Production of Simulated EMG Using a Physiological Model

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1 Simulation of EMG Data

The `simtext` program provides a text-based interface to the simulation routines described in Hamilton-Wright and Stashuk (2005), and were presented at the AAEM (AAEM '03, 2003a, 2003c; AAEM '02, 2003).

The output files of the `simtext` program contain synthetic EMG signals consistent with those acquired through needle electrodes from the medium to large limb muscles of human subjects.

These synthetic signals can be used to exercise decomposition routines based on signal analysis. The default signal generated emulates a signal acquired through a concentric needle electrode at 31250 samples/second and bandpass filtered from 10-10,000Hz.

2 Running the Program

The simulator program is called `simtext`. This program should be run from within a command window (*i.e.*, DOS-style), as it will communicate with the user through text-based option selection.

When run, a screen of options is presented to the user; these options can be changed to reflect different types and sizes of muscle, as well as different disease types. The full list of these settings is outlined in Section 3. The settings last used when the simulator was run are placed in the file `simulator.cfg` in the base directory of the output directory tree.

All command line options may be found with a brief accompanying help text by running the simulator using the option "`simtext -help`."

2.1 Output Location: Windows

The output tree of the simulator will be built in the directory `c:\simulator` unless the option `-use-drive<driveLetter>` is supplied, in which case all output will be placed based on the root of the drive indicated by `<driveLetter>`.

2.2 Output Location: Macintosh & Unix

On non-Windows based operating systems, the top of the output hierarchy just mentioned will be placed in the directory from which the `simtext` executable was run (*i.e.*, the current directory).

2.3 Disease Parameter Setting

When run, the simulator will allow parameter options to be changed by selecting the parameter number and prompting the user to enter a new value. Note that the simulator will produce output reasonable to a limb muscle based on the default values. To simulate disease, the only two factors requiring adjustment are:

Neuropathic MU Loss Fraction

Myopathic Fibre Affected Fraction

Reasonable values for both of these are $[0 \ldots 0.75]$.

The models for these diseases may be found in the following works:

- Harper (2002)
- Basmajian and Luca (1985)
- Shefner (2001)
- Stashuk (2002)
- S. D. Nandedkar, Sanders, and Stålberg (1983)
- S. D. Nandedkar and Sanders (1989)
- E. Stålberg and Karlsson (2001b)
- E. Stålberg and Karlsson (2001a)
- S. Nandedkar and Stålberg (1983)

An interested reader is further referred to the bibliography at the end of this report for other papers providing a background on muscle simulation and simulated disease involvement.

Once a run has begun, the simulator will print output on the screen as the simulation progresses. Portions of the simulation that may take a long time are provided with an estimate of completion, in order that it does not appear the simulation has entered an infinite loop. The simulation of a single contraction may take quite a while; it can be expected that 2-3 minutes may pass on even the fastest machines.

3 Simulator Control Settings

The full list of the simulator control values and description are as follows:

contraction level : contraction level as a percent of MVC — useful values typically range from 5 to 20% MVC

number of motor units in muscle : 200 is typical for a medium limb muscle, and is the value used for evaluation in Hamilton-Wright and Stashuk (2005)

electrode type : concentric needle is reported in Hamilton-Wright and Stashuk (2005) though the other needle types are supported

Use old MFP generation? : this option is intended to allow the user to re-use the previous muscle layout

Neuropathic Modelling Controls:

Neuropathic MU Loss Fraction : if set to a value above zero, this will simulate the loss of fibres through nerve death. Fibres lost will be potentially readopted by nearby surviving α-motor neurons, as would be physiologically realistic

Max Adoption Distance In μm : controls the distance to which a "nearby" neuron is expected to generate twigs to readopt a fibre orphaned by neuronal damage

Neuropathic MU Enlargement Fraction : the fraction by which an adoptive motor unit will grow by adopting new fibres.

Myopathic modelling controls

Myopathic Fibre Affected Fraction : controls the degree of involvement of a myopathy.

Myopathic New Involvement Percentage In Each Cycle : describes the rate at which the myopathy affects the muscle.

Myopathic fibre gradually dying? : a boolean value determining whether fibre death is modelled as a discrete event or whether a "sick" fibre will remain active for some time

Dying and Splitting Depending on Affection Procedure? : choice between internal algorithms to model fibre loss

Myopathic Threshold of Fibre Death : internal threshold of fibre diameter at which fibre death occurs

Percentage Of Affected Fibres Dying : the % of fibres dying in a given epoch

Myopathic Fraction of Fibres Becoming Hypertrophic : regulates the hyper/hypo-trophic tendencies of myopathic degradation

Factor of original area at which hypertrophic fibres split :

Percentage Of Hypertrophic Fibres Splitting : regulates the fraction of fibres for which splitting is possible

Myopathic Rate of Atrophy : another rate control

Myopathic Rate of Hypertrophy :

Needle controls:

tip uptake distance : distance to calculate waveforms from the tip. Shortening this distance will decrease runtime and model accuracy.

cannula uptake distance : as above, but for the cannula

radius of cannula shaft : physical cannula radius

Cannula Length (in mm) : physical cannula dimension modelling depth of insertion

Needle X Position (in mm) : position within muscle — used with "use last muscle" to model needle reinsertion into the same muscle

Needle Y Position (in mm) :

Needle Z Position from NMJ in mm : This will have an effect on the modelling of end-plate potentials — the model will not work properly for positions within the NMJ

tip/cannula reference setup : controls which is positive/negative – tip or cannula

Enable Jitter? :

Jitter (variance) in μs :

MFP threshold for jitter or MU GST inclusion threshold (kV/s^2) : used to determine whether a MUP is included in GST file or discarded as being irrelevant for detection. If discarded, Jitter is not calculated for this MUP.

Generate "super" fibres for jitter? : debugging flag – used to create enormous fibres at known locations for jitter evaluation — not useful for any other reason

Minimum metric to seek needle to : the simulator will attempt to "seek out" a good location for the needle, as a clinician would before performing an acquisition – this value provides a good balance between finding a good location and discarding too many acquisition sites

Bandpass filter raw signal? : boolean bandpass filtering control

Generate noise? : simulated noise

S/N ratio : for simulated noise

Recorded Operator Name : name of clinician to place in DQEmgData output file format

Recorded Patient Name : name of patient to place in DQEmgData output file format

Recorded Muscle Name : name of muscle to place in DQEmgData output file format

Patient ID : DQEmgData ID value

Laterality : muscle side

New Operator : flag for DQEMG debugging

New Patient : flag for DQEMG debugging

New Muscle : flag for DQEMG debugging

Use Last Muscle? : used to reposition needle and use last-used muscle layout

Re-use the old firing times? : for debugging

patient directory name :

maximum recruitment threshold : used to determine slope of recruitment curve

total time for EMG generation : total length of time contraction will be simulated to take

max (scaled) value in 16-bit output : used to calculate the <compression threshold/ > in the output data file

internal interp. factor for jitter :

muscle fibre density :

area of 1 muscle fibre :

min motor unit diameter : minimum diameter used for MU simulation

max motor unit diameter :

IPI firing slope :

min firing rate :

max firing rate :

coeff of variance : in firing times modelled as a Poisson point process

MU Layout Type : internal layout algorithm flag

Generate Second Channel? : generate surface as undersampled copy of needle, or don't include second channel at all?

Dump MFP Peak-to-Peak Values? : debugging

4 Data Files Generated:

The files generated will be on the ”C:” drive (or local directory on UNIX), in a directory structure as follows:

c:\simulator\config\simulator.cfg config file in which last-run values were saved

c:\simulator\data directory in which all output will be created

c:\simulator\data\sim<run-ID/ > a single generated run

- <run-id/ > is a unique number in the directory. the first run is ”000”, and subsequent runs will be monotonically increasing

c:\simulator\data\sim*\<MuscleName/ > directory where muscular output data is put. <MuscleName/ > comes from a user selection in the config screen.

c:\simulator\data\sim*\<MuscleName/ >\eemg directory where final output is placed, in files named: `micro1.dat` and `micro1.gst`

where the dat file contains signal data, and the gst file contains a list of MUPs and offset. See below for a full description of these file formats

5 Data Files:

The `.dat` files are written on IBM PC computers, so data widths and formats are those of the Intel x86 architecture. The following sizes are therefore used:

short 16 bit integer

long 32 bit integer

5.1 EMG `.dat` files:

The file format is as follows:

<**EmgFile**>

<**EmgHeader**> : global values for EMG interpretation

<**channel: short**/ > : unused

<**HP cutoff: short**/ > : unused, currently 5000

<**LP cutoff: short**/ > : unused, currently 500

<**scale: short**/ > : used to calculate data values, in conjunction with <compression threshold/ >

<**sampling rate: long**/ > : rate in samples/second at which data was digitized

<**number of samples: long**/ > : total number of samples in data file

<**elapsed time: long**/ > : time elapsed, in sampling units. This is the same as time.

<**compression threshold: short**/ > : used in conjunction with scale. When read in all data values should be multiplied by:

$$\frac{< \text{scale}/ >}{< \text{compression threshold}/ >}$$

< /**EmgHeader**> : This header is therefore 22 bytes long

<**EmgData**> : actual data "samples"

<**data point : N * short**/ > : This is the EMG data. There will be N shorts in this section, where N is equal to <number of samples/ > in the above header.

< /**EmgData**> :

< /**EmgFile**> : end of file

5.2 MUP `dco/gst` files

Both the `.dco` and `.gst` files have the same format. The only difference is the confidence the user has in the quality of the data in the file: `.dco` files are generated from a decomposition algorithm, while `.gst` files are "Gold Standard" `.dco` files produced by the simulator (or some other authority) to reflect "perfect" knowledge about the signal.

In the case of simulated data files, the `.gst` files record the generating MUP for every firing recorded in the file. It is not expected that a decomposition algorithm will be able to achieve this standard as the simulator has perfect information about superpositions, however an attempt is made by the simulator to avoid recording data for MUPs that are "too distant" (again, see Hamilton-Wright and Stashuk (2005)).

<**DcoFile**> :

<**DcoHeader**> :

<**Name : 60 * char**/ > : name tag from generator of file.

<**Num Trains : short**/ > : Number of Muap trains in this file

<**Num MUPs : short**/ > : Number of Muap structures in total in this file

< /**DcoHeader**> :

<**MUP :** <**N**>> : There will be <N> muap structures in the remainder of the file, where <N> is equal to Num Muaps in the header

<**firing time : float**/ > : time in samples when MUP fired

<**buffer offset : long**/ > : offset in samples when muap fired (same as time)

<**motor unit : short**/ > : the id of the motor unit (train) which this MUP belongs to

<**MUP number : short**/ > : monotonically increasing id of the MUP in the file. The first ID is 0.

<**uncertainty : long**/ > : the certainty with which we believe the result. Normalized $[0 \ldots 1]$

< /**MUP**> :

< /**DcoFile**> :

5.3 MUP files:

MUP files will appear in the directory:

c:\simulator\data\sim*\<MuscleName/ >\tmp-mmuaps

and they have the following form:

<**MuapFile**> :

<**MuapHeader**> :

<**NumMUPs : long**/ > : Number of Muaps in this file. There will be more than one MUP in cases of needle movement. Later there will be many, because of Jitter.

<**Length of Muap : long**/ > : Number of data elements in a MUP.

< /**MuapHeader**> :

<**MUP :** <**N**/ >> : There will be N muaps in the remainder of the file, where N is equal to Num Muaps in the header

<**data point :** <**N**/ > * **float**> : This is the MUP data. There will be M floats for each MUP, where M is the Length of Muap, above.

< /**Muap**> :

< /**MuapFile**> :

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