Haptic Feedback for Stroke Rehabilitation in Virtual Environment

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Abstract

This project combines **Virtual Reality (VR) applications** with **haptic feedback systems** to enhance stroke rehabilitation through interactive therapy. Using the Meta Quest 2 VR headset, patients engage in games designed to simulate real-life exercises using hand glove with varying difficulty levels. The system employs an ESP32 microcontroller connected to eight Flex PCBs, each embedded with DRV2605L haptic drivers and ERM motors. These components deliver precise vibration feedback at different intensities (low, medium, high), synchronized with in-game activities.

Fig 1. Final Prototype

Features

- Precise hand tracking with single and multi-point actuator vibration in the virtual environment.
- Actuator intensity control based on various object interactions in the VR environment.
- Interactive therapy with progressive tasks designed to improve cognitive ability.
- Real time interaction between the objects in virtual world with actuators in the real world.

Early Prototype

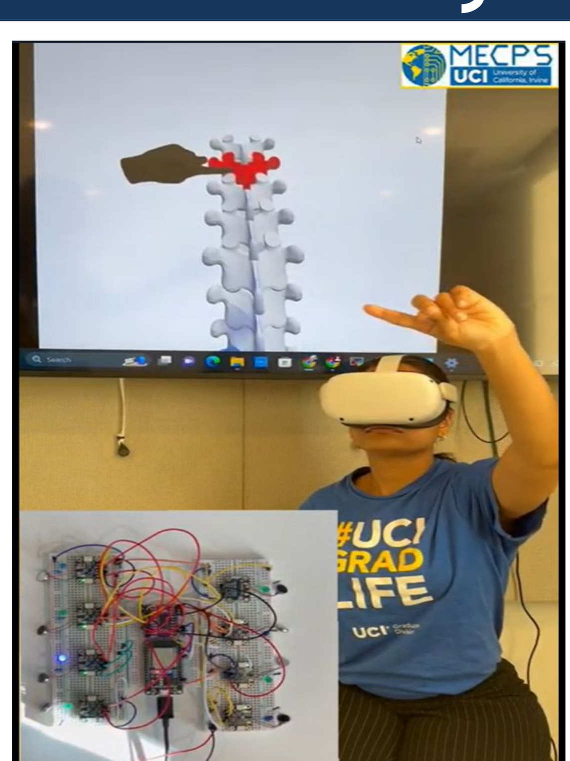


Fig 2. Early Prototype

- Immersive VR application with spine haptic feedback.
- **Early prototype with breadboard connection**: Enables independent vibration of each driver.

System Design & Flow

- The virtual environment is developed using Unity3D and XR Interaction Toolkit with precise joint tracking using XR Hands package.
- Actuator controller consists of
  (a) ESP32 microcontroller, programmed using Arduino IDE
  (b) 3.7V, 450mAh LiPo battery that powers the microcontroller for approximately 2.5 hours,
  (c) 3.7V, 4000mAh LiPo battery supports the entire system of eight Flex PCBs for up to 2 hours when all motors are active.
- Each of eight Flex PCBs house 8 DRV2605L haptic drivers and 8 ERM motors (total of 64 motors), delivering realistic touch sensations with adjustable intensities.

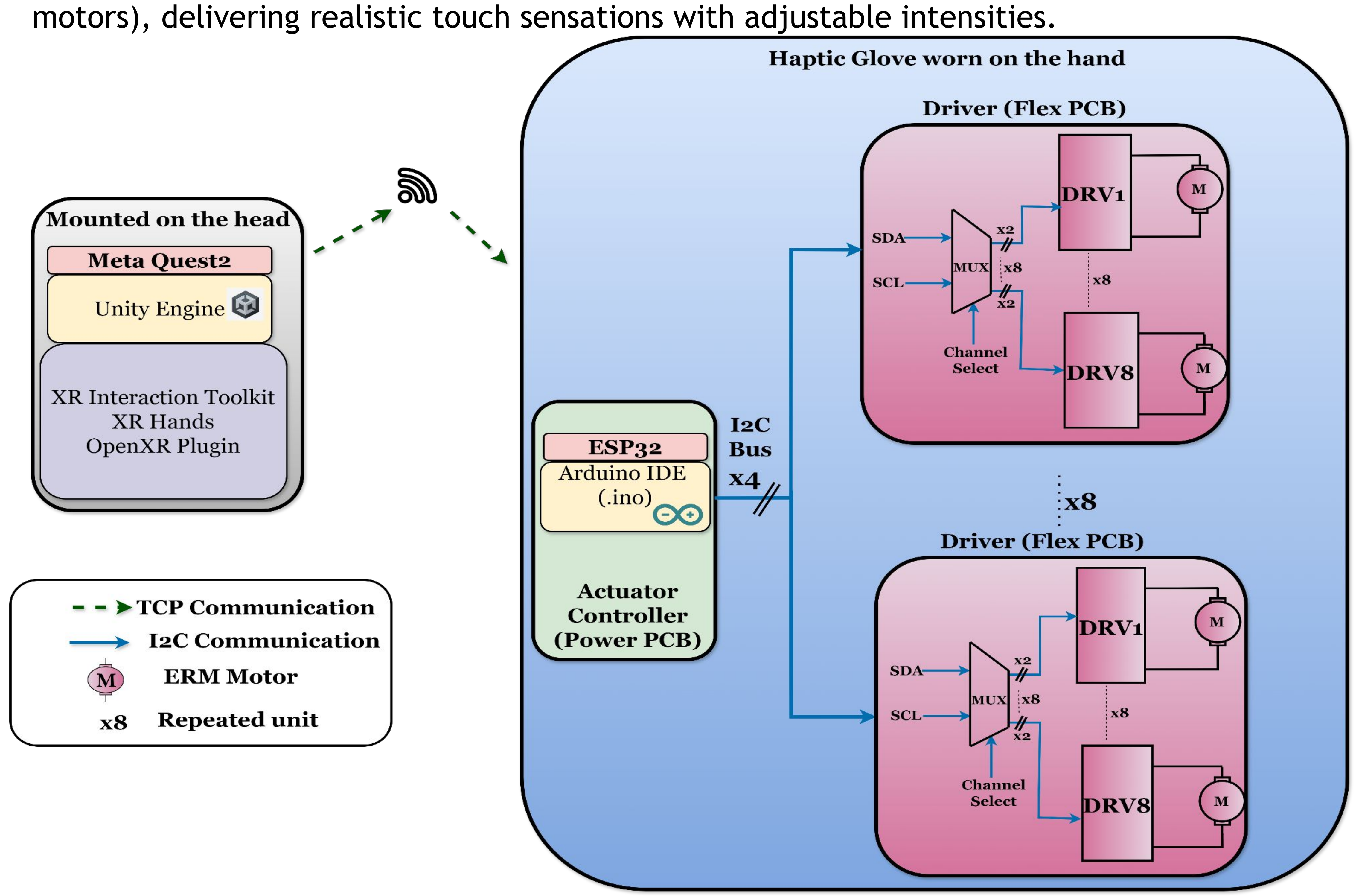
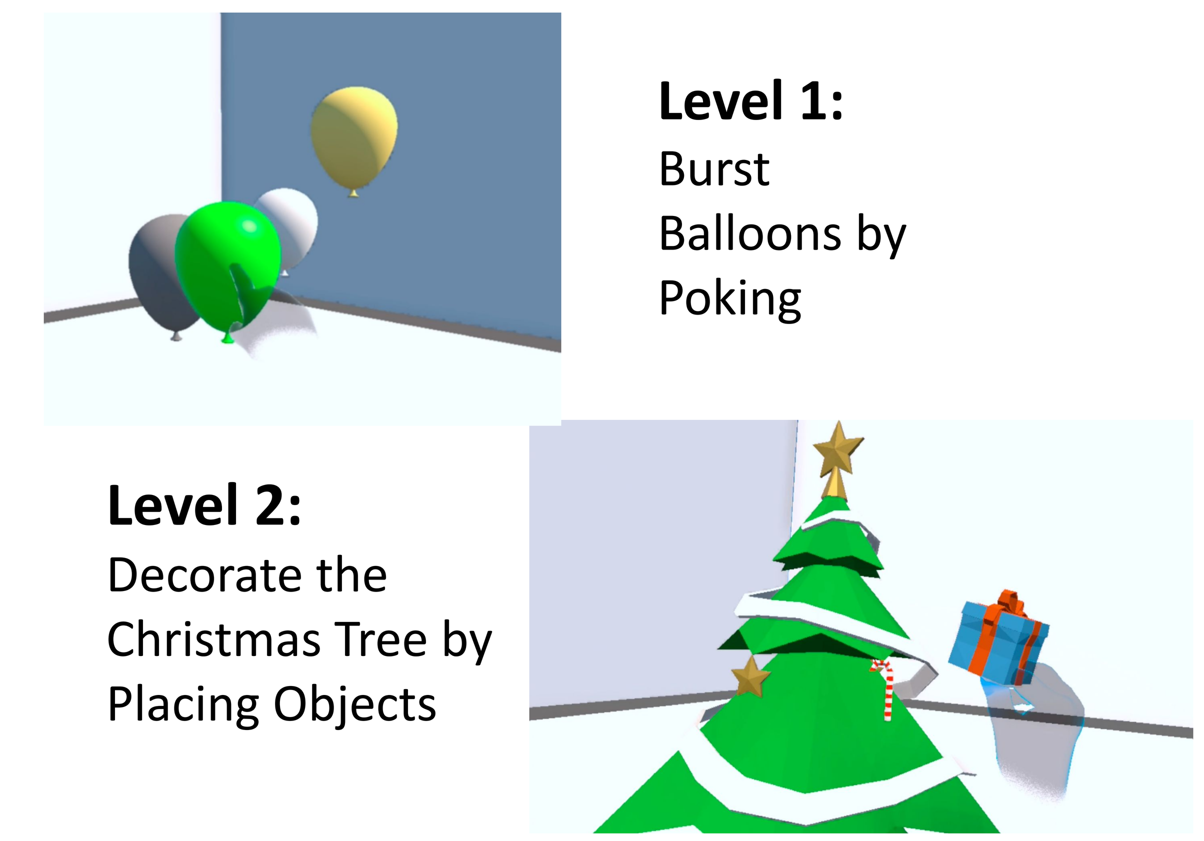


Fig 3. System Design

- **VR Interaction**: User hand-tracking in the VR environment maps object interactions to specific actuator coordinates, sending data to ESP32 through TCP communication.
- **VR-to-Hardware Communication**: The actuator controller processes coordinate and intensity data to determine which ERM motors to activate with their vibration strength.
- **Hardware Feedback**: Drivers activate ERM motors, delivering precise real-time haptic feedback based on mapped intensity patterns.

Results



Level 1:
Burst Balloons by Poking

Level 2:
Decorate the Christmas Tree by Placing Objects

Fig 4. VR Game Console

Fig 5. Driver Flex PCB connected to Power PCB

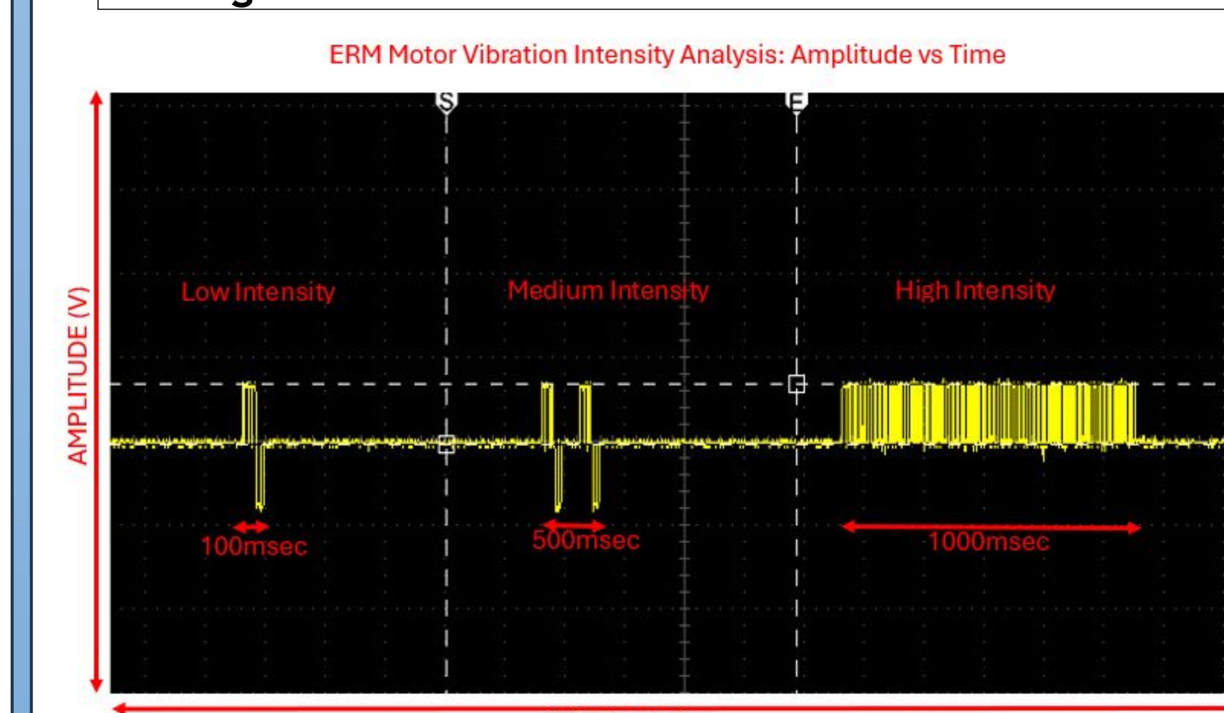


Fig 6. ERM motor3 vibration levels

Future Scope

- Single chip integration for multiple actuators.
- Battery optimization for long run.
- Bluetooth integration for Internet-free communication.
- Cloud-based game performance analysis for medical feedback.
- Multi-user connectivity for collaborative virtual environment.

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