Statistical Modeling of EMG Signal

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Abstract—The aim of this research is to measure and build a statistical model of EMG signals. A linear regression method was applied as a statistical modeling method, the common types of linear regression models were explored.

The electromyography (EMG) was measured from the two hands of a person as a way to perform noise reduction with the use of XOR logical operation facilities.

To measure EMG signals, the research used six OLIMEX EMG shield, controlled by Arduino 328 control board, a new classification and modeling of EMG signals of 5 movements of an arm are presented.

One of the six channels used for the EMG measurements was used as a reference channel, while the remaining as a measuring channels.

The resultant EMG of each channel was considered as an independent variable (emg) for the linear regression model and the movement angle (degree) as a dependent variable for the model.

Index Terms — BrainBay, Electromyography, linear regression, WinQSB.

I. INTRODUCTION

The main purpose of this paper is to present a statistical modeling and classification of EMG signals measured from right and left hand of a person. The aim of using two hands of a person is to simplify the classification of EMG signals. The human hand is a complex system with a large number of degrees of freedom (DOF) [1].

For that the classification of the signal depend on the internal structure of the subject, Including the individual skin formation, blood flow velocity, measured skin temperatures, the tissue structure (Muscle, Fat, ……, etc.), measuring site, and more. These attribute produce different types of noise signals that can be found within the EMG signals [2].

The problem of EMG signals processing and classification is that these signals are not always strictly repeatable, and may sometimes even be contradictory, the advantage of using statistical modeling is to discover patterns in data which are different to be detected.

II. EMG SIGNAL MEASUREMENT:

The EMG signals for this research is measured from left and right hands of a person (LH, RH) the EMG records is differ from hands to another according to the reasons mention before in [2], for the same laboratory environments the six EMG signals will have the same noise effect, for that, first EMG will be considered as a reference and the others as a measuring signals, and by (XOR) the resultant from the ADC converters the equal values will be cancelled which represent the noise and the differ values will be added which represent the resultant of adding the RH and LH EMG signals. EMG signals of five movements will be measured, classified by linear regression modeling:

- Arm flexing
- Grabbing fingers
- Wrist bending
- Arm twisting
- Moving arm away from body

III. LINEAR REGRESSION MODELING:

In linear regression a signal numerical independent variable, X, is used to predict the numerical variables Y [3].

\[ Y_i = \beta_0 + \beta_1 X_i + \epsilon_i \]  

\[ \beta_0 = \text{Y intercept} \]
\[ \beta_1 = \text{slop} \]
\[ \epsilon = \text{random error in Y observation} \]
\[ Y_i = \text{response variables} \]
\[ X_i = \text{explanatory variable} \]

There is several types of relationships found in scatter plots, they are shown in Fig. (2).

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The predict value of $Y_i$ intercept plus the slop times the value of $X_i$.

$$y_i = b_0 + b_1x_i$$ \hspace{1cm} (2)

For finding the regression coefficient $B_0$, $B_1$:

$$SOD = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2$$ \hspace{1cm} (3)

Using equation (2) we get:

$$SOD = \sum_{i=1}^{n} (y_i - (b_0 + b_1x_i))^2$$ \hspace{1cm} (4)

In this research the winQSB is used to calculate the $B_0$, $B_1$ coefficients.

IV. EXPERIMENTAL WORKS:

Using Brain Bay [4] the measurement of EMG is done by using the block diagram shown in fig. (3).

V. ARM FLEXING:

The RH, and the LH EMG’s are shown in fig. (4) and fig. (5) respectively.

While the resultant EMG is shown in fig. (6)

VI. GRIPING FINGERS:

The EMG of a griping hand fingers is shown in fig. (7) (EMG Fing.), the frequency spectrum of the resultant EMG is also shown.

VII. ARM TWIST:

The resultant EMG and its frequency spectrum of arm twist movement is shown in fig. (8) (EMG Arm Twist).
VIII. WRIST BENDING:
The EMG of wrist bending from straight degree to 90° is shown in fig. (9) (EMG Wrist).

IX. ARM OUT:
EMG is taken when moving a straight arm away from the body is shown in fig. (10) (EMG Arm Out).

X. RESULTS:
For the five types of EMG measurement (for this research), the linear regression modules were calculated by using WinQSB software [5]. The arm flexing linear regression is:

\[ \text{degree} = 16.3631 + 4.0148 \text{emg} \]  \hspace{1cm} (5)

A positive linear was chosen for this measurements, Fig. (11) shows the graph of the module and table (1) shows the statistical analysis of the module.

| Degree | Actual | Predicted | Std. Dev. of Prediction | Residual | Std. Residual | Standardized Residual |
|--------|--------|-----------|------------------------|----------|--------------|----------------------|
| 88.3101| 50.000 | 24.7942   | 3.2194                 | -13.7942 | 79.8340      | -1.9495              |
| 100.000| 10.000 | 26.4091   | 3.3404                 | -16.4091 | 62.1274      | -1.8147              |
| 15.000 | 15.000 | 26.0000   | 3.0224                 | -10.0000 | 42.9329      | -1.9356              |
| 20.000 | 20.000 | 30.6134   | 2.5960                 | -10.6134 | 33.3632      | -0.9595              |
| 5.000  | 5.000  | 30.6134   | 2.9322                 | -25.6134 | 18.0744      | -0.5727              |
| 6.000  | 6.000  | 32.6290   | 2.0786                 | -26.6290 | 6.3110       | -0.1936              |
| 7.000  | 7.000  | 32.6290   | 2.6451                 | -25.6290 | 6.2699       | 0.2143               |
| 8.000  | 8.000  | 37.2491   | 2.6600                 | -27.2491 | 7.4111       | 0.2747               |
| 9.000  | 9.000  | 42.4594   | 2.4771                 | -24.4594 | 5.9837       | 0.2501               |
| 10.000 | 10.000 | 44.6863   | 2.4010                 | -14.6863 | 5.1317       | 0.5052               |
| 15.000 | 15.000 | 46.6727   | 2.3603                 | -9.6727  | 19.3765      | 0.8078               |
| 12.000 | 12.000 | 46.8757   | 2.3435                 | -10.8757 | 22.9982      | 1.2922               |
| 13.000 | 13.000 | 49.2846   | 2.2820                 | -15.2846 | 31.8871      | 1.5473               |
| 14.000 | 14.000 | 50.3172   | 2.1383                 | -11.3172 | 20.4464      | 1.1029               |
| 15.000 | 15.000 | 50.3433   | 2.1276                 | -9.3433  | 14.7775      | 0.9507               |
| 16.000 | 16.000 | 53.7379   | 2.2393                 | -7.7379  | 9.0312       | 0.6524               |
| 17.000 | 17.000 | 52.6675   | 2.4793                 | -2.6675  | 2.0962       | 0.2356               |
| 18.000 | 18.000 | 58.4173   | 2.5770                 | 5.4821   | 5.3643       | 0.4511               |
| 19.000 | 19.000 | 90.3672   | 2.7894                 | 4.4362   | 4.8135       | 0.4256               |
| 20.000 | 20.000 | 96.2576   | 3.0254                 | 7.4721   | 3.9876       | 0.3694               |
| 21.000 | 21.000 | 97.8630   | 3.0995                 | 7.3862   | 7.2919       | 0.7026               |
| 22.000 | 22.000 | 115.5290  | 3.5983                 | 5.5290   | 4.7850       | -0.5444              |
| 23.000 | 23.000 | 123.5862  | 4.4652                 | 8.5662   | -2.2283      | -0.8032              |
| 24.000 | 24.000 | 138.4135  | 5.2963                 | 10.4135  | -13.3032     | -1.8129              |

Table (1) statistical analysis of arm flexing model measurements is:

Degree = 88.3101 – 0.2655emg  \hspace{1cm} (6)

A negative linear module was chosen for the EMG measurements, Fig. (12) shown the graph of the module and table (2) shows the statistical analysis of the module.
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Fig(12) A negative linear module

Table (3) statistical analysis of Arm twisting

While for the wrist bending the graph of the module shown in fig. (14) and table (4), shows the statistical analysis.

The module equation is:
Degree = 69.5112 – 0.6342 EMG

Fig(14) wrist bending

Table(4) statistical analysis Wrist bending
The arm out of the body 
EMG measurements is modeled by the equation :

\[
\text{Degree} = 61.3455 - 0.5130 \times \text{EMG} \quad (9)
\]

The graph of the module and the statistical analysis is shown in fig. (15), and table (5).

The reason of that is because all of the EMG measurements are taken from the biceps muscle.

The arm flexing and the arm twisting had a positive linear modules, while the other remaining modules have a negative linear modules, the distance of EMG potential measuring location on arm will effect the resultant EMG values measured so for the response of measuring equipments.

XII. Conclusion:

The aim of this research is to build a linear regression of different EMG signals gathered from left hand LH, and right hand RH of a person as a noise cancelling method. An Arduino EMG shields and Arduino OLIMEX 328 were used.

Brain Bay software was used to build the measuring system, WinQSB used to calculate the linear regression modules.

Table (5) statistical analysis arm out of the body

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | Actual degree | Predicted | Std. Dev of Prediction | Residual | Z Residual | Standardized Residual |
| 1 | 5.0000 | 53.4457 | 10.5476 | 40.4457 | -50.447 | -2.1451** |
| 2 | 10.0000 | 45.5049 | 6.4510 | 39.0493 | -70.1588 | 1.5636 |
| 3 | 15.0000 | 40.7289 | 6.0154 | 25.7289 | -63.1605 | -1.1236 |
| 4 | 20.0000 | 36.4130 | 11.5251 | 10.4130 | -34.2386 | -0.4611 |
| 5 | 25.0000 | 35.4914 | 8.1095 | -10.4914 | -29.5905 | -0.4645 |
| 6 | 30.0000 | 29.3870 | 12.0235 | 6.3870 | 2.0039 | 0.0271 |
| 7 | 35.0000 | 35.4914 | 8.1095 | 0.4914 | 1.3847 | 0.0218 |
| 8 | 40.0000 | 45.5049 | 6.4510 | 5.0493 | -12.6532 | -0.2615 |
| 9 | 45.0000 | 47.0950 | 6.9942 | 7.0950 | -2.1898 | -0.1814 |
| 10 | 50.0000 | 36.1076 | 6.0424 | 11.076 | 31.2073 | 0.5266 |
| 11 | 55.0000 | 40.5186 | 6.0505 | 14.5186 | 35.7400 | 0.6412 |
| 12 | 60.0000 | 46.7770 | 6.7769 | 13.7770 | 31.2321 | 0.5053 |
| 13 | 65.0000 | 47.3055 | 7.3722 | 12.3055 | 35.1845 | 0.7563 |
| 14 | 70.0000 | 25.5932 | 6.2916 | 18.5932 | 76.7080 | 1.3463 |
| 15 | 75.0000 | 40.2132 | 7.4270 | 27.2132 | 55.5580 | 1.1861 |
| 16 | 80.0000 | 54.8387 | 11.4890 | 25.8387 | 45.0867 | 1.1145 |

XI. Discussion

The research achieved applicable modeling of EMG signals for control purposes.

All the modules are built using the degree of the movement angle as dependent variable and the potential of the EMG as independent variable.

The arm flexing module is going to be the perfect module according to the resultant histograms shown in fig.(16).

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