Impedance Control for Ankle Preparation Phase in BALANSens Platform

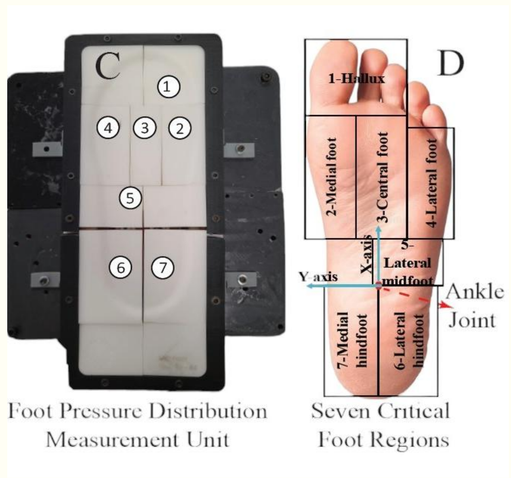
Hafiz Muhammad Bilal[1] Mahmut Beyaz[1] Ramazan Unal[2] Elif Hocaoglu[1*]
[1]Living Robotics Laboratory, Istanbul Medipol University, Electrical and Electronics Engineering, Istanbul, Türkiye.
[2]Human-Centered Design Laboratory, Ozyegin University, Mechanical Engineering, Istanbul, Türkiye
[*]Corresponding author (e-mail: ehocaoglu@medipol.edu.tr)

Introduction

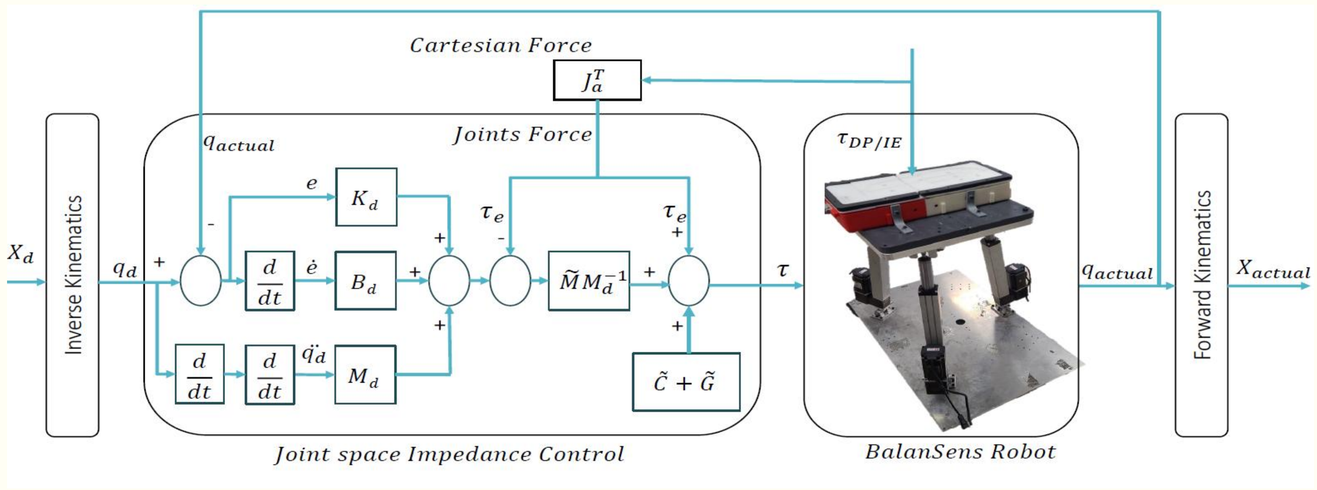
- BALANSens is a 3-DOF parallel robot designed for personalized ankle rehabilitation within the I-BAR framework.
- Ankle injuries affect mobility and balance, requiring extended rehabilitation.
- Impedance control regulates the interaction between the human limb and robotic device, ensuring smooth rehabilitation movements.

Impedance Control

- Seven load cells placed under critical foot regions
- Provides affordable and accurate torque estimation in dorsiflexion-plantarflexion (DP) and inversion-eversion (IE) directions
- Enables tracking of foot pressure distribution for rehabilitation assessment



Foot Pressure Distribution Measurement Unit — Seven Critical Foot Regions

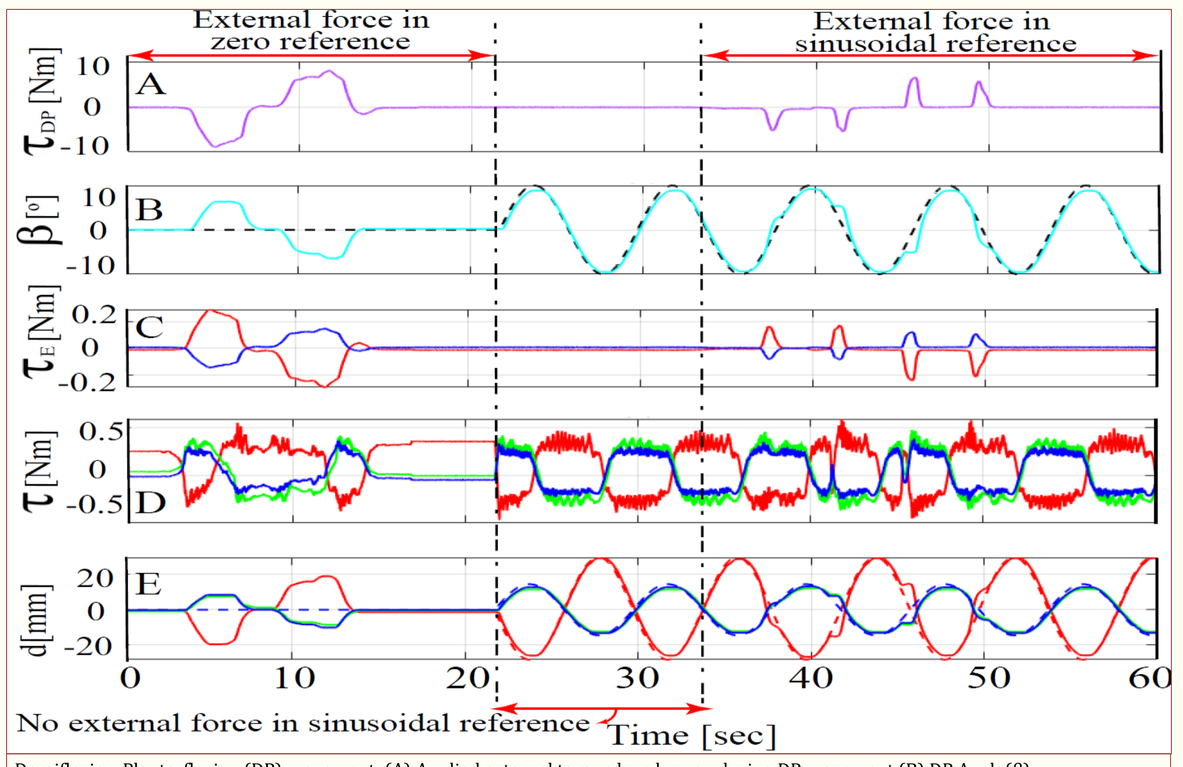


Conclusion

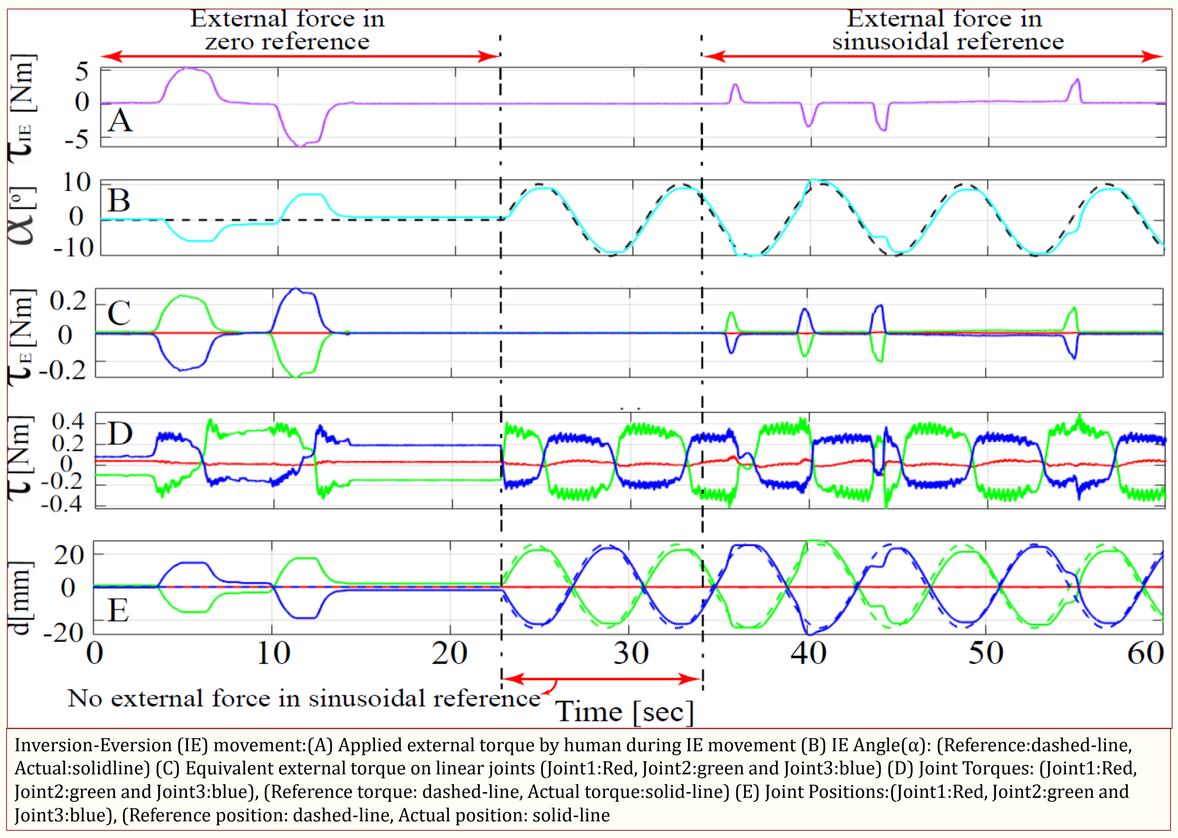
- Impedance control for ankle rehabilitation is successfully implemented.
- Load cell-based force measurement reduces costs while improving data accuracy.
- Experimental results confirm the feasibility and effectiveness of the approach.
- Future work includes real-time compliance adaptation and expansion to full balance rehabilitation.

Implementation and Results

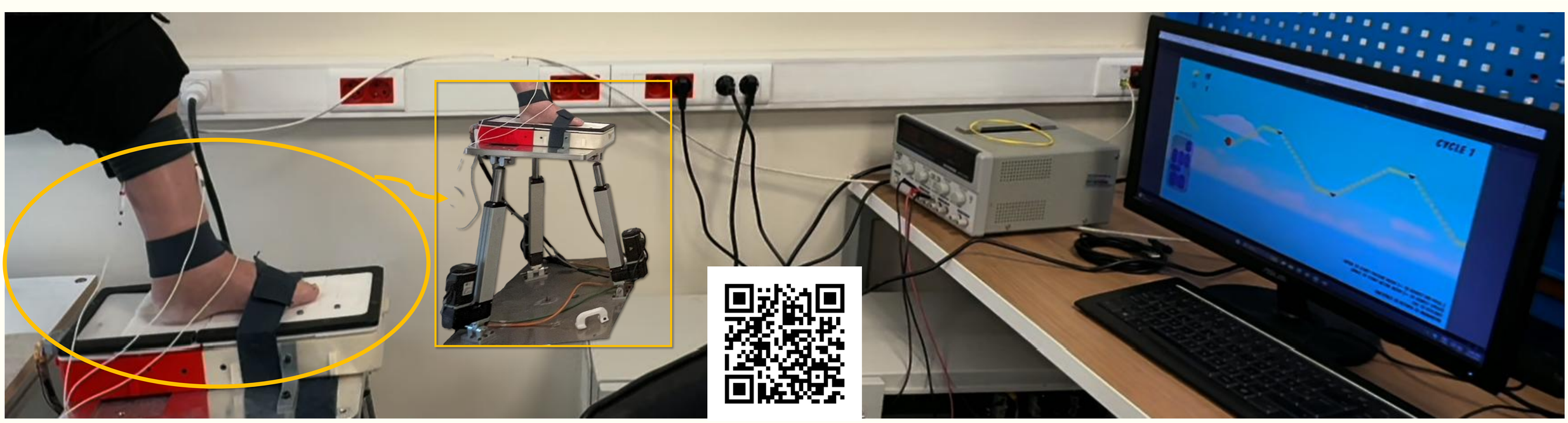
- Experimental Setup and Findings:
  - Subject applied torque in neutral and dynamic conditions
  - Measured response in DP and IE movements.
  - Impedance control achieved desired second-order dynamic response
  - Demonstrated stable tracking of sinusoidal reference under external forces



Dorsiflexion-Plantarflexion (DP) movement: (A) Applied external torque by a human during DP movement (B) DP Angle(β): (Reference:dashedline ,Actual:solid-line) (C) Equivalent external torque on linear joints (Joint1:Red, Joint2:green and Joint3:blue), (green and blue overlapping) (D) JointTorques: (Joint1:Red, Joint2:green and Joint3:blue), (Reference torque: dashed-line, Actual torque:solid-line) (E) Joint Positions: (Joint1:Red, Joint2:green and Joint3:blue), (Reference position: dashed-line, Actual position:solid-line



Inversion-Eversion (IE) movement:(A) Applied external torque by human during IE movement (B) IE Angle(α): (Reference:dashed-line, Actual:solidline) (C) Equivalent external torque on linear joints (Joint1:Red, Joint2:green and Joint3:blue) (D) Joint Torques: (Joint1:Red, Joint2:green and Joint3:blue), (Reference torque: dashed-line, Actual torque:solid-line) (E) Joint Positions:(Joint1:Red, Joint2:green and Joint3:blue), (Reference position: dashed-line, Actual position: solid-line



References

- T. Ersoy and E. Hocaoglu, "A 3-DoF robotic platform for the rehabilitation and assessment of reaction time and balance skills of MS patients," PLoS ONE, vol. 18, p. 0280505, 2023.
- H. Bilal, E. Hocaoglu, R. Unal, and P. Kaya, "An overview of integrated balance rehabilitation (I-BaR) framework," in International Conference on NeuroRehabilitation (ICNR), 2024.

This study was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) under Grant Number 122E246.