Digital Twin

Digital component replication and predictive maintenance

ELECOMP Capstone Design Project 2018-2019

Sponsoring Company:

General Dynamics Electric Boat
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Company Overview:

Electric Boat has a distinguished history, tracing its roots to February 7th, 1899, when the company was established to complete a vessel that would revolutionize naval warfare. Named Holland for its inventor, the visionary Irishman John Phillip Holland, this 54-foot vessel in 1900 became the first commissioned U.S. Navy submarine.

Since then, the Holland's successors have been employed to radically reshape naval warfare and maritime strategy, while contributing to the successful outcome of World War II and play an indispensable role in the country's Cold War victory.

Today, Electric Boat is the design yard and prime contractor for the Virginia-class submarine program. The Virginia class is the first major warship completely designed in a virtual environment, a capability pioneered by the people of Electric Boat. Employing many of the best practices used in the Virginia program, Electric Boat is currently engaged in the development of the Ohio Replacement, the third generation ballistic-missile submarine, which will provide strategic deterrence for the nation well into the remainder of this century. The Ohio Replacement Program represents the future of our company, as we develop new tools and processes to design submarines for the U.S. Navy. Key to our future success will be the new employees who come aboard and learn how to design, build and support nuclear submarines and their undersea systems.

Throughout its distinguished history, Electric Boat has been defined by its people, their skills and the legendary commitment they bring to their jobs. A tangible sense of pride runs through the entire workforce - shipyard trades, designers, engineers and the rest of the disciplines required to produce what is arguably the most complex product built by man.

Technical Director:

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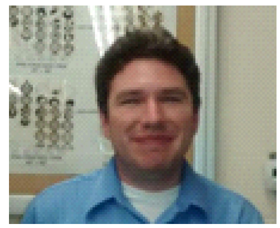

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Project Motivation:

A new mechanical component's long-term performance is not well understood. However, various sensors can be added to the mechanical component in order to monitor and assess its performance. The sensory data can be fed into a digital representation that can predict maintenance and optimize performance. The engineering challenge is to create an optimized sensor architecture on a mechanical component in order to create a Digital Twin of the component that can help predict future maintenance. The concept of "Digital Twin" is a fairly new term in industry that promises to drastically change the way industry maintains operational components.

Digital Twin Supplemental Information:

Digital Twin refers to a digital replica of physical assets (physical twin), processes and systems that can be used for various purposes. The digital representation provides both the elements and the dynamics of how an Internet of things device operates and lives throughout its life cycle.

Digital twins integrate artificial intelligence, machine learning and software analytics with data to create living digital simulation models that update and change as their physical counterparts change. A digital twin continuously learns and updates itself from multiple sources to represent its near real-time status, working condition or position. This learning system, learns from itself, using sensor data that conveys various aspects of its operating condition; from human experts, such as engineers with deep and relevant industry domain knowledge; from other similar machines; from other similar fleets of machines; and from the larger systems and environment in which it may be a part of. A digital twin also integrates historical data from past machine usage to factor into its digital model.

In various industrial sectors, twins are being used to optimize the operation and maintenance of physical assets, systems and manufacturing processes. They are a formative technology for the Industrial Internet of things, where physical objects can live and interact with other machines and people virtually.

References/Video Links:

https://en.wikipedia.org/wiki/Digital_twin
https://www.youtube.com/watch?v=gK5sHDfBMP4
https://www.youtube.com/watch?v=Ri0TD7kYsIQ
https://www.youtube.com/watch?v=2dCz3oL2rTw
https://www.slideshare.net/gbacchiega/embedded-digital-twin-76567196

Anticipated Best Outcome:

The anticipated best outcome is a functional prototype capable of monitoring the state of a component by using a combination of sensors and measuring tools. Using this data, the system will create a digital twin; capable of mirroring the state of the component digitally. Once completed, the team will produce a system capable of both mirroring the current state of the system, and predicting its future state. This information must be presented in a format acceptable to the operator.

Project Details:

Overall System Concept:

The “digital twin” system is a combination of a robust sensor architecture and a software platform capable of receiving and processing data. Therefore, the team will first decide on a mechanical device on which to build the surrounding “digital twin” system. Examples of devices include, but are not limited to: fan, compressor, pump, washing machine, etc. Based on the operating characteristics of the device, as well as the characteristics of its failure modes, the team will select sensors with which to form a sensor architecture.

The sensor architecture will be responsible for capturing all the data needed to replicate the device. Based on the type of mechanical device, these sensors and their importance with respect to others will vary.

Once a sensor architecture has been determined, the team will be responsible for designing the software system responsible for data reception and processing. The platform on which the team will build the software is at their own discretion - the platform should allow the best possible outcome of the project.

Once the component has been replicated successfully, the primary focus of the team will be predictive maintenance: determining future failure states based on current data and projections of that data. Team members will need to understand the core mechanics of the component, and the factors that lead to failure states.

The following will define the various phases of the project:

Phase I - Research and Planning:

The team, upon selection of a component, will produce a project plan composing the estimated timeline and task overview required to achieve the anticipated best outcome.

I. Mechanical device to be procured
II. Sensors to be procured
III. Software/Platform for development
IV. Estimated Project Costs
V. Preliminary Project Schedule

Phase II - Digital Replication:

The team shall develop a proof-of-concept system capable of replicating the device digitally. Additionally, the team shall consider the task of predictive maintenance and revise their project schedule to accommodate these future tasks.

I. Sensor architecture
II. Digital twin architecture
III. Test plans and data to be obtained
IV. Revisions to Project Cost and Schedule

Phase III - Predictive Maintenance

The Best Anticipated Outcome in April 2019 shall include the following

I. Test results
II. Upgraded digital twin model
III. Predicted maintenance periods based on sensor data for future operation of the device

Hardware/Electrical Tasks:

- Identify mechanical device to be procured
- Based on device characteristics, determine sensors to be procured
- Develop a sensor architecture including hardware, software, and networking solutions.
- Develop test plans and conduct preliminary test and data collect
- Refine the hardware design based on the testing results

Firmware/Software/Computer Tasks:

- Identify the software/platform to be used
- Develop necessary interfaces between sensors and primary system
- Replicate the current state of the component digitally; using inputs from a running device
- Refine the digital twin architecture and implementation based on testing results
- Develop software for predicting maintenance periods based on sensor data for future operation of the device

Composition of Team:

1 Electrical Engineer (ELE) & 1 Computer Engineer (CPE)

Preference will be given to electrical engineers who have experience in computer engineering tasks and/or have experience interfacing with sensors on a computer system.

US Citizenship Required.

Skills Required:

For both engineers, a strong background in mathematics will be absolutely necessary. Preference will be given to students with experience in data science and algorithms, as well as those with interest in advanced mathematics.

Electrical Engineering Skills Required:

- Sensor module integration
- Analog circuit theory
- Signal processing experience is a plus
- Experience with power electronics is a plus

Computer Engineering Skills Required:

- Experience with embedded systems and low-level programming
- Strong programming /software development skills in any language; knowledge of Python and C programming is desirable
- GUI Design
- Databases and Data Science
- Experience in simulation is a plus
- Experience with Machine Learning, Artificial Intelligence

Additional preference will be given to students who've completed or are enrolled in the following computer science courses:

- **CSC 440: Design and Analysis of Algorithms**
- **CSC 481: Artificial Intelligence**

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

Electric Boat is in the process of trying to figure out the best way to integrate Digital Twin into R&D and Concept studies. The sponsors of this project are looking for a minimal Digital Twin architecture that can yield the most value in terms of understanding future maintenance needs, performance issues, and operational limitations of certain pieces of equipment. If a minimal architecture is designed, this technology can be leveraged to a greater extent and bring new jobs for different sensor designs and software development to support Digital Twin's proliferation.

Broader Implications of the Best Outcome on the Company's Industry:

The broader implication is for the Navy to save dollars on maintenance and troubleshooting performance issues. These dollars saved can then be invested back into the R&D enterprise to fund new technologies to support the Digital Twin of the future