

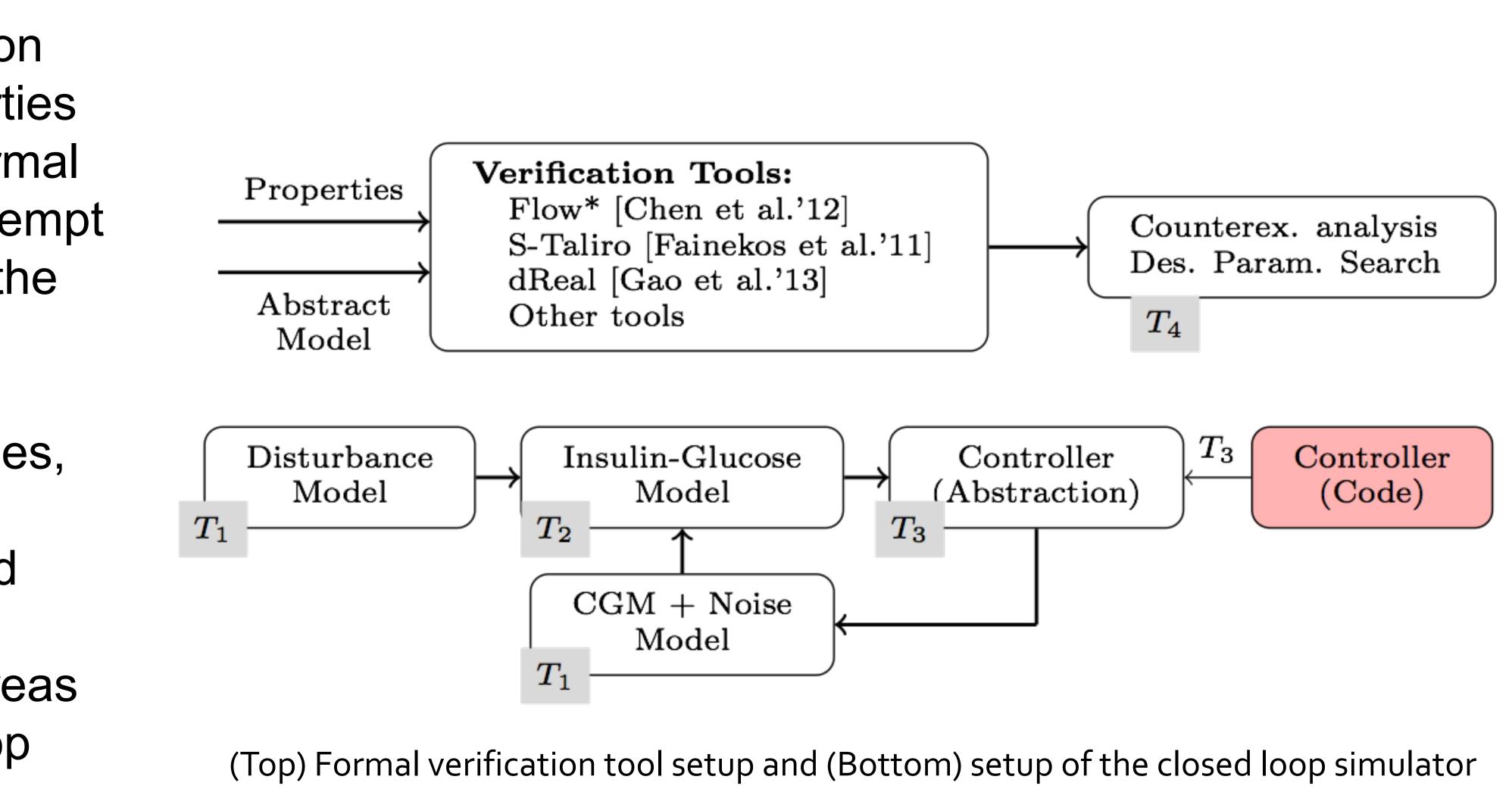
We apply formal specification and verification techniques for checking correctness properties of artificial pancreas control algorithms. Formal specification and verification techniques attempt to systematically and exhaustively explore the behaviors of closed loop in silico models to understand the worst case effects of disturbances such as meals, external boluses, sensor noise, pressure induced sensor attenuation and set failures on the predicted blood glucose levels of a "virtual" patient. Specifically, we examine two artificial pancreas controllers: (a) PID-based hybrid closed loop controller (Steil et al.'2011) and (b) Kalman filter-based predictive pump shutoff system (*Cameron et al.* '2012).

Verification Approach

- Mathematical modeling of closed loop: Meal insulin-glucose regulation models (*Dalla Man al.'2007* [6]).
- Exhaustive simulation of millions of meal and insulin bolus patterns using S-Taliro (Abbas et *al.'201*3 [7]).
- Formulation of temporal properties of the close loop.

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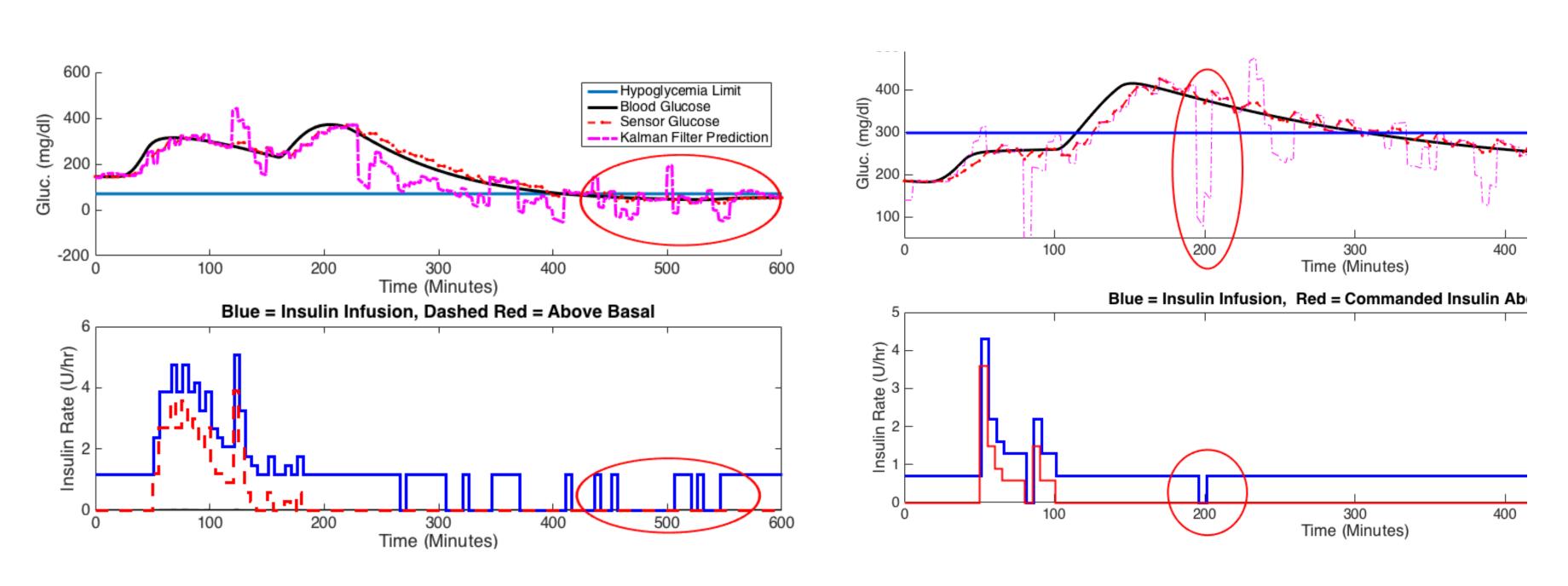
MODEL-BASED IN-SILICO VERIFICATION OF ARTIFICIAL PANCREAS CONTROL ALGORITHMS Sriram Sankaranarayanan, Faye Cameron, B. Wayne Bequette and David Maahs University of Colorado, Boulder, Rensselaer Polytechnic Institute and Stanford University Medical School



Case Studies

	1. PID-based hybrid closed loop contro
and	[3] for details).
n et	 Studied effect of PID gains on varie
	properties.
	2. Kalman filter-based predictive pump
<u>}</u>	Sankaranarayanan et al [1] for detail
L -	 Studied sensitivity to sensor errors
	3. Aiding examination of property viola
	sensitivity analysis of inputs.
osed	

analyzed in our verification setup.



Violations discovered by our analysis for Predictive Pump Shutoff System: (Left) insulin delivery resumption under hypoglycemia, and (Right) pump suspension under hyperglycemia.

oller (see *Cameron et al*

ous correctness

p shutoff algorithm (see ils).

5.

lations through

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