Team 5 - Ride Replay Kit

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***Abstract* – The purpose of this proposal is to introduce Team 5's idea for the Fall 2023/Spring 2024 Capstone Project. The document begins with an overview of the identified problems, followed by a clear formulation of the issues at hand. Moreover, it dives into the necessary specifications, background context, and constraints relevant to the project's scope. The proposal further outlines potential solutions and highlights criteria for assessing success, as well as potential obstacles. Additionally, a consideration of the broader ethical and societal impacts. Lastly, Team 5 provides an overview of the resources available and needed to complete the project, a timeline of due dates, and expectations of the project.**

***Keywords* - Ride Replay Kit, exercise bike, mountain bike, variable resistance, visual and audio interpretation, feedback, work, Capstone Design, exercise, sensors, engineering, resistance, trail**

I. Introduction

From biking The Great Mountain Divide to Cane Creek Park, imagine if you were able to transport yourself to these exotic destinations without having to leave the comfort of your home. Team 5 aims to allow users with limited time and or resources to experience these trails for themselves.

The Mario Kart Exercise Bike along with the Ride Replay Kit were designed by our predecessors to combine video games and exercise, as well as, give users the ability to go out onto a bike trail, film the course, and replay the course on the exercise bike. However, the kit has still not been tested successfully in the field.

The current problem Team 5 is encountering is that there is no way with the current system to accurately recreate the trail. The solution Team 5 has come up with is to completely implement the Ride Replay Kit with the following additions: the ability to replay trials recorded in the real world with accurate work exerted by the user, virtual recreation of the difficulty of the trail with scalability, visuals of the trail that will scale with the user's pace, audio from the trail that will scale with the user's pace, and a closed loop feedback system for the resistance. Team 5 proposes to capture the data from an actual bike trail in Cookeville and implement this.

The generalized goal of Team 5 is to continue to enhance the riding experience of its users and make the Ride Replay Kit appealing to a larger user base. Exercise bikes are still proven to strengthen cardiovascular, muscular, and respiratory health [1]. Continuing to enhance the experience for users in addition to expanding the use cases variety of the device should in turn bring in more users previously not interested in this product. This will make the project appeal to a wider variety of users who would like to go to these destinations but do not have the funds or the resources to do so.

This proposal entails Team 5's plan to implement the enhancements to the project listed above. Team 5 will further explain the background of the project alongside the objectives, specifications and constraints,and standards adhered to by Team 5. This is followed by Team 5's measures of success, unknowns and obstacles to be faced, and broader considerations. Lastly, Team 5 will showcase the components and budget, the skills of Team 5, a timeline, and any outside references needed for this document.

II. Formulating the Problem

A. Background

The first iteration of this project set out to integrate physical exercise in tandem with playing Mario Kart, this was in order to promote health and fitness to a new demographic. The overarching goal was to be able to interact and play through Mario Kart tracks on a Nintendo switch utilizing an exercise

bike. This first iteration achieved its overarching goal but was improved upon by the second revision. The second iteration of the Mario Kart Bike sought out to improve the dynamic resistance system, and to add the Ride Replay system. The second iteration added an actuator with two magnets and an aluminum flywheel attached to the back wheel of the bike to make the resistance system more variable and safer for the user. The team designed a kit from scratch to attach to a bike that can record data from an outdoor ride to recreate the corresponding ride on the exercise bike. Looking at the previous iteration of the bike, the resistance subsystem is an open loop system which makes the system more static. Team 5 intends to make the resistance system more variable and dynamic. Team 5 will seek to implement a work calculation subsystem to provide a more realistic resistance to the user, keeping the total work done on the exercise bike consistent with the trail. The ride replay system did work properly but was damaged during testing and needs to be repaired and officially implemented.

B. Objective

The objective of Team 5 is to accurately recreate the difficulty and ambiance of a bike trail on the exercise bike. Team 5 will achieve this objective by improving the Ride Replay Kit produced by Team 4. The improvements to be made to the Ride Replay Kit are to help enhance the immersion of the user, and to make the user's ride as close to the real trail as possible. The new Ride Replay Kit will have the ability to measure the work done by the user on the trail in order match this to the work done on the exercise bike. The resistance system currently on the exercise bike will be modified to be a closed-loop feedback system to respond to the user's pace on the trail. The audio and visual data will be recorded from the trail to give the user auditory and visual immersion into the trail. Finally, improvements to the user interface will allow the user to input weight, select from different difficulties and trails, see the work they have done, and inform the rider of the time spent on the exercise bike. These additions to the Ride Replay Kit should provide the user with a safe, enjoyable, and accurate experience of how the bike trail being replayed feels.

C. Specifications and Constraints

The Ride Replay Kit will include all the necessary hardware to measure and accurately recreate the trail to provide the user with an immersive experience. These are achieved by the work measurement system, closed-loop feedback resistance system, audio processing system, visual processing system, user interface.

1) Work System: The Ride Replay Kit will record the elevation, distance, and time to calculate the work done on the bike trail.

2) Resistance System: The resistance of the system (or the distance of the actuator) will adjust according to the rider's pace in order to maintain the correct work done on the trail.

3) User Interface: A user interface will allow the user to interact with the ride replay system in the following ways: input of the user's weight, selection of the trails, selection of the difficulty of the trails, display the work done by the user, and notify the user of the time they have spent on the bike to avoid overexertion.

4) Audio System: A microphone will record the audio from the trail in order to replay it for the user to enhance the immersive experience of the bike. The audio playback will not exceed 80 dB to prevent hearing loss or damage.

5) Visual System: A camera will record the video from the trail and replay it at a quality resolution with a consistent frame rate. The video is set at these specifications in order to not cause the user to experience motion sickness while riding the exercise bike.

6) Repairs to Previous System: The Ride Replay Kit was damaged in testing by the last capstone group and needs to be repaired in order to be used. The exercise bike handle bar gears also need to replace since the previous iteration has had issues with them.

D. Standards

1) Mechanics:

- 1926.300b.2 - OSHA Standard for Guarding from Rotating or Moving Parts of Equipment
- ASTM F1250-13 Standard Specification for Stationary Upright and Recumbent Exercise Bicycles and Upper Body Ergometers

2) Electronics:

- 1926.404b OSHA Standard for Wiring Design and Protection
- 1910.137 OSHA Standard for Electrical Protective Equipment
- IEC/IEEE 62209-1528:2020 human exposure to radio frequency fields from hand-held devices.
- Our device will comply with all applicable regulations set within Title 47 Part 15 of the Code of Federal Regulations.
  - 15.1 states that any radiator (that which emits radio energy), whether or not intentional, must be licensed.
  - Prohibits intentional damped wave transmissions such as spark-gap transmitters.

III. Solutions

A. Measures of Success

This section will provide a overview of the measures of success for each subsystem, and the means to test for validation. This is to provide a good grasp on the completeness of the project as a whole, as well as different steps to take around obstacles to ensure a complete project. Team 5 will test each subsystem in the following ways:

1) Work System: In order to validate the success of the Work system Team 5 will compare the work from the trail to the work done on the recreation of the trail on the exercise bike. To do this Team 5 will use the Apple Watch workout app to measure the work done on the trail and use the same app to remeasure the work on the exercise bike. This experiment will be repeated various times using the same trail but with different members of the team of varying weights. The work system will be declared as successful when the work done on the trail matches the work done on the exercise bike.

2) Resistance: In order to validate the success of the Resistance system Team 5 will compare the work from the optimal playback of the trail with different variations of force input from the user. To do this Team 5 will test the bike at varying levels of force making sure that the total work stays comparable to the actual work done over the trail. The resistance system will be declared as successful when the resistance on the exercise bike (or the distance of the actuator) matches the calculated resistance (or distance) to provide the correct work of the specific position on the trail.

3) User Interface: In order to validate the success of the user interface, Team 5 will record interactions between the user and the user interface. To do this Team 5 will use the Technique app to record the interaction at a high FPS in order to get an exact moment of contact and response. This experiment will be repeated with differing speeds and intensity of presses. The user interface will be declared as successful when the measured latency is within the acceptable range.

4) Visual System: In order to measure the success of the visual system Team 5 will compare the recording to the actual visuals on the trail. To do this the test rider recording the trail will have to verify that the surroundings seen on the trail match the video captured of the trail. This experiment will be repeated using multiple recordings of the same trail and comparing them with the physical trail. The visual system will be declared as successful when the desired visual play back matches the captured data from the trail.

5) Audio System: In order to validate the success of the audio system Team 5 will select high and low sounds from the recording and compare them to the outputs of the same sounds on the speaker. To do this Team 5 will compare the audio wavelength of specific sounds recorded to the output wavelengths of the same specific sounds through the speakers. This experiment will be repeated using varying wavelengths of sounds ensuring that the output wavelength matches the input. The audio system will be declared as successful when the audio wavelengths captured from the microphone matches the wavelengths from the speakers on the exercise bike.

B. Unknowns, Obstacles, and Safety Concerns

Team 5 may experience a number of obstacles. One of these may be the sensors on the Ride Replay Kit, these were implemented by the previous capstone group before the Ride Replay Kit was damaged which means they may need to be replaced. Team 5 will test Ride Replay Kit to ensure complete functionality before recording a trail to be replayed.

The current camera within the Ride Replay kit has a less-than-desirable frame rate for a smooth replay experience. When the user is replaying a bike trail, they could potentially slow down their pedaling, which would then slow down the frame rate of the playback video. When slowing down the frame rate a slow frame speed could cause the user to experience choppy visual playback, taking away from the immersion. Team 5 will seek to solve this issue using the testing procedure declared under the ”Measures of Success” section.

To avoid harming the user's hearing, the audio output should not be above 80 decibels to comply with the regulations set by OSHA standards [2]. We will ensure compliance by taking the maximum input from the microphone on the ride replay kit, and the maximum output from the speakers on the exercise bike, and calculating the maximum possible dB output. Careful testing will be done as mentioned in ”Measures of Success” to keep audio levels at a safe value.

Another potential obstacle Team 5 could experience is an unstable or shaky camera when recording trails. This would give an unusable recording for the exercise bike to replay. This can be mitigated by ensuring the camera is mounted firmly and shock absorption devices are correctly implemented.

C. Broader Considerations

- The Ride Replay Kit has minimal ethical concerns beyond reliability of the project and safety of the user. The main concern comes from overexertion of the user during a trail replay. To minimize this concern Team 5 implemented the notification to remind the user of the recommended amount time to spend exercising to prevent over exertion [3].
- The Ride Replay Kit would allow for access to a variety of trails. This would attract a new group of riders who, before seeing the trail replays, might not have been interested in using an exercise bike. This would also make a huge impact on existing mountain bikers by providing a new way to experience the trails without having to leave home.
- The Ride Replay Kit would impact environmental awareness of different locations and places where most people wouldn't normally visit. This could include historical landmarks, national parks, or well-known urban areas. This could also cause users to take greater interest in the environment and potentially bring attention to issues affecting these trails.
- The Ride Replay Kit promotes many positive impacts on mental health. Exercise is known to benefit mental health and general well-being. It reduces insulin resistance, inflammation, and stress hormones, leading to more healthy and strong brain cells [4].
- The Ride Replay Kit will provide accessibility to users who are unable to visit these bike trails due to varying reasons, such as those with solar urticaria, agoraphobia, or severe allergies.

IV. Resources and Requirements for Implementation

A. Budget and Components

TABLE I
THE BILL OF MATERIALS

Bill of Materials		
Material	Cost (USD)	Example
Force Sensor (4x)	$120	https://tinyurl.com/5n8f4cv2
Microphone	$40	https://tinyurl.com/2c6mxmum
Speakers	$40	https://tinyurl.com/5c2j39vm
Camera	$425	https://tinyurl.com/2967surp
Bluetooth Module (2x)	$30	https://tinyurl.com/2uyhm89x
Unforeseen Costs	$105	
Total Cost	$760	

In order to accurately measure work Team 5 requires force sensors that will be mounted on the pedals of the exercise bike to ensure work measured matches work calculated. The Bluetooth modules are needed to transmit the force data from the force sensors to the Arduino for work calculation. This also removes the need to hard-wire the force sensors to the pedals. To simulate audio from the recorded trails, Team 5 needs a microphone to capture the sounds of the environment. Speakers are required to replay these audio files from the recorded trails to create an immersive experience for the user. Team 5 also aims to create an immersive visual experience for the user and will therefore require a camera with a high refresh rate and resolution. A high resolution and refresh rate camera may be provided for recording bike trails, which could possibly save the budget $425. Team 5 added a 15 percent padding to the budget to account for any unforeseen cost and damages or malfunctions to components.

B. Team Members

The following list is meant to reflect the key proficiencies of each team member.

1) Ben Ebel:

- Embedded Systems
- C++/C♯/C
- Circuit Design/Analysis
- SQL
- Excel
- Microsoft Access Database
- Digital System Design

2) Caleb Rozenboom:

- Altium PCB Design and Circuit Schematic Creation
- Soldering
- Circuit Design/Testing/Analysis
- AutoCAD
- Electromagnetic Fields
- PLC installation and troubleshooting
- MS Excel
- LTSpice Simulation
- Project Management

3) Jayden Marcom:

- AutoCAD
- Print Reading
- C++
- Power Automate
- Simulink
- Excel
- Circuit Design
- Power Systems
- Arduino
- Solidworks
- Soldering

4) Jesse Brewster:

- PCB Design and Circuit Schematic Creation within Altium.
- Soldering and Micro-soldering
- AutoCAD
- MS Excel
- PLC design and programming
- Arduino
- 3D Modeling within SolidWorks/Inventor

5) Utsav Singha:

- Experience in AI coding and implementation
- High level competency with Microsoft Suite of Software
- Electromagnetic Fields
- Experience in Spice circuit simulation
- Soldering
- Project management
- Technical Writing
- Experience in MySQL
- Circuit Design/Testing/Analysis

C. Timeline

The timeline shown below represents an accurate chronological order for progress checkpoints throughout the project.

1) September:

- Project Proposal Due

2) October:

- Conceptual Design Due
- Project Proposal Revision due
- Detail Design Checkpoint 1
- Midterm Progress Presentation

3) November:

- Detail Design Checkpoint 2
- GitHub Customization and Update

4) December:

- Final Presentation

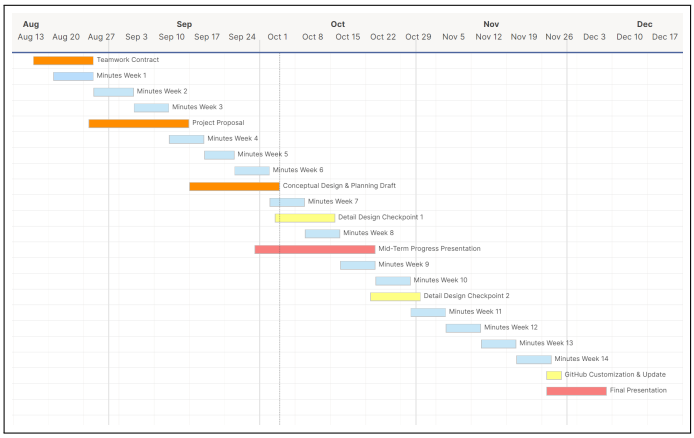

Fig. 1. Gantt chart timeline

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