Team 5 - Ride Replay Kit

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I. Introduction

Team 5's Ride Replay Kit is creating a re-playable trail experience for users to enjoy from their homes. Team 5's kit will provide users with an accurate recreation of the bike trail and will have a "work map" for each recorded trail, which will be calculated within the Resistance System. The kit will also have audio and visual systems to recreate the trail's sounds and video 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 that allows the user to tailor trails to their experience level this will be part of making changes to the exercise bike user interface which will also include informing the user of their time spent riding the bike. The project will also have to abide by regulations set by professional, ethical, and broader considerations.

A. Identified Problems

The Work System shall provide a unique work map dependent on the trail. The Work System should be accurate to the visual experience and be consistent with the actual work done by the trail rider proportional to the user's weight. To accomplish this team 5 will measure distance and elevation, then calculate work done on a trail for each user.

The video feedback 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 user's pace. To accomplish this Team 5 set a constraint to record at minimum of 60 FPS.

The audio feedback 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 with the user's pace. To accomplish this Team 5 set a constraint to limit speaker output to 80 dB. This constraint is 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 will change depending upon the effort put in by the user. The changing resistance shall provide users with a way to complete a trail at their desired pace while keeping the work done during the ride comparable to the recorded work done. To accomplish this Team 5 will monitor the pace of the user and scale the output accordingly.

The changes to the user interface of the exercise bike will ask the user to input their weight, will remind the user of recommended periods of exertion, and allow for the choice of difficulty. Inputting the user's weight will allow for the calculation of work done during a trail. The difficulty choice will tell the Raspberry Pi what difficulty to calculate for and scale it accordingly. The user interface shall remind the user of the recommended time spent on the bike after every trail. To accomplish these tasks Team 5 is adding code to the existing user interface implemented by the previous iterations. Team 5 is setting a constraint to limit maximum latency to 300 ms. This constraint was chosen to meet acceptable latency levels for tapping tasks.

The difficulty option within the user interface will change the overall work done during a replay of the trail. This should create additional options for users who cannot bike a difficult trail giving them the ability to experience it at a level adequate for them. This will also allow users who want a realistic experience to get work comparable to the work they would experience on the actual trail. To accomplish this Team 5 will implement multiple difficulties that adjust the values of the actuators of the exercise bike to change the overall work done.

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 (OTS) can lead to negative health effects, including fatigue, depression, loss of motivation, hypertension, weight loss, and anorexia [2]. Taking this standard consideration into account, this is the reason for the constraint of the acknowledgment button after every ride to prevent OTS [3].

Low frame rate, although not directly harmful, is distracting. Visual appeal is vitally important, especially for a possible marketable product. This is the cause for the frame rate constraint of a minimum value of 60 fps. This will make the user's trail replay that much more enjoyable and immersive [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, which team 5 has elected to be at or below 80 dB to stay within known safety specifications [5].

For interaction with the user interface, latency must be mitigated to avoid user frustration. This broad consideration is solved by limiting the latency to at most 300 ms. Users will have a smoother interaction with Team 5's ride replay system overall with this constraint. [6].

III. SYSTEM DESIGN

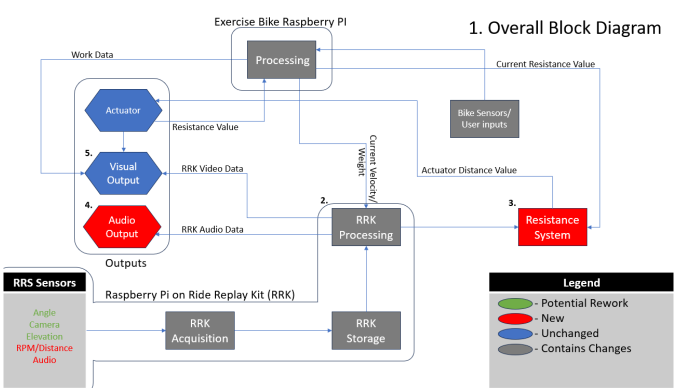

Fig. 1. Overall Diagram

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 per distance remains the same. 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.

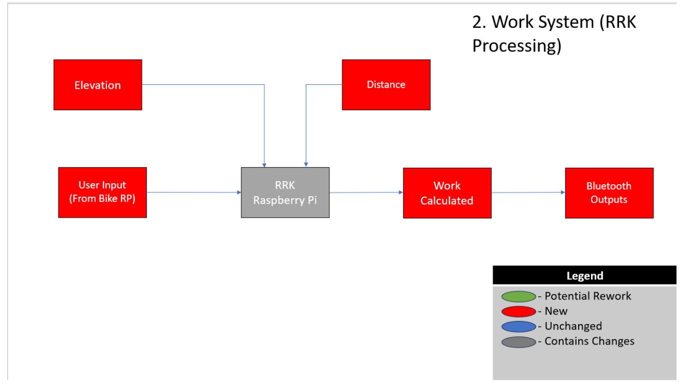

Fig. 2. Work System

A. Subsystem 1: Work

Work will be calculated on the trail by using the elevation and distance of the trail. This information, along with the user's weight provided from the user interface, will provide the work done over the distance of the ride. 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.

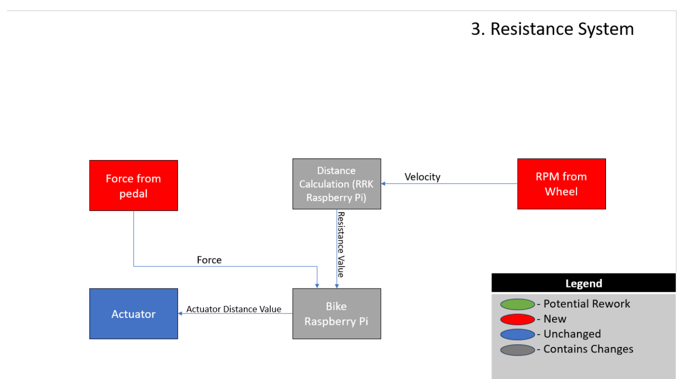

Fig. 3. Resistance System

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 resistance will be calculated in a Raspberry Pi based on work done on the bike and the current velocity which will correspond to the current position on the work map. 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.

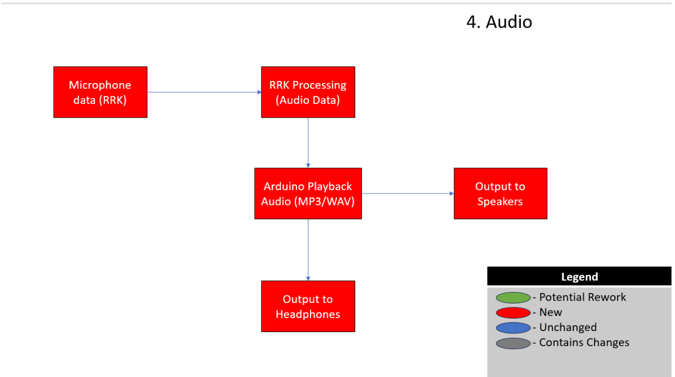

Fig. 4. Audio

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 user's speed 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.

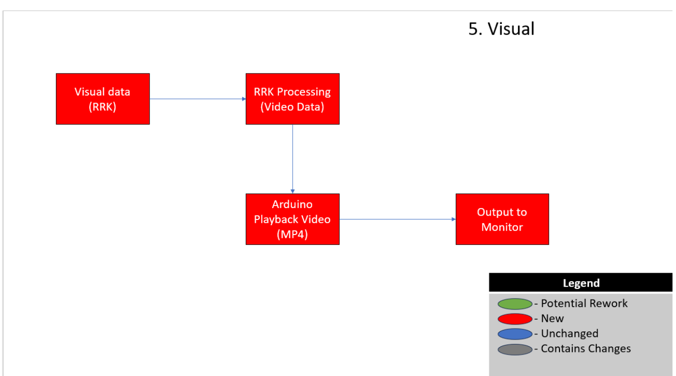

Fig. 5. Video

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.

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 according to the user. 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 their current fitness goals. 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 of the user and prevent the user from overtraining and injuring themselves [2].

IV. ANALYTIC METHODS OF SUBSYSTEM VERIFICATION

A. Subsystem 1: Work Calculation

The work calculation will need to be tested to ensure the accuracy and realism of the work done during a trail. To accomplish this a physics calculations of work must be done. The following formulas can be used: Work equals Force times Displacement or Work equals altitude change times mass times gravity.

$$W = F * D$$

$$W = h * m * g$$

B. Subsystem 2: Resistance System

The resistance system will have to be tested to ensure that the corrective feedback brings the resistance to the proper value and is proportional to the total work done during the ride. This calculation will be done by measuring the corrective resistance value with the corresponding force from the user. Taking in these two values Team 5 can solve for work using the new force value and new total distance to prove that the new work calculation is equal to previous work and scale the resistance accordingly.

C. Subsystem 3: User Interface

The latency will need to be tested to ensure smooth interaction between the user and the touchscreen. To measure latency, calculations within the Raspberry Pi will have to be made. The total time required to execute each piece of code related to the user interface will have to be calculated to be sure that the total is below 300ms of delay.

D. Subsystem 4: Visual

The visual system will have to be tested to ensure steady frame playback at or above 60 frames per second. To ensure that the frame playback is at or above 60 frames Team 5 will take the total frames within a recording and the total seconds elapsed and calculate the average frames per second.

E. Subsystem 5: Audio

The audio will have to be measured to ensure that the audio produced by the speakers is accurate and comparable to the audio recorded during a trail. To complete this Team 5 will measure audio wavelengths in the field and compare them to audio wavelengths from the recording played through the speaker.

V. RISK MITIGATION

A. Subsystem 1: Work

The most applicable risk to the work subsystem is having error in the work calculation, which will provide the user incorrect resistance values, causing possible injury to the user as well as damage to the bike itself. Failure in the work subsystem could also cause damage to the resistance subsystem if the values exceed the declared limits of the actuator.

The risk mitigation in this subsystem will come from careful calculations to verify that the work done is within a reasonable margin of what the expected value would be. The other method will be implementing a minimum and maximum work done over an interval of the work map, which will mitigate extreme values outputting to the resistance system.

B. Subsystem 2: Resistance

The main risk for the resistance system is calibration errors. The resistance system could overcompensate for differences between the actual force being done by the user and the actual work required. This could cause both an over-extension of the arm or inaccurate resistance to be applied. An over-extension of the arm could cause damage to the exercise bike or injure the user. Inaccurate resistance could cause users to hurt themselves when they expect to see a high-resistance hill and have a low resistance applied to the exercise bike. Additionally, inaccurate resistance could affect work calculations providing wrong data to the user.

The way to mitigate this risk is to implement a minimum and maximum distance the actuator can extend. This way, the magnets getting too close or too far away will not be possible.

C. Subsystem 3: User Interface

The user interface risks failure from user inputs. If the weight and difficulty level are not accurate, this can cause overexertion or inaccurate work done, which may cause harm to the user. Another risk for the user interface would be the acknowledgment button pop-up failing. This needs to remain functional to prevent the user from over exhaustion.

To mitigate these risks, many test runs will have to be run, to take into account all possibilities of user interaction, as to avoid any software malfunction.

D. Subsystem 4: Visual

The main risk for the visual replay is not being in sync with the resistance system, which could cause the user to hurt themselves. For example, when the user sees a high resistance hill, but still may have a low resistance on the exercise bike. Another risk for the visual replay is stuttering and video blur which could cause motion sickness to the user. There is a risk of the visual system not being in sync with the audio, or stuttering, which would no longer give the user the immersive experience they would be looking for. There is also a risk of the visual system not working entirely, which would then render the replay bike unusable as there would be no visual to indicate resistance change, which could injure the user.

To mitigate these risks, Team 5 will create a sample of rides, and rerun the samples ensuring that there are no visual breaks, stuttering, or video blur, therefore verifying that the system works as intended. After verifying that the video works as intended, Team 5 will then make sure that the video is in sync with the resistance system by riding the trails and making sure the specific positions on the work map match the positions on the trail ride. Additionally, frame interpolation software will be added to ensure smooth visuals, even if the velocity is low enough to cause choppiness.

E. Subsystem 5: Audio

A major risk for audio replay could potentially be too loud which could result in the user's hearing being damaged. There is also a risk of the audio not being in sync with the visual system, or not working at all, therefore ruining the immersive aspect of the Ride Replay Kit.

Team 5 will mitigate these audio risks by creating a maximum and minimum decibel output, as well as possibly adding an equalizer to reduce harsh frequencies. Additionally, audio interpolation will be added to smooth out the user's auditory experience.

VI. CONCLUSION

Team 5's Ride Replay Kit was designed to give the user an immersive simulated bike trail experience, that will allow them to bike trails completely from within their home with real-time feedback. The built-in dynamic Resistance System will accurately replicate the physical demands of actual bike trails, simulating changes in elevation, and will be customizable for varying fitness levels. The user will also get feedback on how much work they have accomplished after the trail is complete. The audio and video feedback systems will be synced to simulate the trail experience environment and sounds that the user would experience had they actually biked that trail. This accomplishes the goal of prioritizing user immersion and entertainment. 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 bring the experience of a hard-to-access outdoor trail to an ease-of-access home exercise bike.

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VII. APPENDIX

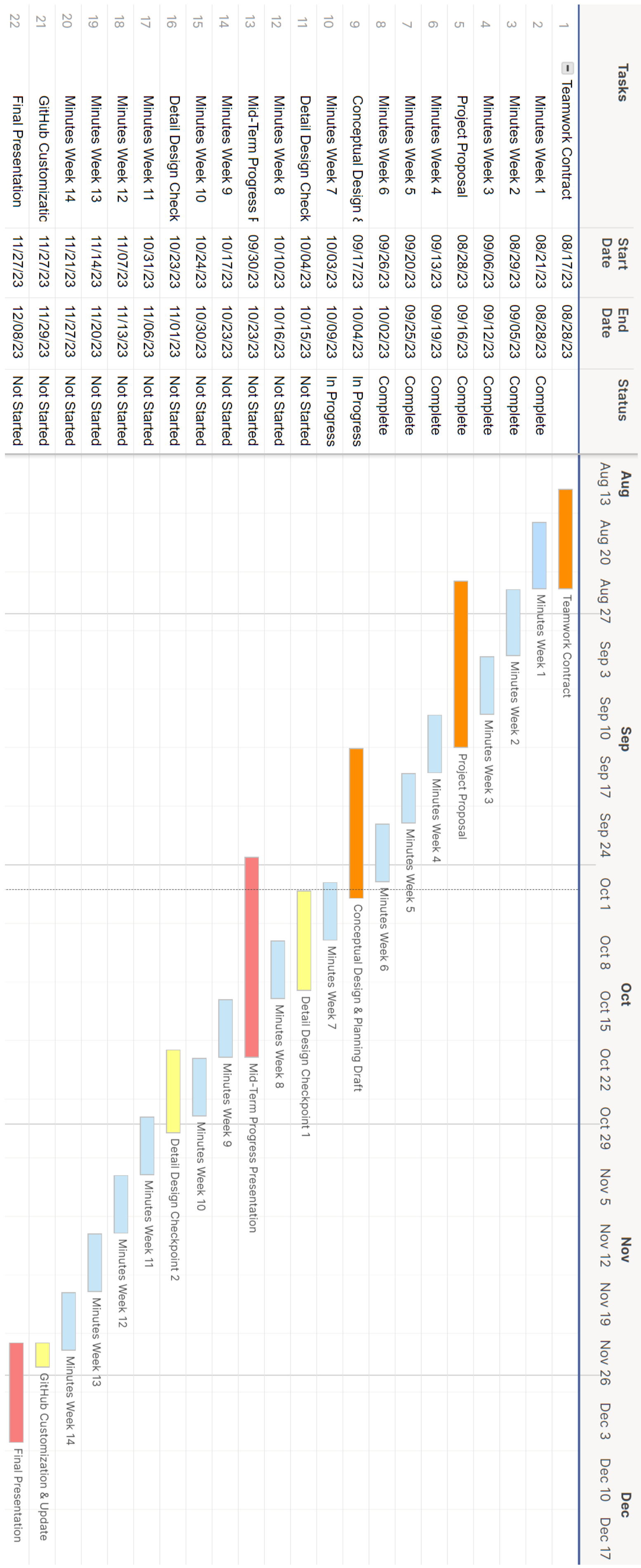

Fig. 6. Gantt Chart