Machine Learning For Natural Sciences, Spring ‘23

Final Project Proposal

Physics-Informed Neural Networks for Parameter Estimation of a meal glucose-insulin model from therapy historical data

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Problem Statement

The problem is to estimate the parameters of a glucose-insulin model for type 1 diabetes mellitus (T1DM) patients based on therapy historical data. The glucose-insulin model is a mathematical model that describes the relationship between blood glucose concentration and insulin concentration in the body after a meal. The parameter estimation is necessary to individualize treatment plans and improve glycemic control in T1DM patients. The therapy historical data includes blood glucose measurements, insulin doses, and meal intake records for a given time period. The goal is to develop a more accurate and personalized glucose-insulin model using Physics Informed Neural Networks for each T1DM patient based on their therapy historical data, which can be used to optimize insulin dosing and improve glycemic control in the future.

Recent Literature on the problem selected

[1] Sánchez OD, Ruiz-Velázquez E, Alanís AY, Quiroz G, Torres-Treviño L. **Parameter estimation of a meal glucose-insulin model for TIDM patients from therapy historical data.** IET Syst Biol. 2019 Feb

[2] D. Boiroux, Z. Mahmoudi and J. B. Jørgensen, **Parameter Estimation in Type 1 Diabetes Models for Model-Based Control Applications**, 2019 American Control Conference (ACC)

[3] Yazdani A, Lu L, Raissi M, Karniadakis GE (2020) **Systems biology informed deep learning for inferring parameters and hidden dynamics**. PLOS Computational Biology 16 (11)

[4] Anderson SM et al. **Multinational Home Use of Closed-Loop Control Is Safe and Effective.** Diabetes Care. 2016 Jul

Baseline model

In the study referenced in [1], the authors have attempted a parameter estimation task given timeseries data of Blood Glucose levels along with carbohydrate meal intake quantity and automatically administered insulin levels data from a CGM (Continuous Glucose Monitor). The *Dalla Man* model of the glucose-insulin system has been chosen as the mechanistic model whose parameters are fit using an evolutionary algorithm, **Evonorm**, and a **Particle Swarm Optimization** technique. The performance of these algorithms are compared against each other across temporal data from two different patients. This data however is protected and inaccessible, so we aim to replicate the study on a different dataset procured from the study referenced in [4]. In addition to the evolutionary and PSO algorithms, the study referenced in [2] uses a **Maximum Likelihood Estimator** (albeit on a different model with synthetic data), which can also be incorporated into our study as a baseline.

Proposed improvements over baseline

We intend to use a **Physics-Informed Neural Network** (as referenced in [3]) for estimating the parameters of the glucose-insulin model. The PINN architecture takes in the time, temporal insulin infusion data and temporal carbohydrate content infusion data as input and outputs the temporal blood glucose level data, while estimating the parameters of the glucose-insulin model during training. We would also like to explore various network architectures to estimate the parameters such as

- **LSTM:** Long Short Term Memory networks have memory that can be selectively updated, allowing them to learn long-term dependencies in the data.
- **CNN:** Convolutional Neural Networks are a type of neural network can also be used for time-series data analysis. CNNs consist of multiple layers that use convolutional filters to extract features from the input data. These features can then be used to estimate the parameters of the glucose-insulin model.