Learning and Verifying Conformant Data-Driven Models for Cyber-Physical Systems.

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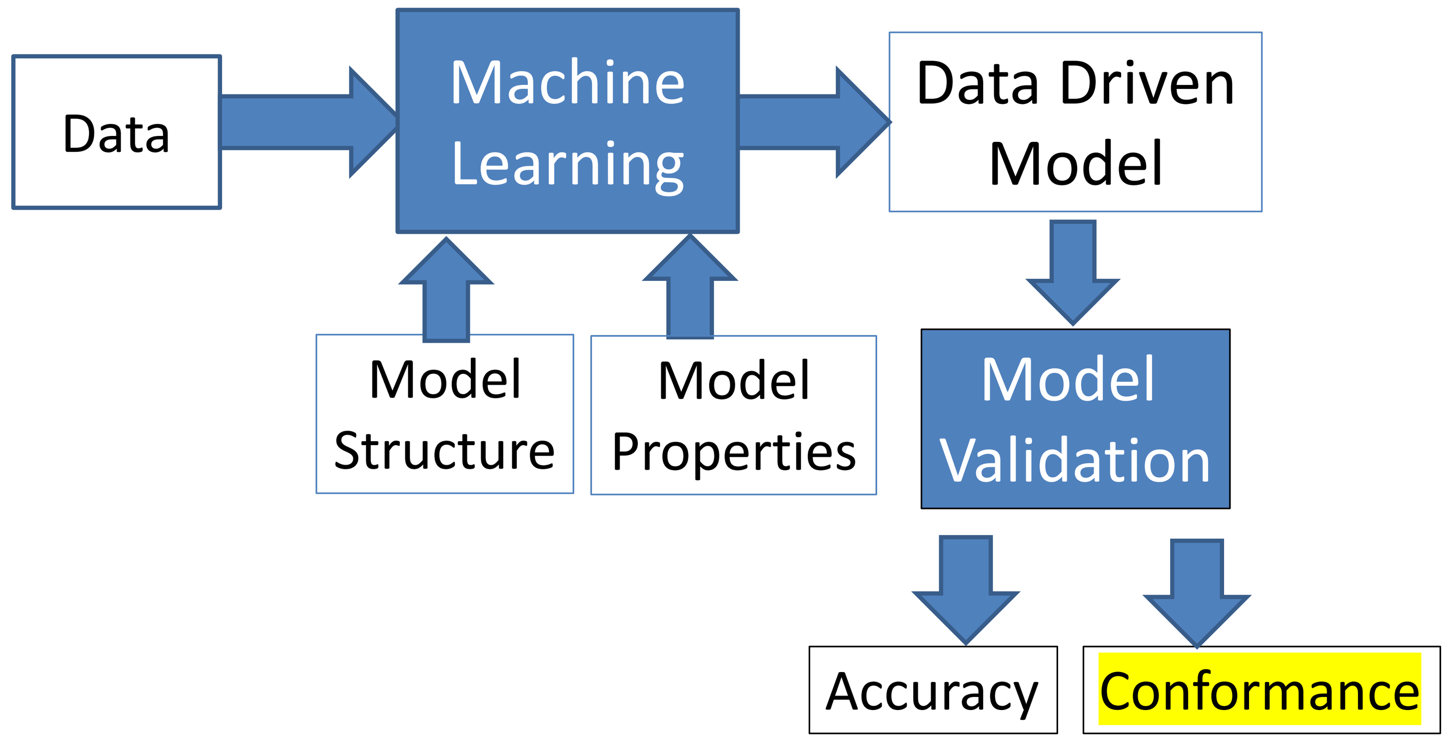
Abstract

This project investigates fundamental techniques for building mathematical models that can be safely used to make trustworthy predictions and control decisions. Mathematical models form the foundation for modern Cyber-Physical Systems (CPS). Examples include vehicle models that predict how a car will move when brakes are applied, or physiological models that predict how the blood glucose levels change in a patient with type-1 diabetes when insulin is administered. The success of machine learning tools has yielded data-driven models such as neural networks. However, depending on how data is collected, and the models are learned, it is possible to obtain models that violate fundamental physical, chemical, or physiological facts that can potentially threaten life and property. The approach of the project is to expose these model flaws through advanced analysis. The project seeks to broaden participation in computing through mentoring activities that will encourage undergraduate women and members of underrepresented minority groups to consider a career in research.



Conformance: Does the model satisfy scientific facts?

- Conservation of energy, mass, momentum, charge,..
- Interrelationships between input and outputs.
- Safety/Liveness properties satisfied by the model.

Examples (Vehicle Model):

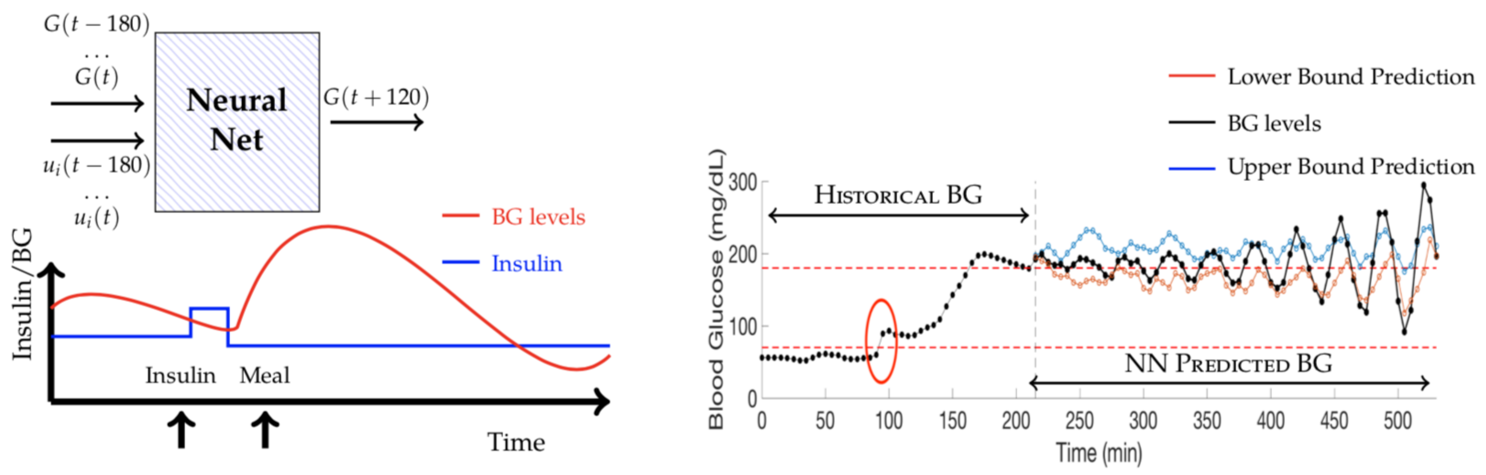
- Application of brakes must never cause speed to increase**.**
- If no throttle or brakes applied, speed must never increase on a flat driving surface.

Specifying and Verifying Conformance

- **Specifications:** Specifying model properties.
- **Falsification:** Finding counterexamples and their use in learning.
- **Verification:** Proving conformance of models.
- **Repair:** Modifying models to enforce properties.

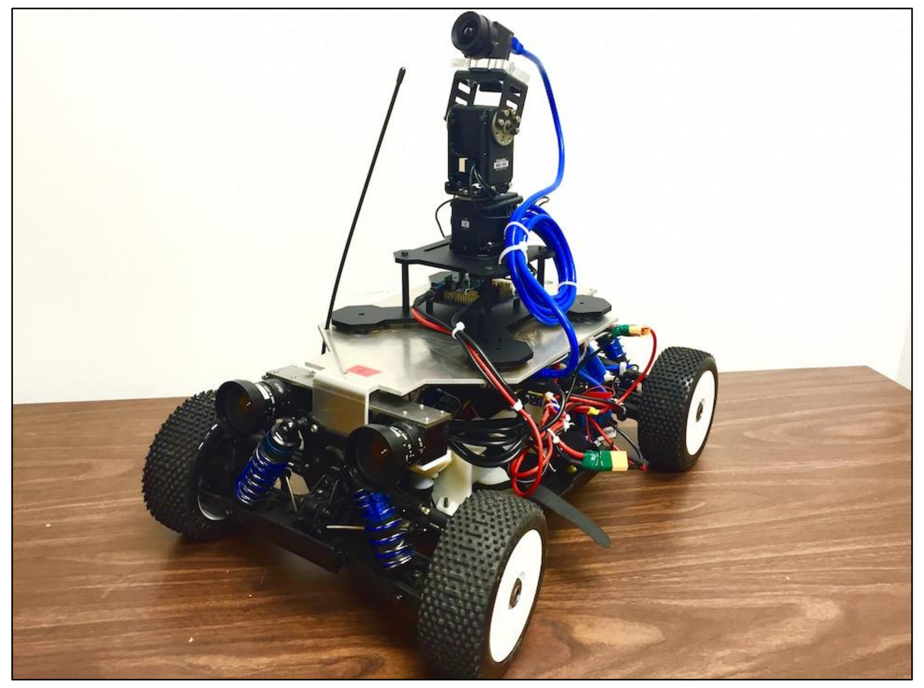
Learning with Conformance Guarantees

- **Transfer Learning:** Synthesis of piecewise affine models from data.
- **Counterexample-driven learning:** Using falsification counterexamples.
- **Reinforcement learning conformant models.**



Failure of conformance in Insulin Glucose Regulation Neural Network Model

Parkour Car Testbed

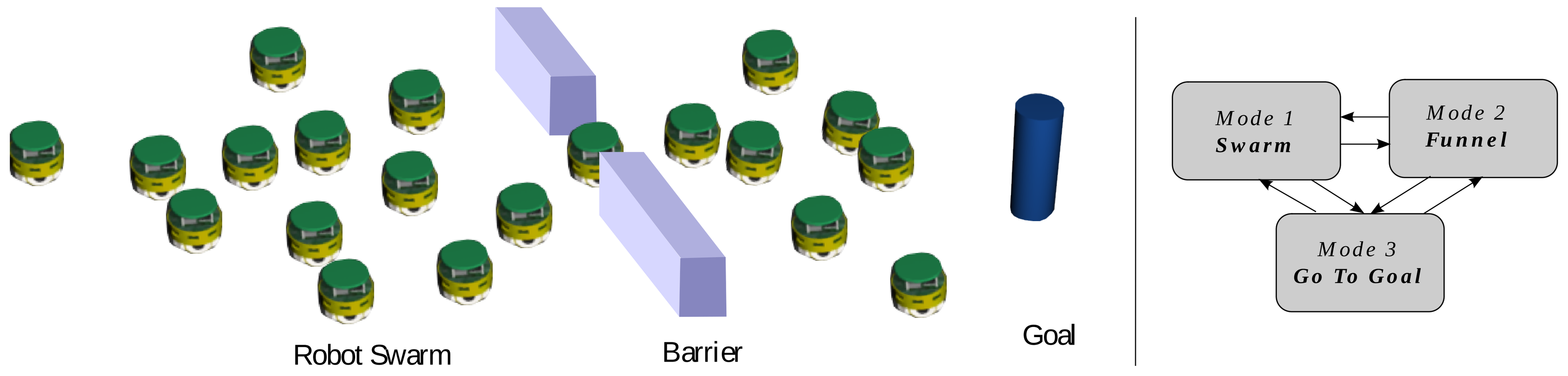


Goal: Construct data driven neural network models from driving data. Verify and synthesize model for key conformance properties under various driving conditions.

Artificial Pancreas Testbed

Goal: Construct conformant data driven neural network models for insulin glucose regulation,

Swarm Robotics Testbed



Goal: Construct data driven decentralized swarm models that exhibit the same qualitative behaviors as natural swarms.

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