Chemical Engineering Doctoral Defense

Dynamic Modeling, System Identification, and Control Engineering Approaches for Designing Optimized and Perpetually Adaptive Behavioral Health Interventions

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Abstract

Behavior-driven obesity has become one of the most challenging global epidemics since the 1990s, and is presently associated with the leading causes of death in the U.S. and worldwide, including diabetes, cardiovascular disease, strokes, and some forms of cancer. The use of system identification and control engineering principles in the design of novel and perpetually adaptive behavioral health interventions for promoting physical activity and healthy eating has been the central theme in many recent contributions. However, the absence of experimental studies specifically designed with the purpose of developing control-oriented behavioral models has restricted prior efforts in this domain to the use of hypothetical simulations to demonstrate the potential viability of these interventions. In this dissertation, the use of first-of-a-kind, real-life experimental results to develop dynamic, participant-validated behavioral models essential for the design and evaluation of optimized and adaptive behavioral interventions is examined.

Following an intergenerational approach, the first part of this work aims to develop a dynamical systems model of intrauterine fetal growth with the prime goal of predicting infant birth weight, which has been associated with subsequent childhood and adult-onset obesity. The use of longitudinal input-output data from the Healthy Mom Zone intervention study has enabled the estimation and validation of this fetoplacental model. The second part establishes a set of data-driven behavioral models founded on Social Cognitive Theory (SCT). The Just Walk intervention experiment, developed at Arizona State University using system identification principles, has lent a unique opportunity to estimate and validate both black-box and semiphysical SCT models for predicting physical activity behavior. Further, this dissertation addresses some of the model estimation challenges arising from the limitations of Just Walk, including the need for developing nontraditional modeling approaches for short datasets, as well as delivers a new theoretical and algorithmic framework for structured state-space model estimation that can be used in a broader set of application domains. Finally, adaptive closed-loop intervention simulations of participant-validated SCT models from Just Walk are presented using a Hybrid Model Predictive Control (HMPC) control law. A simple HMPC controller reconfiguration strategy for designing both single- and multi-phase intervention designs is proposed.

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