Data-Driven Models For Industrial Process Control

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Question

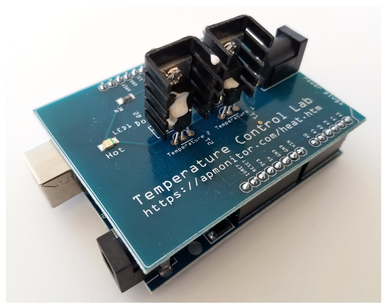
Can we find good models of the dynamic behaviour of an industrial process from limited measurements?

Motivation

- We rarely have good theoretical models of industrial processes
- Identifying system dynamics is difficult due to lack of measurement data, noise, unobservable disturbances, and non-linearities.
- If we can find good models we can optimize the process in real time (model predictive control).

Experiment

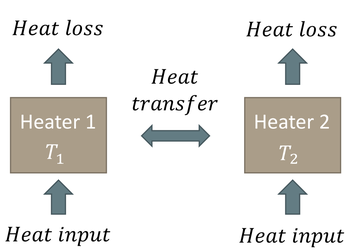
- The Temperature Control Lab is an Arduino module for testing feedback control with two heaters and two temperature sensors.



Temperature Control Lab
(Brigham Young University, https://apmonitor.com/heat.htm)

First-Principles Models

- Traditionally, process models are developed from engineering first-principles and fundamental laws of physics.



$$heat\ accumulated = heat\ inputs - heat\ losses$$

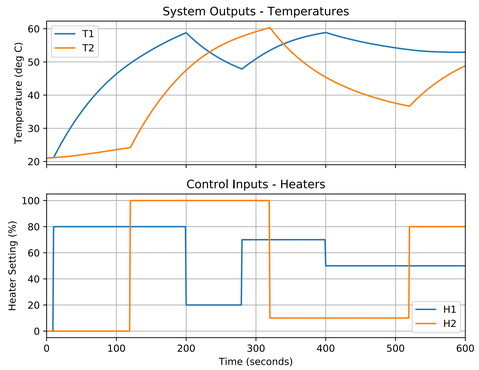
Energy Balance Model

Temperature Prediction

- Simplest case:

$$\frac{dT_1}{dt} = f_1(H_1, H_2, T_1, T_2)$$

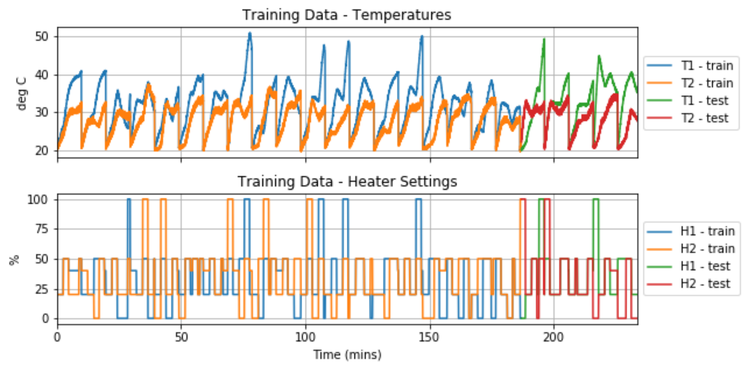
$$\frac{dT_2}{dt} = f_2(H_1, H_2, T_1, T_2)$$



Temperature Predictions with First-Principles Model

Data Collection

- We generated four hours of temperature measurements from the heater system using design-of-experiments methodology



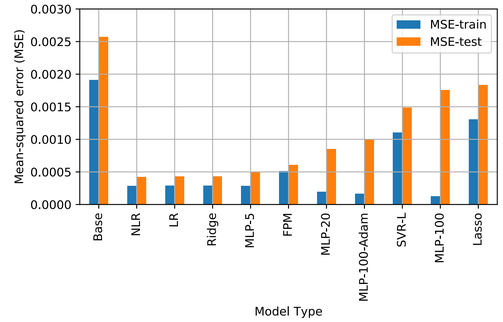
Measurement Data

Function Approximators

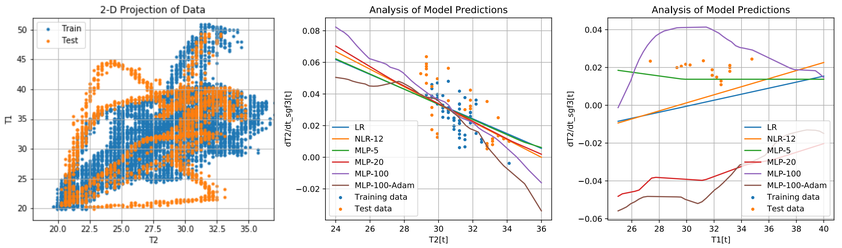
Key	Model Type
Base	Baseline model (dT/dt = 0)
LR	Linear regression
Ridge	Ridge regression
Lasso	Lasso regression
FPM	First-principles model
NLR	Non-linear regression (sparse)
SVR	Support vector regression
MLP	Neural network

Results

- We tested the models by calculating the mean-squared error (MSE) of the predictions compared to the training and test data



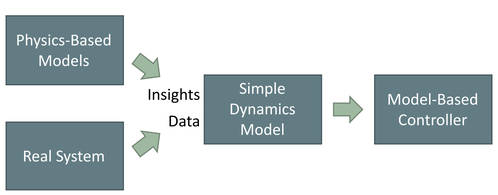
Error Analysis



Discussion

- Model-free optimization techniques can potentially 'learn' complex system dynamics from observed data.
- However, model-based methods are more robust, easier to interpret, and do not require large amounts of training data.
- With model-based methods and a data-driven approach we can improve on the performance of an experienced human operator.

Data-Driven Model-Based Control



Data-Driven Approach to Model-Based Control