Somatosensory Enhancement FPS Gun Controller Design Document

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Group 43

1. Introduction

1.1 Problem:

The functions of video game controllers nowadays are very limited to the gaming machine, and are mostly in the form of joy-stick or gamepad. Playing FPS(First-person shooter) games on PC with a mouse or joystick can lower an user's gaming experience, making it difficult for users to feel realistic and fully immersed during games. Not only do traditional controllers lack realism, they also involve very limited physical movement, where players often sit down for hours which lead to negative effects on player’s health. Prolonged sedentary activities can lead to poor blood circulation, risk of weight gain, back pain and many other increased health risks. Especially when VR games slowly occupy the video game market, a non-traditional controller, or a somatosensory enhancement gun-shaped controller will be necessary.

1.2 Solution:

A gun shaped gaming controller is designed to bring a new level of immersion and realism to FPS video games, such as Call of Duty, Halo and Counter-Strike: Global Offensive. Unlike any traditional controller, the shape of our product mimics that of a real gun, allowing players to perform aiming and shooting in a similar way to how they would actually hold a gun in real life making gaming more exciting and enjoyable. This type of controller offers 3 main benefits to players. Firstly, a more realistic game play, a gun controller with the ability to mimic real life aim and shoot movements can increase the realistic aspect of game play; Second, Improved control, The gun shaped and trigger button replacement can provide players with better control over their movements; Third, increased physical activity. A gun shaped controller can encourage players to stand up and be more active as they aim and shoot, eliminating the risk of negative health problems from prolonged sitting.

1.3 Visual Aid:

Figure 1:Example image for holding a real assault rifle

The gun controller is meant to hold similar to holding an assault rifle in real life (figure 1). Where the left hand holds the hand-guard section and the right hand holds on to the back handle with the index finger lightly pulling on the trigger. Rear stock holds toward the right shoulder to stabilize the recoil. We will be placing our buttons corresponding to this position.

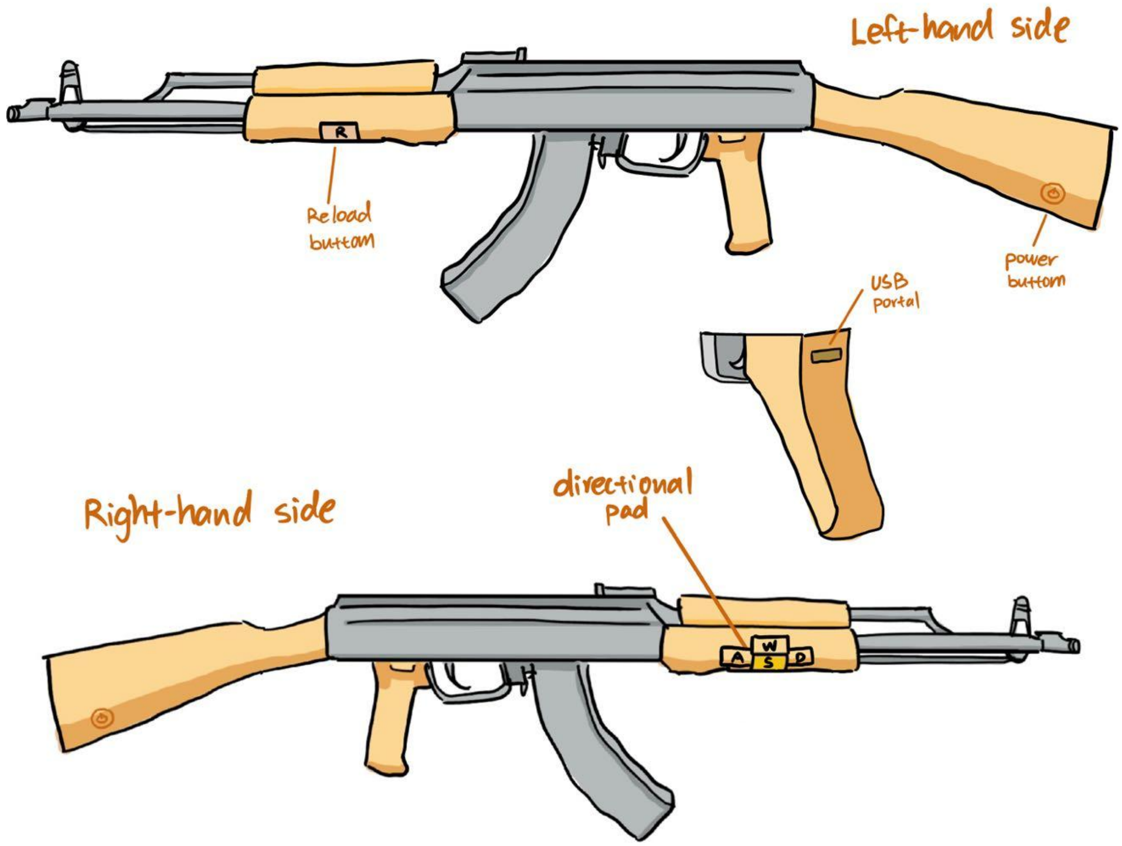


Figure 2:Visual aid for gun controller

This designed controller contains various triggers and buttons around the body to imitate the feeling of holding a real rifle when playing FPS games. On the left hand side, the power button is located on the rear stock where the user needs to press every time before using the controller. Reload button is located at hand guards where the user would typically put their left hand at. Triggers can be accessed by both sides right at the very middle of the controller body. On the right side, opposite of the reload button, the directional pad of WASD buttons are also located at the hand-guards part of the controller.

1.4 High-level requirements list: A list of three *quantitative* characteristics that this project must exhibit in order to solve the problem. Each high-level requirement must be stated in complete sentences and displayed as a bulleted list. Avoid mentioning "cost" as a high level requirement.

Our controller software works properly when

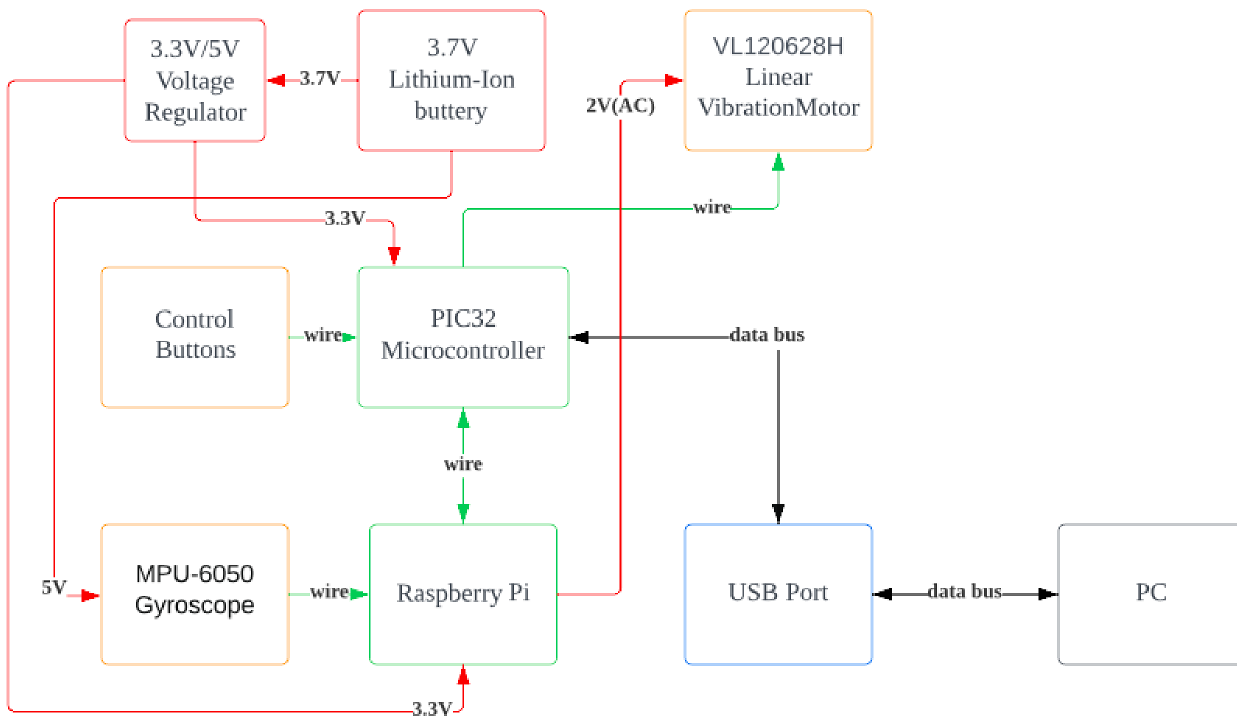
a. Aiming function works: screen position calculation algorithm reflects aiming point correctly on screen. shoot 10 targets in 50 seconds
b. The aiming delay has to be less than 50ms
c. Each button works correctly with desired functions. Explicitly, when two buttons are pushed simultaneously, they can't interfere with each other

Our controller hardware works properly when

d. Recoil function works: 5mm vibration amplitude achieved when trigger is pulled
e. Battery works：30 minutes continuous usage
f. The controller has to be easily recognized as a gun

2. Design

2.1 Block Diagram: Break your design down into blocks and assign these blocks into subsystems. Label voltages and data connections. Your microcontroller can live in multiple subsystems if you wish, as in the example below.



2.2 Subsystem Overview & Requirements: A brief description of the function of each subsystem in the block diagram and explain how it connects with the other subsystems. Every subsystem in the block diagram should have its own paragraph.

- **Control unit:** this is the control unit subsystem consisting of a microcontroller which will incharge of controlling all the other subsystems. (PIC32 microcontroller)

  Button & Trigger: The control unit or the microcontroller is able to control the button & trigger which means if we press a key, the microcontroller needs to detect the keypress then it needs to send the signal to the computer.

  Input: None

  Output: The ASCII code of W, A, S, D, R, and mouse left click.

Button & Trigger	
Requirements	Verification
• When the button & trigger are pressed or pulled, the signal	Use 90Hz video to record the trigger and the motor in the same screen.

should be sent to the microcontroller and the microcontroller will then input the signal to the PC through the USB port with a delay time no more than 50ms.	Verify that the number of frame from the time the trigger is pulled and the time the motor started to vibrate is less than 5 frames(50ms)
Each button or trigger should work independently without interference.	Verity the function of each button while some other buttons or trigger are held.

Linear Vibration motor: The main function of the vibration motor is once you pull the trigger, the motor needs to vibrate and simulates a recoil force as a real gun in real life. This needs to be under the charge of the microcontroller; the microcontroller needs to read the signal when the trigger is pulled and send a signal or a current to the motor so that the motor can vibrate.

Input: 10 Hz 2V AC power supply

Output: None

Linear Vibration Motor	
Requirement	Verification
The motor must vibrate immediately after the trigger is pulled.	Use 90Hz video to record the trigger and the motor in the same screen. Verify that the number of frame from the time the trigger is pulled and the time the motor started to vibrate is less than 5 frames(50ms)
The motor has to continue vibrating at 10 Hz while the trigger is held.	Record the sound of the motor while the trigger is held. Use the audio spectrum to count the number of amplitude peaks in 1 second to verify if the vibration frequency is 10Hz.
The motor has to stop working after every 30 times of vibration, counting from when the reload button is pressed.	Record the sound of the motor while the trigger is held. Use the audio spectrum to count the number of continuous amplitude peaks that are

	less than or equal to 30.

MPU-6050 Gyroscope: The Gyroscope plays a role of motion detection. It means we need to use the Gyroscope to capture the data of how we move the model gun in real life and calculate with a customized algorithm to transport the data into the computer so that the aiming cursor in the game will know the direction we are moving. The output parameters of Gyroscope are acceleration in x, y and z direction, and rotation in degree per second in x, y and z direction. Since the parameters are in terms of 3-dimensional space, and we want to project the movement of the controller on screen in terms of 2-dimensional space, we need to calculate acceleration only in x and y direction. The method we decided to use is calculating the exact distance the user rotated the gun muzzle using the degree given by gyroscope, and increment such a number to acceleration in x and y direction, and disregard acceleration of z direction. In order to achieve this goal, we decided to use Raspberry Pi to program this algorithm. With 2-dimensional x and y acceleration, we can then pass this vector data back to USB through microcontroller and eventually to PC.

Input: The motion of gun controller

Output: Acceleration x, y, z.   Rotation velocity x, y, z

Gyroscope	
Requirement	Verification
The aiming delay on screen has to be less than 50ms	Use 90Hz video to record the movement of the gun controller and the front sight on screen in the same screen scope. Verify that the number of frame from the time the start point of gun movement and the time the front sight on screen started to move is less than 5 frames(50ms)
The rotation direction of the character in game must be the same as the rotation direction of the gun controller.	Face the game character to a wall. Make one shoot. Rotate the controller and make another

	shoot. Calculate the rotation in the game and compare it to the rotation detected by the gyroscope. They should be the same with 10% tolerance. Or there should be a specific linear relation between these two values according to the user's choice.

- Power Supply: A power supply is required for the model gun to function. We will put a 3.7V lithium battery in our model gun to supply the current and voltage. The power supply unit (the battery) will also give current and voltage to the microcontroller and Raspberry Pi in order for it to function. Notice that the Raspberry Pi and the microcontroller only need 3.3V; therefore, a DC-to-DC voltage transformer is needed in order to convert 3.7V to 3.3V.

  Input: giving a input voltage of 3.7V to the regulator

  Output: The regulator will output correct voltage to each different component, such as output a 3.3V to the Raspberry Pi.

Requirements	Verification
● Must be able to regulate the battery voltage to power components throughout the DC-DC voltage converter in order to meet the different voltage standard for each component. For example, the Raspberry Pi needs 3.3V; therefore, using multimeter to make sure its voltage does not fall outside 3.3V $\pm$ 5%.	● Use the multimeter to measure the input voltage for each component that does not fall outside the range.
● Our power supply needs to supply the whole components for a minimum 30 minutes of continuous usage.	● When the battery is fully charged, we can use the multimeter to measure how much current the whole components are consuming. Then we could calculate how long the battery will last.

● The remote battery we have is rechargeable, so we need to make sure the rechargeable battery can be recharged within 3 hours.	● Start with the battery discharged to the point when it reads 2.75V. In order for the battery to be recharged within 3 hours. We could calculate 5AH/3H = 1.67A, which means a minimum of 1.67A charging current is required. Verify that at the end of charge cycle, battery voltage is 4.2V and no current is being delivered to the battery

- USB Port: A USB port unit is required for data transformation from the model gun to PC. We would create a USB port on our PCB so the USB cable would directly connect to the PCB and transform the data into PC.

2.3 Subsystem High Level Requirements: For each subsystem in your block diagram, you should include a highly detailed block description. Each description must include a statement indicating how the block contributes to the overall design dictated by the high-level requirements. Any interfaces with other blocks must be defined clearly and quantitatively. Include a list of requirements where if any of these requirements were removed, the subsystem would fail to function. Good example: Power Subsystem must be able to supply at least 500mA to the rest of the system continuously at 5V +/- 0.1V.

- Power Supply: The power supply We choose has a 5000mah battery tank with 3.7V and 2.5A maximum output. Out estimate power usage is 2.14A*3.7V=9.25W. The estimated time of usage of 5000mah*3.6J/mah/9.25W/60s = 37.3min. Our first high-level requirement "30 minutes continuous usage" is fulfilled.

- Vibration Motor: The motor has vibration force larger than 1.5 grms. Our second high-level requirement "5mm vibration amplitude" should be fulfilled. Further testing is needed to make that sure.

- Microcontroller & Raspberry Pi: In order to achieve the aiming function goal (shoot 10 targets in 50 sec), first of all the Raspberry Pi needs to do the algorithm within time; too much delay would not achieve the goal. The Raspberry Pi 3 model B has a Cortex-A53 (ARMv8) 64-bit SoC processor which would achieve this goal.

- Button & Trigger: The WASD buttons are placed on the right side of the handguards in the same arrangement as that is on regular keyboards. This design is ergonomic. It helps the players to quickly get familiar with the operation method. Besides that, the reload button is placed at the Magazine, and the trigger button is placed at the Trigger. These intuitive designs help the player easily finish the last requirement "shoot 10 targets in 50 sec." The average time to finish this goal by traditional keyboard and mouse is 45 sec.

- GYROSCOPE: The delay time of Gyroscope could not be high. From the datasheet it has 16-bit ADCs enabling simultaneous sampling of gyros which would be sufficient to use.

2.4 Tolerance Analysis: Identify an aspect of your design that poses a risk to successful completion of the project. Demonstrate the feasibility of this component through mathematical analysis or simulation.

- For power supply, the 3.7V lithium battery supplies 3.7V of electricity with a maximum current of 2.5A.
- The VL120628H Linear Vibration Motor needs 130mA current and a 2V voltage.
- The PIC32MK1024MCM100 Microcontroller will have a minimum operational voltage of 2.8V and a maximum operational voltage of 3.3V.
- The GY-521 THREE AXIS ACCELEROMETER/GYROSCOPE will need an input voltage of 5V. Connecting to a voltage of 3.3V might cause irregular output values. Also, it needs an operational current of 3.6mA
- Raspberry Pi 3 model B+ will need an input power of 5V/2A DC.

- The total current added up through all the components is 2A+130mA+3.6mA = 2.1336A; therefore, we can see the battery needs to be able to supply the total current of 2.1336A so that the whole circuit would work.
- Another tolerance analysis we need to consider is the delay time, we are trying to control the delay time under 50ms. The delay time mainly is due to the algorithm done by Raspberry Pi. The Raspberry Pi 3 Model B has a 1.2 GHz 64-bit quad coreARM Cortex-A53 processor, on-board 802.11n Wi-Fi, Bluetooth and USB boot capabilities.
- Since the Raspberry Pi does not contain a hardware clock on board, it uses Internet access to set the time with the help of Network Time Protocol (NTP) servers (Nprasan 2014). In the C library, the gettimeofday function can get the time for Raspberry Pi and it is not rely on updates at each timer tick (Eckhardt 1992). So this function could be used in the Raspberry Pi for calculating delay time. More detailed calculation about delay time needs to be done when we test our algorithm by the Raspberry Pi independently.

3. Cost and Schedule

3.1 Labor Cost Analysis:

Labor: ($44.63/hour) x 2.5 x 50 hrs = **$5,578.75** per group member

Total Labor: $5,578.75 x 3 = **$16,736.3**

We can estimate each group member will devote 50 hours of time into this project. Average starting salary for UIUC Electrical Engineering major is around $80,296, and average starting salary for UIUC Computer Engineering major is around $105,352. We will take an average of both salaries of $92,824, and around 14 days of holidays. We can calculate that the average hourly wage would be $44.63.

3.2 Parts Cost Analysis:

Description	Manufacturer	Quantity	Extended Price	Link
PIC32 Microcontroller	Microchip	1	$20	https://www.mouser.com/c/?marcom=102462339
Voltage regulator	self-designed	1	$20	N/A

Lithium-Ion battery	YDL battery	1	$11	https://ydlbattery.com/products/ydl-3-7v-5000mah-106070-rechargeable-lipo-battery-with-jst-connector?currency=USD&variant=40945537187993&utm_medium=cpc&utm_source=google&utm_campaign=Google%20Shopping&gclid=CjwKCAiA0JKfBhBIEiwAPhZXD_DMjojjn-QJA7Zk8xdY_WAcF1AD7pLMe2520dp9Pm7jXfMG3CZAqRoCIuAQAvD_BwE
VL120628H Linear Vibration Motor	Digi-key	2	$6.42	http://tiny.cc/cfn4vz
Raspberry Pi 3 model B	Raspberry Pi	1	$41.09	https://vilros.com/collections/raspberry-pi/products/raspberry-pi-3-model-b?src=raspberrypi
MPU-6050 Gyroscope	HiLetgo	1	$1.4	https://www.hotmcu.com/gy521-mpu6050-3axis-acceleration-gyroscope-6dof-module-p-83.html
Push buttons	ECE machine shop	10	0	NA
Resistors (100-10k Ohm)	ECE machine shop	20	0	NA
Capacitors (10n - 100u F)	ECE machine shop	20	0	NA

Total: $106.33

3.3 Sum of costs into a grand total estimated

$16,736.3 (labor cost) + $106.33 (parts cost) = **$16,842.63**

3.4 Schedule:

Week	**Task**	**Person**
2/20-2/26	Design Document due Team contract due Research on Gyroscope Research on Raspberry Pi	Everyone
2/27-3/5	Design document review PCB board review Discussion with machine shop Start ordering parts	Everyone
	Discuss PCB order with TA Design PCB	Beining & Haochen
	Research and brainstorm Raspberry Pi algorithm	Peilin
3/6-3/12	Finalize PCB design Pass PCBway audit Teamwork evaluation Finish board assembly Finish ordering parts	Everyone
	Assemble hardware parts with machine shop Test sensors	Beining & Haochen
	Test raspberry pi Start writing algorithm	Peilin
3/20-3/26	Wire microcontroller with control buttons Wire microcontroller with Gyroscope	Everyone
	Test individual parts Wire Lithium Ion battery with voltage regulator Assemble USB port with microcontroller	Beining & Haochen
	Wire Gyroscope with Raspberry Pi and test for correct input/output Test Raspberry Pi algorithm	Peilin
3/27-4/2	Pass second round PCBway orders	Everyone

	Individual progress report Finish wire parts together Debug for any wiring bugs	
	Implement and test battery system Implement and test USB port/data bus	Beining & Haochen
	Implement and test Gyroscope	Peilin
4/3-4/9	Implement and test control buttons Implement and test Vibration motor Debug for any non-functional parts Test connection with PC via USB port	Everyone
4/10-4/16	Put everything together and test on PC Get ready for Mock demo Team contract fulfillment Debug for any non-functional parts Work on lab notebook	Everyone
4/17-4/23	Mock Demo Finish up debugging Prepare for final presentation Work on lab notebook	Everyone
4/24-4/30	Finish up debugging Final Demo Prepare for final presentation Work on lab notebook	Everyone
5/1-5/7	Final presentation Final papers Lab checkout Turn in lab notebook Award ceremony	Everyone

4. Discussion of Ethics and Safety

4.1 Ethics and Safety Issues:

- Our biggest safety issue relevant to our project is when a user uses too much force when swinging the aim, or holding the controller with one hand, it could fall out of the user's hand and hit computers or people around. In reference to 7.8 IEEE code " to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment", we need to eliminate any possibility of risk to harm public's safety and welfare, therefore we will add a wristband to prevent gun controller from swinging out of hand.
- In the spirit of 7.8 IEEE code of Ethics I5 " to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors", we will thoroughly test our design with other team-members, TA, our family and friends of teammates. We will accept and value any feedback they provide and make improvements on our design.
- Our controller is designed to be hand-held, and we must ensure the material of the device is completely safe to hold and grip for a long time with warm body temperature and some degree of sweat. However, our controller is not designed to be water-proof and should avoid any spills or wet environment.

5. Citations

"7.8 IEEE Code of Ethics." *IEEE Section 7 - Professional Activities*, https://www.ieee.org/about/corporate/governance/p7-8.html#:~:text=To%20treat%20all%20persons%20fairly,and%20to%20avoid%20injuring%20others.

Grainger Engineering Office of Marketing and Communications. "Salary Averages." *Electrical & Computer Engineering | UIUC*, https://ece.illinois.edu/admissions/why-ece/salary-averages.

Last Minute Engineers. “In-Depth: Interface MPU6050 Accelerometer & Gyroscope Sensor with Arduino.” *Last Minute Engineers*, Last Minute Engineers, 29 Oct. 2022, https://lastminuteengineers.com/mpu6050-accel-gyro-arduino-tutorial/.