Model of generation of surface EMG with multi-layer volume conductor with variable thickness of subcutaneous tissue

Original
Model of generation of surface EMG with multi-layer volume conductor with variable thickness of subcutaneous tissue / MESIN L. - (2008), pp. 495-496. ((Intervento presentato al convegno Primo Congresso Nazionale di Bioingegneria, tenutosi a Pisa nel 3-5 LUGLIO 2008..

Availability:
This version is available at: 11583/1919729 since:

Publisher:

Published
DOI:

Terms of use:
openAccess
This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)
A structured generation model for EMG requires to address the following issues

The thickness of the fat layer is divided into two contributions: a constant value and a variable function

\[ G(x, z) = y_f + \delta(x, z) \]

A regular perturbation expansion of the potential can be considered

\[ \phi(x, y, z) = \phi_0(x, y, z) + z \phi_0^\prime(x, y, z) + \epsilon \phi_0^\prime(x, y, z) \]

A Taylor series of the boundary condition in terms of \( \epsilon \) is also considered

\[ \phi(x, y, z) = V(x, y, z) \]

Equating the same powers in \( \epsilon \), a hierarchical mathematical problem (each problem with solution depending on the equations of all the preceding ones) is obtained.

Order zero

\[ \phi_0 = 0 \]

First order

\[ \phi_0^\prime = 0 \]

Each of these problems is defined in a plane layer volume conductor. The problem of order zero is not homogeneous (a Dirac delta function is considered here to study the impulse response), but has vanishing boundary condition. The other problems are homogeneous, but have a flux term from the boundary. All these problems can be solved analytically transforming the \( x \) and \( z \) space variables (see Fig. 1) into spatial frequency \( k \) and \( k_y \) by a 2D Fourier transform.

References


Acknowledgements

Work supported by the European Community project n. 016712 “Cybernetic Manufacturing Systems (CyberManS)”.

MODEL OF GENERATION OF SURFACE EMG WITH MULTI-LAYER VOLUME CONDUCTOR WITH VARIABLE THICKNESS OF SUBCUTANEOUS TISSUE

Section 1: Introduction

1.1 Structural generation model of EMG

A two layer volume conductor describing subcutaneous tissue and muscle tissue is considered. The subcutaneous tissue is assumed isotropic, the muscle anisotropic. Muscle layer is a semi-space. Subcutaneous tissue has a variable thickness.

### Table 1: Simulated conductivities

<table>
<thead>
<tr>
<th>Subcutaneous tissue</th>
<th>Muscle: transversal conductivity</th>
<th>Muscle: longitudinal conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \sigma_{st} = 0.09 \ S/m )</td>
<td>( \sigma_{ml} = 0.4 \ S/m )</td>
</tr>
</tbody>
</table>

Section 2: Methods

2.1 Analysis of the Source

A linear variation of the thickness of the subcutaneous tissue layer between 1.4 and 2.6 mm along the direction of the muscle fibres was simulated (Fig. 2c). A linear array with 25 electrodes (5 mm inter-electrode distance), centred over the innervation zone was simulated. Fibres were located in a range of depths 1 - 8 mm and with transversal distances from the detection array in the range -20 mm to 20 mm. Symmetrical muscle fibres with semi-length 60 mm were simulated. Motor unit action potentials (MUAP) were simulated with a spread of neuromuscular junctions and tendons of 8 mm. The number of fibres in the MU was distributed as an exponential function, with ratio of innervation numbers 20. The distribution of conduction velocity (CV) of the MU was Gaussian, with mean 4 m/s and standard deviation 0.5 m/s. Interference EMG signals at 80% of maximal voluntary contraction (MVC) were simulated in monopolar and SD configuration (Fig. 3) for 10 random distributions of the MUs within the muscle.

Average rectified value (ARV) and mean frequency (MNF) were estimated from a 5 s portion of signal for each monopolar and SD channel. CV was estimated by a maximum likelihood method from channel pairs. Results are shown in Fig. 3. Variables can be estimated reliably only far from IZ and tendons. Far from IZ and tendons, ARV and MNF are lower when estimated above a thicker subcutaneous tissue layer (about 10%, 20% variation for ARV and 10%, 5% for MNF estimated from monopolar-SD signals, respectively). CV was not affected by the simulated variation of thickness of the subcutaneous tissue layer.

Section 3: Results

This work introduces an analytical model of simulation in surface EMG that, together with the other models proposed in the literature, is contributing to the understanding of the effects of particular conductivity or geometrical properties of the tissues on the recorded signals. Even simulating small variations of subcutaneous thickness, the results provided show that amplitude and spectral variables extracted from EMG are largely affected by the position of the detection point. On the other hand, CV estimated by a maximum likelihood approach from channel pairs is not affected by the thickness of the subcutaneous tissue in the simulated range of variation.

Section 4: Conclusions

This work introduces an analytical model of simulation in surface EMG that, together with the other models proposed in the literature, is contributing to the understanding of the effects of particular conductivity or geometrical properties of the tissues on the recorded signals. Even simulating small variations of subcutaneous thickness, the results provided show that amplitude and spectral variables extracted from EMG are largely affected by the position of the detection point. On the other hand, CV estimated by a maximum likelihood approach from channel pairs is not affected by the thickness of the subcutaneous tissue in the simulated range of variation.

References


