Modeling Eating Behavior of Adults with Type 1 Diabetes

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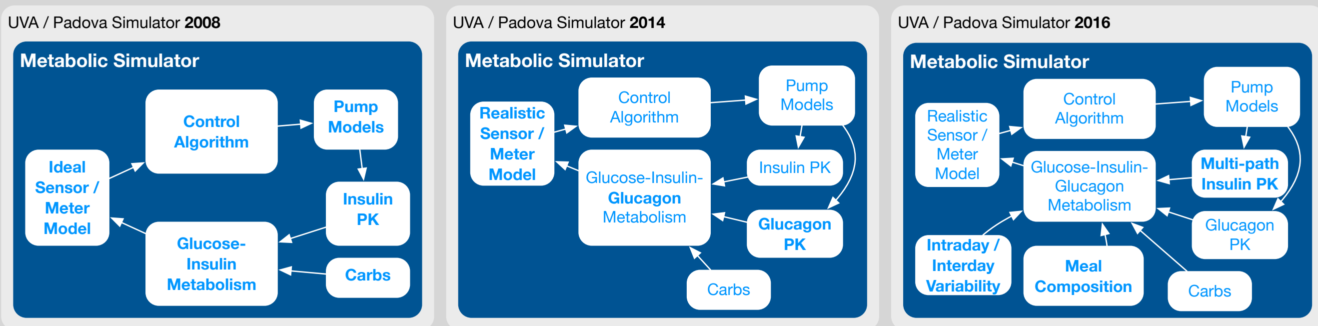
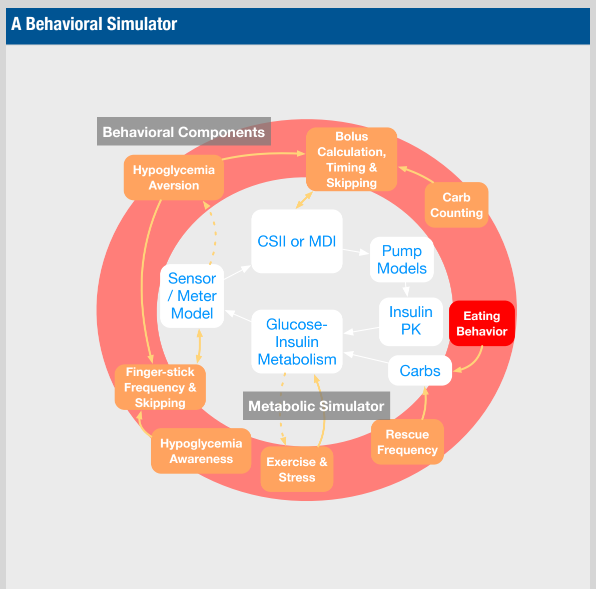
Background

The UVA/Padova simulation platform is now commonly used for testing for novel insulin schedules in T1DM and artificial pancreas research (>300 citations) and frequently augmented by new physiological processes from basic insulin-glucose metabolism, addition of glucagon and realistic CGM models, intraday/interday variability of insulin sensitivity, meal composition and insulin kinetics in intra-dermal and intra-peritoneal spaces. Recent efforts have produced preliminary models of the effect of exercise in the glucose-insulin metabolism.



Insulin-therapy advisory and adaptive closed-loop systems are frequently test in-silico using simplified scenarios where subject behavior is simplified or assumed to be constant across the subjects in the population. In order to move towards individualized therapy improvement systems and adaptive artificial pancreas systems, subject behavior and its variability will play a key role in understanding the long-term efficacy of these new designs.



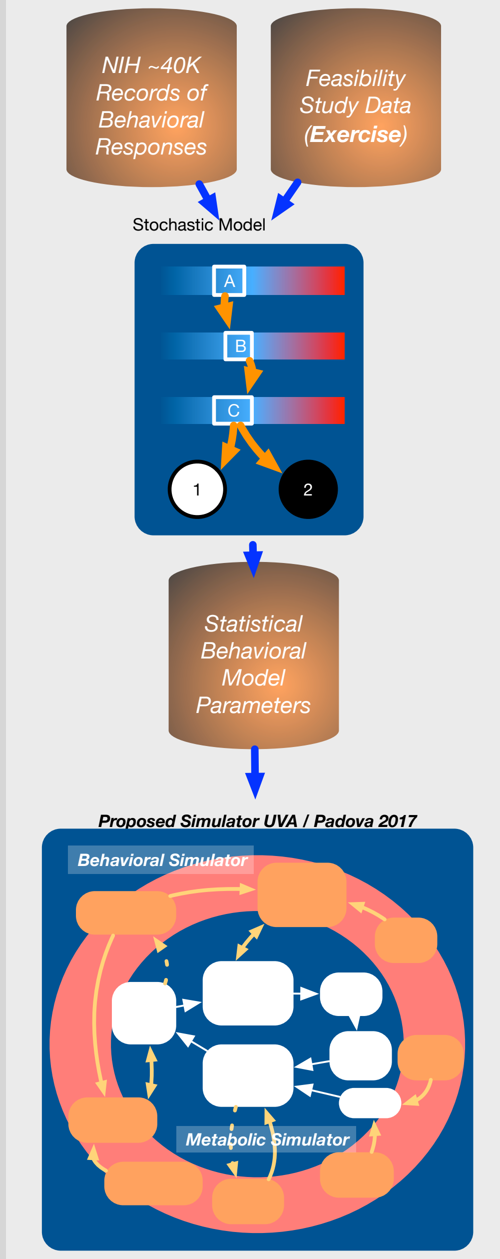
Project Goals

The objective of the project is to create a population of "behavioral personalities" spanning key behavioral characteristics observed in type 1 diabetes patients:

- Eating patterns (meal sizes and compositions, as well as correlation of meal sizes between a day),
- Self-treatment behaviors (finger-stick frequency, bolus, carb counting errors),
- Hypoglycemia awareness
- Hypoglycemia risk compensation
- Physical activity
- Stress

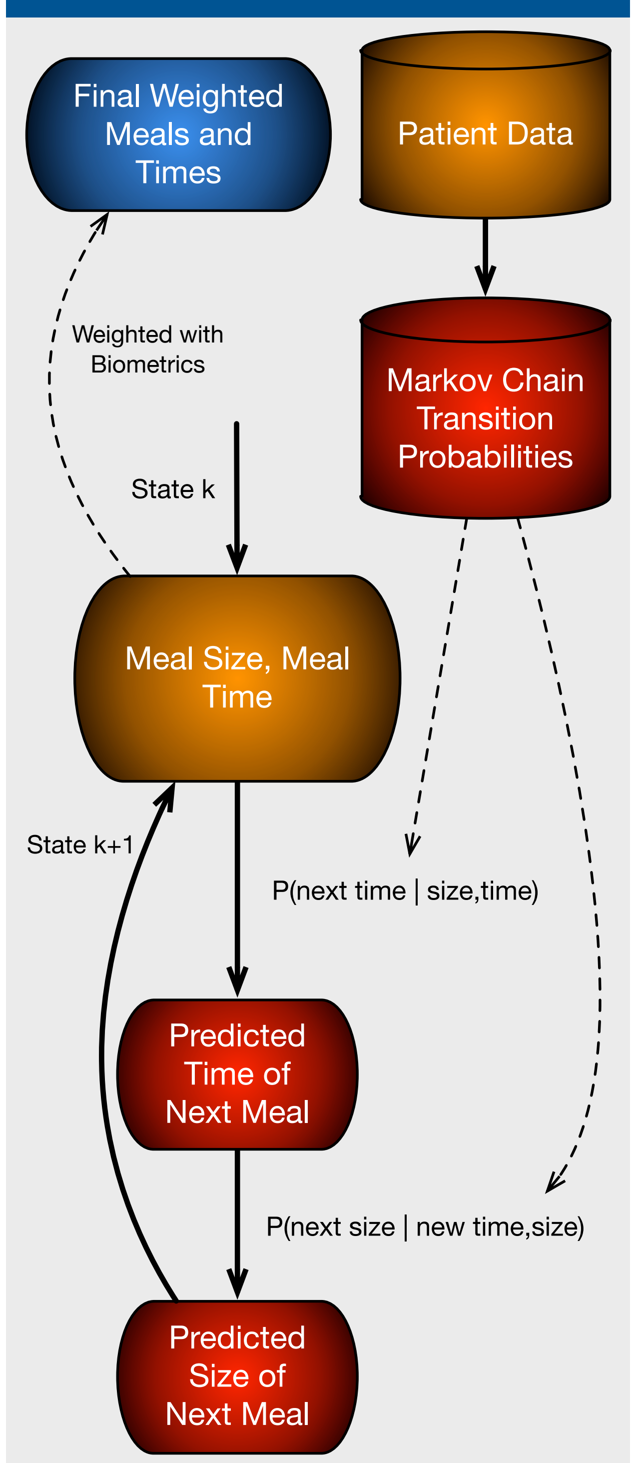
The behavioral simulator will complement the FDA approved simulator by providing access to a library of real-life behaviors to researchers trying to assess the performance of glucose control algorithms and therapy optimization approaches in realistic scenarios.

Approach



Markov Chain Modeling Process for Eating Behaviors

Approach



Validation Approach

Linear and autoregressive models were considered but it was determined they would not be able to accurately incorporate the variability of day to day eating habits. Markov modeling best described the randomness of human behavior. Patient data was cleaned of hypoglycemic treatment (size < 30g, BG < 70). This data was the basis for the probabilities contained in the Markov model. Meal data produced by the Markov model was directly compared to real patient data to prove the validity of the model.

Results

After 500 1-day trials of the Markov chains, the distribution of the meal sizes (in grams per kilogram) and times of meals created by the Markov chains was consistent with the Phase 1 distributions of meal sizes (g/kg) ($p<0.001$) and times of meals ($p<0.001$). The resulting model has been incorporated into the UVA-Padova T1DM Simulator.

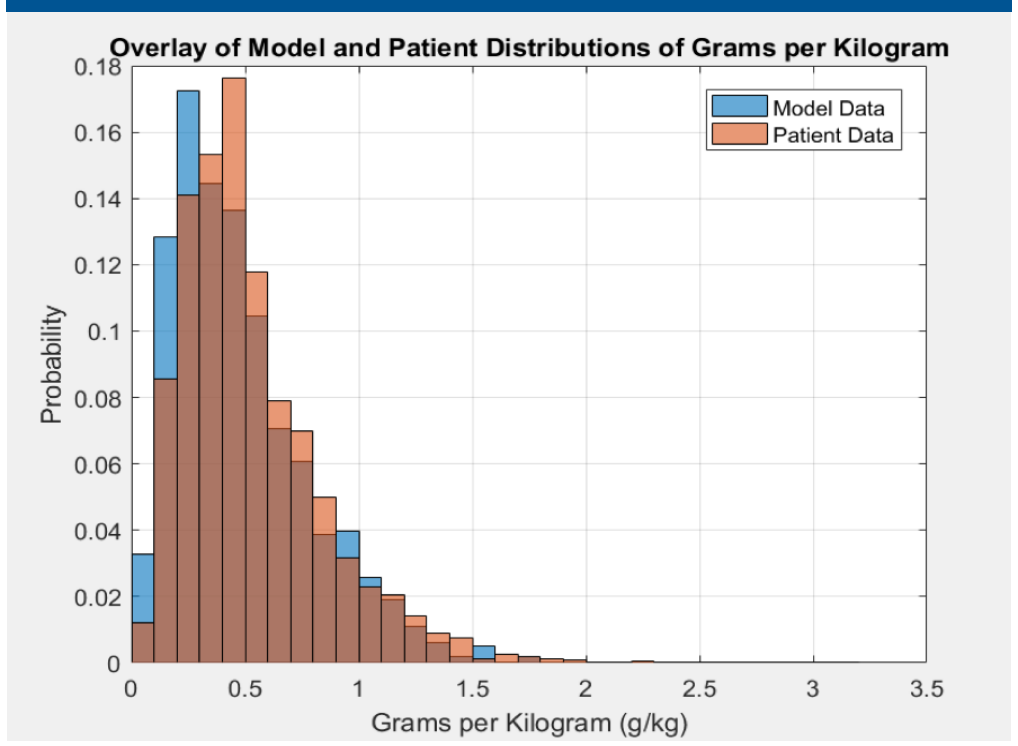
Gender Differences

This model is able to accurately simulate both male and female eating patterns since it was found that basing meal sizes on weight accounted for any differences between the genders. It was also discovered there was no significant difference in the number of meals per day based on gender.

Methods

Phase 1 data from grant RO1-DK-085623 (see clinicaltrial.gov, NCT01434030) were used, this data included CGM readings and meal diaries from 53 patients (21 Male, 32 Female). The time and size of a meal is modeled as the state of a Markov chain. The probabilities for relative meal times and sizes were estimated as empirical frequencies based on this data. The size and time of the last meal were used in specified intervals to predict the next meal time. This predicted next time was used in conjunction with the size of last meal to predict the relative size of the next meal. To test the accuracy of this model, 500 1-day trials were conducted and compared to Phase 1 subject data using a two-sample Kolmogorov–Smirnov test.

Results



Conclusion

The proposed model accurately replicates adult meal behavior and provides a new behavioral component to the UVA-Padova T1DM Simulator. The model will provide a realistic testbed for adaptive technologies such as closed-loop systems and other forms of decision support.

- Kovatchev BP, et al,. In Silico Preclinical Trials: A Proof of Concept in Closed-Loop Control of Type 1 Diabetes. Journal of Diabetes Science & Technology 3: 44-55, 2009.
- Dalla Man, C, et al, The UVA/PADOVA Type 1 Diabetes Simulator: New Features. Journal of Diabetes Science and Technology, 8(1): 26-34, 2014.
- R. Visentin, et all, The UVA/Padova Type 1 Diabetes Simulator Goes from Single Meal to Single Day, forthcoming Journal of Diabetes Science and Technology.

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