Adaptive Treatment and Optimal Control

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In this talk we consider adaptive treatment methods developed in the biostatistical literature from a control theory perspective. We consider the determination of treatment selection rules robust to the presence of model misspecification and noise in the framework of a single longitudinal study.

Since the seminal work of Murphy [10], they have been an increasing interest in A-learning for estimating optimal dynamics treatment (ODT) strategies [11, 8, 5, 1, 12, 13]. These methods involve two steps. First, estimation of the parameters of functions belonging to the set of so-called structural nested mean models (SNMM [12]) and second, from these functions, derivation of expression for the optimal treatment strategy. The structural nested mean models underpinning A-learning are based on contrasts in hypothetical expected outcomes given two treatment strategies. This is in contrast to the standard control or Q-learning approaches based on modelling the response as a function of treatment directly, which is familiar in control or Q-learning. The recent development of doubly-robust methods can provide consistent parameter estimation despite the presence of model misspecification in SNMM [7, 9, 1]. These approaches in principle also allow formal inference, including confidence intervals for parameter estimates and optimal treatment strategies, as well as a range of diagnostic techniques that can be used to verify model adequacy or detect misspecification.

In practice however, users usually adopt the point-wise inferred optimal treatment strategy without taking into account the presence of model misspecification and measurement noise. In terms of control theory [14, 2], considering the patient as the plant and the treatment as the control, this problem can be restated as ODT estimation methods only using the nominal plant without taking into account model uncertainty to determine the feedback control. We propose estimating the model parameters by using the regret regression approach introduced in [5], followed by H-infinity control synthesis to estimate a treatment strategy robust to both model misspecification and noise measurement. H-infinity is used to design a controller stabilizing a given system and optimizing given criteria while uniformly minimizing the impact of exogenous disturbances [6, 4, 15, 3]. We present a simple simulated data example inspired by the study presented in [13] to investigate whether this approach gives us a better treatment strategy than the one straightforwardly derived from regret-regression.

References