sEMG Signal Separation for Wrist Angle Estimation

First A. Author1,2,\*, Second B. Author2, and Third C. Author3

1SRON Netherlands Institute for Space Research, Groningen, the Netherlands

2University of Groningen, Kapteyn Astronomical Institute, Groningen, the Netherlands

3California Institute of Technology, Pasadena, CA 91125, USA

\*Contact: First.Author@sron.nl, phone +31-50-363 4074

Abstract— This document

1. Introduction

Myoelectric signal activity had been known to increase with the muscle movement intensity[1]. With electromyography (EMG), myoelectric signal can be recorded and aid in researches including gait analysis[2], fatigue evaluation[3], motor neuron disease diagnosis[4], and prosthesis control[5]–[8].

Surface EMG (sEMG) is widely employed in EMG signal recording, because of its ease of use and non-invasiveness. sEMG records the summation of action potential generated by a group of motor neurons, as the muscle tissue between the motor neurons and surface electrode acts as a volume conductor. sEMG signal is affected by the crosstalk of multiple muscle groups[9].

sEMG signal can be assumed to be linearly mixed action potential originating from different muscle groups, the effect of crosstalk can be mitigated through the use of blind signal separation (BSS) algorithm. A popular BSS method, Independent component analysis (ICA), were employed to increase the classification accuracy in gesture recognition[10]. However, since the probability distribution of a sEMG signal is close to Gaussian distribution, ICA cannot be applied effectively to separate the action potential from sEMG signal[11]. ICA was mostly used to remove motion artefacts[12].

Crosstalk between muscle groups can be easily observed from the forearm. Multiple muscle groups are present in the forearm, in charge of functions including wrist motion and hand gestures[13].

This paper focus on the estimation of wrist angle with the sEMG signal recorded from the forearm. To mitigate the effect of crosstalk, this paper proposed the separation of sEMG signal power with two BSS methods, and compare their results.

The two BSS methods are Non-negative ICA (nICA) and Temporal Decorrelation Source Separation (TDSEP). nICA treats the data as a group of data point and minimize the mutual information of the data; TDSEP decorrelates multi-channel time series, minimizing the correlation between time series.

Relationship between sEMG signal and muscle tension is highly non-linear[14]. Neural networks are utilized in previous research to model the non-linear relationship[5], [8], [15]–[19]. In this thesis, Long Short Term Memory (LSTM) is used to estimate the wrist angle. LSTM is a type of Recurrent Neural Network (RNN) that includes internal memory cell inside the network. The internal memory can help LSTM model time series, which made it suitable for wrist angle estimation.

1. Methodology
2. sEMG Signal Feature

In this thesis, windowed Root Mean Square (RMS) is used as the feature for wrist angle estimation. RMS can be used to extract signal power. RMS of sEMG signal represents the muscle activity, and is calculated using the following formula.

|  |  |
| --- | --- |
|  | (1) |

Where is the sEMG recording at time , and is the number of sample point in 200 milliseconds. The result of windowed RMS is shown in Fig. 1, sEMG signal after windowed RMS is smoother and non-negative.

|  |
| --- |
| E:\Ubuntu\sEMG\Paper\pic\wRMS.png |
| Fig. 1 Windowed RMS of sEMG  (a) raw sEMG signal (b) windowed RMS sEMG signal |

Title and Author Details

Title must be in 24 pt Regular font. Author name must be in 11 pt Regular font. Author affiliation must be in 10 pt Italic. Contact email address must be in 9 pt Courier Regular font.

TABLE I  
Font Sizes for Papers

|  |  |  |  |
| --- | --- | --- | --- |
| Font Size | Appearance (in Time New Roman or Times) | | |
| Regular | Bold | Italic |
| 8 | table caption (in Small Caps),  figure caption,  reference item |  | reference item (partial) |
| 9 | Contact author email address (in Courier), cell in a table | abstract body | abstract heading (also in Bold) |
| 10 | level-1 heading (in Small Caps),  paragraph |  | level-2 heading,  level-3 heading,  author affiliation |
| 11 | author name |  |  |
| 24 | title |  |  |

All title and author details must be in single-column format and must be centered.

Every word in a title must be capitalized except for short minor words such as “a”, “an”, “and”, “as”, “at”, “by”, “for”, “from”, “if”, “in”, “into”, “on”, “or”, “of”, “the”, “to”, “with”.

Author details must not show any professional title (e.g. Managing Director), any academic title (e.g. Dr.) or any membership of any professional organization (e.g. Senior Member IEEE).

To avoid confusion, the family name must be written as the last part of each author name (e.g. John A.K. Smith).

Each affiliation must include, at the very least, the name of the institute/university and the name of the country where the author is based (e.g. University of Tokyo, Japan).

Email address is compulsory for the corresponding author.

1. Section Headings

No more than 3 levels of headings should be used. All headings must be in 10pt font. Every word in a heading must be capitalized except for short minor words as listed in Section III-B.

1. Level-1 Heading: A level-1 heading must be in Small Caps, centered and numbered using uppercase Roman numerals. For example, see heading “III. Page Style” of this document. The two level-1 headings which must not be numbered are “Acknowledgment” and “References”.
2. Level-2 Heading: A level-2 heading must be in Italic, left-justified and numbered using an uppercase alphabetic letter followed by a period. For example, see heading “C. Section Headings” above.
3. Level-3 Heading: A level-3 heading must be indented, in Italic and numbered with an Arabic numeral followed by a right parenthesis. The level-3 heading must end with a colon. The body of the level-3 section immediately follows the level-3 heading in the same paragraph. For example, this paragraph begins with a level-3 heading.
4. Figures and Tables

Figures and tables must be centered in the column. Large figures and tables may span across both columns. Any table or figure that takes up more than 1 column width must be positioned either at the top or at the bottom of the page.

Graphics may be full color. All colors will be retained in the online proceedings but will be gray scale in the printed proceedings. Graphics must not use stipple fill patterns because they may not be reproduced properly. Please use only *SOLID FILL* colors which contrast well both on screen and on a black-and-white hardcopy, as shown in Fig. 1.



Fig. 2 A sample line graph using colors which contrast well both on screen and on a black-and-white hardcopy

Fig. 2 shows an example of a low-resolution image which would not be acceptable, whereas Fig. 3 shows an example of an image with adequate resolution. Check that the resolution is adequate to reveal the important detail in the figure.

Please check all figures in your paper both on screen and on a black-and-white hardcopy. When you check your paper on a black-and-white hardcopy, please ensure that:

* the colors used in each figure contrast well,
* the image used in each figure is clear,
* all text labels in each figure are legible.
* That each figure is centred.

1. Figure Captions

Figures must be numbered using Arabic numerals. Figure captions must be in 8 pt Regular font. Captions of a single line (e.g. Fig. 2) must be centered whereas multi-line captions must be justified (e.g. Fig. 1). Captions with figure numbers must be placed after their associated figures, as shown in Fig. 1.



Fig. 3 Example of an unacceptable low-resolution image



Fig. 4 Example of an image with acceptable resolution

1. Table Captions

Tables must be numbered using uppercase Roman numerals. Table captions must be centred and in 8 pt Regular font with Small Caps. Every word in a table caption must be capitalized except for short minor words as listed in Section III-B. Captions with table numbers must be placed before their associated tables, as shown in Table 1.

1. Page Numbers, Headers and Footers

Page numbers and footers must not be used. Please leave the header unchanged.

1. Links and Bookmarks

All hypertext links and section bookmarks will be removed from papers during the processing of papers for publication. If you need to refer to an Internet email address or URL in your paper, you must type out the address or URL fully in Regular font.

1. References

The heading of the References section must not be numbered. All reference items must be in 8 pt font. Please use Regular and Italic styles to distinguish different fields as shown in the References section. Number the reference items consecutively in square brackets (e.g. [1]).

When referring to a reference item, please simply use the reference number, as in [2]. Do not use “Ref. [3]” or “Reference [3]” except at the beginning of a sentence, e.g. “Reference [3] shows …”. Multiple references are each numbered with separate brackets (e.g. [2], [3], [4]–[6]).

Examples of reference items of different categories shown in the References section include:

* example of a book in [1]
* example of a book in a series in [2]
* example of a journal article in [3]
* example of a conference paper in [4]
* example of a patent in [5]
* example of a website in [6]
* example of a web page in [7]
* example of a databook as a manual in [8]
* example of a datasheet in [9]
* example of a master’s thesis in [10]
* example of a technical report in [11]
* example of a standard in [12]

1. Conclusions

This template is partly based on the template used for the 19th ISSTT (Groningen, 2008) and the 21st ISSTT (Oxford, 2010), which was in turn based on “Sample IEEE Paper for A4 Page Size” provided by courtesy of Causal Productions (www.causalproductions.com).

Acknowledgment

The heading of the Acknowledgment section and the References section must not be numbered.

References