Comparing Mappings between High-Density Electromyography or Conventional Electromyography and Ankle Moment

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Summary

We aim to create a mapping between ankle moment and high-density electromyography (HD-EMG) for gait. Here, we investigate if such a mapping is more accurate with HD-EMG data than with conventional surface EMG (S-EMG). Contrary to our hypothesis, the mapping from HD-EMG was less accurate than the mapping created from the averaged S-EMG.

Introduction

Recently, a mapping between HD-EMG and kinematics has been developed for the hand [1], with the goal of controlling, e.g., prostheses using HD-EMG. We aim to create a similar mapping for gait. Since gait control is coarser than hand control, we will first investigate the benefit of HD-EMG over S-EMG. We hypothesized that ankle moments can be predicted more accurately from HD-EMG than from S-EMG for both normal and perturbed gait cycles. We included perturbed gait cycles, since mapping to the mean already achieves high accuracy due to the similarity of normal gait.

Methods

For one participant, we recorded optical motion capture and force plate data on an instrumented treadmill and recorded EMG of the tibialis anterior, lateral gastrocnemius, and rectus femoris using a 32-channel HD-EMG sensor (Muovi+Pro, OT Bioelettronica, Italy, sampling frequency 2,000 Hz). We used the protocol described in [2] to record normal gait and gait with random treadmill accelerations during stance.

For the mapping between HD-EMG and ankle moment, we used an approach and neural network similar to [1]. We used two input windows: one where the channels were filtered only with a bandpass filter and one where the channels were also filtered with a low-pass filter. The windows had a length of 240 samples with 66% overlap. The ankle moment was calculated as the mean over the three relevant windows. For training, we used ankle joint moments calculated using inverse kinematics and inverse dynamics in OpenSim [3] on filtered motion and force plate data.

For the mapping between S-EMG and ankle moment, we trained a multilayer perceptron (MLP) with 16 hidden layers to estimate the ankle moment for a full gait cycle. We segmented the joint moments into gait cycles based on the right leg vertical ground reaction force and downsampled all gait cycles to match the shortest gait cycle length. To obtain the S-EMG, we first removed noisy channels and filtered using a bandpass and a notch filter. Then, we averaged the signal over all 32 channels and calculated the root mean square signal over 200 ms sliding windows with 50% overlap. We used the top 255 components from a principal component analysis over time as input to the network.

For training, we split the data into a training and testing dataset with an 80-20 ratio, ensuring that both datasets contained normal and perturbed trials. We trained the model using the ADAM optimizer and the mean square error as loss.

Results and Discussion

The mapping from S-EMG was more accurate and smoother than the mapping from HD-EMG data (Table 1, Fig. 1). For both mappings, we found high correlations and low root mean square deviation (RMSD), which shows that ankle moments can be estimated accurately from S-EMG and HD-EMG.

The correlations were higher and RMSDs smaller for the perturbed than for the unperturbed trials, indicating that both mappings might be overfit to an average ankle moment. Since only about 10% of all gait cycles contained a perturbation, the training was likely biased towards normal gait. Therefore, we aim to record a dataset with a larger number of perturbed trials and balance the number of normal and perturbed trials.

Table 1: Correlations (R) and root mean square difference (RMSD) for ankle moments predicted from HD-EMG and S-EMG for all (total), unperturbed (unp.) and perturbed (pert.) gait cycles.

	Total R	Unp. R	Pert. R	Total RMSD	Unp. RMSD	Pert. RMSD
S-EMG	0.98	0.98	0.96	11.2 N	10.8 N	16.2 N
HD-EMG	0.93	0.93	0.90	16.2 N	15.6 N	20.4 N

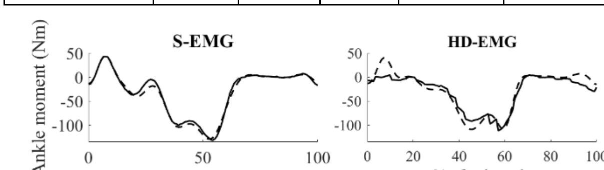

Figure 1: Exemplary perturbed gait cycles for both mappings

Conclusions

Our hypothesis was not confirmed, since the mapping between ankle moment and S-EMG was more accurate than the mapping with HD-EMG. We will further investigate if the higher accuracy is due to differences in signal preprocessing.

References

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