**Control Subject to Human Behavioral Disturbances:** **Anticipating**

**Behavioral Influences in the Control of Diabetes (CNS-0931633)**

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This project addresses the design of control systems where the principle disturbances are the result of routine human behavior, i.e. behaviors that are (i) random but cannot be treated as zero-mean, white noise processes and (ii) occur with statistical regularity but cannot be treated as periodic due to natural variation in human behavior. The principle application of our work is the control of blood glucose concentration for patients with Type 1 Diabetes Mellitus (T1DM), where meals and exercise are the two main disturbances, both of which are random but cannot be treated as zero-mean, white noise processes. Our goals are (i) to develop new mathematical models (“profiles”) of human behavioral disturbances, focusing especially on appropriate statistical characterizations of routine behavior, and (ii) to formulate and solve new control-theoretic models that seek to anticipate human behavioral disturbances without compromising safety. In our work to date, we have focused on the design of control algorithms that respond to different representations of human behavioral disturbances.

*Control Based on Disturbance Regimes*: In [1], we have introduced the notion of “disturbance regimes,” within which single-shot shock disturbances of random size are prone to occur, where the timing of disturbances can be characterized by a relative frequency distribution over slotted time within each regime. (In the context of Type 1 diabetes, disturbance regimes correspond to “breakfast time,” “lunch time,” “dinner time,” etc. and shock disturbances correspond to the meals themselves.) We have formulated the problem of optimal LQ control for a single regime, which we now refer to as “Shock-Anticipating LQR” (SA-LQR), and have characterized the optimal solution in terms of feedback/feedforward gains that are dependent upon the relative frequency distribution for the timing of the disturbance and its mean value (given that it arrives). We have reported on the potential applicability of this method for T1DM in [1] and [2], where simulation experiments show that SA-LQR can advise insulin in anticipation of individual meals without significantly increasing the risk of hypoglycemia. In [3] and [4], we have developed an algorithm for profiling human eating behavior and using this profile to inform the design of SA-LQR control algorithms

*Control Based on Multiple Disturbance Function Hypotheses*: While the optimal solution to SA-LQR is easy to characterize, SA-LQR has the practical disadvantage of treating disturbance regimes as independent. In reality, human behaviors throughout the day are strongly correlated, e.g. a skipped breakfast may imply an early or large lunch. Dealing with correlated disturbances in terms of SA-LQR turns out to be difficult. Recently, we have begun to explore an alternative representation of human behavioral disturbances where correlated disturbance events throughout the day are expressed as a set of disturbance function hypotheses. In [5], we consider the problem of controlling a linear time-invariant system that, in addition to one of the disturbance function hypotheses, is also subject to a zero mean white Gaussian disturbance process and sensor noise. Imposing a quadratic objective function (so that our setting is a generalization of Linear Quadratic Gaussian (LQG) control), we have begun to evaluate the suboptimal but convenient strategy of Open Loop Feedback Control (OLFC). Preliminary simulation experiments suggest that with the right set of hypothesized disturbances, OLFC may represent a suitable alternative to SA-LQR for the control of diabetes.

References:

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[4] C. Hughes et al., “In-Silico Experiments of Human Eating Patterns: Making a Case for Behavior-Informed Control of T1DM,” Proc. UKACC International Conference of Control (to appear), Sept. 2010.

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