AI-Enabled IoT-Based Hand Rehabilitation System

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Background :

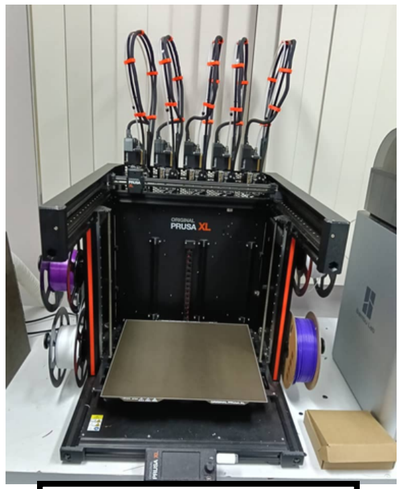
Stroke and neurological disorders limit upper-limb function across ASEAN, calling for AI- and IoT-based home rehabilitation to overcome limited clinical access.

- **Stroke and neurological disorders cause severe upper-limb impairment across ASEAN**
- **Conventional rehab = labour-intensive, expensive, clinic-dependent**
- **Low access in rural / low-resource ASEAN communities**
- **ICT (AI + IoT + AR) enables scalable, personalised, home-based rehabilitation**

Lab facility

Experiments and system development were conducted at the MakersLab, Universiti Teknologi Brunei, equipped with essential tools and instruments.

Prusa XL



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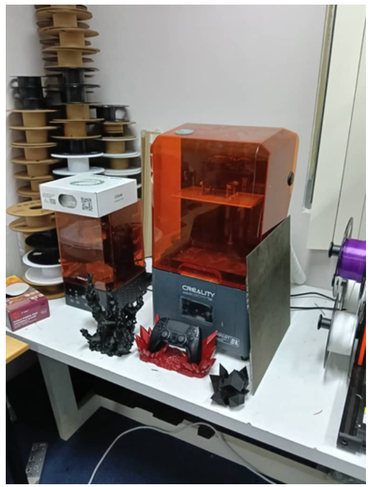
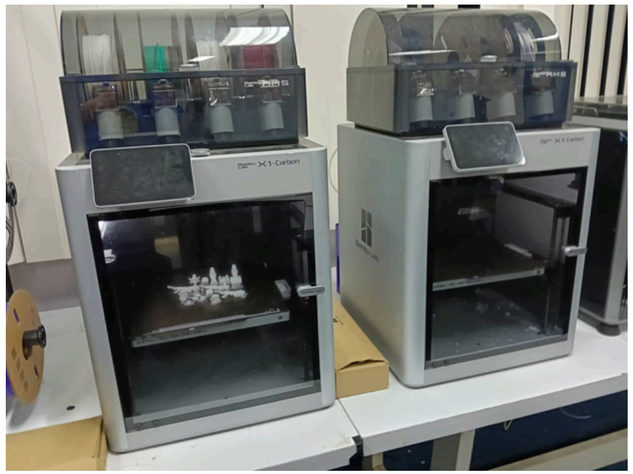
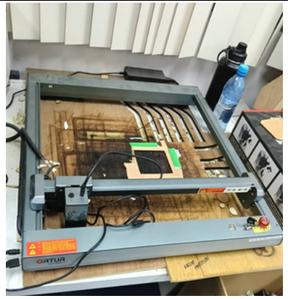


Bambulab X1

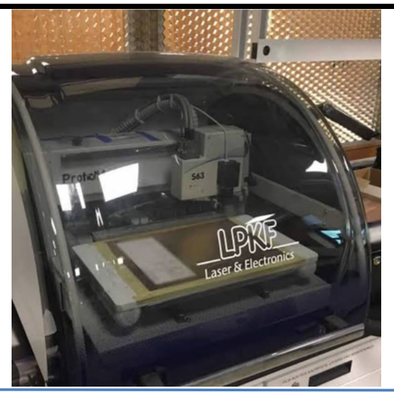


Creality

Laser Engraver



Pcb lpkf machine



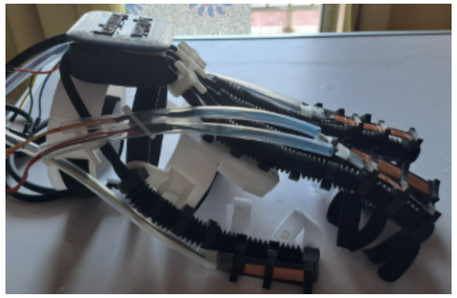
Targets:

- Enable affordable soft hand rehabilitation outside hospitals
- Use AI + IoT + AR to personalise therapy and boost adherence
- Support tele-rehab and remote clinical supervision
- Build a system compatible with ASEAN deployment at scale

System Architecture

Phase 1: System Development

- Built soft 3D-printed exoskeleton with flex + sEMG sensors
- Integrated AI (gesture + recovery), IoT and AR (Unity3D)
- Designed compact antenna for stable wireless data



Unity

Phase 2 — Testing & Validation

- Bench tests on sensor accuracy, AI performance, AR usability, and IoT stability
- Collected user feedback on comfort and motivation

Phase 3 — Outcomes

- Accurate sensing and reliable connectivity achieved
- AI models performed consistently
- AR feedback improved engagement
- Supports scalable home-based rehab for ASEAN communities

Scientific / Technical Method

Data Collection

- EMG and motion datasets were collected from both healthy and post-stroke participants to capture a wide range of movement patterns and muscle signals.

AI Module

- Machine learning models were trained for:
- • Gesture classification – identifying specific hand movements from sensor inputs.
- • Motor recovery trend prediction – estimating user progress over time for personalised therapy.

AR Interface

- Developed using Unity3D, the augmented reality interface overlays therapy tasks and provides real-time biofeedback to enhance engagement and motivation.

IoT Integration

- A closed-loop IoT pipeline continuously monitors sensor data via embedded system and cloud systems, ensuring seamless communication between hardware, AI processing, and AR feedback.

Antenna Design

- A compact, low-power antenna was designed and optimized to enhance wireless data transmission range and reliability, ensuring stable communication for IoT-based rehabilitation even in low-connectivity environments common in some ASEAN regions.

Implementation / Evaluation

Bench and Pilot Testing

- Conducted controlled bench tests to validate sensor accuracy and latency, ensuring reliable detection of finger motion and muscle activity.
- Evaluated AI inference accuracy to confirm that gesture recognition and recovery prediction models perform consistently in real-time use.
- Assessed AR usability and engagement, observing how effectively users interacted with virtual therapy tasks and responded to visual feedback.
- Tested tele-rehabilitation connectivity stability through IoT cloud monitoring to verify smooth data streaming and minimal communication delay.

User Feedback

- Collected usability feedback from both healthy and post-stroke participants, focusing on comfort, ease of use, and motivation during therapy sessions.
- Insights were used to refine exoskeleton ergonomics, AR interface design, and feedback mechanisms to improve overall user experience and compliance.

Impact: Scientific & Technical

- Converges AI + AR + IoT + soft robotics in one rehab platform
- Provides dataset foundation for clinical AI models
- Enables objective, quantified rehab metrics instead of subjective observation

Impact: Societal / ASEAN

- Affordable alternative for B40 and rural communities
- Reduces travel & clinician workload through home-based rehab
- Improves motivation via interactive AR feedback
- Enables remote therapist oversight across ASEAN borders

Impact: Collaboration

- Cross-discipline bridge (Robotics + AI + Rehabilitation + AR)
- Platform suitable for joint ASEAN research & telehealth pilots
- Expandable to upper-limb beyond hand

Outcome

- Working prototype with AI-enabled sensor integration
- Initial EMG + motion dataset established
- AR rehab interface and IoT dashboard functioning
- Basis for clinical validation and technology transfer

Conclusion

- Target: democratize stroke rehabilitation in ASEAN
- Method: AI-enabled IoT-integrated soft exoskeleton with AR feedback
- Impact: lowers cost, extends access, increases adherence, enables remote therapy
- Next: AI adaptation, clinical trials, ASEAN-wide telehealth deployment