Chemical Engineering Doctoral Defense

System Identification, State Estimation, And Control Approaches to Gestational Weight Gain Interventions

School for Engineering of Matter, Transport and Energy

Penghong Guo

Advisor: Daniel E. Rivera

abstract

Excessive weight gain during pregnancy is a significant public health concern, and has been the recent focus of novel, control systems-based interventions. Healthy Mom Zone (HMZ) is an intervention study which aims to develop and validate an individually-tailored and intensively adaptive intervention to manage weight gain for overweight or obese pregnant women using control engineering approaches. Motivated by the needs of the HMZ, this dissertation presents how to use system identification and state estimation techniques to assist in dynamical systems modeling, and further enhance the performance of the closed-loop control system for interventions. Underreporting of energy intake (EI) has been found to be an important consideration that interferes with accurate weight control assessment, and the effective use of energy balance (EB) models in an intervention setting. To better understand under-reporting, a variety of estimation approaches are developed; these include back-calculating energy intake from a closed-form of the EB model, a Kalman-filter based algorithm for recursive estimation from randomly intermittent measurements in real-time, and two semi-physical identification approaches that can parameterize the extent of systematic underreporting with global/local modeling techniques. Each approach is analyzed with intervention participant data and demonstrates potential of promoting the success of weight control. In addition, substantial efforts have been devoted to develop participant-validated models and incorporate into the Hybrid Model Predictive Control (HMPC) framework for closed-loop interventions. System identification analyses from Phase I led to modifications of the measurement protocols for Phase II, from which longer and more informative data sets were collected. Participant-validated models obtained from Phase II data significantly increase the model predictive ability for individual behaviors and provide reliable ``open-loop" dynamics for HMPC implementation. The HMPC algorithm to assign optimized dosages in response to participant real-time intervention outcomes is designed based on a Mixed Logical Dynamical framework which can address the categorical dosage components, and convert sequential decision rules and other clinical considerations into mixed-integer linear constraints. The performance of the HMPC decision algorithm was tested with participant-validated models, the results demonstrating superiority to ``IF-THEN" decision rules.

November 2, 2018; 2 PM; LSA 109