ECE 4961- Group 2 - Mario Kart Bike Proposal

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***Abstract* --- This report introduces group two's project idea. An introduction of the problem begins the report, followed by the formulation of the problem. Necessary specifications and background information are given, as well as constraints and possible solutions. Finally, group two's resources for completing the project are listed.**

Keywords --- Capstone Design, gaming, emulation, exercise, sensors, electromagnetics, engineering

I. INTRODUCTION

Imagine yourself blazing down the road as your favorite Mario Kart character, racing and drifting through your favorite tracks, dodging rogue shells and bananas that litter the course, and finally sailing past the finish line just millimeters away from that other player who has been right on your tail since the start. An activity unlike most others, this kind of game inspires a competitive and energizing rush in many players. While most everyone can agree that games such as this are a highly mentally engaging experience, excessive gaming, and a correspondingly sedentary lifestyle, however, can actually be quite dangerous to one's physical health over time. According to the CDC, adult obesity prevalence in the U.S. from 2017-2018 was found to be approximately 42.4% of the population, and has been shown to be steadily increasing since then [1]. While this is not necessarily directly linked to exercise habits, incorporating basic aerobic activity even without diet or routine change otherwise is proven to aid in weight loss and general health improvement [2]. However, many people find going to the gym, or rather exercise in general, to be too much effort, too inconvenient, too difficult, or just plain boring. Whatever the reason, If one could combine that great excitement and enjoyment that, as previously mentioned, often comes with their favorite video games with the extensive benefits of physical activity, it could likely make exercise a much simpler process that people would feel more readily willing to participate in given the choice.

The objective for this project is to develop a system that integrates basic physical exercise with the process of playing a video game, and the end goal is to create a fun and enjoyable way to work out while gaming in order to inspire gamers or other casual groups to fit more physical activity into their day-to-day routines to ultimately improve the general health of society. From these ideas, a logical first plan would be to utilize exercise equipment to control the game itself. Using an exercise-bike style system, the idea being proposed here is to connect the bike to the game in such a way that pedaling and steering motions from the user are tied to the standard control systems of accelerating and steering in Mario Kart. Additionally, feedback from the game itself, such as race speed choice or the act of being struck by an item or obstacle, will be used to affect the resistance against pedaling in varied ways. This is the basic plan for how the whole system will work, and in the following sections, this proposal will describe in more detail the specifications, constraints, and background behind this system as well as who this team consists of, our skills and resources, and the timeframe in which the development should take place.

II. FORMULATING THE PROBLEM

A. Objective

One of the biggest cons of gaming is a lack of physical activity. Most games are played in a seated position with no activity besides small wrist and finger movements. Our objective is to merge exercise with gaming in an enjoyable and practical way, and our approach is through a piece of equipment the majority of people can operate: a stationary bike. To us, the most logical game to pair with such a system is a game involving vehicles. We've chosen Mario Kart because it is a well-known and loved game that all ages can enjoy.

B. Specifications

The end goal is to build a system that allows the player to immerse themselves in the Mario Kart experience. Therefore, many modifications must be made to meet this goal. Physically, the system must support a wide range of ages and sizes. It must also be stable and comfortable for long gaming sessions. The system must be adjustable in order to provide the rider with varying levels of pedalling difficulty. The handlebars must be able to freely move left or right to provide steering, potentially with some resistance for realism.

Electronically, the system must be able to communicate with either an existing gaming system or a game emulator on a PC. The action of pedalling the bike should tell the game's character to "go" and a rate of pedalling under a certain threshold should tell the character to "stop". Potentially, the resistance of the pedalling could be adjusted electronically for a more seamless experience. Situations like difficulty selection and "crashing" should cause the bike to be harder to pedal. The handlebars should also be equipped with appropriate buttons for actions such as drifting, shooting projectiles/using items, and selecting menu items. If needed, the system should draw power either from batteries or from a standard 120V electrical outlet. Ideally, the system should also apply some sort of regenerative power option if possible. This, combined with low power components, will keep the whole thing as power efficient as achievable.

Safety wise, the system should be calibrated so that there are no sudden changes in resistance that could potentially cause injury. Instead, some ideal gradual rate of change would be the best choice and can be determined through consistent testing. Additionally, there should be some fail-safe in place for the pedal system in case the resistance suddenly gives out, again in the interest of preventing injury. It should be robust enough to handle forceful pedaling while still protecting the user from quick changes in difficulty.

C. Background

To address the first series of specifications, it is necessary to explore what kinds of stationary bikes are on the market. Generally, there exists three types: upright, recumbent, and indoor cycles. Upright bikes hold the user in a vertical position, similar to a bicycle. They typically have smaller footprints because the pedals are below the seat. Next is recumbent bikes, which keep the user in a fully-seated position. The pedals are directly in front of the seat, allowing the user to relax the rest of their body and focus on pedalling their legs. Finally there's indoor cycles, which closely resemble road bicycles. The handlebars are directly in front of the seat, meaning the user's back is nearly parallel to the floor. While this position may seem less comfortable, most users report that this is the most realistic riding position that stays comfortable through long sessions [3]. All of these bikes have adjustable seats and can support around 250-300 pounds, making any of them suitable for our requirements

The above bikes are all constructed in the same basic fashion. The user sits on the seat and turns the foot pedals, just like a normal bicycle. The pedals are attached to a chain or belt, which drives a large flywheel. The flywheel is where the resistance of the pedalling is typically adjusted. There are several ways to add resistance to the system, but the two most common ways are through friction or magnetics. Friction bikes have a contact pad attached to a rod that the user can adjust. Turning a knob will move the rod up or down, causing the pad to be pushed into or pulled away from the flywheel. The benefit to these is that the knob includes an emergency stop feature where the user can push the rod all the way in and the contact pad forces the flywheel to stop spinning. Magnetic bikes work very similarly, with one key difference: there is no contact with the flywheel. Instead of a contact pad, a series of magnets is attached to the adjustable rod. The closer the magnets get to the flywheel, the higher the resistance becomes. This is due to a phenomenon called eddy currents. When a non-magnetic metal comes in contact with a magnetic field, eddy currents are produced in the metal. These currents flow perpendicular to the magnetic field, creating a friction-like resistance between the magnet and the metal [4]. What's useful about this is that there is no actual contact or friction involved. This saves the materials from wear and greatly prolongs the lifespan of a magnetic bike. Magnetic resistance is highly adjustable and some bikes even come with an electromagnet that is electronically controlled, allowing the resistance to be adjusted by changing the strength of the magnet rather than its position. Either form of magnet resistance would be suitable for our purposes. One con of magnetic bikes is they are generally more expensive than other variants.

An uncommon way to add resistance to one of these stationary bikes is to attach the flywheel to a permanent magnet DC motor. A DC motor has two wires, positive and negative. By shorting/connecting these two wires, a force called back torque is created. Back torque is caused by the internal voltage created when the wires are shorted. When back torque is present, the shaft becomes harder to spin [5]. To control when the two wires are shorted, some kind of switch is required. A switch that is easily controlled by a computer is called a transistor. Transistors are essentially voltage controlled switches. When a signal is sent to one, the switch is flipped. One of the most common kinds of transistors used in small-scale electronics is called a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) [6]. MOSFETs have 3 terminals: the source, the drain, and the gate. Current travels from the source, through the MOSFET, and out of the drain. When a certain voltage is applied to the gate, the MOSFET allows the current to travel through. A MOSFET acts as an open when there is no gate voltage, and as a short when there is voltage at the gate. By varying the voltage at the gate, the level of resistance between the source and drain can be changed. Higher voltage at the gate means lower resistance. With some sort of microcontroller, the gate voltage could potentially be controlled by the game.

Another common feature - or lack thereof - of stationary bikes is immobile handlebars. Some bikes come with an additional arm workout in the form of two handles that move with the motion of the flywheel, like an elliptical stepper machine. However, this kind of motion is not what this project requires. We need bicycle-like steering. With any stationary bike selection, modification would be required to allow for free steering. Most stationary bikes come with bent or vertical handlebars, which fortunately would provide our users with a more realistic riding experience.

To get the bike to communicate with the game, it needs switches, buttons, and sensors. Most of the hardware required comes conveniently packaged in video game controllers. Buttons to scroll through menus and select options, use items, and drive the Kart are readily available in these controllers. Additionally, these buttons are designed to be pressed often and be responsive since they are for gaming. To control the game, either an electromechanical or a computerized approach will be taken. In either case, a sensor to measure the speed or frequency of the rotating pedals will be needed. A tachometer is a sensor designed to measure the RPM (rotations per minute) of rotating objects.

For this project, an optical tachometer would be suitable. These operate by shining a light, like an LED, against the rotating object. The light reflects off the surface back into the sensor, triggering a signal. The rate at which the signal is triggered is used to determine the RPM of the object [7].

Regarding the running of the game itself, it may prove difficult to use an actual console given how securely and privately Nintendo handles its proprietary systems. Therefore, for the purposes of this project, an emulator will be used in order to allow us to run the game client on a PC, which will give us greater options regarding interactions between the control system and the game data. An emulator is generally a piece of software that allows one computer to simulate the processes and conditions of another virtually identically. This allows the host machine to access programs and features that are typically only available to the system being emulated [8]. An emulator will allow more versatility to the type of controls available for usage in this project, as well as increased performance from the game itself as compared to the original console. Most emulation software designed for games provide the option to create a custom map of controls based on inputs received from the control system. This makes it quicker and easier to test and replace control options than that of a dedicated console. For the purposes of this project, the N64 version of Mario Kart will likely be used due to its relative simplicity and ease of emulation.

D. *Constraints*

With the specifications and background in mind, there are constraints that must be followed to make the project successful. The system must be housed entirely within or on the stationary bike. No component may be located away from the bike assembly for a more minimalist look. Wires coming out of the bike should be kept to a minimum for both aesthetics and safety. Controls not related to driving or steering should be located on the handlebars for easy access to the user. The pedalling system must be able to withstand the torque produced by an average cyclist. Additionally, the resistance system must be able to handle rapid changes. As far as controls, accessing and modifying game code or memory while running may prove too difficult a process even through the emulator, so external control systems or alterations to already existing controllers may be the only feasible options. If necessary, the user may need to make the initial base resistance choice separately from race speed choice due to this issue. Since this bike would most likely be operated in a gym or other public setting, it would be powered ideally by a standard wall outlet, meaning the system needs to comply with the power rating and safety standards accordingly. Below is a list of known safety standards concerning the project.

a) Electromagnetics

- 299 - IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures
- 299.1 - IEEE Standard Method for Measuring the Shielding Effectiveness of Enclosures and Boxes Having all Dimensions between 0.1 m and 2 m
- 1309 - IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz
- C63.2 - American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications
- C63.14 - American National Standard Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3)
- C95.1 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

b) Electronics

- NESC HBK - National Electrical Safety Code (NESC) Handbook

c) Batteries

- 946-2020 - IEEE Recommended Practice for the Design of DC Power Systems for Stationary Applications

III. SOLUTIONS

A. *Measures of Success*

1) Measuring the latency of the game: One way to measure success within the project is verifying that the input lag is less than 40 ms. One way to test this would be to create a circuit or use Raspberry Pi software to measure the input lag to the game monitor. The alternative option would be to qualitatively evaluate the latency by playing the game and determining if the lag is noticeable or negligible.

2) *Bike Immersion:* Throughout this project, the main focus will be to provide realistic haptics created in the bike in order to keep the user invested in the game. The bike should provide stimuli to the user that creates an overall enjoyable and challenging exercise experience. Testing different age groups and asking those groups for feedback via survey will be a way to measure the player's enjoyment as well as the immersion of the bike. For example, a player might say their experience was a 7 out of 10 on a number scale and the haptics or pedaling were a 5 out of 10. Then participants could explain why they answered those numbers in a box below and offer suggestions.

3) *Range of Resistances:* The expectation of the resistive component of the bike is that it operates in a range that feels natural to the user. The resistance component should have three levels of strength including: 50 cc, 100 cc, and 150 cc. The range should not change too slowly or too quickly. To be safe, we will be measuring the existing resistance of the bike chosen by creating or buying a gauge to test the resistive components and determine if our system meets the standards for resistance for that particular bike.

Pedaling ranges that are low intensity on bikes range from 50 to 80 RPM.

B. Unknowns/Obstacles

1) Covid Regulations: Social distancing will be a relatively small obstacle for this project, however, it will determine a very significant design decision. In the case that there are two players, the bikes will need to be separated six feet apart. This will determine whether a wired controller or a bluetooth controller is used for the bike. If the wired controllers are not long enough, bluetooth controllers may be more convenient to use for the project.

2) Obtaining Game Data: The amount of data that will be obtainable is currently unknown. Depending on what is available to map to the bike, the scope of the project may be limited to this data. For example, the cc levels may not be possible to obtain via the emulator, so the bike may be designed instead to have external buttons for the user to select their cc level.

C. Already Available Solutions

1) Mario Kart Labo Kit: This Labo kit is a similar solution that utilizes a simple wheel design. The controller is squeezed by the user to use power-ups and rotate mid-air to steer while they use a personal exercise bike. The only downside to this method is that it is not as immersive because it has no variance in resistance.

2) *RealRyder Hong Kong Bike:* This bike is used as a controller that is attached to a nintendo switch controller. The player uses their body to turn in the game and pedal to move forward. However, it also does not have varying levels of resistance. This solution is very similar to the Mario Kart Bike but is lacking in areas providing haptic feedback as well.

D. Skeleton Solutions

1) Game Emulator: As part of this project's solution, the Project 64 game emulator will be used. The game will be tested on a pc platform and some of the game data extracted by the emulator will be used to control the resistance of the bike, and some will be used to control haptics.

2) *Controller:* The N64 controller or the bluetooth controller configuration with the emulator will be mapped to the steering and motors for haptic feedback and resistance.

3) *Resistive component:* A DC motor or an electromagnet will be used in combination with the bike to increase or decrease resistance on the flywheel for the user.

E. Broader Implications, Ethics, and Responsibility

1) Environmentally Friendly Materials: To make sure that this project contributes to the environment, materials used for the bike will be made from recycled 3D printer filament. This will reduce the number of new materials needed for the bike.

2) *Licensing for Nintendo:* This project should not infringe on Nintendo's intellectual property. Further research will be conducted on what is allowed and not allowed to be used for the project's purpose. This project is not intended for commercial use. It will also be using an emulator running the copy of the game that will be licensed to use.

3) *Varying The Resistance:* As engineers, there is a responsibility to protect the consumer from injury. In this project, research must be conducted to determine the range of resistance that is safe for the human body. The bike should be safe and easy to use for elders and children, especially with the bike advertised as a consumer product.

IV. RESOURCES

A. Personnel

Compiled in the list below are the skills each member of the team possesses or may need in order to make the project successful.

1) Reed
   - Soldering
   - AutoCAD
   - SPICE simulation
   - 3D printing
   - Electromagnetics
   - Gear mechanics
2) Chase
   - Soldering
   - Serial data programming
   - Experience with emulator programs
   - X86 Assembly
3) Leah
   - Soldering
   - LTSpice
   - C
   - Programming sensors

B. Materials/Funding

Materials list may vary based on component prices and availability. Known materials required are as follows:

- Bicycle/Exercise Bike(s)
- Emulator Software
- Emulated Game Copy
- Game Controller(s)
- DC Motor
- Magnets
- Wires/Connective Elements

Regarding funding of the project, from the known components, the roughly estimated range of pricing in total spans from \$500 - \$1500. This assumes all components are newly acquired and of high enough quality to meet the previously defined specifications. This also factors in the desired stretch goal of building a second identical system in order for two players to play interactively with one another.

C. Timeline

Listed below is a rough estimate of the overall timeline of the project. Each date gives a basic idea of when each formal step of the process will be completed.

1) Project Proposal: September 20th, 2021
2) Design 1 Draft: November 1st, 2021
   a) Ideal estimation for when the first draft of design 1 documents should be completed.
3) Design 1 Final: December 8th, 2021
4) Design 2 Draft: March 1st, 2022
   a) Ideal estimation for when the first draft of design 2 documents and prototype should be completed.
5) Final Presentation: April 31st, 2022

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