Project Title: Virtual Band

Team Number: 34

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1. Objective and Backgrounds

1.1. Goals & Functions:

The goal of the Virtual Band project is to provide a new instrument interface that provides users with a unique and engaging experience. Many Musical Instruments, due to their size and fragility, cannot support users to carry and play anytime and anywhere, such as the piano is very large. Using cutting-edge audio processing technology, pressure sensing systems and positioning systems, electrical pulses are converted into high-quality instrument sound output, providing consumers with a smooth, authentic music performance experience. To create a dynamic and engaging music interface, the Virtual Band project combines motion tracking, audio processing, and sensor technology - a new approach to music technology.

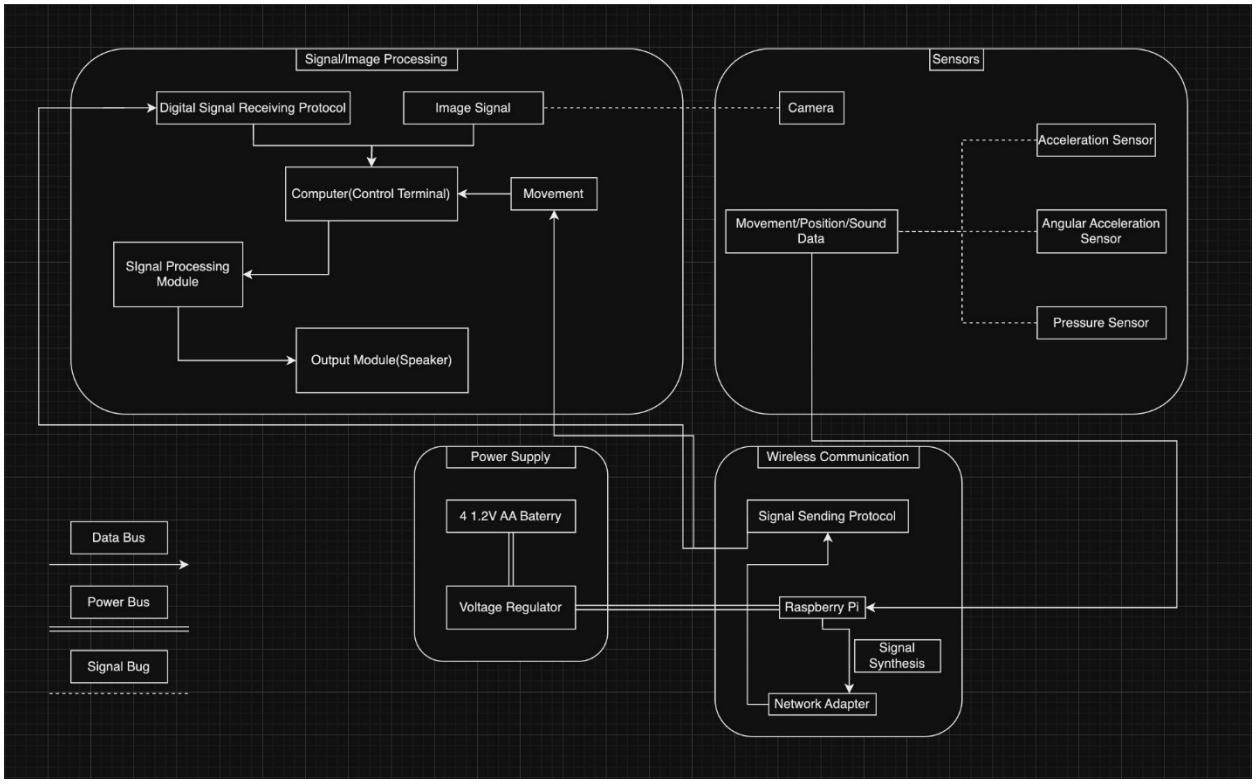
The virtual Band project objectives include three main objectives. The first goal is to create a portable instrument interface that can mimic a variety of instruments so that players can perform anytime, anywhere. Second, add a special feature that allows two hands to play two instruments at the same time, increasing the expressiveness and originality of the music. The ultimate goal of the project is to investigate how the system's ability to detect hand movement and stress sensitivity can be used to diagnose Parkinson's disease. If the team hits its target, the project will showcase software and hardware innovations such as seamless audio processing, compact and user-friendly sensor integration, and real-time instrument recognition algorithms. It may also make a significant contribution to the diagnosis of Parkinson's disease through new methods of motion tracking. If these goals are met, virtual bands will be recognized as cutting-edge and important instruments in the field of music technology and medical innovation.

1.2. High-Level Requirements List

- We can play piano music with the final project product.
- We can switch piano into another instrument and play music.
- Find the solution of combining the system's ability of detecting hand movement and stress sensitivity with diagnosing Parkinson's disease.

2. Design

2.1. Block Diagram



2.2. Block Description

2.2.1. Power Supply Module:

The power supply module is the power supply source of the modeling module, computer, Raspberry PI and virtual band gloves for our virtual band model,It is divided into two main components: voltage regulator and battery.

2.2.1.1. Voltage regulator:

It ensures that the connected devices receive a consistent and reliable power supply, protecting them from potential damage due to overvoltage or undervoltage situations.

Requirement 1: The voltage regulator must maintain a stable output voltage within a specified range, typically around 5 volts, to ensure consistent operation of the connected devices.

2.2.1.2. Battery: Power for our portable gloves.

Requirement 1: Standard 4 1.2V AA Battery

2.2.2. Signal Processing Module:

The signal Processing Module acts as our terminal processing module which contains multiple features. It contains a Digital Signal Processing Protocol used to receive and process electrical signals from external modules, and a terminal computer used to model virtual keyboard, and adjust the output of timbre and volume according to the incoming electrical signal.

2.2.2.1. Digital Signal Processing Protocol:

C/python programming task, performing as a UDP-like receiving Protocol

Requirement1: Implement efficient algorithms and techniques (a UDP-like protocol)for receiving and decoding electrical signals with minimal delay and processing overhead.

2.2.2.2. Terminal Computer:

Analyze and provide audio output capabilities to produce synthesized sounds based on the processed electrical signals, allowing users to hear the music generated by the virtual band model. The keyboard key position is modeled by computer based on the camera position

2.2.3. Sensor Module:

The sensor Module includes Acceleration Sensor, Angular Acceleration Sensor, Pressure Sensor and a camera. They are used to detect the position information of virtual keyboard gloves and the pressure when virtually pressing keys. The camera is also included to capture more accurate information.

2.2.3.1. 6DOF Sensors:

Translational and angular sensors are chosen to be GY-521 PU6050, which detects the translational and angular motion of the fingers and hands. Data collected by sensors will be sent to Raspberry PI and then computer for signal processing through WIFI.

Requirement 1: The sensors must be able to detects the translational motion with a precision of 1mm and angular motion with a precision of 1°.

2.2.3.2. Pressure Sensors:

Pressure sensors are chosen to be FSR 402, which detects the press of fingers with the help of camera.

Requirement 1: Pressure sensors' dimensions should be within 1 cm^2. In the meanwhile, the sensors should be flexible which allows appropriate attachment to the fingers.

Requirement 2: Pressure sensor should be able to detects force ranging from 1-20N.

2.2.4. Wireless Communication Module:

Communication Module contains Signal Sending Protocol, Rasberry Pi and a Network Adapter. The raspberry Pi is used for wireless communication between virtual band gloves and terminal computer by the signal sending protocol.

2.2.4.1. Signal Sending Protocol:

C/python programming task, performing as a UDP like Sending Protocol

Requirement1: Ensure reliable delivery of data packets, even in the presence of network disturbances or interference. Requirement2: Minimize delay in data transmission to provide real-time interaction between the gloves and the terminal computer, no greater than 25ms

2.2.4.2. Rasberry Pi:

It provides the necessary computing power and interfaces to facilitate communication between the virtual band gloves and the terminal computer.

Requirement1: Sufficient computational capabilities to handle the signal processing and communication tasks including data transfer for 3-freedom-degrees acceleration sensor

Requirement2: Support for wireless connectivity protocols such as Wi-Fi or Bluetooth to communicate with the virtual band gloves, with a bandwidth approximately 70kb/s.

2.2.5. Network Adapter 2.4 GHz and 5.0 GHz IEEE 802.11ac Wireless, Bluetooth 5.0, BLE

Requirement 1: Sufficient range to establish and maintain connections over the desired distance between the Raspberry Pi and the terminal computer.

2.3. Risk Analysis

The most challenging aspect lies in Requirement III: finding a solution to combine the system's ability to detect hand movement and stress sensitivity with diagnosing Parkinson's disease. This requirement introduces complexity and potential risks due to the need for accurate and reliable detection of Parkinson's disease symptoms based on hand movement and stress sensitivity data. Parkinson's disease diagnosis typically involves clinical assessment by healthcare professionals, and translating this into a technological solution requires careful consideration of various factors such as sensor accuracy, data analysis algorithms, and medical validation. The acceptable tolerance for this component would involve ensuring that the system can provide reliable and clinically relevant information for Parkinson's disease diagnosis, while minimizing false

positives and false negatives. Relating back to the high-level requirements, this component aligns with the overarching goal of using technology to improve healthcare outcomes by leveraging the system's capabilities for hand movement and stress sensitivity detection to aid in Parkinson's disease diagnosis.

3. Ethics and Safety

3.1. Ethics

In developing the Virtual Band Model Project, our team is committed to adhering to the highest ethical standards as outlined by the IEEE/ACM Code of Ethics. We recognize the importance of ethical responsibility in the development and implementation of our technology, particularly given its innovative integration of hardware and software components to create a virtual musical experience.

3.1.1. Professional Responsibility

We commit to making decisions and taking actions that are in the best interests of society, public safety, and the environment. This involves ensuring that our power supply module, signal processing module, sensor module, and wireless communication module are designed and tested to prevent harm. For instance, our voltage regulator and battery design considerations prioritize user safety and device reliability, avoiding potential overvoltage or undervoltage situations that could lead to damage or injury.

3.1.2. Quality and Reliability

We pledge to uphold the quality and reliability of our system by rigorously testing our components, such as the GY-521 PU6050 sensors and FSR 402 pressure sensors, to ensure they meet specified requirements for precision and force detection. By doing so, we safeguard against inaccuracies that could affect the user experience or cause unintended harm.

3.1.3. Privacy and Data Protection

Our project incorporates the use of cameras and sensors to detect user movements and interactions. We are committed to protecting the privacy of users by implementing robust data handling and storage protocols. Personal data collected through our system will be anonymized and encrypted to prevent unauthorized access or misuse.

3.1.4. Accessibility and Inclusivity

In line with the IEEE/ACM Code of Ethics, our project aims to be accessible and inclusive, providing a virtual musical experience that can be enjoyed by a wide range of users, including those with disabilities. We will seek to design our virtual band gloves and accompanying software with user-friendly interfaces and adaptive features to accommodate diverse needs.

3.1.5. Transparency and Honest

We will be transparent and honest in our communication about the capabilities, limitations, and ongoing development of our virtual band model. This includes openly discussing any potential risks or uncertainties associated with the use of our technology, as well as our strategies for mitigating such risks.

3.1.6. Compliance with Legal and Ethical Standard

Our project will comply with all applicable laws, regulations, and ethical guidelines, including those related to human and animal testing. Should our project's development process require any form of testing that involves human participants or animals, we will obtain the necessary approvals from Institutional Review Boards (IRB) or Institutional Animal Care and Use Committees (IACUC), respectively.

3.2. Safety

Safety is paramount in any project, and the virtual band model is no exception. Various safety concerns need to be addressed to ensure the well-being of both project developers and end users:

Electrical Safety:

- Implement measures to prevent electrical shocks, such as using insulated cables, ensuring proper grounding, and enclosing high-voltage components.
- Clearly label areas with electrical hazards and restrict access to unauthorized personnel.
- Incorporate circuit protection devices like fuses and circuit breakers to prevent overloads.

Mechanical Safety:

- Ensure that all mechanical components, including moving parts and sensors, are properly designed and securely fastened to prevent accidents or injuries.
- Conduct regular inspections of mechanical components to identify and address any wear or damage that may compromise safety.

Lab Safety:

- Establish clear guidelines for laboratory use, including the proper handling of equipment, tools, and materials.
- Provide personal protective equipment (PPE) such as gloves and safety goggles where necessary.
- Clearly mark emergency exits and ensure that fire extinguishers and first aid kits are easily accessible.