Monitoring, Modeling, and Regulation for Indoor and Outdoor Exercises

By

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Certificate of Authorship / Originality

I, Yi Zhang, certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as part of the requirements of a degree, except as fully acknowledged within the text.

I also certify that this thesis has been written by me. Any help that I have received in my research work and in the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

This thesis focuses on the modeling and regulation of exercise intensity by using non-invasive portable sensors. Firstly, an innovative switching Resistance-Capacitor (RC) model has been proposed to depict the dynamics of human cardio-respiratory (CR) responses to the onset and offset of exercise. This switching model utilizes electronic terms with switching mechanism to explicitly depict dynamical characteristics at the onset/offset of exercise and the transition in between. It can not only guarantee the continuity of model output between onset and offset of exercise but also quantify lactate metabolism at onset and offset by using the term 'oxygen debt'.

Secondly, to effectively regulate human CR responses to exercise, a single-input single-output (SISO) closed-loop control framework is proposed. Within this framework, a control oriented modeling approach using support vector regression (SVR) is presented. Based on that, a novel model predictive control (MPC) algorithm is developed for the regulation of exercise intensity. Simulation study shows the proposed machine learning based model predictive control approach can achieve desired performance requirements for both the onset and offset of exercise and the transitions in between.

The third research topic is related to the monitoring of outdoor exercise. A reliable Android application based monitoring system is developed. This system includes a portable HxMBT HR sensor (Zephyr®), an easy-to-use interface, and a supervisory module. This technique is applicable to cardiovascular disease detection and diagnosis, home based rehabilitation monitoring, and exercise strength regulation under free living conditions.

Finally, in order to provide a more reliable automated treadmill system for running exercise, the multi-loop integral controllability (MIC) analysis is introduced, which extends the concept of decentralized integral controllability (DIC) from square systems

to multiple-input single-output (MISO) processes. A condition to ensure MIC for 2ISO is proposed and its sufficiency has been proved by using singular perturbation theory. Then, a sufficient MIC condition for MISO processes is provided.

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