Smart Trainer Homologation for Virtual Cycling – Operating Software Optimizations

Sports Integrity, Fairness and Societal Integration • Cycling, Smart-Trainer, Power

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ABSTRACT

As the Smart-Trainer Homologation initiative gains traction within the virtual cycling competitive scene, it is important to have strict validation of the hardware and software used to conduct testing. Typically, sensors and hardware have certification included in the documentation from the manufacturer and only need minimum validation and recalibration once in place. Operating software has less stringent standards, if they exist at all. Due to the customized nature of the smart trainer homologation operating program, it is important for us as the developers to conduct our own validation and testing procedure to ensure program performance is consistent across all operating conditions. These optimizations focused on communication with the system's encoder and torque brake, as well as how the program records, stores and displays data in the user interface. Each component required isolation from the system to test individual performance, then additional testing to validate system integration. These exercises resulted in validating the accuracy of sensors within the system and decreasing the computational requirements for data processing.

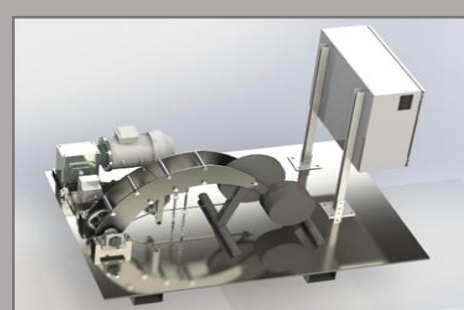

Fig. 1 - Homologation Apparatus with Trainer

PROJECT OVERVIEW

The smart trainer homologation project was started by RESEC in 2020 in collaboration with the Union Cycliste Internationale (UCI) to better regulate the emerging virtual cycling competitive discipline. In virtual cycling, athletes attach their bicycle to electronic units (trainers) capable of generating resistance to simulate the feel of outdoor riding and measuring rider's power output. The data is sent to an avatar in a virtual environment, where software calculates simulated speed based on the received power output and virtual conditions such as simulated gradient, wind and rider weight. With the onset of the COVID-19 pandemic, higher level cycling events became virtual, and discrepancies between the hardware that reports cyclist power became apparent. The homologation project seeks to establish accuracy standards and evaluate units from different manufacturers to ensure participants are not advantaged or disadvantaged by their equipment choice. As with any measurement device, it is crucial to be able to validate the accuracy of the device before it can be trusted to measure data and make informed conclusions. Complex systems such as the homologation apparatus require validation and optimization at both the component and system level, presenting the design team with a unique challenge of creating tests to validate performance at each level. This project details the motivation, methods and results of several optimizations performed during the fall 2022 semester.

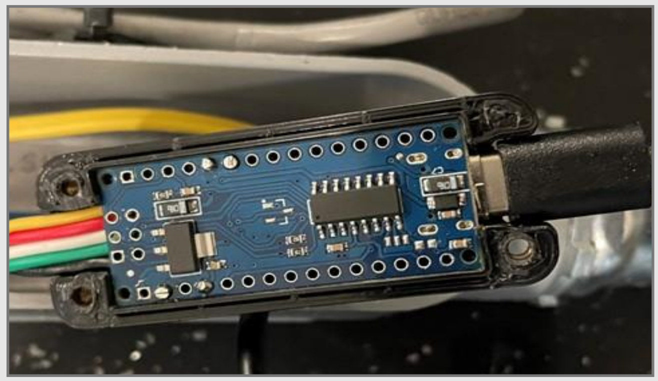

Fig. 2 – Updated Arduino-based Encoder Serial Converter Module

PROJECT METHOD AND RESULTS

In the summer of 2022, the homologation team performed an operating program restructure to better utilize the object-oriented features of the python programming language. One of the most useful results of this exercise was better visibility to the internal performance of individual components within the system, and better ways of tracking system level performance such as the computational time of the functions used to record, process and store data from the sensors. With this new visibility, we discovered errors in the data being sent from the encoder sensor and the control data being sent to the torque brake.

The system computer communicates with the hardware via a USB interface utilizing a series of virtual COM ports. Each component has a conversion module to reformat its data to be interpreted by the operating program. We

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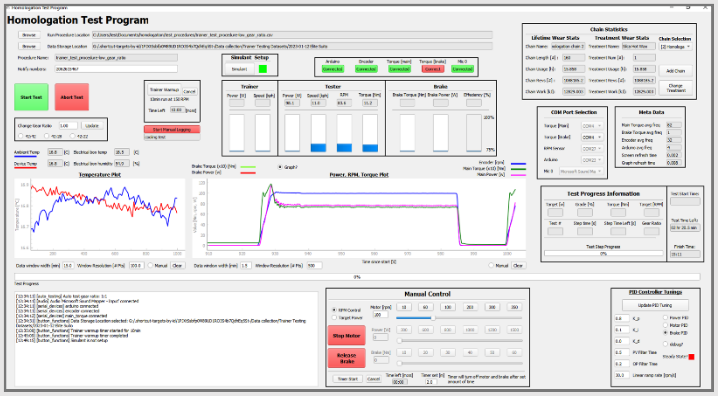

Fig. 3 – Updates to User Interface Showing Performance Diagnostics

PROJECT METHODS AND RESULTS CONT.

discovered roughly 5% of the readings from the OEM encoder sensor converter were being converted and received improperly, decreasing the quality of data and introducing new possibilities for unexpected errors. Rather than trying to create checks for every potential error, we decided to design and integrate our own conversion module using an Arduino nano. This allowed us to customize the format and frequency of the data to better suit our application. We performed extensive validation of the new module to verify the quality and accuracy of the data and were able to achieve a 100% transmission success rate with the new architecture.

On a similar thread, we noticed unexpected control behavior of the system's torque brake, which is used to quantify drivetrain frictional losses between the drive motor and the trainer. Upon isolation, we noticed the control behavior of the brake differed from the manufacturer's specification, especially when requesting torque resistance on the extremities of the operating range. Recharacterizing the control behavior allows the

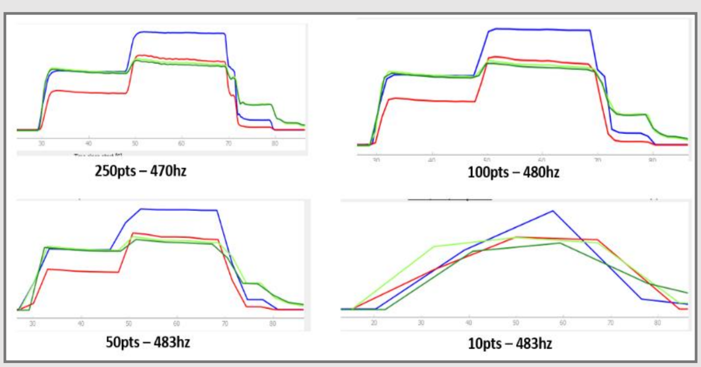

Fig. 4 Display Graph Resolutions (# of pts) and Torque Sensor Data Rate

PROJECT METHODS AND RESULTS CONT.

entire operating range and allows the program to better accommodate the upper and lower limits of operation.

The third optimization target of this semester involved how the program handles the data generated during testing. One of the strengths of the homologation testing apparatus is the high-resolution data it can produce. A single 2-hour test generates upwards of 2 million data points that are used to draw conclusions about trainer measurement accuracy. Full resolution data is written to files for later analysis, but down- sampled data is displayed in real time on the GUI to diagnose potential issues and assist with feature development. With our new visibility to program operation, we discovered our methods for handling real-time data had been decreasing the performance of the operating program by noticeably increasing screen refresh time and decreasing sensor communication frequencies. Utilizing built-in graphical functions and custom down-sampling methods, we tested how varying the resolution of graphical display data affected the program performance metrics listed above and determined optimal resolutions for general operation and created the capability to increase display resolution only if more detailed data is required.

CONCLUSIONS AND FUTURE WORK

- Isolating and validating component performance is essential to improving the reliability and robustness of any complex system
- Future controlled gage studies may be useful to validate reliability and reproducibility at the system level

RELATED PUBLICATIONS

Heflin, D., Miller, J., Dowd, T., Rodgers, M., & Mansson, J.A. (2022). Homologation and certification approach for smart bike trainers. *Proceedings of 14th ISEA Engineering of Sport Conference 2022.* https://doi.org/ 10.5703/1288284317531

Dowd, T., Miller, J., Heflin, D., Sweldens, W., Krasilnikau, A. & Mansson, J.A. (2022). Smart trainer homologation system. P*roceedings of 14th ISEA Engineering of Sport Conference 2022.* https://doi.org/ 10.5703/1288284317531

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ABOUT RESEC

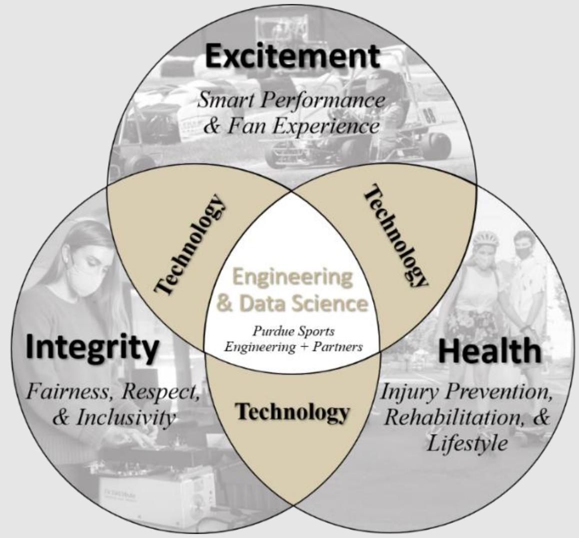
The Ray Ewry Sports Engineering Center (RESEC) was launched as a joint collaboration between Purdue College of Engineering and Purdue Intercollegiate Athletics, highlighting Purdue's reputation as the Cradle of Quarterbacks and Astronauts.

Sports have the power to unite, to teach, to challenge, and to initiate change, and those are our goals for RESEC. We are driven by our passion for sport and a deep understanding of the influence it has in shaping society. As technology continues to advance, there is enormous room for opportunity to rethink how athletes train, coaches coach, fans engage, and event organizers plan events. We collaborate closely with partners in athletics, industry, academia, and more to create the solutions that will help bring sports into the future, specifically in the three key research areas highlighted below.

Smart Performance & Fan Experience

Injury Reduction & Rehabilitation

Sports Integrity, Fairness, & Societal Integration



WHAT IS SPORTS ENGINEERING?

Sports engineering is a global, fast-paced, and multidisciplinary industry that brings people from different backgrounds, cultures, and experiences together. It is an industry that is heavily influenced by advances in other sectors as well as societal pressures and shifts, making working as a sports engineer very exciting. However, it also means being keenly aware of how these innovations and discoveries can be integrated and applied, especially as digitalization expands and what people – the athletes, fans, coaches, governing bodies – expect from sport evolves.

Engineering and data science are at the center of excitement, health and safety, and the integrity of sport, and by bringing a data-driven, human-centered approach to this industry, we can address the growing need and desire to increase participation and engagement of athletes and fans.

WHO IS RAY EWRY?

A Boilermaker track and field athlete, Ewry (1873-1937) won eight gold medals in three Olympic Games from 1900 to 1908. But his story is relatively unknown: at the age of five he became an orphan, and at seven he contracted polio and was confined to a wheelchair. Doctors had little hope he would be able to walk. Later nicknamed "The Human Frog," Ewry won gold in the standing long and high jumps and standing triple jump. By the end of the 1908 Games, Ewry had set a medal count record that lasted more than 100 years.

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