I/UCRC November 30, 2023 Update

Machine Learning for MEMS Sensor Validation

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Date: November 30, 2023

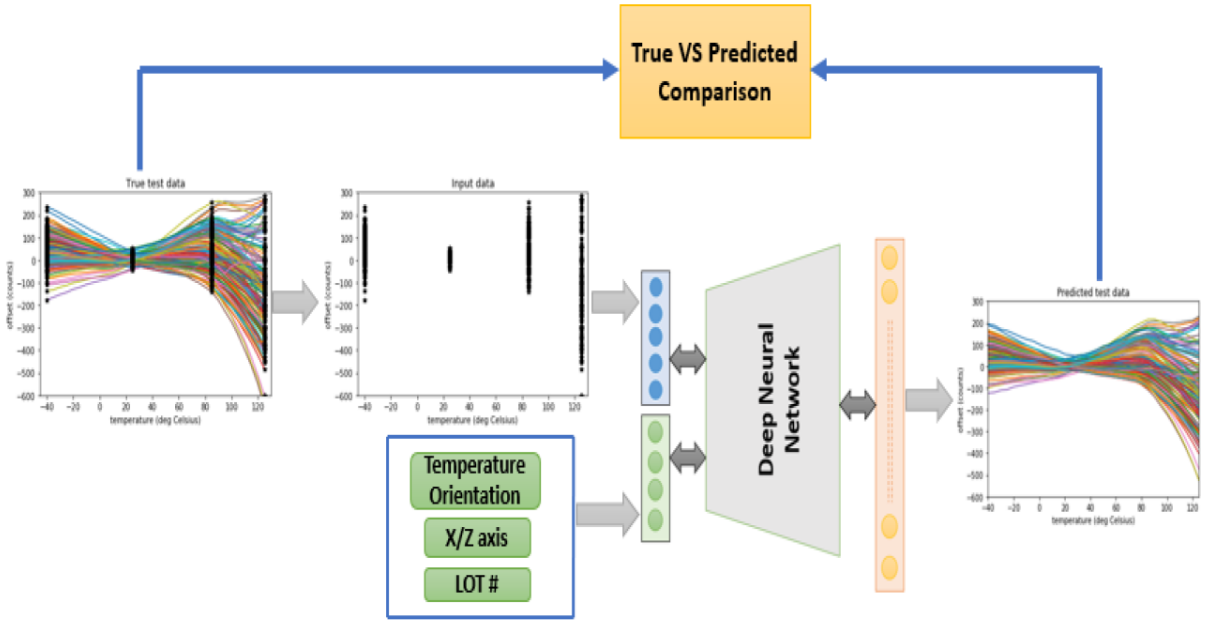
Project Overview

Motivation:

- Requirement of a smart, resource efficient sensor calibration system
- Characterizing sensor behavior/reliability as a function of temperature
- Reducing insertion/data measurements at significantly low temperatures
- Uncertainty quantification of the sensor measurement/prediction

Broad Research Question: How to effectively leverage tools from statistical machine and deep learning for sensor calibration/validation ?

Gyro / Accelerometer MEMS Sensor



Tasks, Goals, Milestones and Benefits

Tasks:

Task#	Task Description
1■	Data collection from NXPs tester on MEMS Gyro readings across different temperature. Feature selection and validation
2■	Develop a DNN/ML tools to predict/quantify uncertainty the sensor measurements for un-observed temperature, given the collected data.
3■	Develop tools for Anomaly detection across different lots
4■	Develop JMP, MATLAB/Python software packages

Project Milestones:

Task #	Planned Completion	Milestone (Deliverable)
1■	2/13	Feature identification and selection of the target temperature to predict, to optimally reduce resource consumption
2■	3/27	Trained a Gaussian Process model and Heteroscedastic DNN for prediction and uncertainty quantification
3■	5/8	Comparison of the ML models
4■	9/15	Optimize the models and explore other methods such as belief networks, drop out methods in DNN for uncertainty quantification.
5■	12/4	Implementation of ML models in C/C++ and documentation of the results

Research Goals:

1. Develop an end-to-end, data collection, modelling, DNN prediction and uncertainty quantification pipeline via JMP, MATLAB/Python interface.
2. Identify key features from the MEMS data and use ML to identify the optimal features to be collected.
3. Use ML algorithms to minimize resource consumption. Reducing a temperature sampling by one saves 20% of resources.
4. Clear documentation of research, lessons learned and recommended approaches

Benefits to Industry Partners:

1. Smart and resource efficient validation and testing system
2. Deep learning toolbox for predictive modelling compatible with Periodic system training to handle distribution shifts.
3. Active learning techniques and their implementation on an actual application.

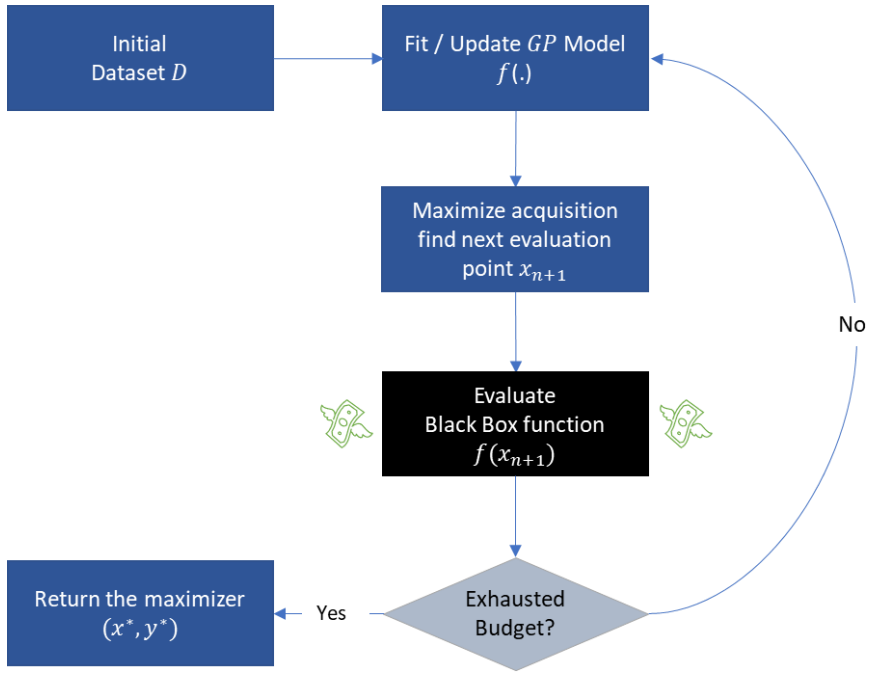
[2] ■ Milestone complete or is on track for planned completion date
■ Milestone has changed from original sponsor-approved date (Why?)

Progress to Date and Accomplishments

Task#/Description	Status	Progress and Accomplishments
1. Initial data collection	■	- Data collection from NXPs tester (feature selection) - Real data collection is completed and performed monthly
2. Feature Engineering (Key temperature for MEMS Sensor)	■	- Conducted experiments with MEMS Gyro sensors. - Used Gyro readings at different temperatures.
3. Develop Bayesian and deep learning algorithms for regression and uncertainty measurements	■	- Developed predictive Modelling for gyro measurement prediction. - DNN takes in 2 temperatures as input and predicts the measurement for the unseen temperatures. - Gaussian process models can both predict and provide uncertainty over the measurements - Can also help detect anomalies in the measured data
4. Comparison between various models to measure uncertainty	■	- Implement Heteroscedastic DNN system via Python pipeline integration. - Implement dropout strategy - Fixed the uncertainty quantification model to GPR
5. Documentation of research and development	■	- Implementation of model in C++ - A well written document with procedures and protocols followed in building the DNN system is underway.

■Significant Finding/Accomplishment ■Task Complete ■Task Partially Complete ■Task Not Started

Project Pictorial



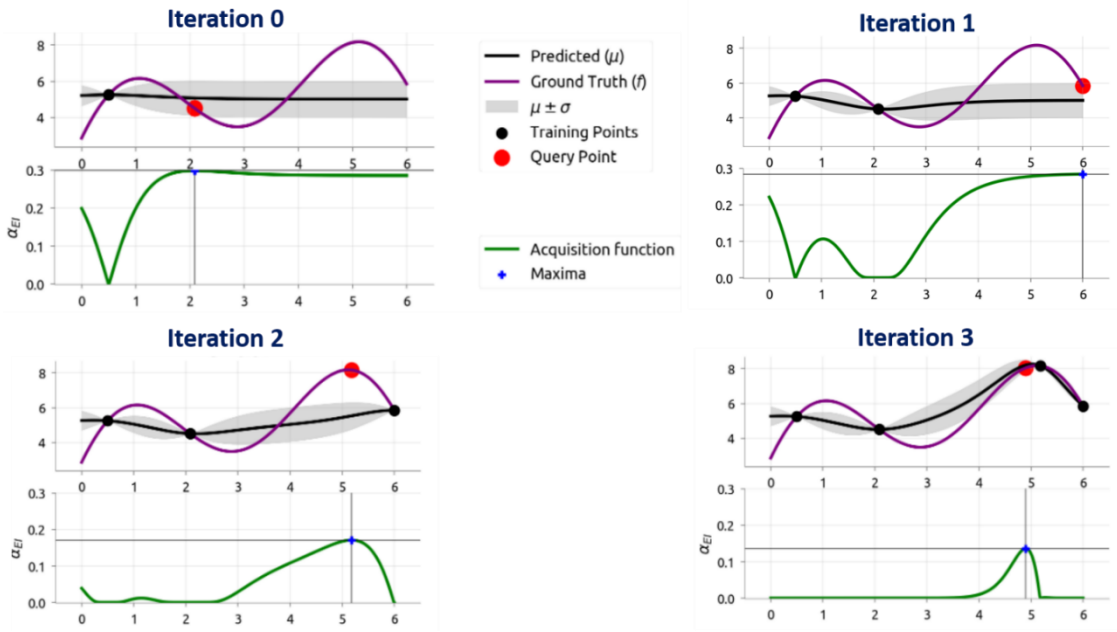
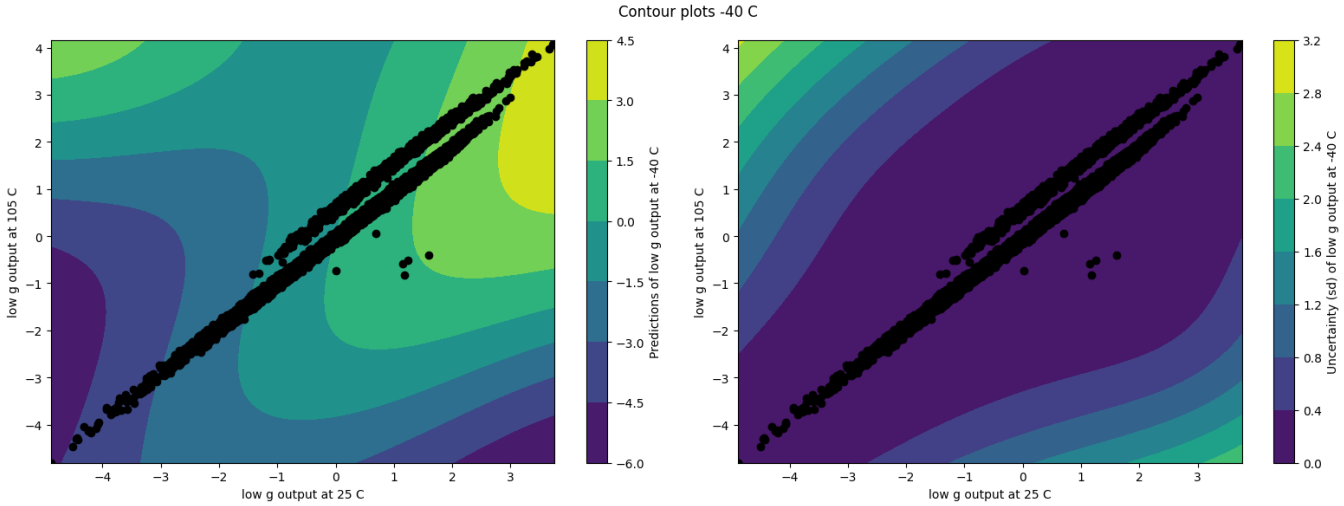
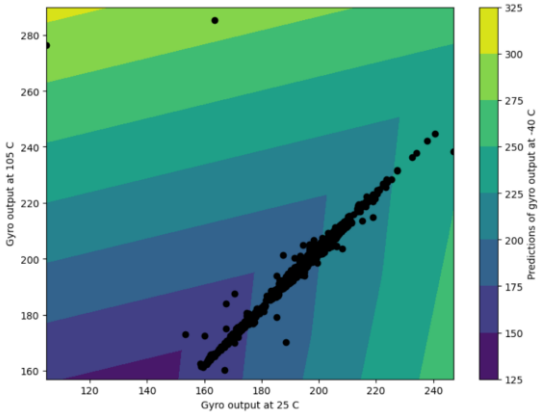
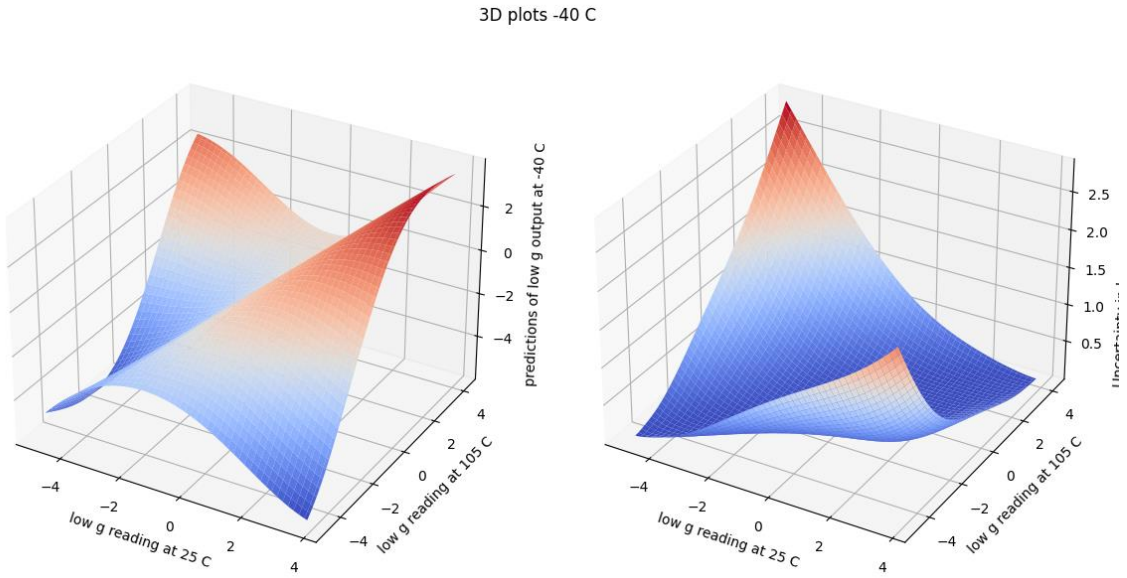


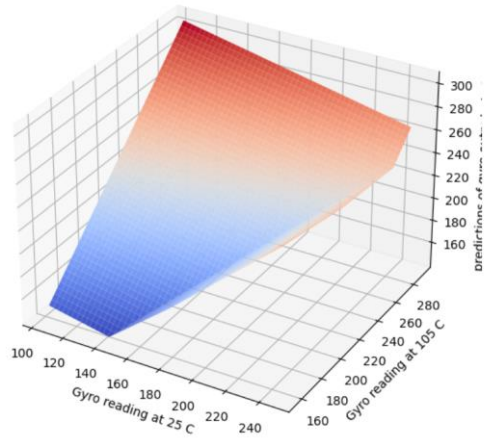
Image credit: https://distill.pub/2020/bayesian-optimization/

Preliminary Results









Efforts to Seek Additional Sponsorships and Collaborations

- NXP Semiconductors
- Possibly Intel
- Possibly Onsemi
- Possibly Microchip

Objective Evidence Supporting NCSS Value Proposition

Category	Objective Evidence
Papers, Publications, Presentations/Venue	-
Products (Software, Data, Designs, etc.)	1. DNN/ML model training codes in MATLAB/Python. 2. Experimental results shows great promise that could lead to a significant reduction in total resource consumption
Student Placements	1. Mohit Malu, graduate research associate position.