Team 5 - Ride Replay Kit

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I. Introduction

Currently there are no commercially available devices that officially allow for personal recordings of bike trails to be uploaded or shared to other users. The Ride Replay Kit will provide users with an accurate recreation of a recorded bike trail and will have a work-map for each trail, which will be calculated within the Resistance System. The kit will also have audio and visual systems to recreate the sounds and video of the trail on the exercise bike. Additionally, an actively changing resistance will be implemented to accurately reflect the work done during a recorded trail. The last new addition to the kit will be a difficulty system that tailors trails to the experience level of the user. This will be part of making changes to the exercise bike user interface which will also include informing the user of time spent riding the bike. The project will also have to abide by industry regulations, ethical considerations, and broader impacts of the Ride Replay Kit.

A. Identified Problems

The Work System shall provide a unique work-map dependent on the trail. The work subsystem should be accurate to the visual experience and be consistent with the actual work done by the trail rider proportional to the weight of the user.

The Visual System shall provide users with a smooth visual experience. The visual experience should allow users to operate the bike without inducing headaches or nausea. The visual experience will also scale with the pace of the user. Team 5 set a constraint to record at minimum of 60 FPS.

The Audio System shall provide an appropriate output given the current state of the trail being ridden. The audio should create an immersive experience for the user that is synced with the video playback from the previous system. Audio playback will also scale alongside the video playback depending on the pace of the user. Team 5 set a constraint to limit speaker output to 80 dB in order to not cause hearing damage to the user [1]. Team 5 also established a constraint to match the audio wavelength input from the trail with the audio output wavelength from the trail. This constraint was set to ensure accurate audio feedback during a trail replay.

The Resistance System will change depending upon the effort put in by the user. This will change resistance of the bike to provide users with a way to complete a trail at desired pace while still doing the entirety of the work of that trail.

The User Interface of the exercise bike will ask the user to input weight, remind the user of recommended periods of exertion, and select a difficulty option. The weight input of the user will be used for the calculation of work done during the trail. The difficulty option within the user interface will change the overall work done during a replay of the trail. This will give the user the ability to experience the trail at an adequate difficulty level. To accomplish this Team 5 will implement multiple difficulties that adjust the values of the work map of the exercise bike to change the overall work done. The user interface shall remind the user of the recommended time spent on the bike after every trail. Team 5 is setting a constraint to limit maximum latency to 300 ms [2]. This constraint was chosen to meet acceptable latency levels for touchscreen tapping tasks.

II. Ethical, Professional, and Standard Considerations

As beneficial as exercise is to the body, it is only beneficial up to a certain point. Exercising too much can actually cause the opposite intended effect of exercise. Over-training can lead to negative health effects, including fatigue, depression, loss of motivation, hypertension, weight loss, and anorexia [3]. Taking this ethical consideration into account, this is the reason for the constraint of the acknowledgment button after every ride [4].

Exposure to high decibels for certain periods of time can cause irreparable hearing damage. Even exposure to relatively lower decibel ranges can be harmful if subjected to long enough periods of time. OSHA limits exposure to 85 dB at or below 8 hours. This constitutes the need for a dB limit for the audio subsystem. Team 5 has set this value to be at or below 80 dB to stay within known safety specifications [5]. This is intended in the event that the Ride Replay Kit is installed in commercial gyms, resulting in employees being exposed to the sounds for long periods of time.

There is currently an exposed flywheel and actuator on the Ride Replay Kit. OSHA requires guards protecting the user from rotating or moving parts of equipment, of which the bike has both [6]. Team 5 will encase the components in question to comply with this standard.

The goal of the Ride Replay Kit is to be immersive for the user, and to give an accurate simulation of the trails recorded. Since this is the goal it could cause a negative affect on tourism within the areas surrounding the bike trails. For instance a user who could have potentially gone to one of the locations to ride the trail may no longer do so due to ease of access of the trail on the Ride Replay kit. To combat this Team 5 will include pictures of the towns or areas nearby the trails after it has been completed to promote tourism. The user would have to interact with the menu to acknowledge that the advertisement has been seen.

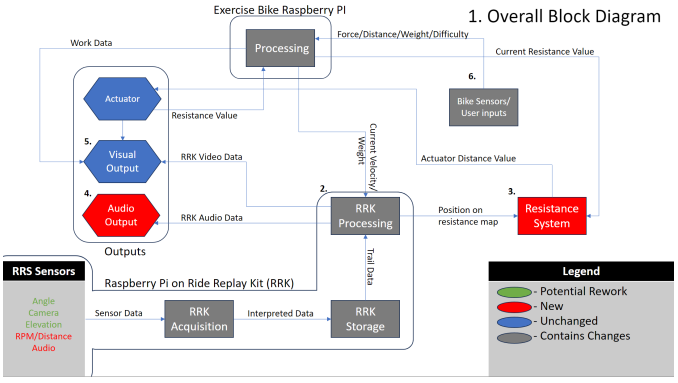

Fig. 1. Overall Block Diagram

III. SYSTEM DESIGN

The Ride Replay Kit is split into 5 subsystems, all interacting and influencing each other. These subsystems are work, resistance, user interface, visual, and audio. The Work subsystem calculates the work done by the rider recording the trail and then compares this data to the work done by the user replaying the trail. This data goes to the Resistance subsystem to make sure the work done on the trail remains the same even if the user were to exceed or fail to match the original pace of the rider. The user interface takes in data, displays information, and relays the user's data to the work calculations. Finally, the Audio and Visual subsystems provide the visual and audio components to make the ride experience as immersive as possible.

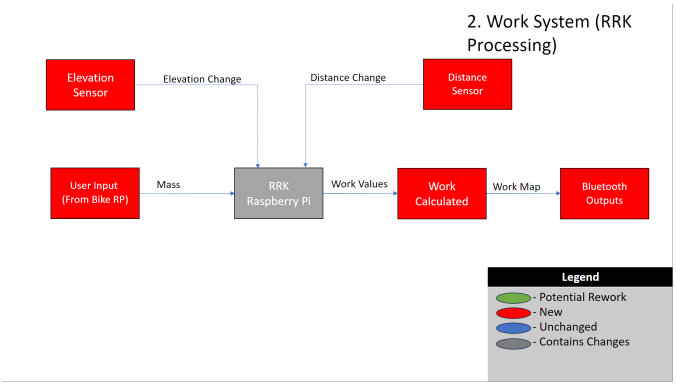

Fig. 2. Work System

A. *Subsystem 1: Work*

The work will be calculated on the trail by using the elevation and distance of the trail, along with the weight of the user provided from the user interface. This work data will provide the comparative value that the resistance subsystem uses to stay consistent with the ride. As the user rides through the virtual trail, the work done will be calculated and sent to a Raspberry Pi, which will then change the resistance to keep the work done and the work recorded equal. The work-map will be created from work calculated and sent to Bluetooth outputs.

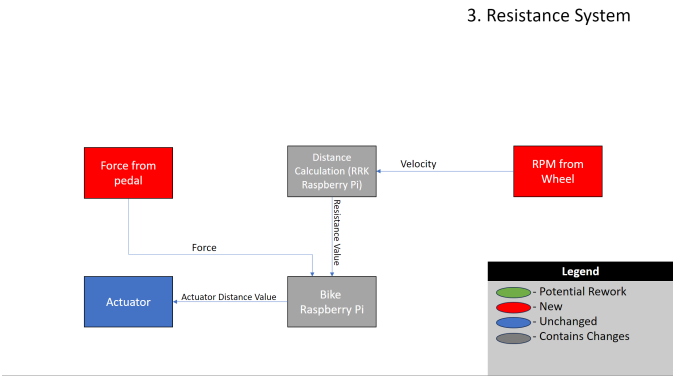

Fig. 3. Resistance System

B. *Subsystem 2: Resistance*

The resistance subsystem will be a closed-loop feedback system in tandem with the work calculations. The output of the resistance subsystem is the actuator which changes the resistance of the bike based on the distance between the two magnets on the actuator and the aluminum flywheel attached to the exercise bike. The actuator distance will be calculated in a Raspberry Pi based on force input on the bike and the current resistance. The velocity will be taken based on rotations per minute of the back tire on the exercise bike. The map will change position based on velocity and change the resistance value accordingly. There must also be a minimum

and maximum resistance value to maintain accurate total work done during the replay of a trail.

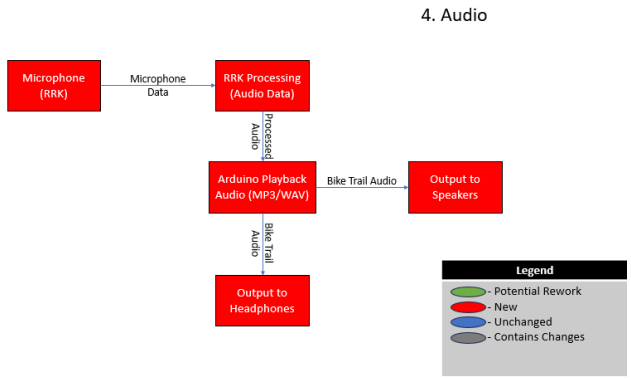

Fig. 4. Audio System

C. Subsystem 3: Audio

To add to the immersion of the bike, the audio subsystem must be integrated alongside the visual subsystem. The microphone on the Ride Replay Kit will record and stay in sync with the camera. The audio data will be processed by a Raspberry Pi and output to speakers on the exercise bike. The audio subsystem will also have to be interpolated based on the speed of the user and must stay in sync with the visual playback. Headphones may also be added to provide more variety and variability in the user's experience.

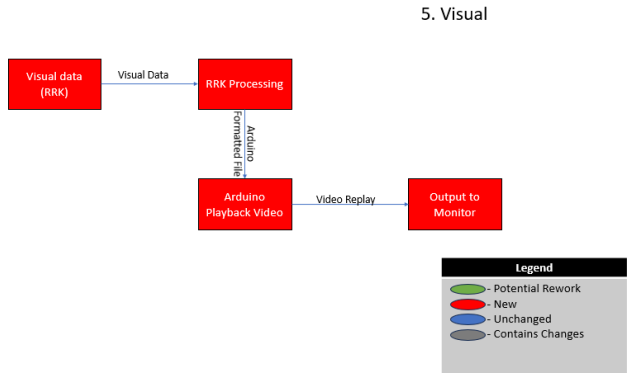

Fig. 5. Visual System

D. Subsystem 4: Visual

The Ride Replay Kit would not be complete without proper visuals. The visual subsystem keeps the user immersed in the virtual trail by updating the current location on the trail based on the current velocity from the resistance subsystem. The visual data from the trail camera will be processed by a Raspberry Pi, which then outputs to the monitor. Based on what speed the user rides the trail, a Raspberry Pi will have to interpolate between frames to provide a smooth playback.

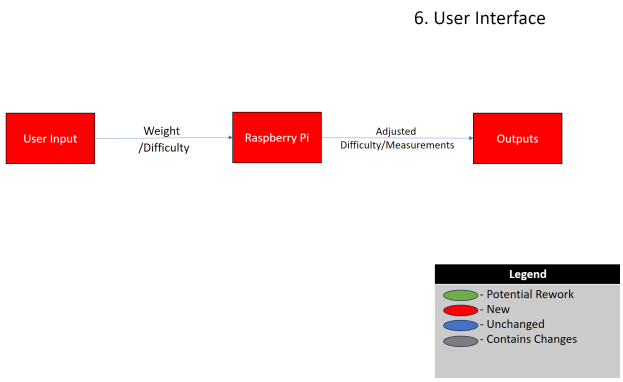

Fig. 6. User Interface

E. Subsystem 5: User Interface

The user will be prompted with two inputs which the Ride Replay Kit will use to calculate the total work done and the resistance as the distance value changes. The first input will be the weight of the user. This will be used to calculate the work-map in a Raspberry Pi and adjust the resistance values accordingly. The second input will be the difficulty level. This will be added for users with the inability to complete trails at a realistic level but still wish to have a comparable ride experience that matches the current fitness goals of the user. Based on the difficulty the user selects, the work done will be scaled down, which will also decrease the net resistance. The user interface will also remind the user after every trail of the appropriate amount of time spent exercising, prompting the user with an acknowledgment button. This will ensure the health and safety by preventing the user from over training and injury [3]. Finally, the user interface will show the user information about the trail ridden and the surrounding area in hope to promote tourism to areas affected by the Ride Replay Kit.

IV. Analytic Methods of Subsystem Verification

A. Subsystem 1: Work Calculation

The work calculation subsystem will utilize CAD software to simulate work based on distance, elevation, and weight. Using this information, a work-map can be created. To simulate work per interval, a range of realistic distance and elevation values will be used in the software to accommodate for the various trails the system will experience. Then, similar to the user inputting weight into the user interface, generating the specific work-map, a range of weight values will be used to ensure accurate work is calculated throughout the simulation.

B. Subsystem 2: Resistance System

The resistance subsystem will be verified using control system simulation software. The work profile required to complete a trail will first be calculated. The exercise bike and linear actuator will then be simulated in the software per the specifications of the exercise bike and the actuator.

Team 5 will model the bike at the highest resistance of the actuator and the lowest resistance of the actuator to find the minimum and maximum amount of work possible for the bike. These will then be used to format the work profile within these bounds. This is to ensure that whether the user is going faster or slower than the original trail, the work profile will scale within these bounds to ensure the correct amount of work is done and is physically possible based on the bike and actuator specifications.

C. Subsystem 3: User Interface

Using the specifications of the Raspberry Pi, the amount of time for an instruction to be executed by the CPU will be calculated. Using this time, Team 5 will calculate the maximum amount of instructions possible to be executed without causing the processor to have a delay of longer than 300 ms [2]. The code for the graphical user interface will then be limited to this amount of instructions in order to maintain a smooth interaction between the user and the system.

D. Subsystem 4: Visual

Using the data sheets from the Raspberry Pi and camera on the Ride Replay Kit, the visual subsystem output can be calculated. Team 5 will ensure the specifications are within range of the project's design, specifically the frames per second is at or above 60 fps. Additionally, visual interpolation software with the ability to meet the specifications of a smooth playback at 60 fps will be found and verified using the specifications of the software.

E. Subsystem 5: Audio

To ensure the audio subsystem is verified Team 5 will use the specifications from the microphone and speaker data sheets. The microphone data sheet will be checked to verify that it is omnidirectional to ensure it will pick up audio in a wide area. Additionally, the speaker data sheet will be checked to verify that it is or can be limited to 80 dB to ensure the safety of the user. This means that the system will not only pick up the wide array of sounds on the trail when it is actually put into practice but the speakers will also have the ability to output a safe dB level for the user.

V. CONCLUSION

Team 5's Ride Replay Kit was designed to give an immersive simulated bike trail experience that will allow the user to personally record bike trails and replay them completely with real-time feedback. The built-in dynamic Resistance System will accurately replicate the physical demands of actual bike trails by simulating changes in elevation and will be customizable for varying fitness levels. The user will also get feedback on how much work has been accomplished after the trail is complete. The Audio and Visual systems will be synced to simulate the trail environment and sounds that the user would experience on the actual trail. This prioritizes user immersion and entertainment making the replay of the trail enjoyable. Automatic post-ride messages will emphasize exercise duration within health limits to promote user safety. The kit's customizable difficulty options will cater to users of most fitness levels, enhancing accessibility and engagement. Overall, the goal of Team 5's Ride Replay Kit is to officially give users the ability to replay and share personal recordings of bike trails.

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[4] "How long to ride a stationary bike for improved fitness," https://www.onepeloton.com/blog/workout-length (accessed Oct. 4th, 2023)/.

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VI. APPENDIX

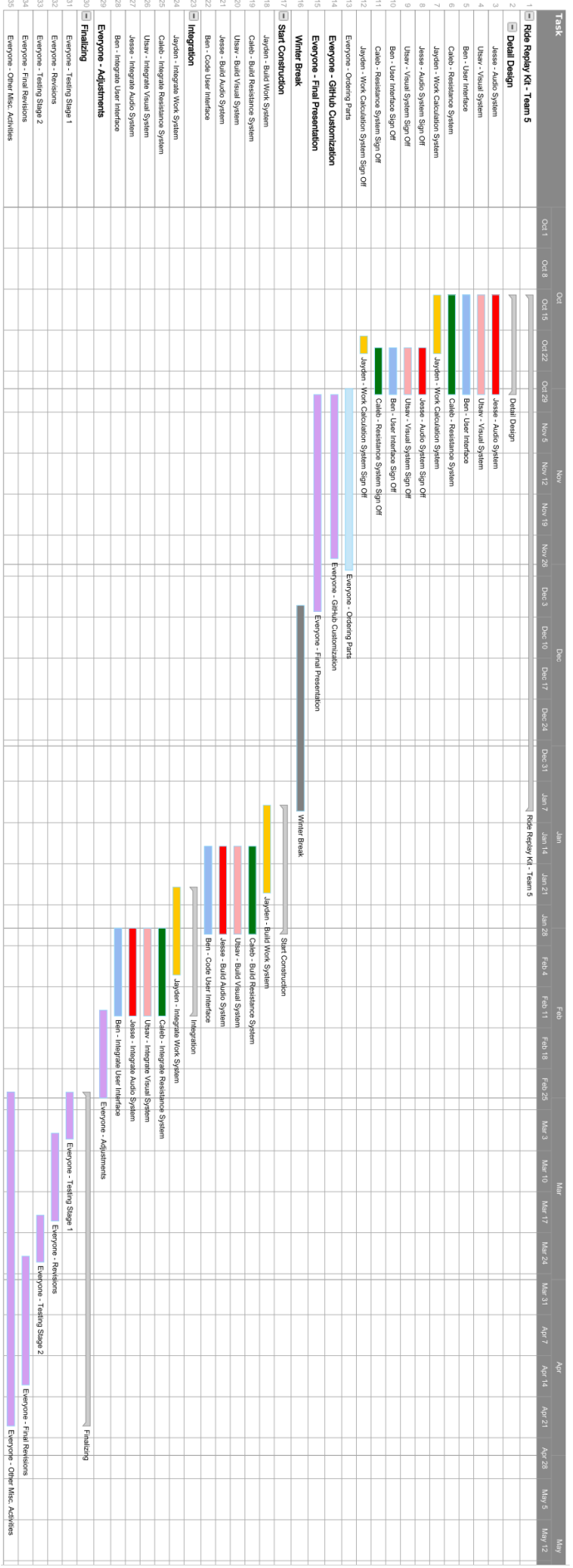

Fig. 7. Gantt Chart