Control Subject to Human Behavioral Disturbances: Anticipating Behavioral Influences in the Control of Diabetes

Stephen D. Patek (PI), Project CNS-0931633
School of Engineering and Applied Science, University of Virginia

Project Overview:

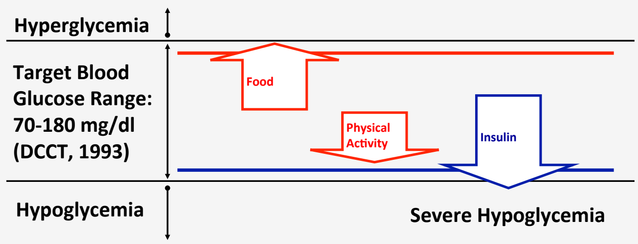
This project addresses the design of control systems where the principle disturbances are the result of routine human behavior, i.e. behaviors that are (i) random but cannot be treated as zero-mean, white noise processes and (ii) occur with statistical regularity but cannot be treated as periodic due to natural variation in human behavior.

Goal 1: To develop new mathematical models ("profiles") of human behavioral disturbances, focusing especially on appropriate statistical characterizations of routine behavior.

Goal 2: To formulate and solve new control-theoretic models that seek to anticipate human behavioral disturbances

Target Application:

Control of blood glucose concentration for patients with Type 1 Diabetes Mellitus (T1DM), where meals and exercise are the main disturbances.

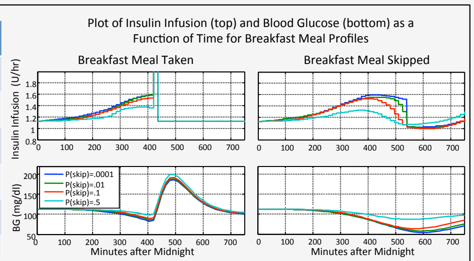


Models Based on Disturbance Regimes:

Human behavioral influences often come as discrete events according to a relatively fixed schedule, e.g. meals happen (or not) at breakfast time.

- To model this type of disturbance we introduce the notion of a ``disturbance regime." Disturbance regimes are intervals of time in which single-shot disturbances of random size are prone to occur, where the timing of the shot can be characterized by a relative frequency distribution over slotted time.
- In prior work, we have developed an LQ optimal control scheme in which feedback/feedforward gains are dependent upon the relative frequency distribution for the timing of the disturbance and its mean value.

Meal Profile Data	Breakfast Regime
Meal size (gCHO)	55
Earliest meal time (min)	240
Most likely meal time(min)	420
Latest meal time (min)	525
Std. Dev. of meal time	30
p(skip)	{.0001,.01,.1,.5}

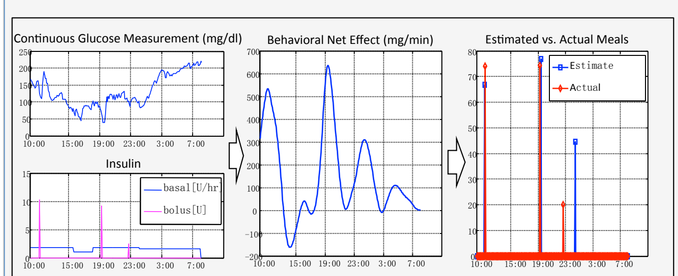


- We are extending the regime-based framework in the direction of "advisory" systems that provide on-demand insulin bolus recommendations based on the optimal solution to an indefinite-horizon LQ problem defined by the uncertain time of the next disturbance.

Models Based on Multiple Disturbance Function Hypotheses:

Daily human behaviors are strongly correlated, e.g. skipped breakfast may imply an early lunch.

- To account for correlated behaviors, we are investigating the opportunity to use a set of representative (historical) disturbance patterns to inform control decisions.
- In prior work, we have demonstrated that it is possible to adapt control decisions to behavioral disturbances represented as multiple disturbance function hypotheses via open-loop feedback control.
- We are working to develop a method of constructing a representative set of behavioral hypotheses. The main challenge is that humans are notoriously inaccurate when it comes to behavioral self-reporting (e.g. food diaries). However, with a sufficiently rich set of measurements it may be possible to estimate the activities and behavioral influences that are affecting the system.



Acknowledgement: NSF-CNS-0931633. Please direct correspondence to patek@virginia.edu.