A Novel Biointerface for Detection of Volition and Muscle Activity

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Abstract

The standard interface for registration of muscle activity is the electromyogram (EMG). While EMG precisely maps individual muscles, it has fundamental limitations for many applications. Our new method is the myokinetic interface (MKI), that records muscle activity as a 2-dimensional map of dynamic pressure produced in limbs. The present study compared the MKI with EMG records of leg muscles during gait, and tested the ability of MKI to discriminate among specific hand grasps. Results showed: (1) MKI closely approximated the EMG records for selected muscles and (2) MKI readily discriminated among several grasp types.

MyoKinetic Interface

Motivation: To improve the man-machine interface, enhancing the coupling between the human user and his assistive devices.

The MKI sleeve is an adjustable array of pressure sensors aligned over the major muscles of the forearm, measuring kinetic activity via the external pressure that results from a muscle contraction.

Figure: The MKI sleeve.

Applications

When coupled with assistive devices, MKI will help users retrain their affected arm and hand through biofeedback of their progress during rehabilitation.

May provide an alternative means for detection of volition in movements of the upper limb.

Muscle Activity

Subjects walked on treadmill moving at 1.2, 3, and 6mph. EMG was performed on left leg, MKI on the right leg. The results demonstrate that the MKI exhibits reliable and repeatable waveforms which carry information in the same way as the EMG.

Figure: Subject dons MKI on lower leg.

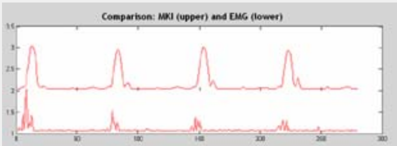


Figure: Sample waveforms for MKI (top wave) and EMG (bottom wave) : 3mph, adjusted for contralateral-leg timing differences.

After filtering and realigning legs for inter-leg synchrony, it is apparent that the waveform outputs of the MKI and the EMG disclose the same (or complementary) information.

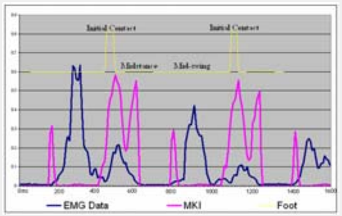


Figure: MKI (pink) and EMG (blue) data for 6mph. Data normalized for fit. Step cycle indicated by foot-switch line (yellow).

The highest correlation between EMG and MKI was in the anterior thigh, and lateral hamstrings. Correlation did not vary greatly with change in walking speed.

Grip Discrimination

To test MKI as a decoder for grasp types, volunteers performed 5 different grips for 4 cycles each, repeated for 2 intensities.

-Power Grip: High and Low intensity

-Precision Pinch:

High and Low intensity

-Key Grip

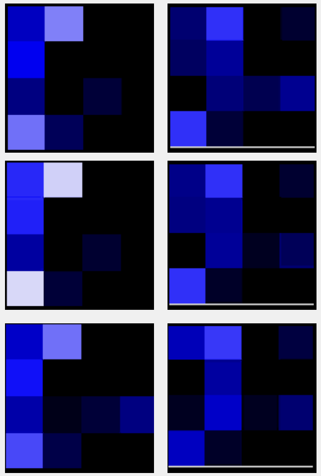


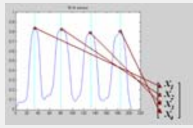
Figure: *Left:* 3 cycles of Power grip, high intensity. *Right:* 3 cycles of Precision Pinch grip, medium-high intensity

Figure: Intensity Gradation Scale.

Initial data descriptions have demonstrated high correlation between cycles within subjects, and very low correlation between tasks. This demonstrates the separability of pressure data between tasks

Grips Analysis

Within each grip task, 4 cycles yield four steady-gripstates. Each state is represented by x_{ij}, thus a second order tensor is developed over the j runs (four: 2 power grips, 2 precision pinches).



$$x_{ij} = \sum_{1}^{4} x_i - x_{i-1}$$

From this tensor we develop the *difference matrix*, the difference of all x_{ij}'s at the selected time. Because there were 4 cycles (i=4), we expect a series of 4x4 minors to yield small intra-point differences.

$$\begin{bmatrix} x_{11}-x_{12} & x_{11}-x_{13} & x_{11}-x_{14} & x_{11}-x_{21} & x_{21}-x_{22} & \cdots & x_{11}-x_{43} & x_{11}-x_{44} \\ & x_{12}-x_{13} & x_{12}-x_{14} & x_{12}-x_{21} & x_{21}-x_{22} & \cdots & x_{12}-x_{43} & x_{12}-x_{44} \\ & & x_{13}-x_{14} & x_{13}-x_{21} & x_{21}-x_{22} & \cdots & x_{13}-x_{43} & x_{13}-x_{44} \\ & & & x_{14}-x_{21} & x_{21}-x_{22} & \cdots & x_{14}-x_{43} & x_{14}-x_{44} \\ & & & & x_{21}-x_{22} & \cdots & x_{21}-x_{43} & x_{21}-x_{44} \\ & & & & & \cdots & x_{22}-x_{43} & x_{22}-x_{44} \\ & & & & & & & \cdots \\ & & & & & & & x_{43}-x_{44} \end{bmatrix}$$

Figure: grip comparison matrix

Where the elements of the matrix's 4x4 minors are summed and averaged (over non-zero entries) to yield *group descriptor points*, of the *grip comparison data* shown above. Each entry in the descriptor matrix (m_{rs}) is given by

$$m_{rs} = \frac{1}{N} \sum_{\substack{i=1 \\ j=1}}^{4} x_{ri} - x_{sj}.$$

$$\begin{bmatrix} PowGr1 & (PG1, PG2) & (PG1, Pin1) & (PG1, Pin2) \\ & PowGr2 & (PG2, Pin1) & (PG2, Pin2) \\ & & Pinch1 & (Pin1, Pin2) \\ & & & Pinch2 \end{bmatrix} \longrightarrow \begin{bmatrix} 0.1573 & 0.3484 & 0.6867 & 1.0000 \\ 0 & 0.0424 & 0.3535 & 0.6516 \\ 0 & 0 & 0.3969 & 0.3133 \\ 0 & 0 & 0 & 0.4313 \end{bmatrix}$$

Figure: descriptor matrix; normalized.

These numbers show very low differences on the diagonal and increasing differences off-diagonal. *Thus, related grips correlate will with each other, dissimilar grips do not correlate well.*

Discussion

•Hand motion volitions produce kinetic patterns in the arm that can be topographically mapped as myokinetic images.

• These images uniquely represent different grasp requests and thus can encode for central commands.

Feature	EMG	MKI
Detects both superficial and deep muscular activity	No	Yes
Operates without precise electrode placement	No	Yes
Operates without electrodes or gel	No	Yes
Easily donnable by users	No	Yes
Useable in MRI	No	Yes
Useable raw signals	No	Yes

•The MKI can discern the volition of movement and muscle activity into reliable and separable signals.

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