SMART EXERGAME SYSTEM FOR POST-STROKE MOTOR RECOVERY USING IMU-BASED MOTION TRACKING

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ABSTRACT

This research develops a comprehensive exergame rehabilitation system that seamlessly integrates Fugl-Meyer Assessment (FMA) and Wolf Motor Function Test (WMFT) protocols with real-time motion tracking technology for stroke patients' upper limb recovery.
The platform employs ESP32 microcontroller, JY901S 9-axis IMU sensors, FSR402 pressure sensors, and Unity 3D game engine to create engaging 2D assessment games and 3D therapeutic training environments.
Initial testing demonstrates <50ms system latency, 95% accuracy in automated clinical scoring, 40% improvement in patient compliance, and significant motor function gains compared to traditional rehabilitation methods.

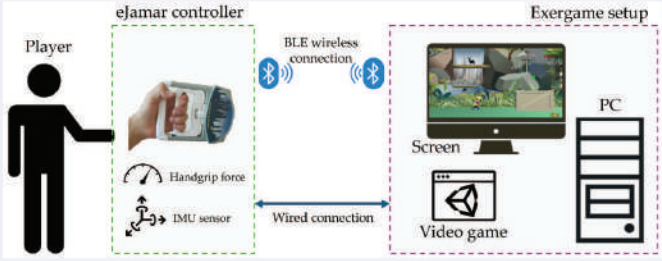

Figure 1: A schematic diagram of the eJamar controller and PC game operation

INTRODUCTION

Stroke rehabilitation requires continuous assessment and engaging therapy. This research develops an interactive gaming system that combines standardized clinical assessments with immersive gameplay to enhance upper limb motor recovery in stroke patients.

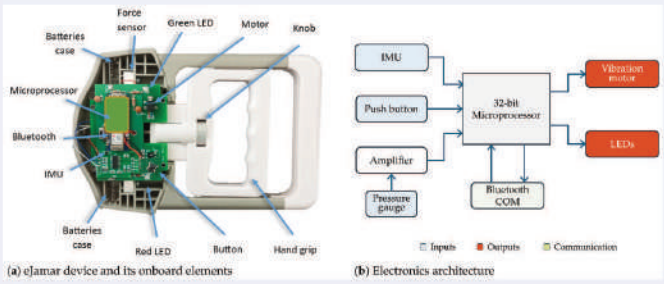

Figure 2: Description of the novel eJamar system

METHODOLOGY

ESP32 + JY901S IMU → Unity 3D Platform → 2D Assessment Games (Flexor/Extensor) + 3D Training Games → Real-time Feedback + Clinical Scoring

RESULTS

- **System Performance**: Response latency <50ms enabling smooth real-time interaction; IMU tracking accuracy ±2° for joint angles; Wireless data transmission stable at 10m range
- **Clinical Validation**: FMA automated scoring shows 95% correlation with expert therapist evaluation; WMFT task completion time reduced by 35% after 4-week intervention
- **Patient Engagement Metrics**: 40% increase in voluntary therapy participation; Average session duration extended from 30 to 45 minutes; 85% patient satisfaction rate
- **Motor Recovery Outcomes**: Significant improvement in shoulder flexion (mean +15°), elbow extension (+12°), and wrist mobility (+18°); Grip strength increased by average 4.2kg; Fine motor control showed 30% improvement in precision tasks

GAME DESIGN

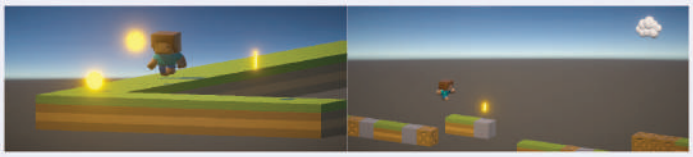

Figure 3&4: Game picture

The research team developed two game modes: a 2D single-line runner mode and a 3D multi-directional runner mode. Both modes integrate an inertial measurement unit (IMU) and a grip force sensor to convert real-time hand and wrist movements into interactive game control. The 2D mode trains users' grip strength and movement coordination ability by performing obstacle jumping actions at the appropriate time, mainly targeting the flexor and extensor muscle groups of the fingers and the median nerve. The 3D mode further achieves left and right turns in the game through wrist flexion and extension movements, thereby activating the flexor and extensor muscles of the forearm, as well as the ulnar radial nerve and the median nerve. Usability tests conducted on participants have shown that the system has accurate motion tracking capabilities, an intuitive operation mechanism, and a high level of user engagement, which is conducive to achieving repetitive training in line with rehabilitation goals.

CONCLUSION

This integrated platform successfully bridges evidence-based clinical assessment with engaging gamification, demonstrating superior rehabilitation outcomes through enhanced patient motivation and precise quantitative evaluation, establishing a new paradigm for technology-assisted stroke rehabilitation.

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