Towards Unsupervised Incremental and Proportional Myocontrol based on Higher-Density Surface Electromyography

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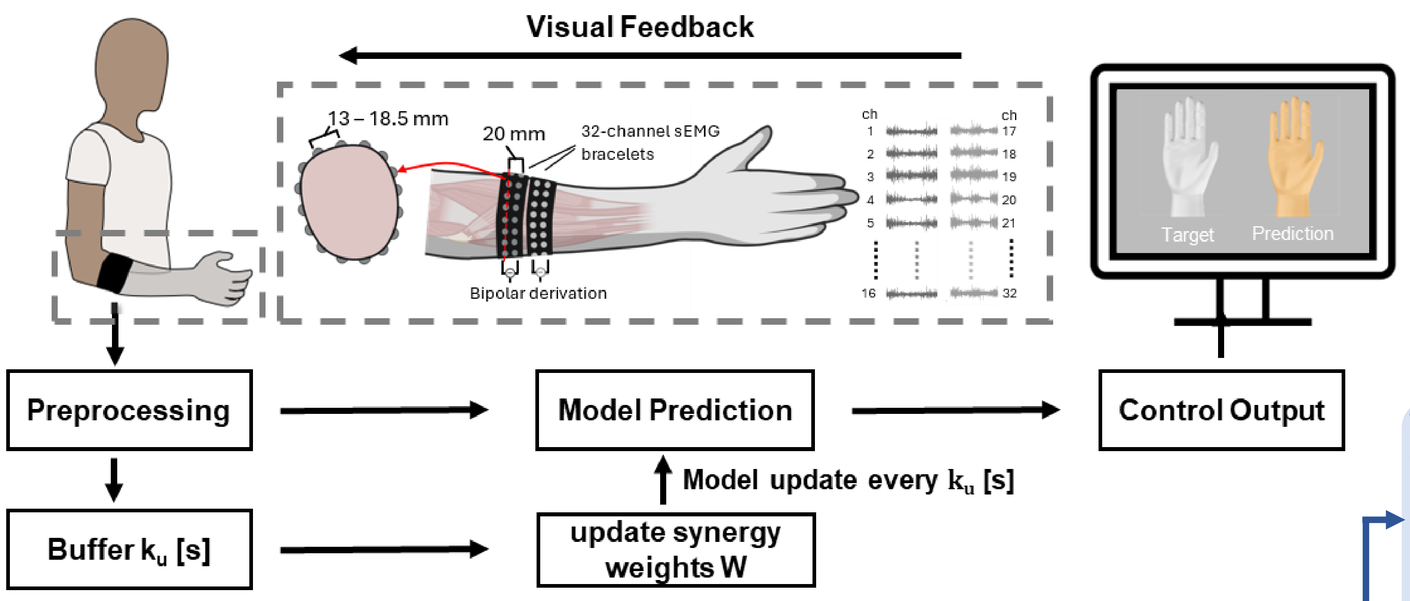
Abstract

- We tested the incremental sparse NMF (ISNMF) of Gigli et al. [4] with two 32-channel sEMG bracelets to extract muscle synergies in real-time for upper limb myocontrol
- Eight able-bodied participants trained ISNMF models with increasing number of extracted synergies
- TAC test as objective measure, NASA-TLX Questionary as subjective measure
- Up to six independently controllable synergies in full-intensity tasks.
- Proportional control was challenging, with 10% median success at half-intensity targets.
- Cognitive and physical workload remained stable despite increased complexity.
- Approach is promising but needs to be refined and tested with users with limb differences.

Introduction

- 1 in 500 babies is born with an upper limb difference [1].
- Supervised myocontrol requires labeled data, which is difficult to obtain for individuals with limb differences [2]. Unsupervised algorithms extracts patterns without labels.
- sEMG-based myocontrol is challenging due to signal non-stationarity (e.g., muscle fatigue, sweat)[3]. Incremental algorithms adapt to signal changes over time.
- ISNMF (Sparse Incremental Non-Negative Matrix Factorization) is an incremental unsupervised algorithm able to extracts and updates muscle synergies in real-time [4].

Methods



Study Setup

Algorithm:	ISNMF of Gigli et al. [5]
EMG:	two 32-electrode sEMG bracelets in bipolar configuration (32 channels)
Preprocessing:	Amplification (factor 100), Rectification, 20-90 Hz band pass, 45-55 Hz band stop, RMS (window: 500 ms, step size: 50 ms)
Participants:	8 able bodied subjects (sex: 2 f , 6m; age: 26.6±3.0, range[20,30])

Study Protocol

Training
- Participant trains a ISNMF model with n synergies ($r_0 = 3$), thus n handfunctions
- $r \in \{3,4,5,6,7\}$
- max. 10 minutes

Test

NASA-TLX questionary:
- Objective Measure
- record perceived workload
- For $r \in \{4,5,6,7\}$

TAC Test:
- Subject Measure
- activate and holt each synergy at half and full intensity
- For $r \in \{3,4,5,6,7\}$

Increment number of synergies r = r+1

Fig. 1 Experimental Setup
The sEMG was recorded at the forearm with two 32-electrode sEMG bracelets (bipolar configuration), pre-processed and fed into an ISNMF model. The prediction was visualized on a display in real-time .

Result & Discussion

Objective Measure: TAC Test Results

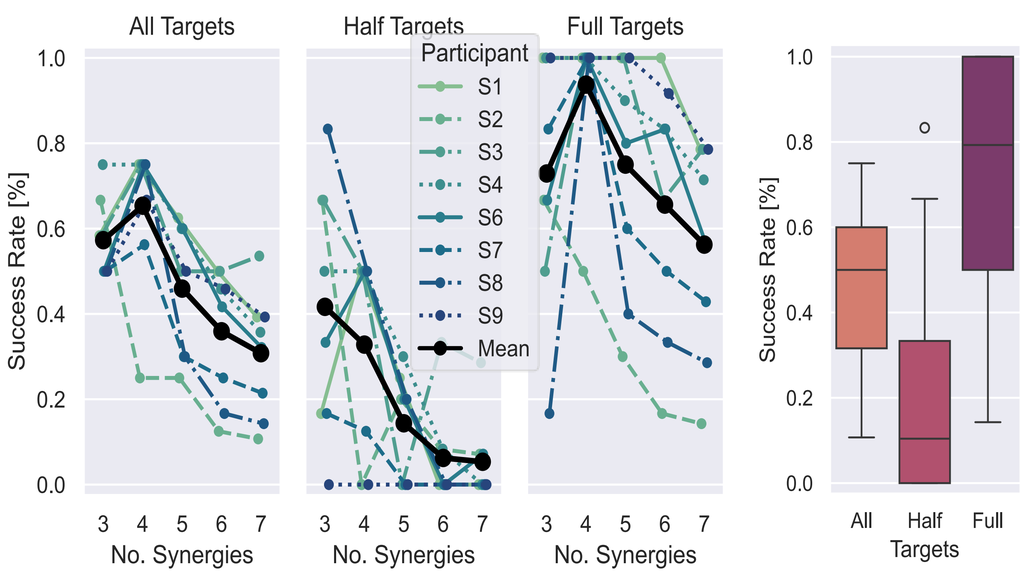


Fig. 2 Results: Success rate in TAC
Left: Mean (black) and individual success rates across synergies (r) and target types (all, half-, full-intensity). Missing values for S2(7), S7(6,7), S8(7), S9(7) were filled in.
Right: Success rates by target category with median and IQR.

Downward trend in success rate with increasing number of synergies, except in TAC 3
- → probably due to increased model complexity
- → probably difficult to identifying/separating new muscle synergies.

- Half-intensity tasks had on average lower success rates than full-intensity tasks
- One participant controlled up to 6 HFs with 100 % success rate for full-intensity activation

Subjective Measure: NASA-TLX Questionary

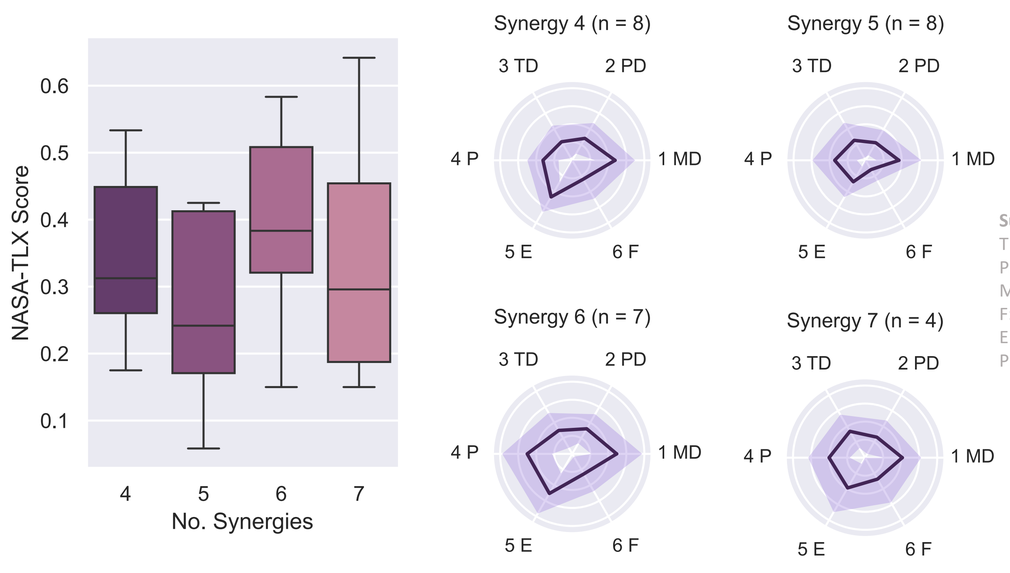


Fig. 3 Results: NASA-TLX Questionary
Left: NASA-TLX scores for synergies.
Right: Averaged subcategory results for synergies 4–7 (0.0–0.8 scale; 0.8 = high workload).

- Highest combined perceived workload at TAC 6
- Highest scores: Mental demand (MD), Effort (E) &Performance (P)

→ No consistent decrease or increase of physical demand (PD), mental demand(MD), or frustration(F) with increasing number of synergies despite decreasing success rates towards higher synergy numbers.

→ Increased difficulty of controlling more HFs might be counteracted by familiarization.

Limitations

- Small number of participants
- Only non-disabled participants.
- Controlled laboratory conditions
- TAC-test did not include simultaneous control
- Gradual increase in controllable HFs influenced the results due to familiarization.

Conclusion

- Previous studies: sEMG (8 channels) & controlled 4 hand actions
- Our study: higher density sEMG (32 channel) & control of up to 6 hand functions
- Proportional control remains challenging

→ It is possible to achieve more controllable actions by increasing the number of electrodes

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