Artificial Intelligence based Control of Lower Limb Rehabilitation Device for Elderly People

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OUTLINE

- Background
- Target
- Method
- Result
- Conclusion

Past Research

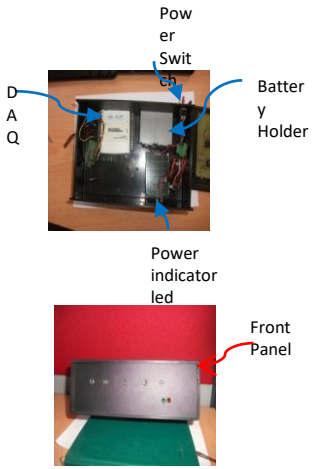
- Ankle rehab

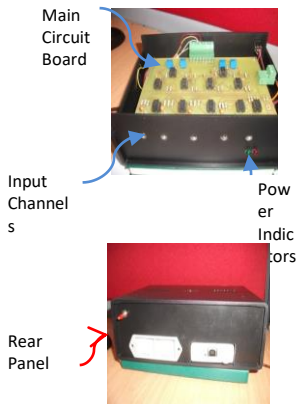
Current Research

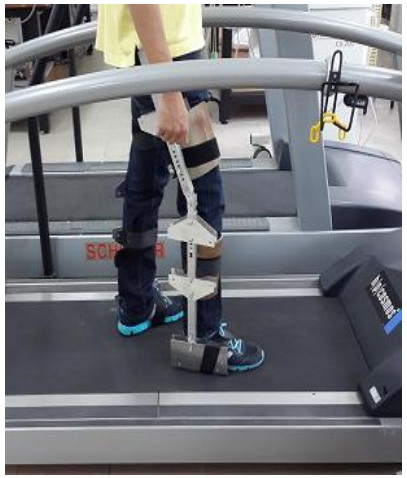
- Knee Rehab

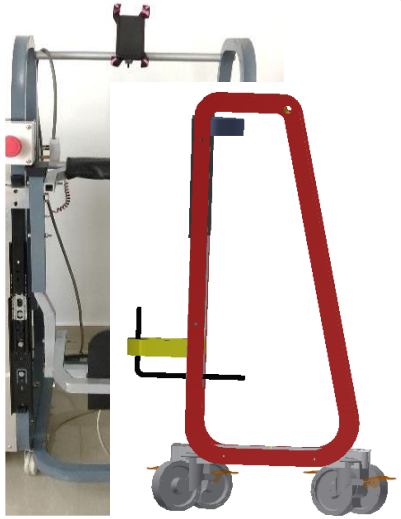
Future Research

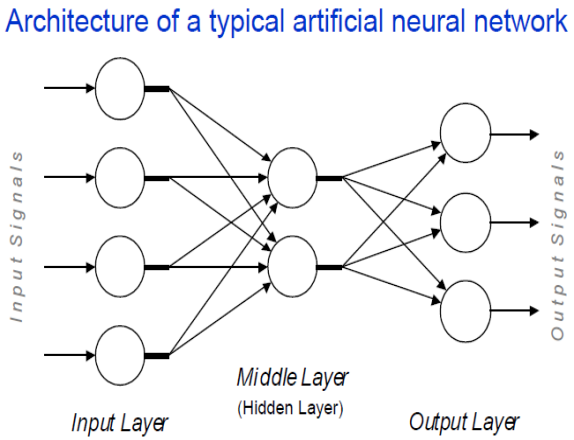
- Ankle + Knee Rehab + AI_EMG based control







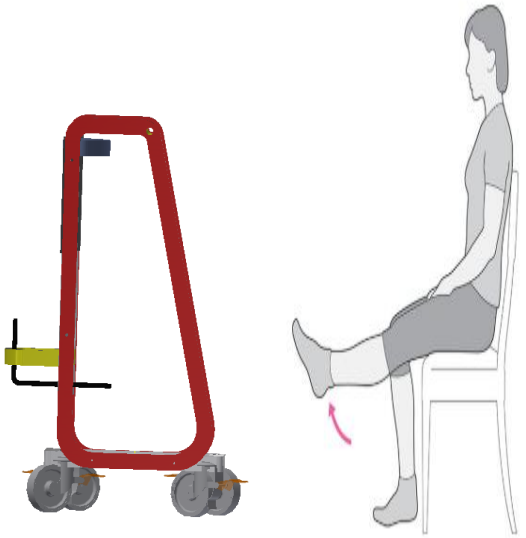




dorsiflexion, plantar flexion, adduction and abduction

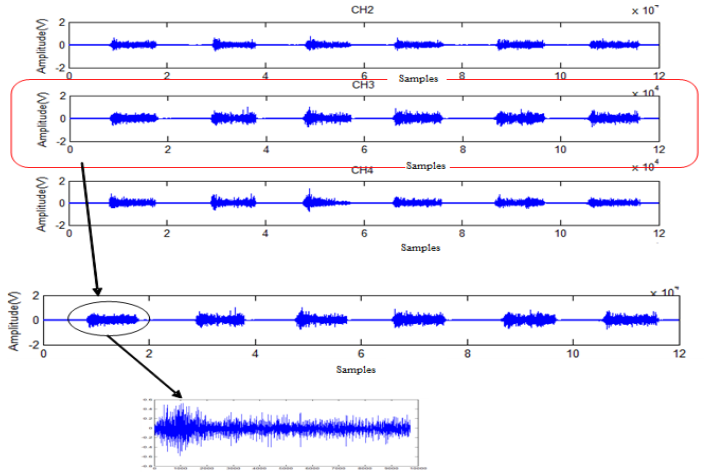
Background

- In Malaysia, the percentage of the elderly population, aged 65 and over (old age) increased from 7.0 per cent in 2020 to 7.4 per cent in 2021.
- Elderly population have problem in neurological disorders and chronic diseases.
- Knee pain caused by traffic incidents, osteoarthritis, and Anterior Cruciate Ligament (ACL) strain or tear.
- Nonsurgical treatment such as physiotherapy or exercise are first recommended to knee osteoarthritis patients before opting for knee replacement surgery.
- Often, joint stiffness and decreased knee Range of Motion (ROM) have been reported following surgeries such as Total Knee Replacement and ACL reconstructions
- Therefore, ROM exercise is crucial in treating knee osteoarthritis, relieving stiffness after surgery, restoring ROM and improving muscle strength of patients.



Target

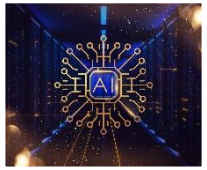
Develop an intelligence control of knee rehabilitation device for improving ROM and muscle strength of patients



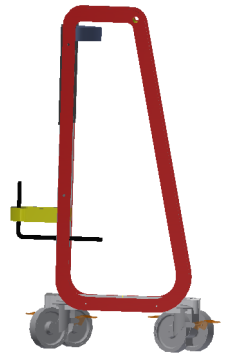
Objectives:

To investigate an EMG based and force control for analyzing human disabilities and observe the improvement of the rehabilitation processes

To develop a rehabilitation device: model simulation , fabrication

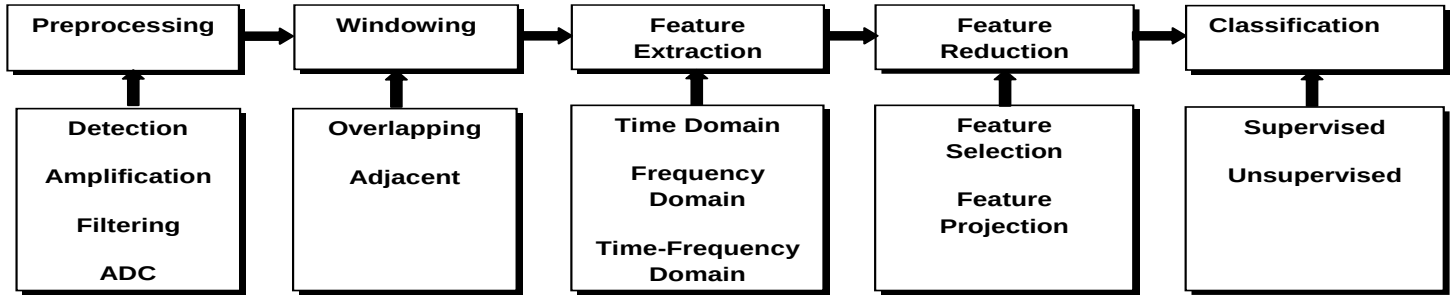


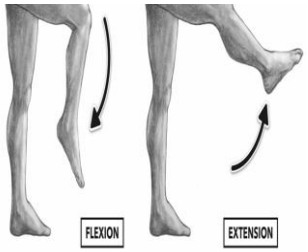
To design an effective control using intelligent method for identify the unique EMG pattern and force pattern

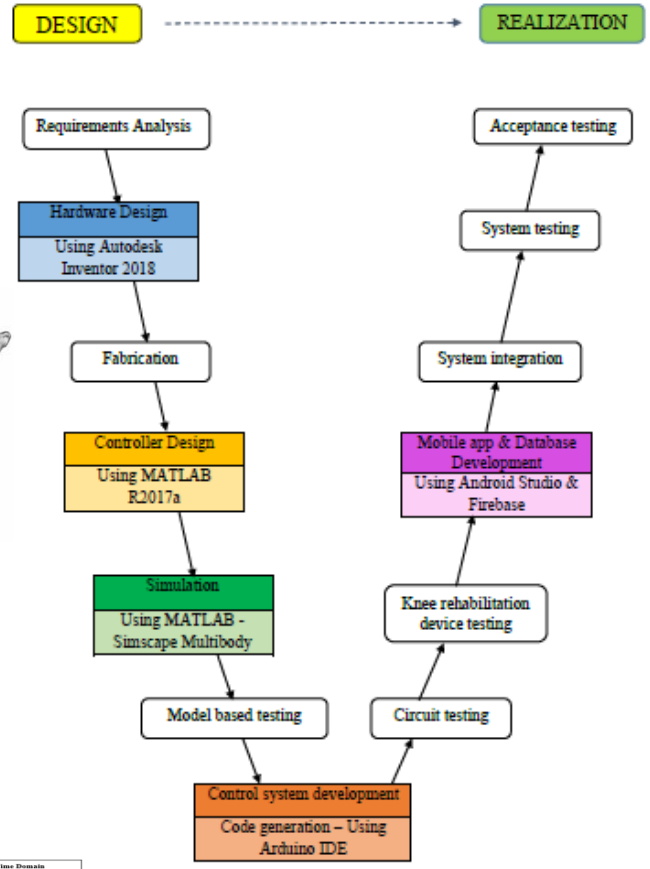


Methodology

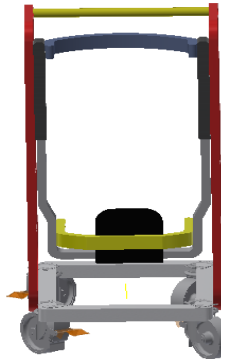
1 Stage 1: Data collections and characteristic of neurological disorder; EMG & force signal





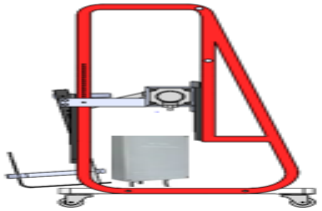


2 Stage 2: Model Simulation & Fabrication



No sharp edges
Moderate weight
Ergonomic
BLDC with sufficient torque
Strong casing of BLDC

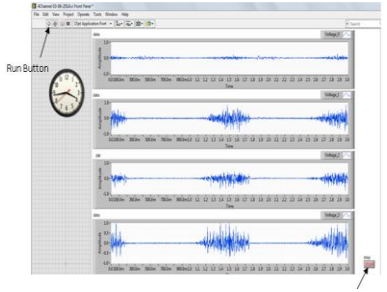
Knee Rehabilitation Device



Control System

- Accurate stimulation signal
- Record patients' progress
- Select suitable exercise mode

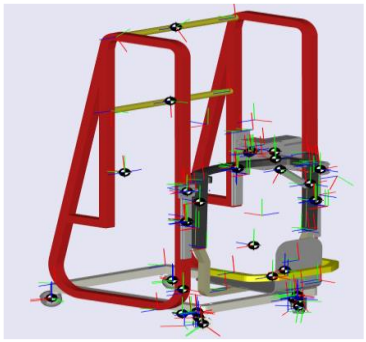
Mobile Phone



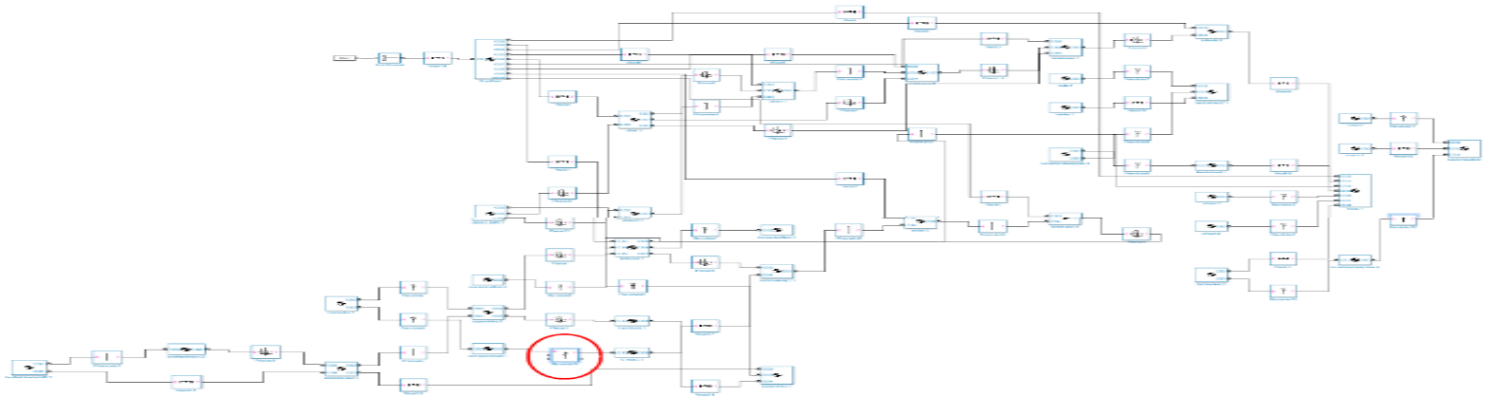
Feature	Traditional Time Domain Features(TTD) algorithm	Logarithmic based Time Domain Features(LTD) algorithm
MAV	$X(\cdot)_{MAV} = \frac{1}{N}\sum_{n=1}^{N}\lvert x(n)\rvert$	$\log(MAV) = \log(X_{MAV})$
RMS	$X(\cdot)_{RMS} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} x_n^2}$	$\log(RMS) = \log(X_{RMS})$
WL	$X(\cdot)_{WL} = \sum_{n=1}^{N}\lvert\Delta x_n\rvert$	$\log(WL) = \log(X_{WL})$
SD	$X(\cdot)_{SD} = \sqrt{\frac{\sum_{n=1}^{N}(x_n - \bar{x})^2}{N-1}}$	$\log(SD) = \log(X_{SD})$

2 Features	3 Features	4 Features
97.0388	97.1966	97.2310
± (4.2)	± (4.76)	± (4.68)

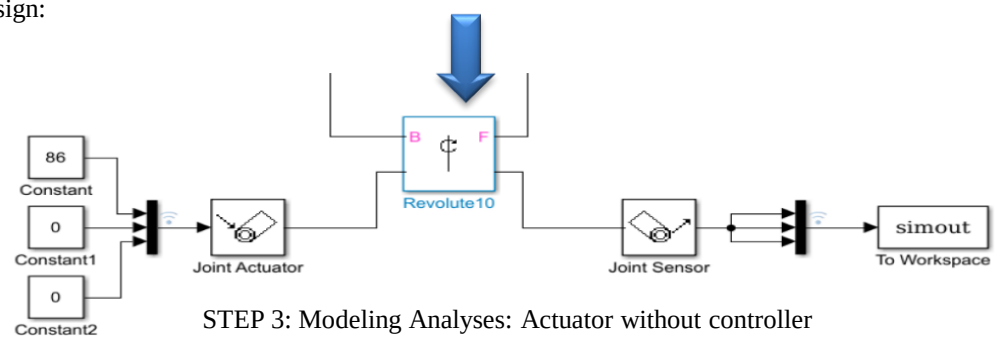
2 Stage 2: Model Simulation & Fabrication



STEP 1: Mechanical design:
AUTOCAD software



STEP 2: Modeling of Knee device:
SimMechanis



STEP 3: Modeling Analyses: Actuator without controller

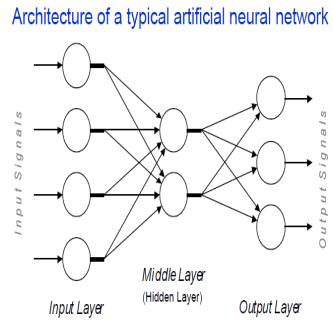
Figure 2. Flow chart of Knee Rehabilitation device Model

Future Work 1

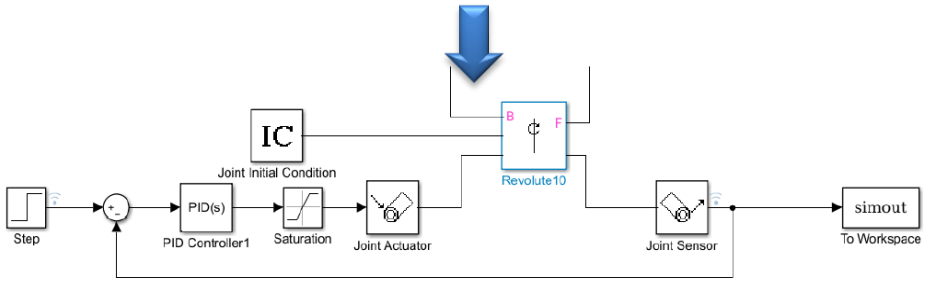
Optimal gains

Future Work 2

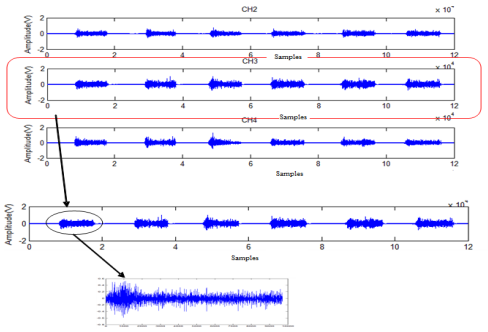
Mapping/ compare the previous EMG signal before training started with the current EMG after first /several training to control motor speed

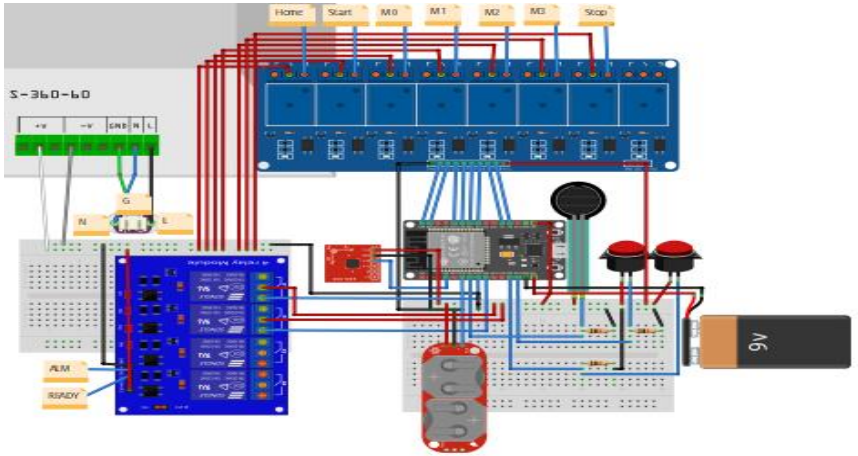


3 Stage 3: Control development- EMG & force control system and intelligent method



STEP 4: Modeling Analyses: Actuator with controller : NN_PID





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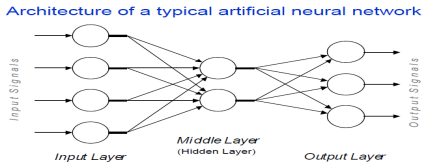
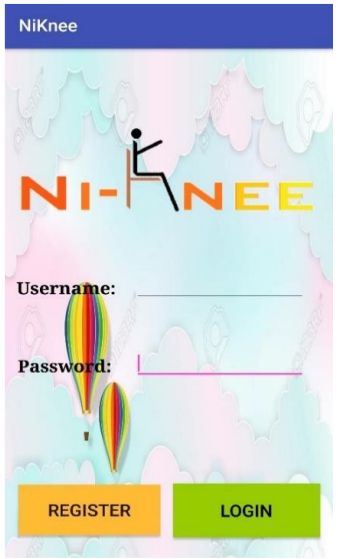


Future Work 3

-Mapping/ compare based on force signal and EMG signal: find the correlation,
-monitoring system based on real-time data

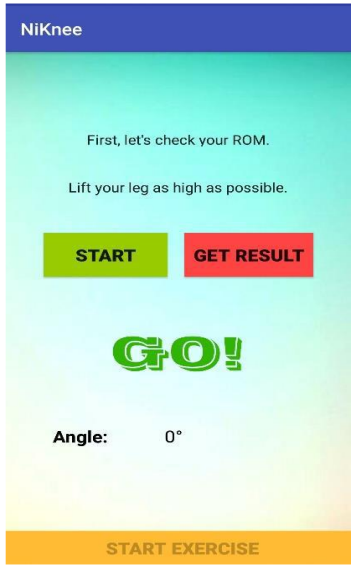
Output

Monitoring System

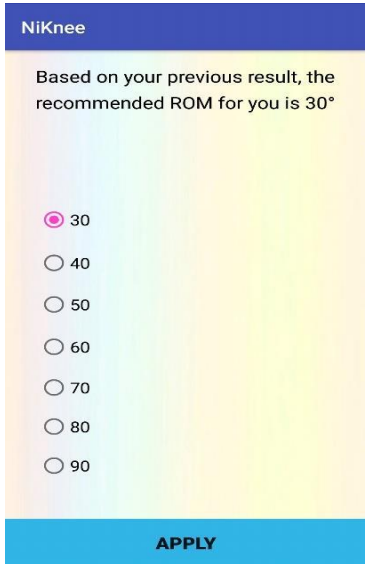


Ni-Knee application – Register/Login

Exercise Mode Selection

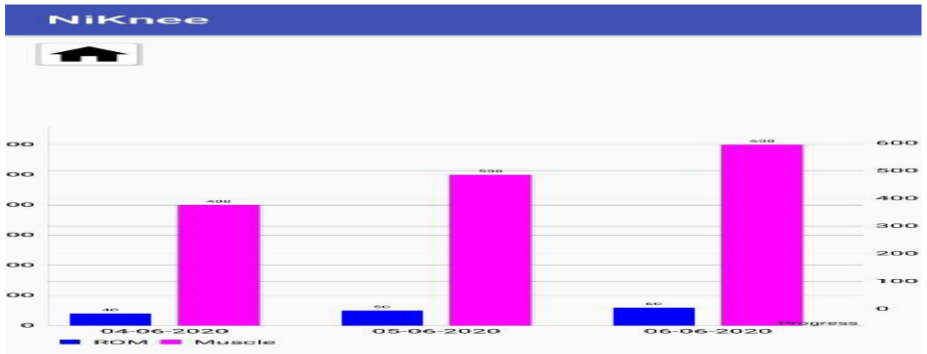


Initial ROM Measurement



Auto

Manual



Progress Bar Chart

Impact

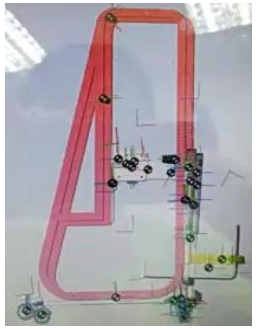
The EMG based control can be implemented on rehabilitaiton devices or therapy machine.

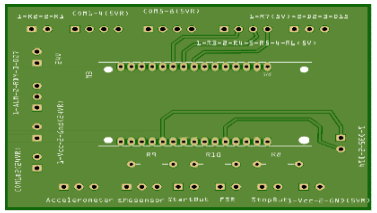
-EMG based control for home knee therapy device

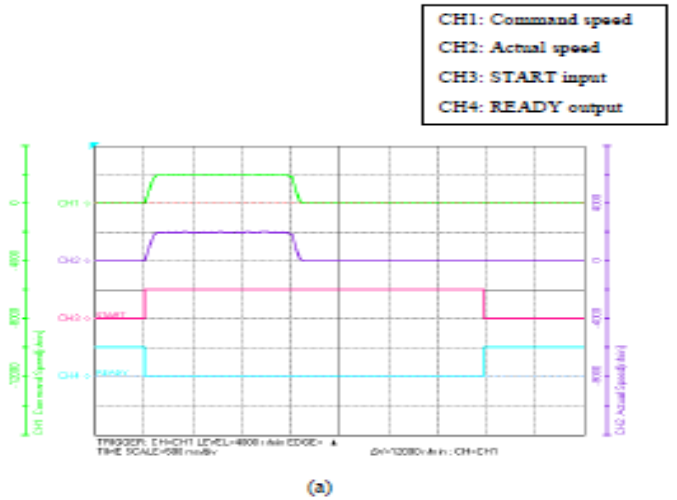
Trainer tool to new therapist and health officer

Open EMG database offering different kinds of lower limb joint motion

Decision making system with AI implementation



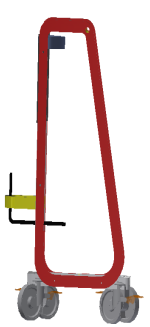


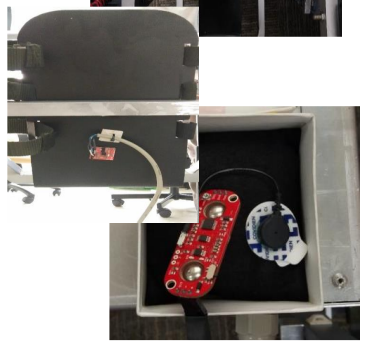


Waveform monitor of motor's actual operation.
(a) 30º position, (b) 0º (Home) position

Conclusion

Current Research Achievement





Knee rehabilitation device was designed and simulated

-Simulation of the flexion and extension movement

Control system was designed and developed for the knee rehabilitation device. Experiments and tests were carried out to validate and analyse the performance of the motor controlled by the mobile app

Knee rehabilitation device was fabricated with the control panel installed at the side of the device

The simulation for the PID controller designed in MATLAB resulted in fast response time, low overshoot and zero error between the set value and the actual value, with a rise time of 0.00744s, settling time of 0.0539s, overshoot of 12% and steady-state error of 0.

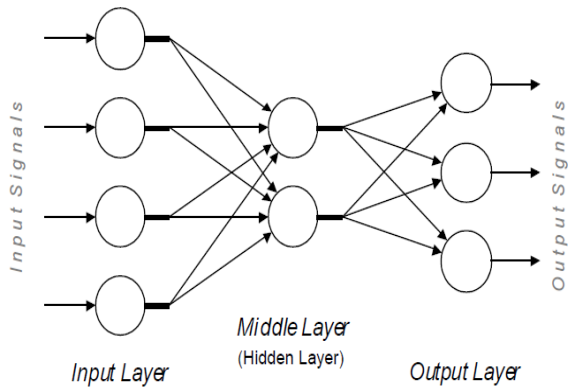
Future improvement

- Future work 1, future work 2 and future work 3

Plans for connected projects

Medical data signal and data analysis
AI based control development
Healthcare monitoring system
Actuator Rehabilitation Applications

Architecture of a typical artificial neural network




Thank you