Digital Twin Testbed for NASA Space and Aeronautics Applications

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Background

This project focuses on creating a simple model of a Digital Twin for an electric motor. It will be used to educate others on what a Digital Twin is.

A Digital Twin is a digital representation of a physical system. Using various sensors on the physical system, data can be collected and then sent to the Digital Twin. This is so that the Digital Twin can "copy" the data and be used to run various simulations. The data from the simulations can then be applied to the physical system. The Digital Twin is designed to have a two-way flow of information so that it is constantly adapting and changing based on the data it gets from the sensors.

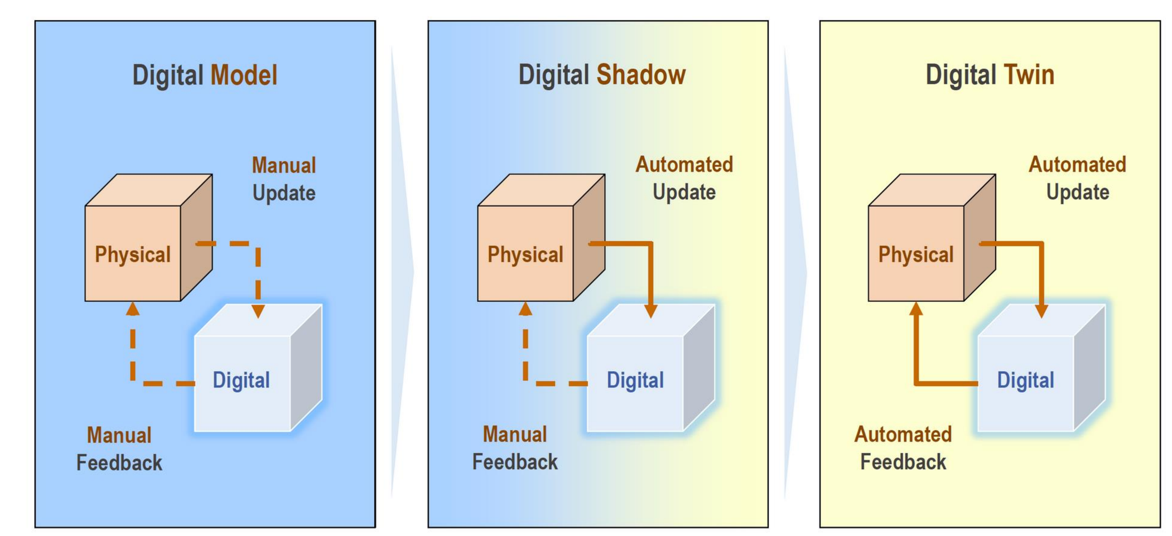

Figure A: Difference between Digital Twin and Models/Shadows

Why Does NASA Care?

Digital Twins originated from NASA during the Apollo mission. After the Apollo 13's oxygen tank explosion that caused damage to the main engine, NASA created a "living model" of the vehicle. This was to predict any possible failure to prevent any future harm. Digital Twins are now needed for physical systems that are too large in scale to be tested physically, hence the Digital Twin.

Other rising uses:

- Jet engine health management
- Self tuning Digital Twin technology

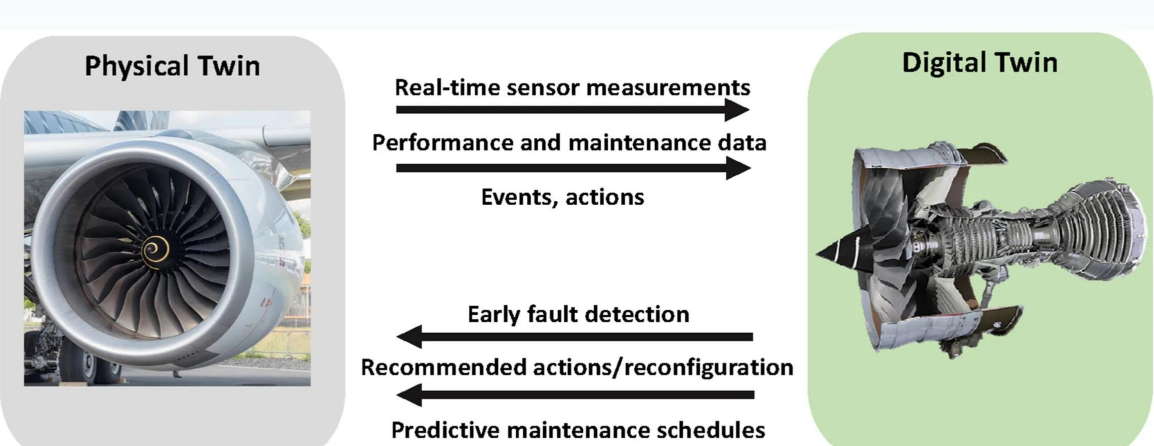

Figure B: Example of Engine Application

Methods

System Characterization

$$R = \frac{V}{I}$$

Where:
R = Motor Winding Resistance
I = Motor Winding Current
V = Voltage
Under stall conditions.

$$K_v = \frac{V - IR}{\omega}$$

Where:
Kv= Motor Voltage Coefficient
ω = Motor Shaft Speed

Mechanical Hardware

Physical System Parts:

- Motor to be characterized
- Arduino Mega
- Digital Temperature Sensor
- Accelerometer
- Sound Sensor
- Current Sensor
- Brake Motor

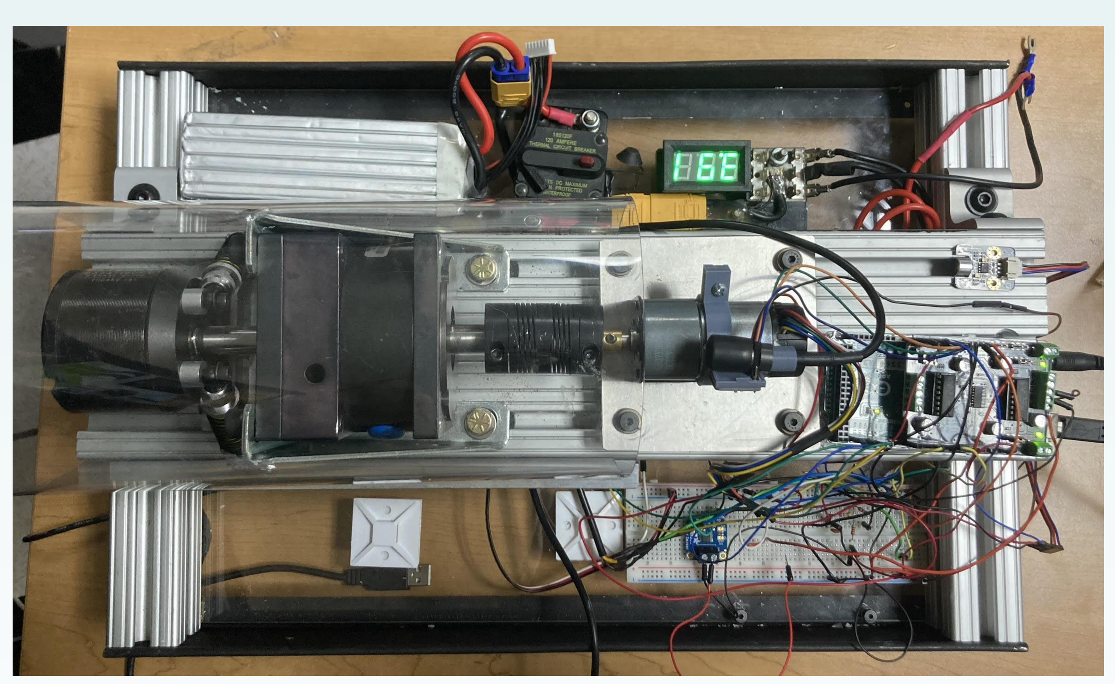

Figure C: Mechanical System

Software Programs

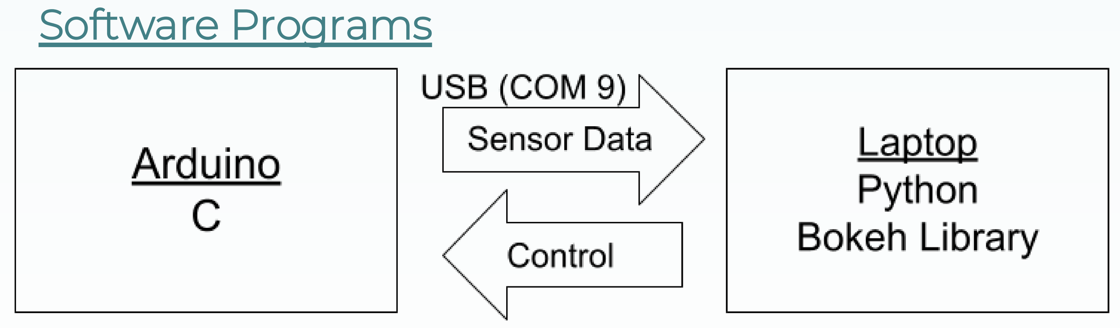

Figure D: Software Diagram

1. The Arduino Code reads the raw values by calling functions
2. The data is then sent to the laptop where python and bokeh creates a plot of calculated engineering values that can be analyzed
3. Signal processing used to clean noisy data

Results

Resistance chart:

Current (A)	Voltage (V)
1.1 A	2.7 V
.86 A	2.5 V
.74 A	2.1 V
.62 A	1.8 V
.55 A	1.4 V

R= 2.29

Figure E: Experimental Data Values from Stall Condition

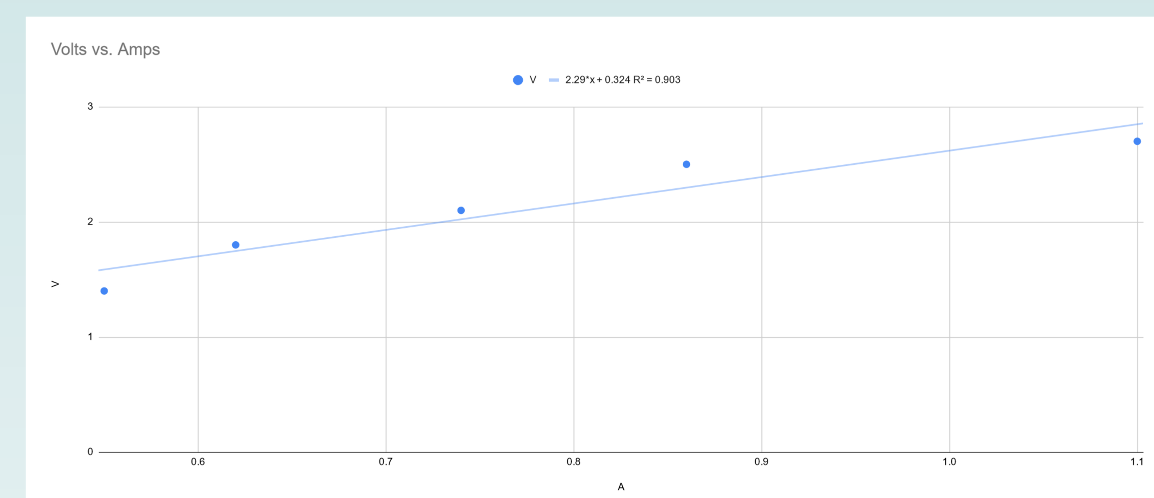

Figure F: Graph of V vs. A in Stall Conditions

Kv Chart:

180 rpm = 18.850 rad/s	6.85 V	.205 A	.3395 Kv
160 rpm = 16.755 rad/s	6.45 V	.195 A	.3594 Kv
138 rpm = 14.451 rad/s	5.45 V	.185 A	.3480 Kv
99 rpm = 10.367 rad/s	3.75 V	.146 A	.3307 Kv
55 rpm = 5.750 rad/s	2.2 V	.120 A	.3367 Kv

Avg Kv = .34286

Figure G: Experimental Data from Unloaded Conditions

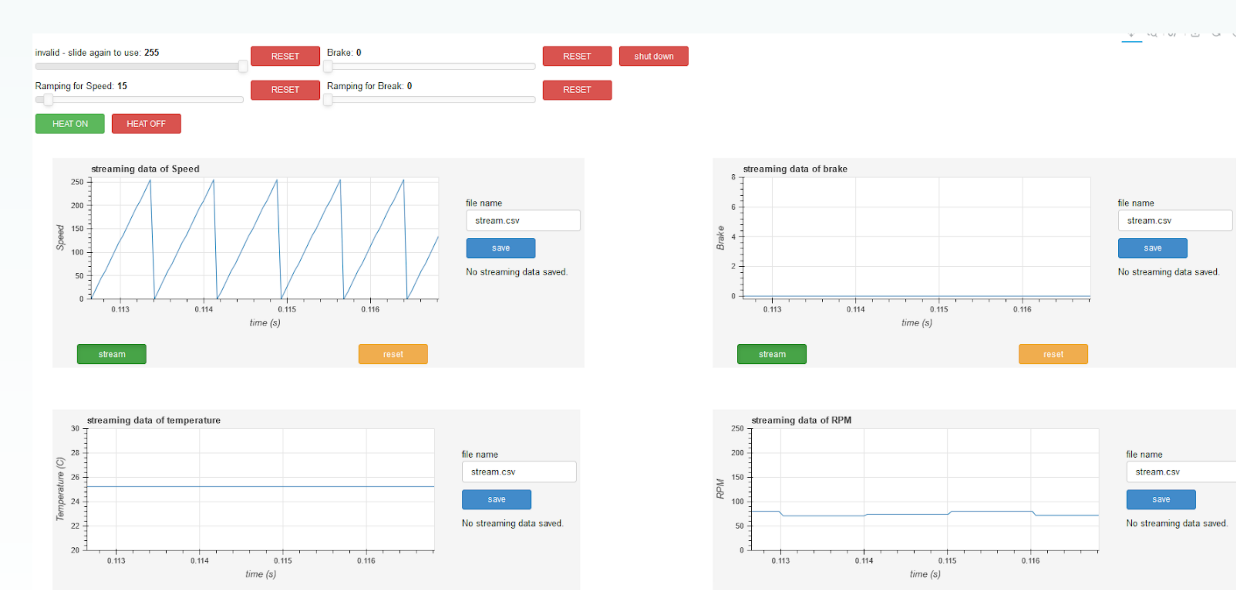

Figure H: Digital Twin User Interface When Set to Ramping Mode; Speed, Brake, Temperature, RPM

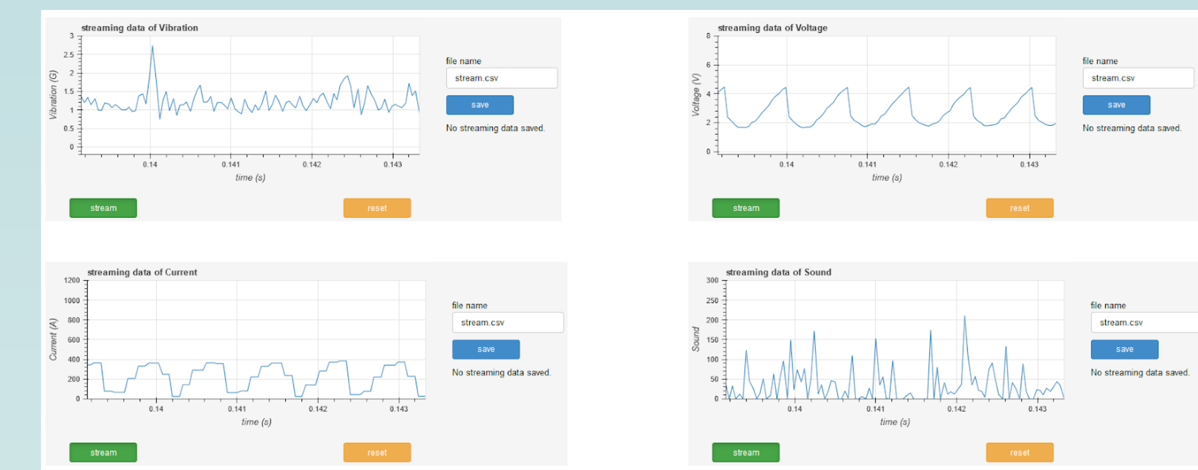

Figure I: User Interface Continued; Vibration, Voltage, Current, Sound

Challenges Overcome

- Finding a reliable load system
- Integrating brake motor and VESCUART Library
- Adding sound sensor
- Clean noisy data
- Communicating with motor to control from laptop
- Created user interface that receives data and can send data to motor (speed, heat)

Future

- Getting all data in real units
- Create individual Digital Twins for motors of the same model
- Complete system characterization
- Integrate automated feedback system using digital twin technology
- Create indicator for dangerous motor temperature
- Reach wider audience with a polished demonstration

References

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