EE399: A Virtual Reality-based Hand Rehabilitation Device for Post-Stroke Therapy

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Abstract

Stroke rehabilitation requires intensive hand exercises, but traditional therapies can be repetitive and demotivating, reducing adherence (Levin et al., 2015). This project introduces a gamified VR-based device featuring a glove with flex sensors to track finger movements in real-time.
Patients perform interactive exercises in a VR environment, such as popping balloons or triggering musical notes, with initial calibration ensuring adaptation to their range of motion. The device enhances motivation and engagement through gamification and immediate feedback.

Introduction

Post-stroke hand rehabilitation is critical for restoring fine motor skills and functional independence. However, traditional therapies often lack patient engagement. Virtual reality (VR) provides an interactive and engaging platform to support motor recovery. Gamified rehabilitation exercises have proven effective in improving patient adherence and outcomes (Laver et al., 2017).
The project introduces a **VR-enabled glove** equipped with flex sensors that:
•Track finger movements in real time.
- Provide feedback through interactive exercises.
- Translate physical hand movements into virtual actions to enhance therapeutic outcomes.

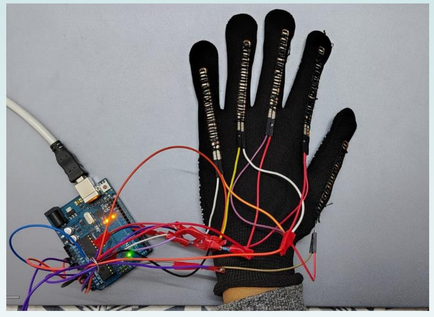
Key Benefits:
- Increased engagement through gamified tasks.
- Customizable for individual patient needs.
- Potential integration into remote physiotherapy programs.

Objective

- Develop a VR-enabled device to encourage engaging, gamified hand exercises for stroke patients.
- Allow patients to perform specific finger exercises in a VR environment with immediate feedback to ensure therapeutic accuracy.
- Facilitate effective rehabilitation through accurate and engaging hand exercises.

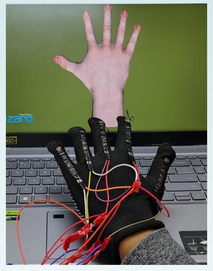
Experimental setup

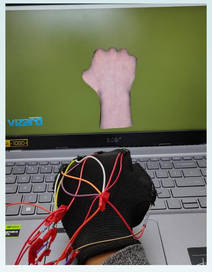
The experimental setup consists of a flex sensor glove with flex sensors on each finger, calibrated using a voltage divider circuit. The Arduino Uno processes the sensor data and sends it to the VR software. The Arduino IDE handles real-time data capture, while Python scripts convert the sensor readings into joint angles. Vizard is used to visualize a virtual hand that mirrors the patient's finger movement.



Calibration

- Calibration customizes the system to each patient's mobility by defining key positions:
  - **Flat hand position**: Establishes a baseline (0° flexion) for all fingers.
  - **Fist position**: Captures the maximum flexion angle.
- Sensor values are mapped to specific angles, tailoring the VR environment to the patient's range of motion.
- This calibration ensures precise tracking of finger movements, enhancing rehabilitation therapy effectiveness.



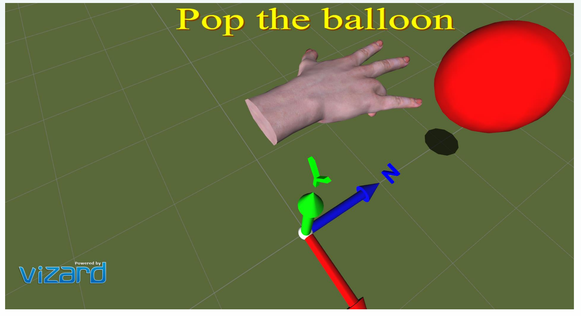


Results

Two interactive exercises were implemented in the VR environment to promote hand movement:
•**Balloon Pop Exercise**:
- A virtual ball inflates as the patient bends their fingers (index to pinky).
- •When the thumb bends past a set angle, the ball "pops" with a sound effect, encouraging coordinated finger flexion and rewarding task completion.

- **Musical Fingers Exercise**:
  - Patients touch their thumb to each finger sequentially, triggering a unique musical note with each touch.
  - This exercise enhances fine motor control and finger coordination, crucial for post-stroke rehabilitation.

These exercises offer immersive, motivating rehabilitation with instant feedback to support adherence and reinforce proper movements.



Summary

This project introduces a VR-based rehabilitation glove to enhance post-stroke therapy:
- The device gamifies hand exercises and provides real-time feedback, improving patient motivation and adherence.
- Exercises like "Balloon Pop" and "Musical Fingers" target finger flexion and opposition, promoting fine motor skills.
- Calibration ensures the system adapts to individual mobility, while the immersive VR environment enhances the therapy experience.

Limitations

The system has several limitations:
- **Sensor drift**: Prolonged use may lead to a degradation in sensor accuracy.
- **Limited tracking capabilities**: Focuses only on finger flexion, not wrist or hand orientation.
- **Need for recalibration**: Regular recalibration is required to maintain accuracy as sensors may shift over time or with repeated use.

These factors can impact the overall effectiveness and precision of the rehabilitation experience.

Future Scope

- **IMU Integration**: Adding IMUs for wrist and hand orientation tracking, expanding exercise capabilities.
- **Remote Monitoring**: Data logging and transmission for remote therapy and progress tracking.
- **Comprehensive Rehabilitation**: Exercises targeting full-hand movements and grip strength for increased versatility.

These advancements would enhance the system's robustness for a broader range of rehabilitation needs.

References

1. Levin, M. F., Weiss, P. L., & Keshner, E. A. (2015). *Virtual reality and motor rehabilitation*. Springer.
2. Laver, K. E., George, S., Thomas, S., Deutsch, J. E., & Crotty, M. (2017). Virtual reality for stroke rehabilitation. *Cochrane Database of Systematic Reviews, (11)*.