Preliminary results of a Multimodal Bidirectional Armband for Sensing and Feedback

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INTRODUCTION

People with upper limb impairments often face challenges in daily activities. Prosthetics can restore functionality and improve quality of life, but many users reject them due to issues with the socket or lack of sensory feedback [1]. Force feedback is important to modulate grip in real time, reducing dependence on visual cues and enhancing motor control. Non-invasive interfaces using wearable haptic feedback devices can improve control and perception, but many existing solutions are bulky or lack customization. Traditional sockets can cause discomfort, sweating, and skin irritation. Recently, adjustable-volume sockets like the Socketless Socket have improved comfort and stability. However, few devices successfully integrate sensing and feedback in a compact and ergonomic design.

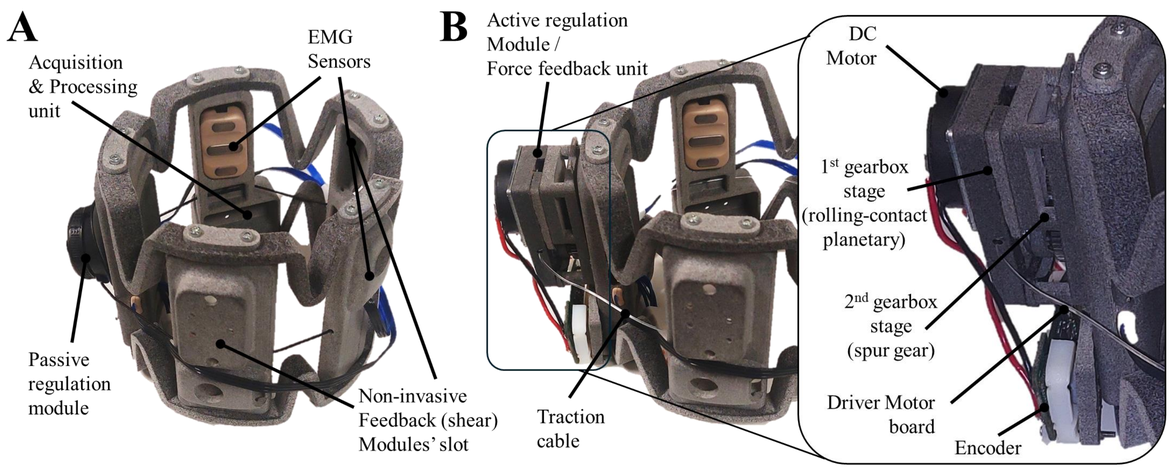
To address these gaps, the **Multimodal Bidirectional Armband for Sensing and Feedback** (MBASF) was developed—a wearable, customizable device combining sEMG sensing and haptic feedback. It was preliminarily validated with the Hannes prosthetic hand and shows potential for integration with adjustable sockets or replacement in osteointegrated users.

This paper presents the following key contributions:

- A bidirectional armband combining sEMG sensing and force feedback in a single wearable device (MBASF).
- MBASF is compatible with adjustable prosthetic sockets or osteointegration and supports multiple types of feedback actuators.
- Demonstrated feasibility and comfort through tests with the Hannes prosthetic hand in upper limb applications.

METHODS

MBASF enables **proportional myoelectric control** of a prosthetic hand and delivers **modality-matched feedback** via a motorized squeezer that tightens around the forearm in response to grip force. It combines rigid (PA12) and flexible (TPU) SLS-printed components, ensuring sensor stability, skin adherence, and user comfort. Up to four Ottobock-like EMG sensors can be positioned flexibly around the arm for optimal signal acquisition. A compact winch mechanism with a DC motor (Faulhaber 2607) and dual-stage gearbox (12.6:1 and 4:1) delivers up to 50 N of tightening force, simulating the natural feel of gripping.



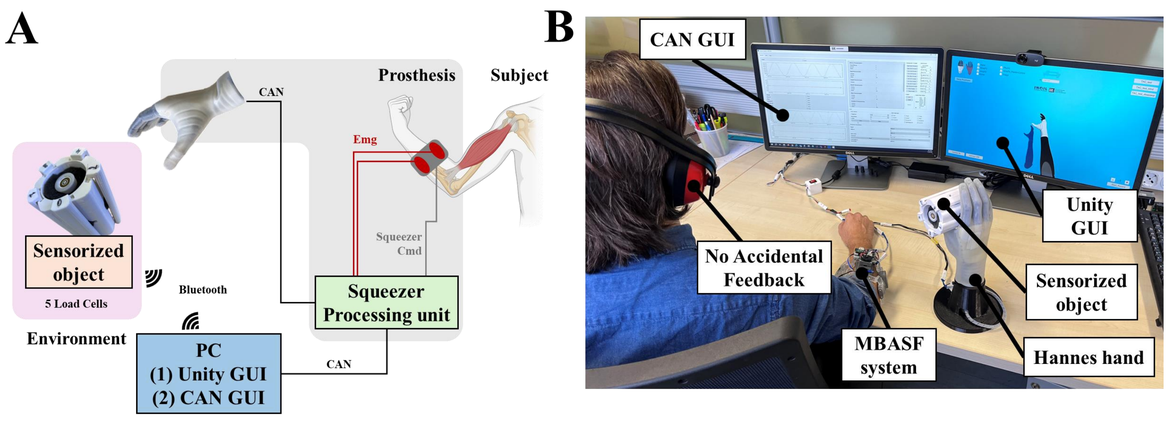
The system uses dual-site proportional control for hand movement and activates the haptic feedback based on motor behavior. When the motor current I_k (related to the grip force) exceeds a threshold and the hand velocity $\dot{x}_k$ (computed from position change) drops below a set threshold $\dot{x}_{th}$, the motorized squeezer tightens accordingly. The control law is:

$$u_k = \begin{cases} \frac{I_k}{I_{max}} \cdot 100, & \dot{x}_k > \dot{x}_{th} \\ 0, & \dot{x}_k \leq \dot{x}_{th} \end{cases}$$

where u_k is the squeezer motor command and I_{max} is the maximum current of the hand motor. This allows intuitive, force-based feedback aligned with the user's grip strength.

EXPERIMENTAL SETUP AND VALIDATION METHODOLOGY

The setup included the MBASF armband, the Hannes prosthetic hand [2], and a custom sensorized object with five load cells to measure grip force. The Hannes hand provides adaptive myoelectric control and up to 150 N of grasp force. The sensorized object streamed grip data to a Unity-based GUI. Ten able-bodied participants and one trans-radial limb different took part in a feasibility study, controlling the prosthesis via EMG signals from the MBASF armband, which also provided haptic feedback.



A.MBASF System Characterization: A sinusoidal input was applied to the squeezer motor, and force was recorded using the sensorized object to verify the force-current relationship.

B. Feedback Efficacy Test: Participants identified object presence based on feedback from the armband across 10 trials, with success rate measuring feedback effectiveness. A System Usability Scale (SUS) questionnaire assessed the amputee user's experience.

C. Sensing Efficacy Test: The test evaluated the effectiveness of the armband EMG sensors during simulated dynamic movements, by verifying the Hannes prosthesis' response Performance was measured by counting EMG signal alterations and calculating the overall success rate of the system.

RESULTS

A. MBASF System Characterization

The armband's constriction force increases exponentially with supply current, ranging from 0 to 900 mA (current) and 0 to 32 N (force). After reaching 32 N (at ~800–900 mA), the current drops to zero (see Figure 3).

B. Feedback Efficacy Test

A 95% success rate was achieved with healthy subjects. The limb-different participant had 1 error in 10 trials (90% success). Figure 4.B illustrates data from one participant, showing the correlation between grip force and motor current. The SUS usability score for the limb-different subject was 87.5/100.

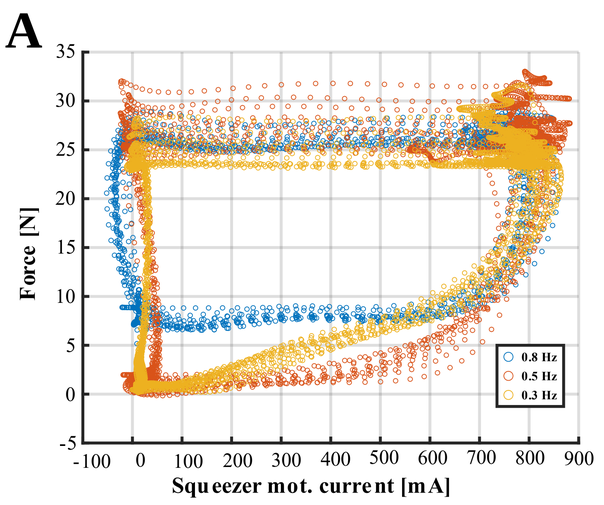


Figure 3 - Validation results for the MBAFS characterization.

C. Sensing Efficacy Test

No EMG signal issues were observed during squeezer operation, with both healthy and limb-different participants, achieving a 100% success rate: EMG signals matched hand closures and openings (see Figure 4.C).

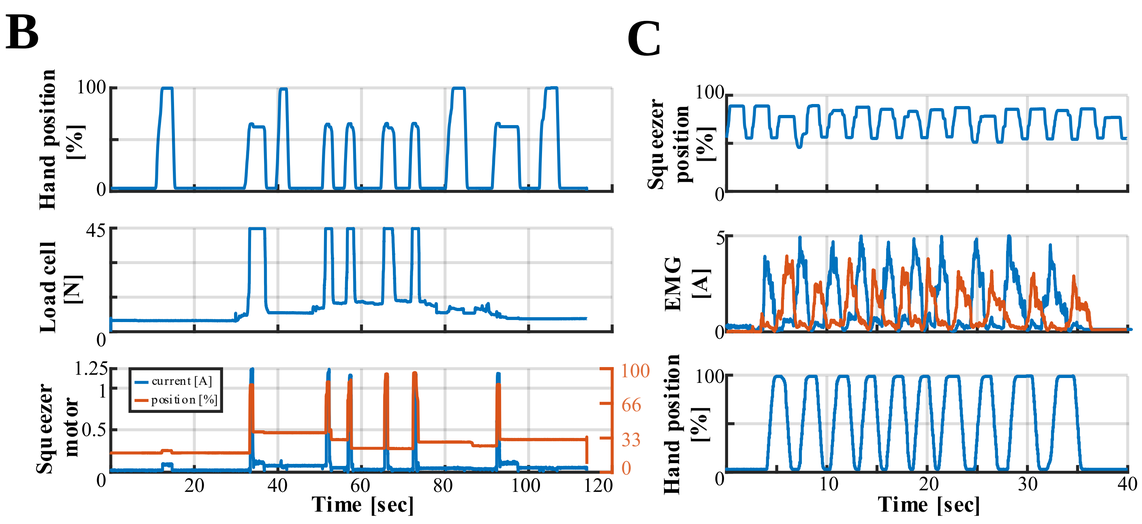


Figure 4 - Single person example for B) Feedback efficacy test and C) Sensing efficacy test.

CONCLUSION

We developed and tested a non-invasive multimodal armband that integrates surface EMG sensing and force feedback in a single wearable device. The armband's design and function were validated through lab characterization and experiments with 10 healthy subjects and one limb-different participant, showing early signs of usability and grip force perception. The system may reduce reliance on visual feedback and improve force control, although further testing in daily-life tasks and with prosthetic use is needed. The armband is easily customizable for research, adaptable to trans-humeral users, compatible with advanced interfaces like osteointegrated systems, and can integrate multiple types of feedback actuators. Despite the small sample size, results support its potential for enhancing human-machine interaction [3] and bidirectional control [4].

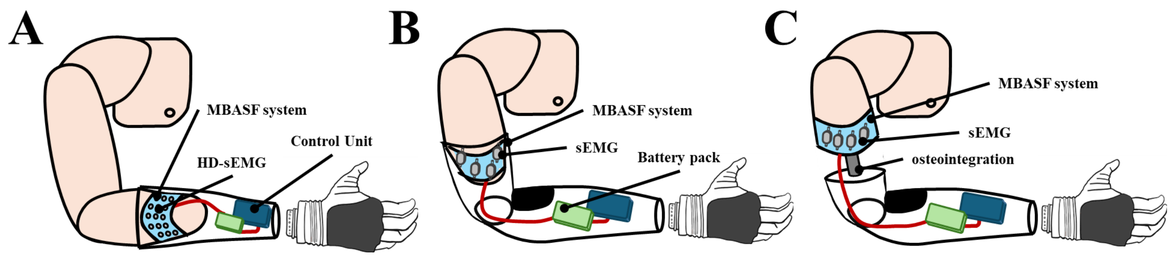


Figure 5 - Target scenarios of the MBASF armband integrated in standard sockets for A) trans-radial and B) trans-humeral, with C) osteointegration.

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