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Estimating Electromyogram (EMG) Resting Noise Standard Deviation Without Rest Trials

N. Mehta, B. Islam, and E. A. Clancy, *Senior Member, IEEE*

***Abstract*— EMG amplitude estimates (EMGσ), particularly at low contraction levels, must subtract the resting noise level (σ_{Noise}) from the estimate, typically by estimating the noise standard deviation of a rest trial. However, rest trials are not always available or routinely recorded. In biceps-triceps recordings from 62 subjects, we compared (1) direct "truth" rest noise measurements to, (2) a machine learning (ML) method based on active contractions to, (3) a fixed value of 3% maximum voluntary EMG (MVE). Direct "truth" measures had a median absolute difference of 0.38% MVE between trials. ML had a median absolute difference from "truth" of 1.4% MVE. Fixed estimates had a median absolute difference from "truth" of 1.71% MVE (not significantly different than the ML method). While direct rest noise measurement is recommended and performed best, either the ML or fixed 3% MVE method were useful alternatives.**

***Clinical Relevance*— EMGσ estimates are used in numerous musculoskeletal studies, including gait analysis, ergonomics analysis and myoelectric prosthesis control. Quality EMGσ estimates account for noise standard deviation (σ_{Noise})—a quantity that is not always measured (i.e., from a rest trial). Thus, we examined methods to estimate σ_{Noise} without the need for a rest trial recording.**

I. Introduction

EMG is necessarily recorded along with additive background noise (σ_{Noise}) [1]. EMGσ processing must account for σ_{Noise} by subtracting the rest noise variance from the square of the noise-free EMGσ estimate [2]. This power-domain subtraction is critical during lower-level muscle contractions, including activities of daily living. However, many existing data sets and protocols do not/cannot routinely measure σ_{Noise}.

To attempt to resolve this problem, we developed methods to estimate σ_{Noise} from active contractions (which are always available). As a baseline, we compared "truth" σ_{Noise} computations from distinct rest contractions to each other. We then compared σ_{Noise} estimates using a ML method and by using a fixed estimate of 3% MVE. A fuller description of this work is available in [3].

II. Methods

We utilized existing constant-force and force-varying, 5 s duration, and constant-posture EMG recorded over the biceps and triceps muscles of 62 subjects (see [3]). This data re-use was not considered human subjects research (WPI IRB letter 25–0498). We matched the spectral shape of these data to simulate 10,000 constant-force and 10,000 force-varying trials with known σ_{Noise}. We used these data to pre-train a 16-layer ML model (5 1D convolutional layers interspersed with 5 max-pooling layers, three LSTM layers, a dropout layer, and two fully connected dense layers). We then fine-tuned and tested the full model on the original recorded data (5-fold subject-wise cross-validation, 80/20 train/test split). In addition to the ML approach, we evaluated performance with σ_{Noise} set to the fixed value of 3% MVE, a value suggested by preliminary analysis of our experimental data. Finally, as a baseline, we had multiple rest trials available from each data set, so compared the σ_{Noise} computed between these alternate "truth" rest trials.

III. Results

Table I shows the summary test results. A Friedman test found a significant overall difference between the methods (p<1e-273). Post-hoc Wilcoxon signed-rank tests (Bonferroni-Holm corrected) found the "truth" rest measurements to have lower differences then either the ML or fixed 3% MVE estimate, but no differences between the ML and fixed 3% MVE estimate.

TABLE I. Absolute Error Summary (All Results in % MVE)

Error from …	Median	Mean	Standard Deviation
Alternate Rest Trial 2 ("truth")	0.38	0.85	1.63
ML Predictions	1.40	1.87	1.97
Fixed 3% MVE Estimate	1.71	1.83	1.76

IV. Discussion & Conclusion

We found that noise correction based on rest recordings performs best, when such data are available. Else, either our ML method or a fixed 3% MVE σ_{Noise} estimate (which requires an estimate of MVE) perform similarly and offer an effective alternative.

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N.M. (email: nmmehta@wpi.edu), B.I. (email: bislam@wpi.edu) and E.A.C. (email: ted@wpi.edu; phone: +1 508 831-5778) are with Worcester Polytechnic Institute, Worcester, MA 01609, USA

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