Fuzzy Logic Controller for Insulin Dosing

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Introduction

Fuzzy logic (FL) provides a powerful vehicle to incorporate human reasoning in the control algorithm. Unlike PID and MPC controllers, FL need not be based on the explicit mathematical model of the process. The controller designed using FL implements human reasoning that has been programmed into FL language algorithms. However, similar to PID and MPC controllers, FL controllers may incorporate real-time methods for adapting the controller to the changing conditions of the system being controlled. FL controllers also allow a medical expert to communicate control in a manner they understand, can easily visualize, and readily adapt to the conditions of their patients.

Objective

To evaluate the feasibility of a fuzzy logic based controller for an artificial pancreas

Methods

FLC uses a Dosing Rules Matrix that visually portrays insulin dosing covering all blood glucose situations. The matrix allows dosing to be customized as a function of any combination of Blood Glucose (BG), BG rate and BG acceleration without the mathematical constraints required by other methods. This method provides an intuitive mechanism for significant physician input allowing for individual customization. FL is well suited for the control in non-linear or poorly behaved systems, such as the human glucoregulatory system.

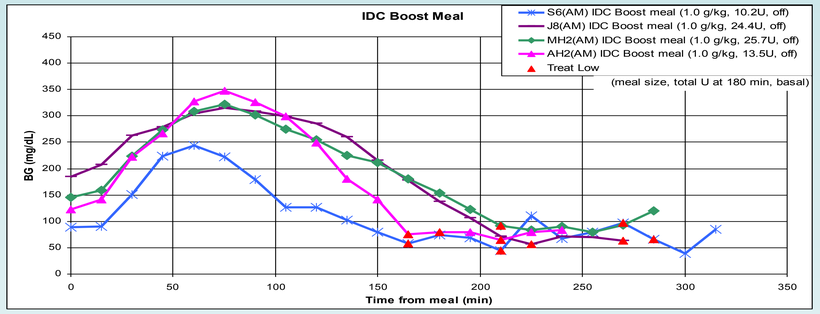
Four patients ages 16-33 with well controlled Type I diabetes and using an insulin pump were tested. BGL was checked at 15 min intervals and dosing was advised by the FLC with physician review. The test duration was 4 to 5 hours.

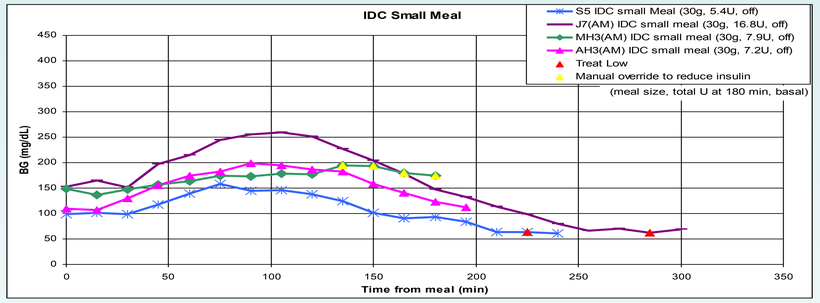
Dosing Rules Matrix

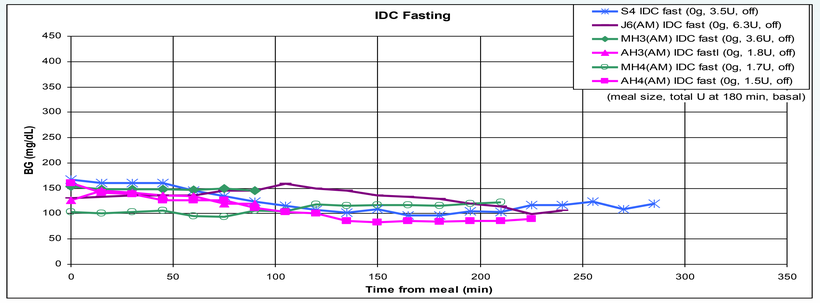
Subcutaneous insulin infusion rates. Units of insulin. 5 min sample time

BGL Rate: Very Negative, Negative, Zero Positive, Very Positive	VN			N			Z			P			VP		
BGL Acceleration: Negative, Zero Positive	N	Z	P	N	Z	P	N	Z	P	N	Z	P	N	Z	P
BGL Trajectory: previous two sample times	↘	↘	↘	↘	↘	↘	↗	→	↘	↗	↗	↗	↗	↗	↗
> 250 mg/DL	0.00	0.00	0.00	0.13	0.17	0.83	0.17	0.30	1.00	0.50	0.90	1.17	0.53	1.50	1.67
180-250 mg/DL	0.00	0.00	0.00	0.10	0.13	0.27	0.13	0.27	0.67	0.27	0.73	0.90	0.30	1.40	1.50
120-180 mg/DL	0.00	0.00	0.00	0.07	0.10	0.13	0.10	0.13	0.27	0.13	0.50	0.57	0.17	1.00	1.17
80-120 mg/DL	0.00	0.00	0.00	0.23	0.03	0.03	0.03	0.07	0.10	0.03	0.10	0.13	0.03	0.13	0.17
< 80 mg/DL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.03	0.03	0.04	0.05

Results







Results

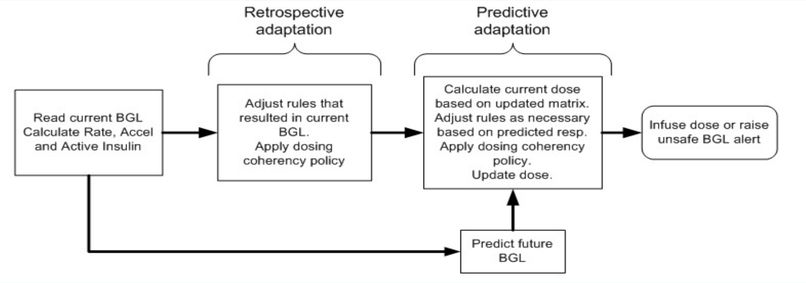
Four patients were studied in fasting, small meal (SM) (30 grams CHO) and large meal (LM) (1 g/kg) regimens using a FLC with 15 minute BG testing. Comparison between the patient's treatment for the LM and the FL controller were made. The FLC reduced BG AUC for all regimens compared to manual control. BG AUC was reduced 28% from 20647 to 14835 mg/dl*min over the 180 minute period following a LM. Good control was achieved for SM (BG AUC = 6668 mg/dl*min) and fasting regimens (BG AUC = 3491 mg/dl*min) with low BG requiring treatment in 2 of 12 trials.

Conclusion

Safe BG levels in the fasting and SM studies were maintained by the controller. Better control after a LM may be achieved by more frequent BG sampling (Q5minutes), potential faster-acting, shorter duration insulin and more customization to individuals. FLC warrants more investigation as a potential artificial pancreas technology solution.

Future Research

FL can be readily modified to accept adaptive and predictive components. These two areas are our current focus of further research, which will use in silico testing.



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