ELECOMP CAPSTONE
VIRTUAL SUMMIT
FRIDAY, MAY 8, 2020

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Digital Twin

Digital component replication and predictive maintenance

GENERAL DYNAMICS
Electric Boat

Team Members: Charles Humphries (CPE), Hennjer Alcantara (CPE), Amy Drake (ELE), Zachary Zezeus (ELE)

Technical Directors: Jefferson T. Wright, Denny Moore

Project Motivation

The idea behind the "Digital Twin" is to create a software representation of a physical component that will give insight into the physical component's reliability due to changing environmental factors. The information provided will be updated in real-time, showing the impact of changing environmental factors on predicted reliability to the user, as well as logging this data so that it can be used to establish a trendline of wear that will be used to determine lifespan. Armed with that information, engineers can use the digital twin to predict the reliability, and maintenance requirements of the physical component, ensuring that the physical component does not break down unexpectedly.

Key Accomplishments

Raspberry Pi Dependencies: For the project to properly function, the Raspberry Pi required proper installation of dependencies such as Python libraries, virtual environments, GUI dependencies and proper GPIO and database libraries to connect sensors and database necessities.

Water Pump Assembly: The "Water Pump Assembly" includes the pump, associated piping, and the water reservoir. The pump has been located at ground level for maximum effectiveness, and PVC piping was installed to connect the pump to the water reservoir. The PVC piping is installed to prevent water from draining out of the reservoir in the event of a pump failure, so that the system is passively safe. Shown in **Fig 4**.

Sensor Installation and Testing: The following sensors were installed on the water pump setup: DHT-11 Temperature and Humidity, 2 MPU Gy-512 Accelerometer Gyroscopic Modules with a built-in AD converter, GR-105 water flow sensor with a flow range of 5-150L/min, and a waterproof temperature sensor. The location of each sensor is shown in **Fig. 3**.

Data analysis: Proper installation of sensors led to testing data and realizing average operational datasets. Within the process of experimentation, the project can analyze data live, from data inserted previously into the database, or from randomly generated data that simulates that of a operational water pump.

Database Created and IoT: Remotely accessible database created utilizing PostgreSQL and EleplantSQL. This utilizes the AWS service and data queries such as SELECT and INSERT can be created with the use of Python with proper library dependencies installed (psycopg2). This completes our software design backend shown in **Fig 1**.

Live Analysis Tool: Successfully created a Python code to detect sensor data and present operational temperature, humidity, and water flow rates to the user. The analysis tool also alerts the user if specific thresholds are reached that portray a failing, or soon-to-be failing water pump. This is mainly successful through manual data analysis and inserting manual data thresholds based on time increments of data readings.

Data Prediction: Through the use of Python libraries included within Jupyter Notebook, we were able to predict the outcome of some data values - namely our temperature. We were able to calculate the mean and standard deviation of the temperature readings from our DHT-11 temperature sensor, however we noticed a flaw within our data readings. Our data reflects the powering on and off of the Raspberry Pi - there are major fluctuations within data readings that clearly indicate when the Raspberry Pi has shut down. Calculations include all data, which causes inaccuracy within predictions.

Graphical User Interface(GUI): A GUI is provided so the user can view the current, historical and predicted status of the hardware. A good GUI makes the entire system more user friendly and allows detailed information (such both past and predicted trends) to be cleanly and accurately conveyed to the user so that it can be appreciated at a glance.

Fail Testing: In order to develop an accurate model of the pump's performance under a variety of circumstances and due to several variables, the pump needed to be tested as it proceeded to the point of failure. Data would then be gathered on the pump's performance and the conditions that drove it to fail, to develop an accurate model of the pump's durability under those conditions.

Documentation: The project is backed with an ample amount of data to easily view, duplicate, and follow for future project development in order to successfully achieve the ABO. Good technical documentation is vital to ensure that a project can be well understood by entire teams, repeated as necessary, and optimized and improved on over the course of its existence.

Anticipated Best Outcome

The ABO of this project is a digital twin prototype that can monitor the state of a given physical component and use the gathered information to mirror that component in software. This digital twin will be able to monitor and predict the state of the physical system based on the impact of various environmental factors and present that information to human operators. The system will present the information to the user in an easy to read graphical user interface (GUI), which will display current status, historical trends, and predicted reliability based on extrapolation of that information.

Project Outcome

The Anticipated Best Outcome was not yet achieved. We have acquired a large amount of data and tested it against our data prediction algorithm, but a new dataset may necessary for greater accuracy in data prediction.

Figures

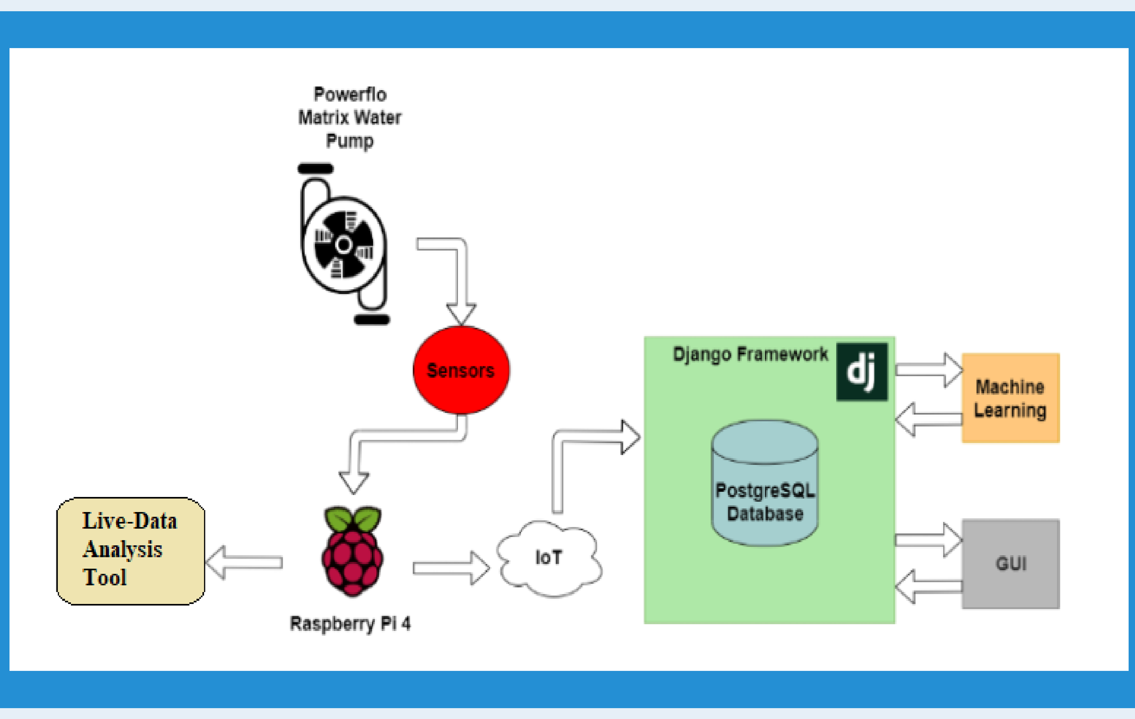

Fig 1: System Block Diagram

Fig 2: Water Pump Setup

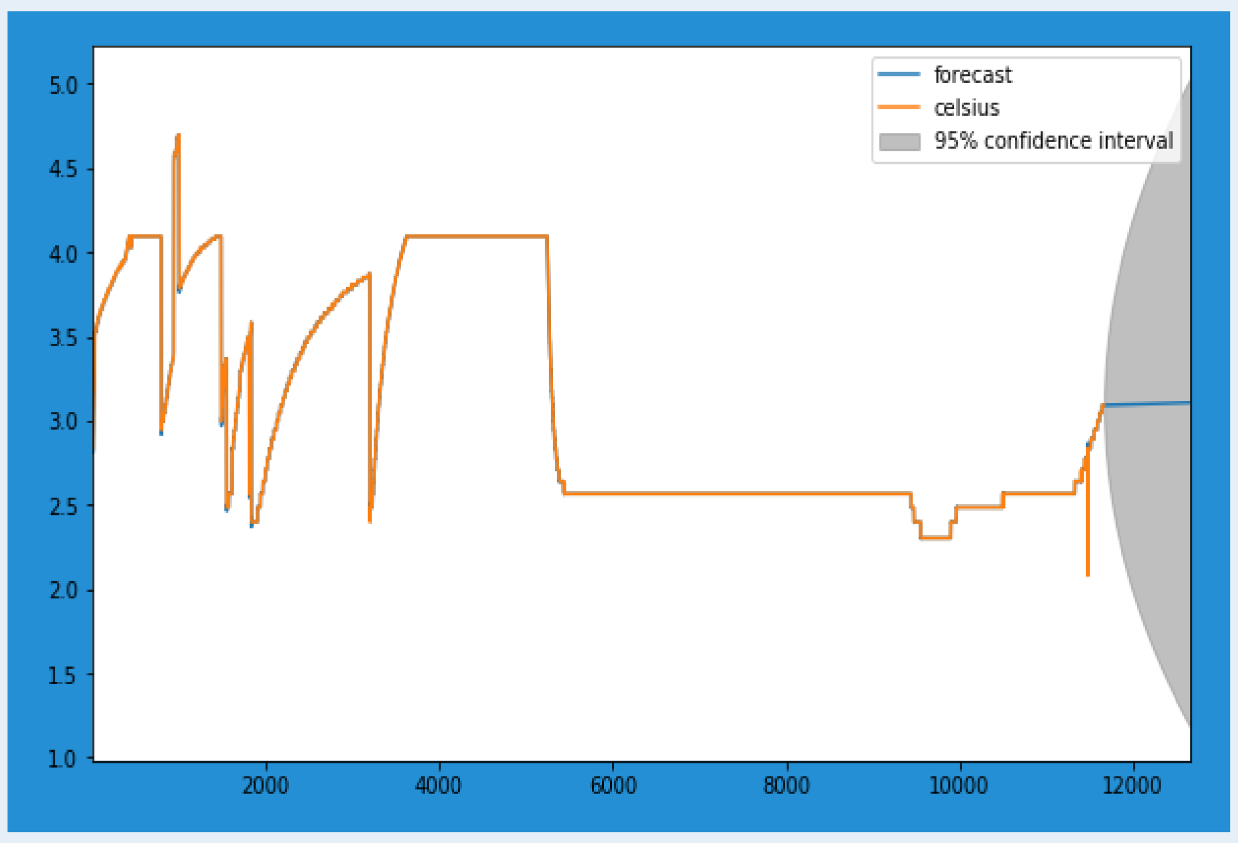

Fig 3: Data Prediction

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone