Identification of Cardiovascular Baroreflex for Probing Homeostatic Stability

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This paper presents a method to identify the cardiovascular baroreflex parameters that are useful for probing homeostatic stability. The work is built upon a physiology-based model of the closed-loop cardiovascular-baroreflex feedback system describing the regulation of heart rate and blood pressure. We propose a reduced-order system identification in which the model parameters having significant influence on the system responses are identified whereas the remaining model parameters are fixed at their typical values.

To this aim, parametric sensitivity analysis is conducted on the model to classify the model parameters into high-sensitivity, low-sensitivity, and invariant (constant within individual) groups based on their relative impacts on the system outputs. The baroreflex identification is formulated as a nonlinear optimization problem in which only high-sensitivity model parameters are identified whereas low-sensitivity and invariant parameters are fixed at their typical values. The possible advantage of the method is its computational efficiency without significant compromise in performance and accuracy.

The feasibility of the proposed strategy was validated using 500 Monte-Carlo system identification trials. Using heart rate, blood pressure and cardiac output measurements, the proposed method was able to accurately estimate high-sensitivity parameters even with low-frequency and invariant parameters fixed at their typical values.

The method was also applied to the experimental data of 10 individuals in the MIMIC Database in the PhysioBank. It was observed that the sympathetic and parasympathetic responses on heart rate and total peripheral resistance estimated by the proposed method were consistent with our a priori knowledge on the behavior of cardiovascular-baroreflex system. Overall, results suggest potential of the proposed method in probing homeostasis based on the estimates of sympathetic and parasympathetic tones. The method may also be useful for a variety of diagnostic applications involving sympathetic and parasympathetic activities.