Error Assessment and Bias Detection in EMG Decomposition

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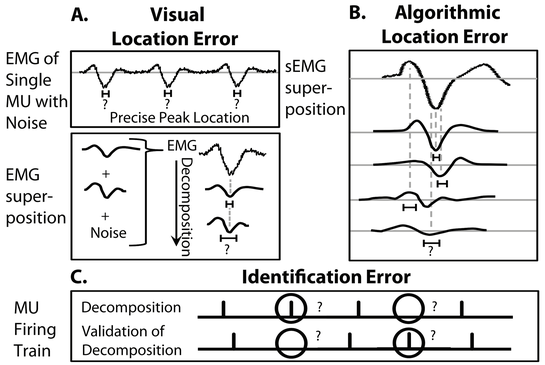
INTRODUCTION

Motor unit firings can be extracted from electromyographic (EMG) signals using a variety of human-operated or automated techniques. This process of decomposing EMG signals increases in complexity with greater noise and abounding motor unit activity. As consequence, any decomposition output provides only probabilistic estimates of physiological motor unit action potentials (MUAPs) corrupted by two types of decomposition errors. The purpose of this study is to classify the nature of these errors and identify whether their source is systematic or data-dependent.

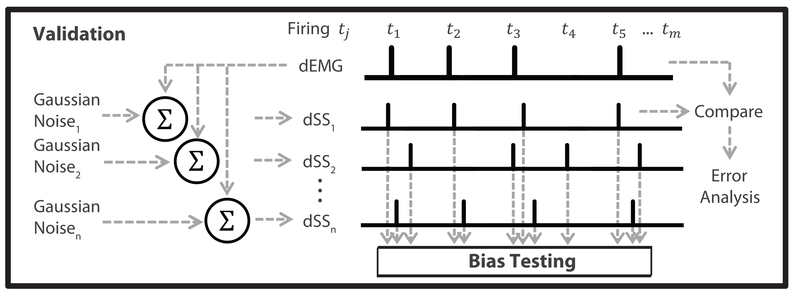


Decomposition Errors

A,B) The precise temporal location of each MUAP in an EMG signal is subject to variability, which will be termed the "Location Error."

C) An "Identification Error" can occur when the firing of one MUAP is erroneously identified with that of another similarly shaped MUAP.

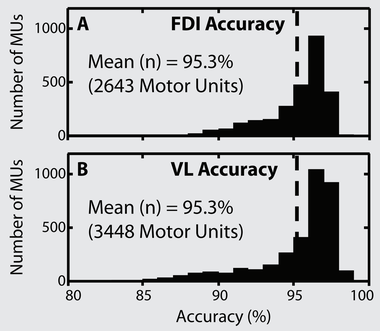
METHODS



Experiment 144 voluntary isometric contractions were performed by six healthy subjects, with the first dorsal interosseous (FDI) muscle of the hand and the vastus lateralis (VL) muscle of the lower limb. Recorded surface electromyographic (sEMG) signals were decomposed into their constituent MUAPTs using algorithms described by Nawab et al. (2010). Each decomposition was validatedusing the Decompose-Synthesize-Decompose-Compare (DSDC) test (Nawab et al, 2010; De Luca and Contessa, 2012).

Analysis The validation was repeated multiple times, each with a consistent amplitude but unique manifestation of random noise. We set out to quantify the location and identification errors in sEMG decomposition. We then derived a test to determine whether errors are caused by biases within the decomposition algorithm.

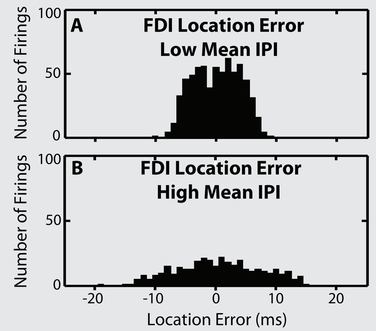
EXPERIMENTAL RESULTS



Identification Errors were indicated by false positives or false negatives and were quantified as:

$$Accuracy = 1 - N_{error} / N_{truth}$$

- N_{error}: number of unmatched events.
- N_{truth}: number of matched events.

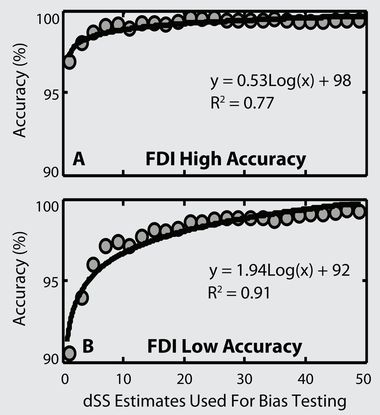


Location Errors were computed for all firing instances as:

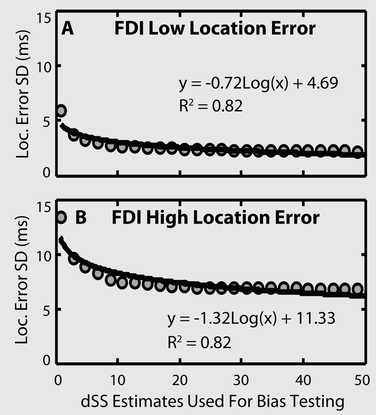
$$\varepsilon_{i,j} = MU_{i,j} - MU^*_{i,j}$$

- $MU_{i,j}$: j^{th} firing time of the i^{th} motor unit in the dEMG.
- $MU^*_{i,j}$: j^{th} firing time of the i^{th} motor unit in the dSS.

BIAS TESTING RESULTS

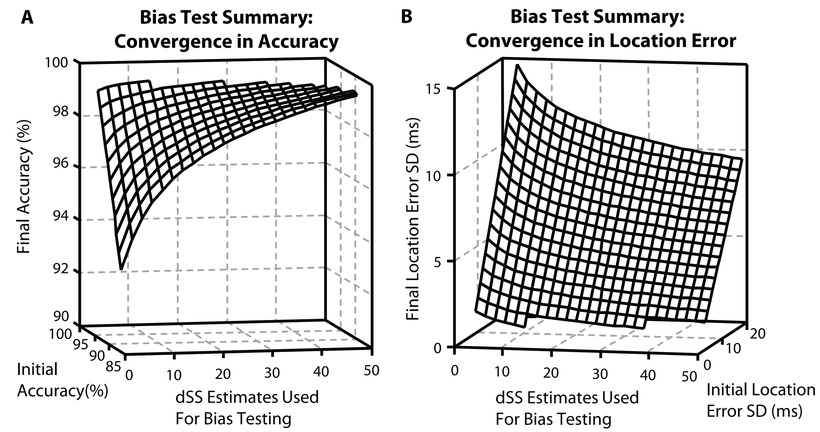


Accuracy Convergence is displayed with an increasing number of firing train estimates used in our bias testing algorithm. This result indicates that identification errors do not arise from bias in the decomposition algorithm.



Location Error Convergence is shown over an increasing number of firing train estimates used in our bias testing algorithm. This result indicates that location errors are not a consequence of bias in the decomposition algorithm.

SUMMARY



Decomposition, error analysis and bias testing of sEMG data yielded the following:

1. Location error standard deviations ranged from 2.9 ms to14.3 ms.
2. More than 70% of all 6,091 motor units were decomposed above 95% accuracy. All motor units were decomposed with an average accuracy of 95.3%.
3. On average, motor unit location error standard deviations were consistent within 0.7 ms and motor unit accuracies were consistent within 2.8%.
4. Using our bias testing algorithm, we found that our sEMG decomposition technique produces non-biased, data-dependent results.
5. We recommend that the above error metrics and bias test become an issue of concern prior to any analysis of motor unit firing behavior. We propose this not only for automated decomposed sEMG signals, but for other methods, such as visual template matching, even if few motor units are tracked.

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