Toward Electromechanical Measurement of Muscle Activity

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***Abstract*— A prototype system was developed that integrates electromyography (EMG) and mechanomyography (MMG) to capture electromechanical signatures of muscle activity. Off-the-shelf EMG and MMG sensors were interfaced with a microcontroller to enable simultaneous signal acquisition. Results showed EMG increased by 168 ± 15% and MMG by 42 ± 10%, both with signal-to-noise ratios (SNRs) above 10 dB. These findings suggest that multimodal sensing can provide richer information than conventional single-modality measurement systems.**

I. Introduction

Individual muscle assessment methods have inherent limitations. Surface EMG measures neural activation but cannot directly assess force output, while MMG detects mechanical vibrations but provides limited information about neural drive [1]. Integration of EMG and MMG may enable more comprehensive characterization of muscle activity than either alone by leveraging their complementary nature to capture the complete neural-to-mechanical process. This work presents an early stage EMG-MMG system for comprehensive muscle assessment.

II. System Architecture

The sensing system is composed of a microcontroller unit (Teensy 4.0, PJRC), two EMG sensors (MyoWare 2.0, Advancer Technologies), and two inertial measurement units (IMUs, ICM-20948, TDK). As shown in Fig.1a, EMG signals are acquired via the MCU's analog-to-digital converter (ADC), while MMG signals are obtained from the accelerometers within IMUs over an I^2C interface. The collected data are transmitted to a personal computer for signal processing—Butterworth filtering (20–450 Hz for EMG, 5–100 Hz for MMG) and 50 ms smoothing. This pipeline enables synchronized acquisition and analysis of dual-modality muscle activity signals.

III. Experimental Validation

Following SENIAM guidelines [2], bipolar Ag/AgCl electrodes (10mm diameter, 20mm spacing) were placed on the biceps brachii and flexor digitorum (Fig. 1b). The experimental procedure consisted of six maximum voluntary contractions (3 s each) with 4 s of rest, designed to demonstrate the proposed system's multimodal sensing capability and to relate electromechanical measurements to muscle activity under controlled conditions.

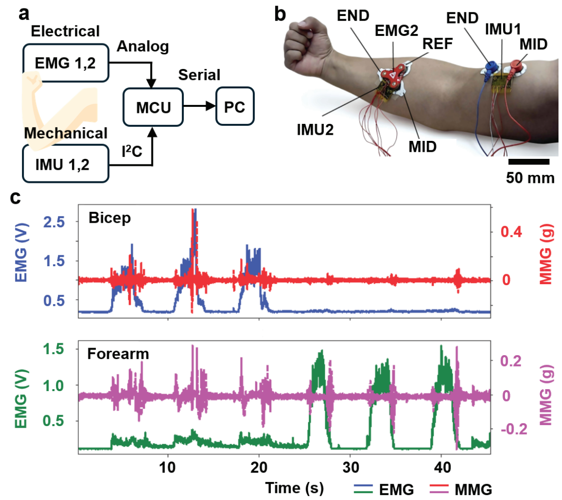

Fig. 1. EMG-MMG dual-modality sensing system: (a) System architecture. (b) Experimental setup showing sensor placement on the biceps and forearm. END, MID, and REF represent end, mid, and reference EMG electrodes. (c) Representative experimental time-series data.

IV. Results and Discussion

The results clearly reveal complementary aspects of EMG-MMG measurements (Fig. 1c). During biceps contractions, EMG onset precedes MMG activation by 110 ± 20ms, indicating the delay between neural excitation and mechanical response. Their amplitudes also increase with the contractions (EMG by 168 ± 15% and MMG by 42 ± 10%). Along with distinct frequency bands of power concentration (EMG: 50–150 Hz, MMG: 10–30 Hz), cross-correlation ($r = 0.65 \pm 0.05$) confirms that EMG and MMG provide related yet distinct information. Additionally, reasonably high SNRs (12.1 dB for EMG and 10.5 dB for MMG) demonstrate sufficient signal quality to reliably capture muscle activity.

V. Conclusion

This work demonstrates an early-stage EMG–MMG system for multimodal sensing, enabling more comprehensive assessment of muscle activity through complementary electrical and mechanical measurements.

References

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[2] H.J. Hermens et al., "Development of recommendations for SEMG sensors and sensor placement procedures," *J. Electromyogr. Kinesiol.*, vol. 10, no. 5, pp. 361–374, 2000.

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