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Statistical Modeling of EMG Signal

Naufel B. Mohammed , Atta A. Saeed , Avan M. Ahmed

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 was 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, Electromayogrphy, 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 tow 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 :

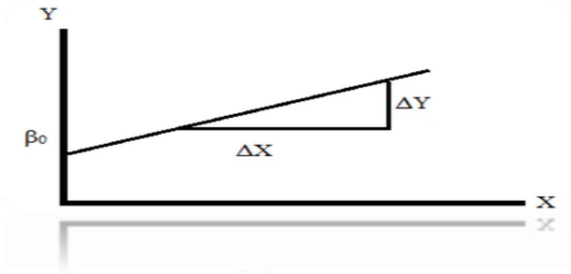
The EMG signals for this research is measured from left an right hands of a person (LH , RH) the EMG records is diffe from hands to another according to the reasons mentione before in [2] , for the same laboratory environments the six EMG signals will have the same noise effect , for that , first EMG 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] .

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \qquad (1)$$



β_0 = Y intercept
β_1 = slop
ε_i = random error in Y observation
Y_i = response variables
X_i = explanatory variable

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

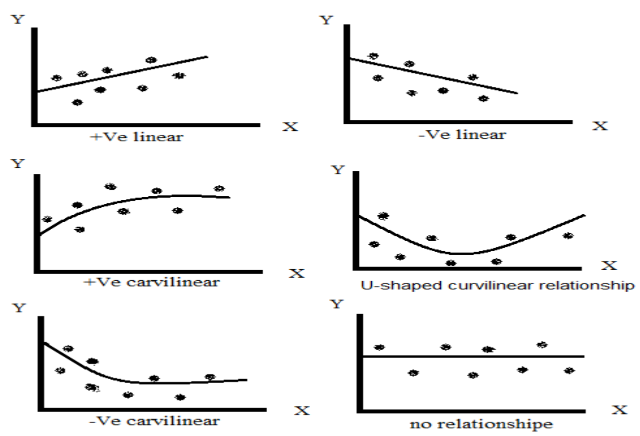


Fig. (2) Types of Relationship Found in Scatter Plots

Naufel B. Mohammed, Kurdistan Institution for Strategic Studies ar Scientific Research, Qirga, Slemani, As Sulaymaniyah, Iraq, University Human Development, Qirga, Slemani, As Sulaymaniyah, Iraq, Te 009647702478274
Atta A. Saeed, Kurdistan Institution for Strategic Studies and Scientif Research, Qirga, Slemani, As Sulaymaniyah, Iraq.
Avan M. Ahmad, Kurdistan Institution for Strategic Studies ar Scientific Research, Qirga, Slemani, As Sulaymaniyah, Iraq.

The predict value of $Y_i^{\wedge}$ intercept plus the slop times the value of X_i .

$$y_i^{\wedge} = b_0 + b_1 x_i \qquad (2)$$

For finding the regression coefficient B_0 , B_1 :

$$SOD = \sum_{i=1}^{n} (y_i - y_i^{\wedge})^2 \qquad (3)$$

Using equation (2) we get :

$$SOD = \sum_{i=1}^{n} (y_i - y_i^{\wedge})^2 = \sum_{i=1}^{N} [Y_i - (b_0 + b_1 x_i)^2] \qquad (4)$$

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)

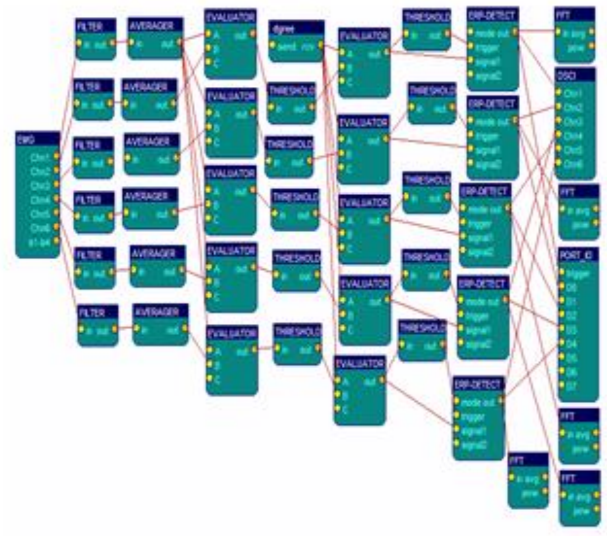


Fig. (3) BrainBay Block Diagram For Measuring EMG

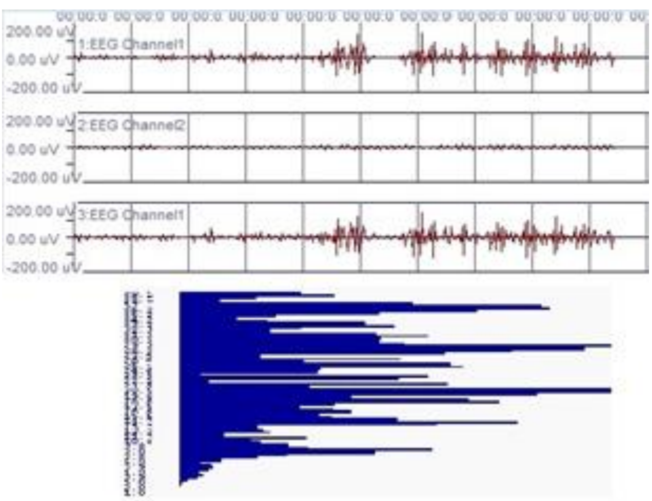


Fig. (4) EMG of RH

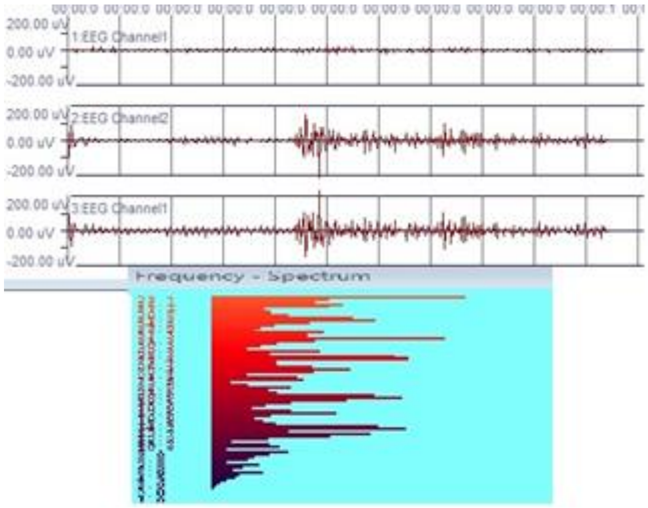


Fig. (5) EMG of LH

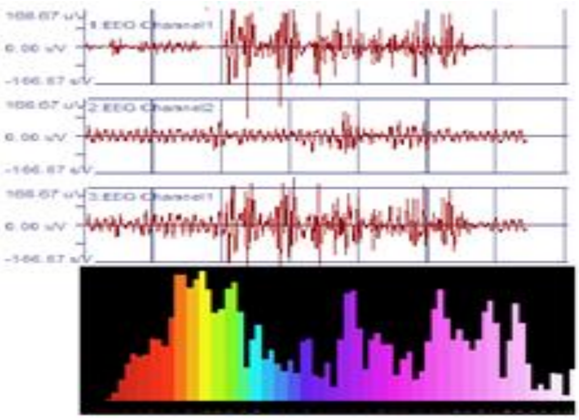


Fig. (6) resultant EMG

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.

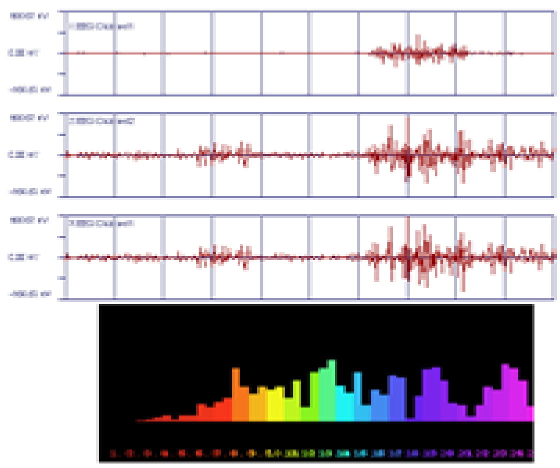


Fig.(7) EMG of a griping fingers

VII. Arm Twist :

The resultant EMG and its frequency spectrum of arm twist movement is shown in fig. (8) (EMG Arm Twist).

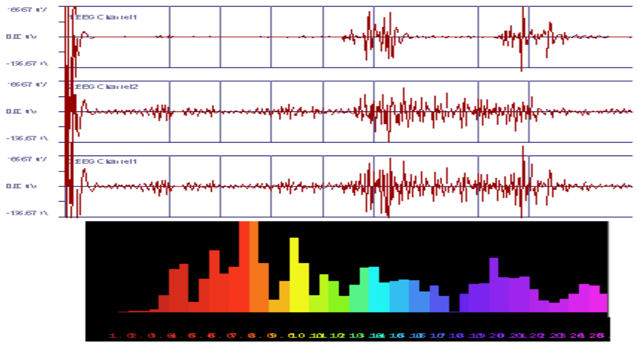


Fig. (8)EMG of Arm Twist

VIII. Wrist Bending:

The EMG of wrist bending from straight degree to 90° is shown in fig. (9) (EMG Wrist).

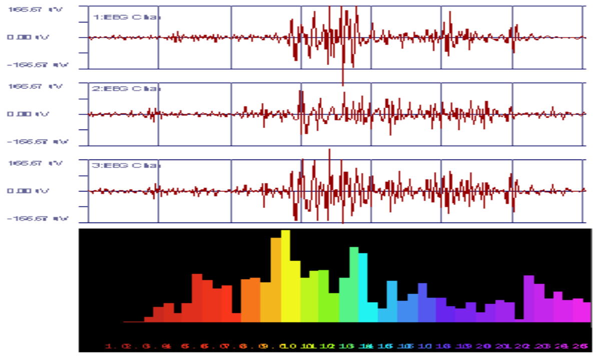


Fig. (9) EMG of Wrist Bending

IX. Arm Out :

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

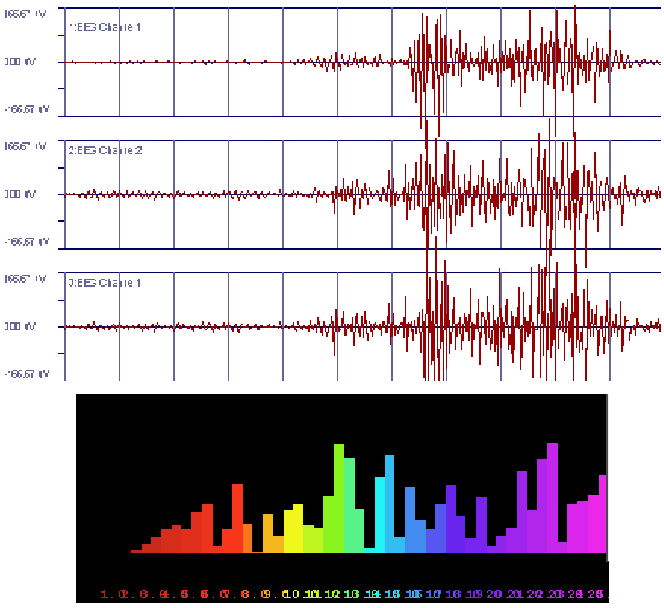


Fig. (10) EMG of Arm Out

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 :

$$degree = 16.3631 + 4.0148emg \qquad (5)$$

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 .

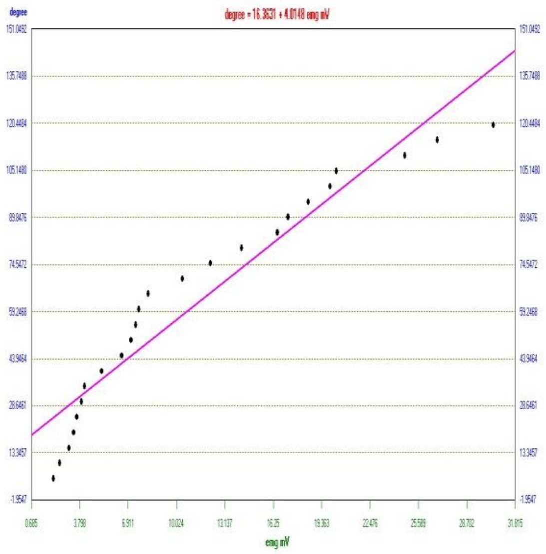


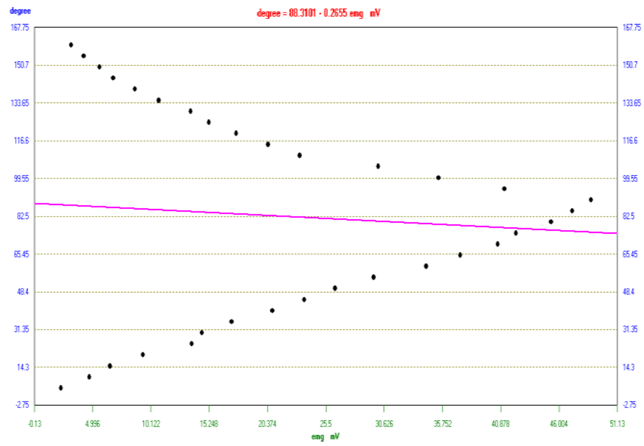
Fig. (11)Arm flexing model

09-29-2016 10:55:36	Actual degree	Prediction	Std. Dev. of Prediction	Residual	% Residual	Standardized Residual
1	5.0000	24.7942	3.2104	-19.7942	-79.8340	-1.9489
2	10.0000	26.4001	3.1340	-16.4001	-62.1214	-1.6147
3	15.0000	28.8090	3.0224	-13.8090	-47.9329	-1.3596
4	20.0000	30.0134	2.9680	-10.0134	-33.3632	-0.9859
5	25.0000	30.8164	2.9322	-5.8164	-18.8744	-0.5727
6	30.0000	32.0209	2.8796	-2.0209	-6.3110	-0.1990
7	35.0000	32.8238	2.8451	2.1762	6.6299	0.2143
8	40.0000	37.2401	2.6650	2.7599	7.4111	0.2717
9	45.0000	42.4594	2.4771	2.5406	5.9837	0.2501
10	50.0000	44.8683	2.4010	5.1317	11.4373	0.5053
11	55.0000	46.0727	2.3658	8.9273	19.3765	0.8790
12	60.0000	46.8757	2.3435	13.1243	27.9982	1.2922
13	65.0000	49.2846	2.2820	15.7154	31.8871	1.5473
14	70.0000	58.1172	2.1383	11.8828	20.4464	1.1699
15	75.0000	65.3438	2.1276	9.6562	14.7775	0.9507
16	80.0000	73.3735	2.2309	6.6265	9.0312	0.6524
17	85.0000	82.6075	2.4793	2.3925	2.8962	0.2356
18	90.0000	85.4179	2.5770	4.5821	5.3643	0.4511
19	95.0000	90.6372	2.7804	4.3628	4.8135	0.4296
20	100.0000	96.2579	3.0254	3.7421	3.8876	0.3684
21	105.0000	97.8638	3.0995	7.1362	7.2919	0.7026
22	110.0000	115.5290	3.9989	-5.5290	-4.7858	-0.5444
23	115.0000	123.9602	4.4652	-8.9602	-7.2283	-0.8822
24	120.0000	138.4135	5.2968	-18.4135	-13.3032	-1.8129

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

$$Degree = 88.3101 - 0.2655emg \qquad (6)$$

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.



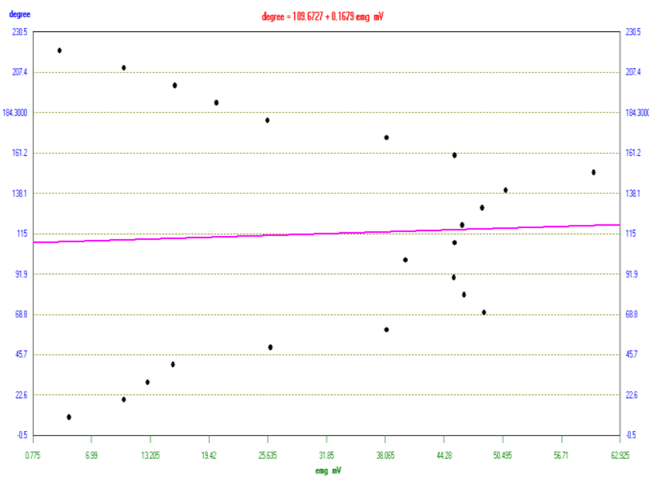
Fig(12) A negative linear module

09-29-2016 11:31:36	Actual degree	Prediction	Std. Dev. of Prediction	Residual	% Residual	Standardized Residual
1	5.0000	87.7259	14.2642	-82.7259	-94.3004	-1.7698
2	10.0000	87.0622	13.1091	-77.0622	-88.5140	-1.6486
3	15.0000	86.5842	12.3182	-71.5842	-82.6758	-1.5314
4	20.0000	85.8143	11.1362	-65.8143	-76.6938	-1.4080
5	25.0000	84.6726	9.6710	-59.6726	-70.4745	-1.2766
6	30.0000	84.4336	9.4209	-54.4336	-64.4691	-1.1645
7	35.0000	83.7433	8.8363	-48.7433	-58.2056	-1.0428
8	40.0000	82.7874	8.4238	-42.7874	-51.6835	-0.9153
9	45.0000	82.0440	8.4599	-37.0440	-45.1514	-0.7925
10	50.0000	81.3271	8.7894	-31.3271	-38.5199	-0.6702
11	55.0000	80.4244	9.5669	-25.4244	-31.6128	-0.5439
12	60.0000	79.2030	11.1112	-19.2030	-24.2453	-0.4108
13	65.0000	78.4065	12.3332	-13.4065	-17.0987	-0.2868
14	70.0000	77.5303	13.8113	-7.5303	-9.7127	-0.1611
15	75.0000	77.1055	14.5664	-2.1055	-2.7306	-0.0450
16	80.0000	76.2824	16.0840	3.7176	4.8735	0.0795
17	85.0000	75.7938	17.0124	9.2062	12.1463	0.1969
18	90.0000	75.3531	17.8643	14.6469	19.4377	0.3133
19	95.0000	77.3710	14.0919	17.6290	22.7851	0.3771
20	100.0000	78.9109	11.5432	21.0891	26.7251	0.4512
21	105.0000	80.3182	9.6812	24.6818	30.7301	0.5280
22	110.0000	82.1502	8.4353	27.8498	33.9011	0.5958
23	115.0000	82.8936	8.4447	32.1064	38.7320	0.6869
24	120.0000	83.6371	8.7664	36.3629	43.4771	0.7779
25	125.0000	84.2743	9.2671	40.7257	48.3252	0.8712
26	130.0000	84.6991	9.7002	45.3009	53.4845	0.9691
27	135.0000	85.4425	10.6158	49.5575	58.0009	1.0602
28	140.0000	86.0001	11.4095	53.9999	62.7905	1.1552
29	145.0000	86.5046	12.1902	58.4954	67.6212	1.2514
30	150.0000	86.8232	12.7088	63.1768	72.7649	1.3515
31	155.0000	87.1949	13.3352	67.8051	77.7627	1.4506
32	160.0000	87.4870	13.8416	72.5130	82.8844	1.5513

table (2) shows the statistical analysis of the module

The linear regression graph and statistical analysis of arm twisting EMG measurements are shown in fig. (13) and table (3) ,Where the equation of the module is :

Degree = 88.3101 – 0.265 EMG (7)



Fig(13) arm twisting EMG

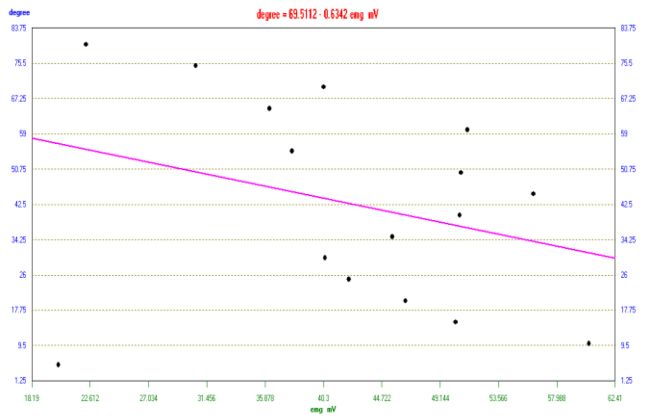
09-29-2016 11:43:31	Actual degree	Prediction	Std. Dev. of Prediction	Residual	% Residual	Standardized Residual
1	10.0000	110.4451	26.6661	-100.4451	-90.9457	-1.5484
2	20.0000	111.4190	22.7205	-91.4190	-82.0497	-1.4093
3	30.0000	111.8388	21.1333	-81.8388	-73.1757	-1.2616
4	40.0000	112.2921	19.5238	-72.2921	-64.3786	-1.1144
5	50.0000	114.0216	14.9795	-64.0216	-56.1486	-0.9869
6	60.0000	116.0868	15.1622	-56.0868	-48.3145	-0.8646
7	70.0000	117.8163	19.8973	-47.8163	-40.5855	-0.7371
8	80.0000	117.4637	18.7114	-37.4637	-31.8938	-0.5775
9	90.0000	117.2790	18.1266	-27.2790	-23.2599	-0.4205
10	100.0000	116.4226	15.8309	-16.4226	-14.1061	-0.2532
11	110.0000	117.2958	18.1786	-7.2958	-6.2200	-0.1125
12	120.0000	117.4301	18.6031	2.5699	2.1885	0.0396
13	130.0000	117.7827	19.7808	12.2173	10.3728	0.1883
14	140.0000	118.2025	21.2854	21.7975	18.4409	0.3360
15	150.0000	119.7640	27.5502	30.2360	25.2463	0.4661
16	160.0000	117.2958	18.1786	42.7042	36.4073	0.6583
17	170.0000	116.0868	15.1622	53.9132	46.4421	0.8311
18	180.0000	113.9712	15.0623	66.0288	57.9347	1.0179
19	190.0000	113.0645	17.1165	76.9355	68.0457	1.1860
20	200.0000	112.3257	19.4096	87.6743	78.0537	1.3515
21	210.0000	111.4190	22.7205	98.5810	88.4778	1.5197
22	220.0000	110.2772	27.3751	109.7228	99.4972	1.6914

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 (8)



Fig(14) wrist bending

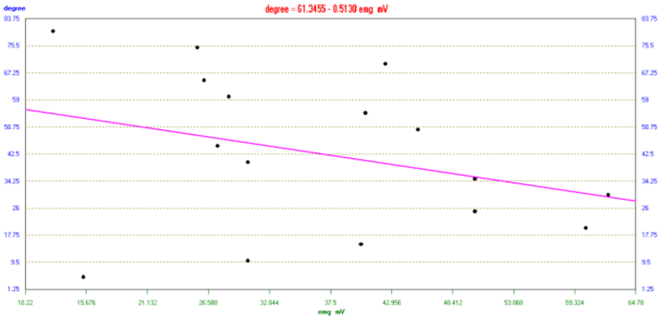
09-29-2016 11:12:45	Actual degree	Prediction	Std. Dev. of Prediction	Residual	% Residual	Standardized Residual
1	5.0000	56.7012	13.3685	-51.7012	-91.1818	-2.2778**
2	10.0000	31.2080	11.2108	-21.2080	-67.9569	-0.9344
3	15.0000	37.6130	7.1818	-22.6130	-60.1202	-0.9963
4	20.0000	40.0228	6.2361	-20.0228	-50.0285	-0.8821
5	25.0000	42.7497	5.8775	-17.7497	-41.5201	-0.7820
6	30.0000	43.8912	5.9904	-13.8912	-31.6491	-0.6120
7	35.0000	40.6570	6.0769	-5.6570	-13.9139	-0.2492
8	40.0000	37.4228	7.2756	2.5772	6.8868	0.1135
9	45.0000	33.8715	9.3670	11.1285	32.8552	0.4903
10	50.0000	37.3593	7.3074	12.6407	33.8353	0.5569
11	55.0000	45.4766	6.3903	9.5234	20.9414	0.4196
12	60.0000	37.0423	7.4700	22.9577	61.9771	1.0114
13	65.0000	46.5547	6.8012	18.4453	39.6208	0.8126
14	70.0000	43.9546	6.0011	26.0454	59.2552	1.1475
15	75.0000	50.1060	8.7103	24.8940	49.6828	1.0967
16	80.0000	55.3695	12.3668	24.6305	44.4839	1.0851

Table(4) statistical analysis Wrist bending

The arm out of the body
EMG measurements is modeled by the equation :

Degree = 61.3455 – 0.5130 EMG (9)

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



Fig(15) arm out of the body

09-29-2016 11:19:45	Actual degree	Prediction	Std. Dev. of Prediction	Residual	% Residual	Standardized Residual
1	5.0000	53.4457	10.5476	-48.4457	-90.6447	-2.1451**
2	10.0000	45.9049	6.4510	-35.9049	-78.2158	-1.5898
3	15.0000	40.7238	6.0154	-25.7238	-63.1665	-1.1390
4	20.0000	30.4130	11.3211	-10.4130	-34.2386	-0.4611
5	25.0000	35.4914	8.1095	-10.4914	-29.5605	-0.4645
6	30.0000	29.3870	12.0335	0.6130	2.0859	0.0271
7	35.0000	35.4914	8.1095	-0.4914	-1.3847	-0.0218
8	40.0000	45.9049	6.4510	-5.9049	-12.8633	-0.2615
9	45.0000	47.2899	6.9942	-2.2899	-4.8423	-0.1014
10	50.0000	38.1076	6.8242	11.8924	31.2073	0.5266
11	55.0000	40.5186	6.0565	14.4814	35.7400	0.6412
12	60.0000	46.7770	6.7769	13.2231	28.2683	0.5855
13	65.0000	47.9055	7.2772	17.0945	35.6838	0.7569
14	70.0000	39.5953	6.2916	30.4047	76.7888	1.3463
15	75.0000	48.2133	7.4270	26.7867	55.5588	1.1861
16	80.0000	54.8307	11.4890	25.1693	45.9037	1.1145

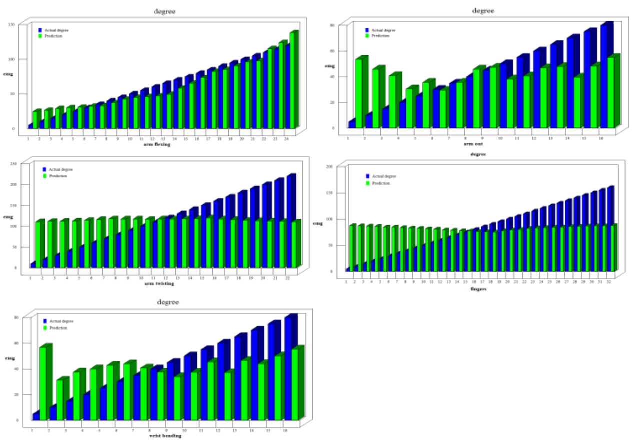
Table (5) statistical analysis arm out of the body

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) .



Fig(16) resultant histograms

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.

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Dr.Naufel B. Mohammed : born at 24\12\1961. Kurdistan _Iraq. BSC (1983),MSC(1997) . PhD (2000) in electrical engineering /machine control system from university of technology –Baghdad .Assist .prof..since 2007,head of IT department in Kurdistan (KISSSR) institution for stragic studies and scientific research .publication in field of simulation ,fuzzy, robots and data acquisition system. Currently research on EMG,EOG and EEG signal for robot control purposes.

Atta A. Saeed : Bsc. In statistical and computer sciences .wide experience in data analysis and data base system .member of IT research team at KISSSR mob, 09647701226630

Avan M. Ahmad :Technical School of electrical maintenance**.** An expert of libratory technical and measuring techniques, wide experience in data collection of bio signal equipment ,member of IT research team at KISSSR.