Self-Diagnosing Machines

Fault Detection and Classification for Galvanometer-based Scanning Systems

ELECOMP Capstone Design Project 2021-2022

Cambridge Technology is continuing support of the Program for the 3rd year:
https://web.uri.edu/elecomp-capstone/project-details-by-team/2019-2020/cambridge-technology/

Sponsoring Company:

Cambridge Technology
One Corporate Place
125 Middlesex Tpk, Bedford MA 01730
https://cambridgetechnology.com

Company Overview:

Cambridge Technology designs, develops, and manufactures leading-edge laser beam steering solutions including galvanometer and polygon optical scanning components, 2-axis and 3-axis scan heads, scanning subsystems, high power scanning heads, and controlling hardware and software. Our company partners with OEM customers to deliver scanning solutions that support advanced industrial processes, electronics, and laser-based medical applications.

As the inventor of galvanometer-based optical scanning technology, we make it our mission to drive innovations in photonics by delivering unprecedented technical capabilities through the critical lens of collaboration, quality, and customer service. We dedicate ourselves to excel at:

Collaboration with our partners to ensure our goals and pathways align

- Innovation to bring tomorrow's beam steering solutions to life today
- Engineering to perfect our products and our processes
- Delivery from the largest engineering solution to the smallest component

Technical Directors:

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Project Motivation:

Our galvanometer-based scanning systems are integral in very demanding applications such as Laser Additive Manufacturing, Via Hole Drilling, Laser Marking and Coding, and Medical Imaging. In these spaces, the system must be able to complete the job without failing. Imagine having to scrap an entire tray of 3D printed metal on hour 13 of a 14-hour job because the scanner failed! We want to use machine learning to analyze galvo health, classify failures, and predict useable lifetime

Anticipated Best Outcome:

Have a fully working (in C on hardware) Fault Detection and Classification algorithm! This is a big ask so there will be multiple meaningful milestones along the way which constitute great outcomes:

- Complete steps 1-3 in each domain – Detection and Classification.
- Complete steps 1-5 on the fault detection

Fault Detection:

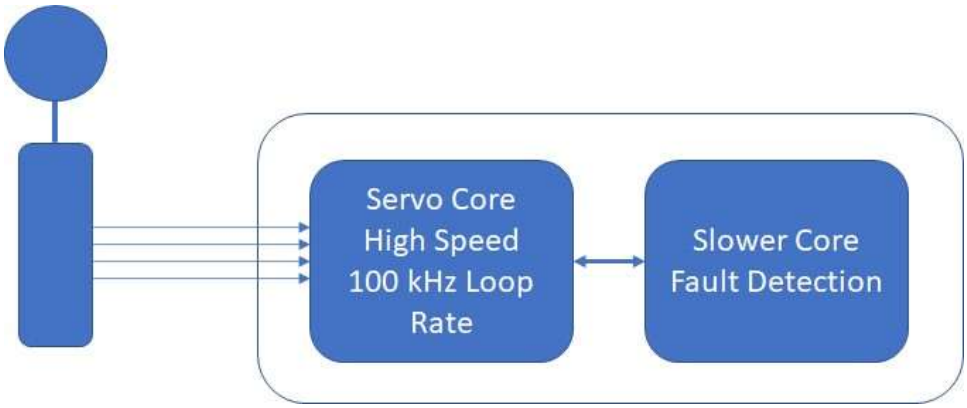
- Review current technology and algorithms and select 1-3 for initial prototyping
- Build a prototype in MATLAB/Simulink which can be used to test the algorithms
- Simulate faults and select the best detection algorithm
- Implement the algorithm(s) in C on hardware for real word testing
- Test by purposefully breaking a galvo and running the algorithm(s)

Classification:

- Review current technology and algorithms, select the best 1-3 for prototyping
- Using the previously built simulation platform generate a list of faults for the algorithm(s) to classify
- Review the results and select the best for implementing on the hardware
- Implement the algorithm(s) in C on hardware for real world testing
- Test by purposefully breaking galvos and running the algorithm

Project Details:

Overall system concept:



The Servo uses a dual core microprocessor to gather feedback from the galvo, process these into a state estimate, then uses that to calculate a control signal. This must happen every 10 us so there is not much time left for higher level functionality.

The slower core can be used to run higher level more abstract code, and this is where the fault detection will live. Ideally, this would also run at 100 kHz rate but that is not required, only a known rate.

The full classification can be run on a server at Cambridge while a rudimentary one can be run on the slower core itself.

Composition of Team:

1-2 Electrical Engineer & 1-2 Computer Engineer

Skills Required:

Electrical Engineering Skills Required:

- Linear System Analysis
- Classical Controls
- MATLAB/Simulink

Computer Engineering Skills Required:

- Machine Learning
- MATLAB/Simulink
- C programming

Skills to Be Learned:

- State Space Control Techniques
- Linear State Estimation
- Linear Model Generation from Input/Output Data
- Recursive Model Estimation from Input/Output Data
- Neural Networks
- TensorFlow

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

Having predictive failure analysis will position Cambridge Technology further ahead of our competition and lay the groundwork for future innovation. Increase yield by identifying good and bad galvos in the factory before we build them into scan-heads. Reduce rework time by determining failure modes of returned product for targeted repair. Improve quality and achieve more accurate lifetime and quality metrics.

The fault detection algorithms can determine if galvos have degraded through internal testing cycles, if returned product is defective, and how the galvo reacts under intense operating conditions

The classification algorithms can determine what the specific failure modes are, enabling targeted rework and faster service cycles. Additionally, the classification techniques can identify trends in tunes, and identify common features in given application spaces.