(t)$. Aortic elastance E_A can be computed from:

$$P_A(t) = P_{VC} + (\max[P_A(t)] - P_{VC})\cdot\exp(-E_A\cdot t/R_S).$$

3 Results

The derived formulae permit to directly and exactly retrieve model parameters from the model outputs (left and right ventricular pressures and volumes, aortic pressure and pulmonary artery pressure) without requiring any model simulation.

In addition, the fact that model parameters can be uniquely retrieved from model outputs proves that the two submodels of the systemic and pulmonary circulation are structurally globally identifiable from these model outputs.

Finally, finding bounds of the formulae provides physiological limits on the parameter values that are useful constraints for iterative identification methods.

4 Conclusion

The identification method presented here is not clinically applicable as such since it relies on ventricular measurements, which are typically not available in a clinical setting. Unavailable measurements can be replaced by the result of model simulations [1], implying iterations of the method. This clearly is a future task.

References

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