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Judul:

Finger Movement Regression with Myoelectric Signal and Deep Neural Network

disusun oleh:

Khairul Anam, Dwiretno Istiyadi Swasono, Aris Zainul Muttaqin, Faruq Sandi Hanggara

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Foreword from General Chair ICOMITEE 2019

In the name of Allah, the Most Beneficent and the Most Merciful.

On behalf of the organizing committees, I would like to welcome all of you to Jember, Indonesia for the 2019 International Conference on Computer Science, Information Technology and Electrical Engineering (ICOMITEE)

ICOMITEE 2019 is the international conference hosted by University of Jember (UNEJ), co-hosted by State Polytechnic of Jember (POLIJE) and Nahdlatul Ulama University of Surabaya (UNUSA). ICOMITEE 2019 is officially approved by IEEE Indonesia Section and IEEE Indonesia Section Computer Society Chapter for technical co-sponsored. ICOMITEE 2019 is also officially sponsored by IEEE Signal Processing Society Indonesia Chapter.

This event is intended to provide technical forum and research discussion related to advance engineering on electrical & electronics, computer science and informatics. The Conference is aimed to bring researchers, academicians, scientists, students, engineers and practitioners together to participate and present their latest research finding, developments and applications related to the various aspects of Information System Management, Data Analytics & Big Data, IT Infrastructure and Security, Electrical and Telecommunication

Allow me to express my deepest gratitude to those who have made this conference possible. My thanks go to the Rector of University of Jember. I would also like to thank the invited speakers: Prof ASM Sajeev from Melbourne Institute of Technology, Australia, Prof. Richardus Eko Indrajit, chairman of ID-SIRTII and Associate Professor Kamal Kant Sharma from Chandigarh University, India for accepting our invitation in the conference.

At this conference, the committee received total 82 full manuscript from various cities in Indonesia and abroad such as Australia, Algeria, Iran and Sri Lanka. But, after the review process, 49 full manuscripts were accepted.

We also want to thanks and appreciation for your dedication for ICOMITEE 2019 to all committee, all TPC Sponsorship and Financial Sponsorship, TPC member, and 301 high reputation reviewer from various country.

We look forward to having a successful conference, and we hope that all the attendees enjoy and benefit from this conference.

Prof. Saiful Bukhori ST., M.Kom.
General Chair of ICOMITEE 2019

Foreword from IEEE Indonesia Section

Dear distinguished guests, keynote speakers, colleagues, researchers, professionals, ladies and gentlemen, good morning, a prosperous, warm, and spirited greeting.

On behalf of IEEE Indonesia Section, we would like to extend our warmest welcome to all keynote speakers, presenters, and participants to the 2019 International Conference on Computer Science, Information Technology and Electrical Engineering (ICOMITEE). The conference is organized by Universitas Jember (UNEJ) and technically co-sponsored by IEEE Indonesia Section. The conference aims to bring together researchers and experts in information systems to share their ideas, experiences and insights.

IEEE Indonesia Section has conducted many activities over 32 years. in Indonesia. In terms of collaboration, IEEE Indonesia section has a good and mutual relationship with ICT organizations, Industries, Government, Universities as well as the Community in Indonesia. IEEE Indonesia Section has contributed in about 58 different International conferences annually. This conference shows its sustainability due to the hard work of the conference organizers, well organized conference and high quality papers. We do hope in the near future some high quality conferences will be continued and strengthened, so the result will give more benefit and positive impact to the human being, especially to Indonesian people.

In this occasion, I would also like to say welcome to Jember, which serves beautiful heritages, culture, with warm, polite and friendly people, a vibrant culture and lifestyle.

Finally, we do hope all of you will have enjoyable and valuable experience during this event. You may share your best knowledge in your area of research and professional activities.

Thank you.

Prof. Dr.Eng. Wisnu Jatmiko
Chairman, IEEE Indonesia Section

Foreword from IEEE Computer Society Indonesia Section

Dear colleagues, Professors, researchers, ICT professionals, ladies and gentlemen,

Representing IEEE Computer Society Indonesia Section of The 2019 International Conference on Computer Science, Information Technology, and Electrical Engineering (ICOMITEE) 2019, we would like to express our deep gratitude, to the researchers, paper authors, and all the participant of ICOMITEE 2019. Welcome to Jember in Indonesia!

The conference is an annual event, organized by University of Jember, Jember, Indonesia.

This ICOMITEE 2019 was has been approved and technically co-sponsored by IEEE Computer Society Indonesia Section, with the conference No. #47614

With nearly 100,000 members, the IEEE Computer Society is the world's leading organization of computer professionals. Founded in 1946, it is the largest of the 37 societies of Institute of Electrical and Electronics Engineers (IEEE). The Computer Society's vision is to be the leading provider of technical information and services to the world's computing professionals.

The IEEE Computer Society Indonesia promotes and facilitates the computer-related activities of the IEEE Indonesia. It is one of the IEEE Indonesia technical chapters.

Through this opportunity, I would also like to highlight that Indonesia is an emerging country, one of the fastest growing countries in South East Asia and Pacific. Based on International Data Corporation, Indonesia has become the largest spender on ICT in South East Asia and is ranked 19th by spending globally.

The ICOMITEE 2019 provides a good platform for researchers, scientists and the entire engineering community to meet each other and exchange ideas on electronic and computer related fields, and their applications including research stimulation, the applications of electronic and information technologies, and the discussion to advance for region-wide cooperation in related disciplines. It also offers opportunity, exhibition, and business meetings.

I do hope in the near future the event will be continuing continued and strengthened, so the result will be give more benefit and give more positive impact to the Indonesian people. Technology drives innovation, people can do more, do better. Technology drives higher quality of life, people can live better.

In this occasion, I would also like to say welcome to Jember, one of the famous destinations in Indonesia. , where Jember serves beautiful heritages and scenery with warm and friendly people, a vibrant culture and lifestyle.

Finally, we do hope all of you will obtain an enjoyable and valuable experience. During this 2 days conference, , and also you may share your best knowledge in your area of research and professional activities., during this 2 days conference.

Thank you.

Dr. Tanty Oktavia
Treasury and Vice Chair of IEEE Computer Society Indonesia Section

Foreword from Rector of University of Jember

In the name of Allah, the Most Beneficent and the Most Merciful.

First of all, I would like to welcome you all to the University of Jember, Indonesia. I am delighted to have you here to participate and attend the 2019 International Conference on Computer Science, Information Technology, and Electrical Engineering (ICOMITEE 2019). Thank you for coming, many of you travel long distances serves to remind us to conduct a highly fruitful conference.

This great event facilitates interaction among academics, researchers, and policymakers in this region through plenary sessions and parallel paper presentations. I am glad to know that this conference takes up some subjects like telecommunication, electrical, data analytics & big data, IT infrastructure & security, also management information system. I expected that every paper would inspire us to make more contributions to the related field. Hopefully, everyone will benefit from this event by sharing paper and experiences. Also learned new ideas from each other, which we could adopt to improve our work in this era further.

I would like to appreciate the Organizing Committee that has been working hard for the preparation of this international academic event. Also, I thank our sponsors (IEEE Indonesian Section, IEEE Computer Society Indonesian Section, IEEE Signal Processing Society), for providing support and assist us for the conference. Let me also thank the scientific conference committee.

Finally, let me reiterate my warm welcome to all of you to the university, and I wish you all a very successful conference.

Assoc. Prof. Moh. Hasan
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Finger Movement Regression with Myoelectric Signal and Deep Neural Network

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***Abstract*— Research on electromyographic (EMG) signals is intensively carried out to help disabled people to control prosthetic hands. Neural Networks have been widely used in research on the classification of finger movements using EMG. The study of a classification system generally still works on a limited number of movements, even though the human body, especially fingers, has a nearly unlimited combination of movements to help do daily activities. To overcome this, a proportional control system is needed. In its recent development, research on myoelectric control using EMG devices is still in a laboratory environment. Hence, the results obtained in a clinical setting are often different. However, along with technological developments, the emergence of affordable and wearable commercial EMG devices such as Myo Armband, has encouraged this study to develop control systems of prosthetic fingers using regression. One of many options available is neural networks that have been widely used in various fields. By estimating each joint with a different neural network, the result shows the predicted is fitted to the actual angle with R^2 as high as 99%.**

Keywords*— *electromyographic (EMG) signals, neural network, regression.

I. Introduction

The interface of prosthetic robots or assistive devices for the disabled that use hands (joysticks or keyboards), sounds, or facial expressions, is inconvenient to use. Therefore, it is necessary to use a hand-free interface. A myoelectric signal should be able to provide an accurate, intuitive, and responsive interface. Thus, myoelectric control systems (MCS) have been widely used to interface prosthetic robots and assistive devices by using electromyographic (EMG) signal patterns[1].

Electromyographic (EMG) signals are signals generated from the process of evaluating and recording the electrical activity produced by muscles (Myoelectric). Electromyography can be done by inserting an electrode needle into the skin or attaching an electrode plate over the skin so that it can capture the electrical signal from the muscle. The Myoelectric signals produced vary depending on ongoing muscle activity. The myoelectric signal is formed by a sum of motor action potentials generated by muscle contraction [1].

The myoelectric control system has many potentials, including but not limited to, multi-functional prostheses, wheelchairs, grasping controls, virtual keyboards, and gait generations [1], even though the myoelectric control system is still far from widespread commercial applications due to obstacles to have good control. Myoelectric control system research centers on arm movements [2][3] and uses a classification system [1][4][5][6]. However, one of the most common losses suffered by people with arm disabilities is the loss of functional hand positions whereas daily activities depend on this functional hand position [7], such as using a spoon, buttoning a shirt, holding a ball, and so on.

Research on finger movements also yields impressive classification results but with non-wearable surface EMG and more sensor channels that may bother the user and make replacement more difficult [8][9][10]. Research with fewer sensors is done and produces a good classification though it only works on very limited movement class [10][11][12]. The fact that previous research focused on the classification means that it is contrary to the number of body movements like fingers which are almost unlimited. This type of control is inadequate to exploit all functions offered by prosthetic robot as only one class of movement activated at a time in classification system [13]. Therefore, a proportional control system is needed [14]. Proportional control systems require predictions in each joint.

Although better results are obtained with invasive EMG electrodes [15], this technique needs special medical treatment and further observation of long-term effects. Myo Armband, a wearable surface EMG device, is a non-intrusive tool that allows users to slip the device on. However, the limitation comes as quality and quantity of signals of dry electrodes on Myo Armband are less accurate than gel-based one [16]. Some previous studies such as [17] and [18] also estimate finger joints, but we found that previous studies (although estimating one joint with a different estimator) used recording EMG signals on non-functional movements such as extensions on one finger while the other fingers were in flexion. Finger gesture such as thumb up, V-sign, and horn-sign is the result of different muscle synergies. Thus, this study proposes regression of the finger joint for functional movements using a deep neural network.

II. Method

A. Dataset

This study uses a database of NinaPro (Non-Invasive Adaptive Hand Prosthetics) [19], which is a surface EMG signal benchmark data resource from the upper arm. NinaPro has a dataset that was of concern in this study. The dataset (called NinaPro DB5) was obtained by recording using the Myo-Armband device, the surface EMG signal recording device with low prices issued by Thalmic startup (Ontario, Canada) in 2013. Myo-Armband has a much lower price than other devices used in NinaPro but provides competitive performance with Cometa miniWave and Dormo in the classification system [20].

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As with the dataset available at NinaPro, DB5 provides hand kinematic data recordings obtained using 22-channel CyberGlove II and EMG data obtained with two Myo Armbands, each of which has 8-channel EMG sampled at 200Hz. Each of CyberGlove II finger has four sensors. Two are to record distal and proximal interphalangeal (DIP, PIP) joint angles. The remaining two are for measuring extension/flexion and abduction/adduction in the metacarpophalangeal (MCP) joint (Fig. 1) [21]. The acquisition setup is described in detail [20].

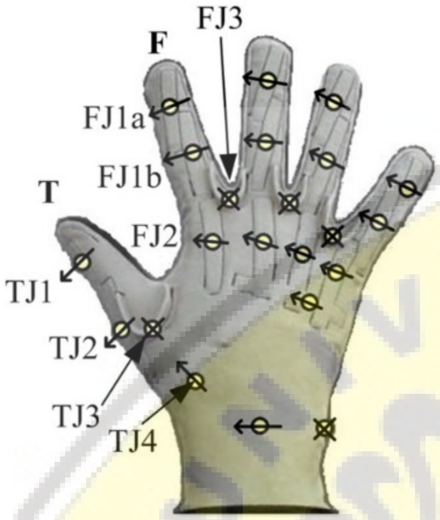


Fig. 1. Channel sensor placement depicting joint movement [21]

Fig. 2 shows the arrangement of devices during recording. This study uses exercise C from a paper [19], which consists of 23 grasping and functional movements that use everyday objects (Table 1).

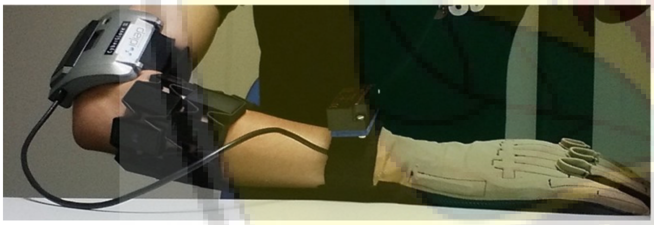
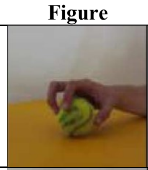
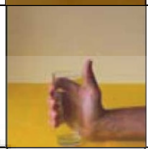
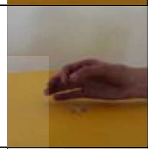
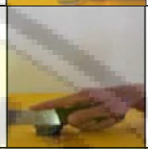
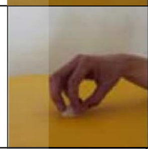
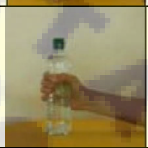
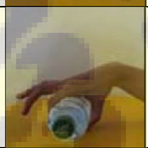
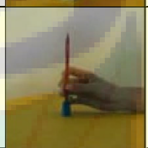
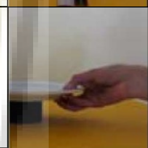
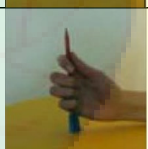
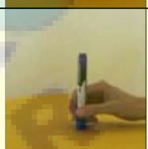
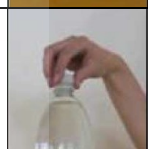
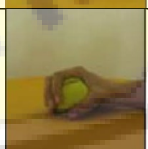
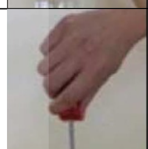
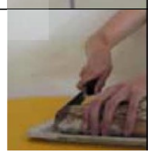
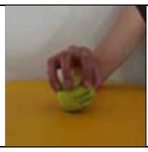


Fig. 2. NinaPro DB5 data acquisition setup [20]

NinaPro DB5 has ten subjects consisting of 8 male subjects and two female subjects. Nevertheless, this study used two male subjects and two female subjects. This study also only uses two fingers, the thumb, and index finger as [22] mentioned that previous studies [23][24] have shown digits such as the thumb and index finger. These are moved relatively independently, whereas the others are most often moved together. Thus, channel number 1, 2, 3, 4, 5, 6, 7, and 8 of CyberGlove have been used (Fig. 3).

TABLE I. TWENTY-THREE FUNCTIONAL MOVEMENT OF FINGERS AND REST [19]

Action	Figure	Action	Figure
Large diameter grasp		Tripod grasp	
Small diameter grasp (power grip)		Prismatic pinch grasp	
Fixed hook grasp		Tip-pinch grasp	
Index finger extension grasp		Quadpod grasp	
Medium wrap		Lateral grasp	
Ring grasp		Parallel extension grasp	
Prismatic four fingers grasp		Extension type grasp	
Stick grasp		Power disk grasp	
Writing tripod grasp		Open a bottle with a tripod grasp	
Power sphere grasp		Turn a screw (grasp the screwdriver with a stick grasp	
Three fingers sphere grasp		Cut something (grasp the knife with an index finger extension grasp)	
Precision sphere grasp		Rest	

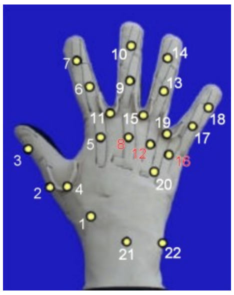


Fig. 3. The sensor channel position of 22-channel Cyberglove [25]

B. Feature extraction

Successfully recorded EMG signal cannot be used directly because the nature of the EMG signal is complex and is a synergy of several muscles. The DB5 exercise C dataset contains 23 types of movements and is interrupted by rest time in a file. Pre-processing data before feature extraction was split into groups of 23 functional movements and one rest movement. This grouping is done to make windowing of the EMG signal easier to eliminate transition signal. The windowing itself produces a different number of windows, so down sampling is then done. This leads to the same number of samples for each movement. This grouping and down sampling are done because the NinaPro data acquisition protocol requires repeating each type of the movement six times interspersed with resting movements.

The features of this study are extracted from the time domain because it is simpler and only based on amplitude [1]. The features are obtained from the sliding window instead of using the disjoint window, to get redundant data. The feature obtained are mean absolute value (MAV), root means square (RMS), waveform length (WFL), integrated absolute value (IAV), zero crossings (ZC), dan slope sign change (SSC). A detailed definition of these features can be found in [26] and [3]. Thus, each channel will produce six different features. Some equations of the features are described in equation (1) to (3).

$$MAV = \frac{1}{N}\sum_{k=1}^{N}|x_k| \quad (1)$$

$$RMS = \sqrt{\frac{1}{N}\sum_{k=1}^{N} {x_k}^2} \quad (2)$$

$$WL = \sum_{k=1}^{N}|x_k - x_{k-1}| \quad (3)$$

Where x is a signal window, N is the length of window x and k-th element of window x correspond to x_k.

C. Deep Neural Network

A neural network (NN) is a collection of algorithms arranged to mimic how relationships between neurons in the brain work [27]. Neural networks are almost used in every field, from self-driving cars to drug discovery [28]. A neural network works forward (feed-forward) from the input layer to the output layer [27]. Nevertheless, neural networks learn by doing repeated weighing, which is done after a neuron receives feedback from a neuron that is right in front of it (moves backward) [29]. Thus, it named backpropagation. For the regression process with a neural network, this study uses Keras [30], the deep learning framework in the Python programming language.

III. Result

This study uses data from 2 men (M 1, M 2) and 2 women (F 1, F 2). After windowing with window length 200 frames and increment 25 frames, each produces 3552, 2904, 3120, and 3816 windows. Then, the features of windows have been extracted. The features are normalized before being inserted into the neural network. Neural network (NN) is used to study the relationship between EMG signals and finger positions. This paper uses a different NN for each joint. The neural network model created in this study uses four hidden layers (Fig. 4). The neuron number ratio between a former and latter was fixed to 2:1, so that the number of hidden neurons is (128, 64, 32,16) with each having ReLU as the activation function. The model fitted dataset with batch size 32, shuffled (which are the default values of Keras), and compiled with Adadelta as optimizer [31] and mean square error (MSE) as loss function and metric model.

Data is separated for training and validation/test 0.8 and 0.2, respectively. NN with 4 hidden layers is chosen, because in general, training Deep NN will be more difficult as the network gets bigger [32]. The problems that can be effectively solved by a single layer feed-forward network (SLFN) turn out to be inefficient when applied at DNN [33] . This problem can be overcome by implementing dropout, batch normalization, and similar regularization, but these will add to the variation of the network architecture created. To keep the model simple, we used 4 hidden layers.

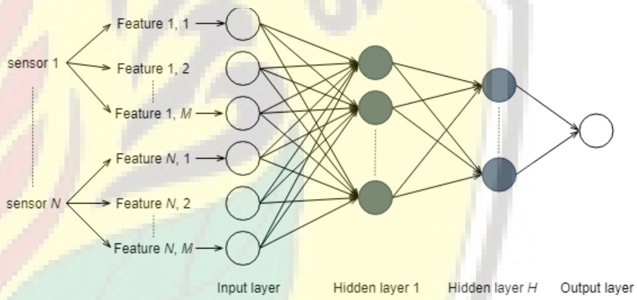


Fig. 4. Neural network regression model with multiple hidden layers and feature extractions before the input layer.

The neural network is first tested by doing five cross-validations (5-CV) with 100 epochs to see a general picture of the performance of the neural network on each channel and subject (Table 2). 5-CV was chosen because it can be assumed that 4/5 of the data as training data is enough to estimate how well each fold represents the whole without sacrificing computing time. Performance is measured with MSE.

TABLE II. NEURAL NETWORK 5-CV AVERAGE PERFORMANCE (MSE)

	Channel Number							
	1	2	3	4	5	6	7	11
M 1	26.5	3.9	4.9	2.0	8.5	7.3	1.8	510.5
M 2	30.7	3.8	10.2	2.9	13.1	11.3	1.2	739.2
F 1	45.6	9.7	5.1	2.3	9.1	10.4	1.5	885.7
F 2	31.9	1.8	2.6	1.4	6.9	5.0	0.2	495.7
Avg.	33.7	4.8	5.7	2.1	9.4	8.5	1.2	657.8

Moreover, using the same parameters and data with the help of Keras, a neural network is trained by limiting the number of epochs to avoid overfitting. The training will early stop if, for the last ten epochs, the validation loss does not decrease (Table 3). The R^2 score (the percent variability in the actual angular values explained by the estimated values) is shown in Table 4 to tell how close the data are to the fitted regression line. The results of prediction errors of subject male 1 can be seen in Fig. 5 and Fig. 6.

TABLE III. NEURAL NETWORK PERFORMANCE (MSE) WITH AN EARLY STOP

	Channel Number							
	1	2	3	4	5	6	7	11
M 1	24.3	11.7	5.8	4.2	9.8	14.3	3.1	627.1
M 2	60.6	3.1	11.8	2.2	8.8	12.1	1.7	727.6
F 1	33.9	9.7	3.3	1.6	7.0	9.7	1.7	725.5
F 2	13.9	1.7	1.9	1.1	4.5	6.2	0.2	269.1
Avg.	33.1	6.5	5.7	2.3	7.5	10.6	1.6	587.3

TABLE IV. NEURAL NETWORK COEFFICIENT OF DETERMINATION (R^2) IN PERCENT

	Channel Number							
	1	2	3	4	5	6	7	11
M 1	93.9	67.6	98.7	97.0	97.0	96.5	97.0	99.1
M 2	85.8	95.8	97.8	97.4	96.7	94.5	98.4	98.2
F 1	89.2	92.3	95.8	97.6	98.0	95.7	94.3	98.8
F 2	93.7	97.6	98.4	98.7	98.5	97.6	98.9	98.8
Avg	90.7	88.3	97.7	97.7	97.6	96.1	97.2	98.7

We also measure results of epsilon-support vector regression (SVR) and indicate, in Table 5, that SVR hardly reaches 80%.

TABLE V. SVM COEFFICIENT OF DETERMINATION (R^2) IN PERCENT

	Channel Number							
	1	2	3	4	5	6	7	11
M 1	79.3	87.7	61.6	90.3	79.9	65.1	89.0	23.7
M 2	70.4	76.5	42.6	67.4	72.0	62.6	75.8	41.0
F 1	53.9	67.6	71.5	54.9	64.2	60.9	58.9	20.1
F 2	89.0	75.3	79.4	68.5	70.1	80.0	91.4	41.7
Avg	73.1	76.8	63.8	70.3	71.6	67.1	78.8	31.6

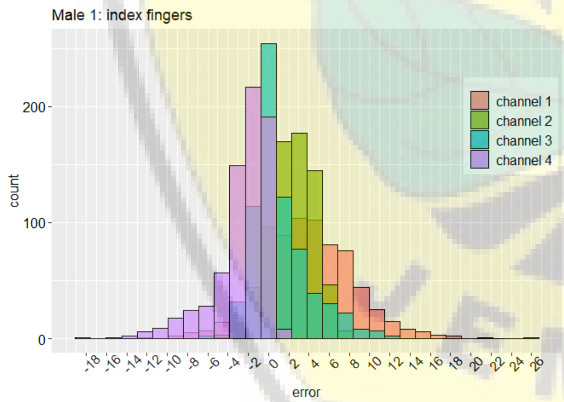


Fig. 5. Index finger movement prediction error histogram for male 1

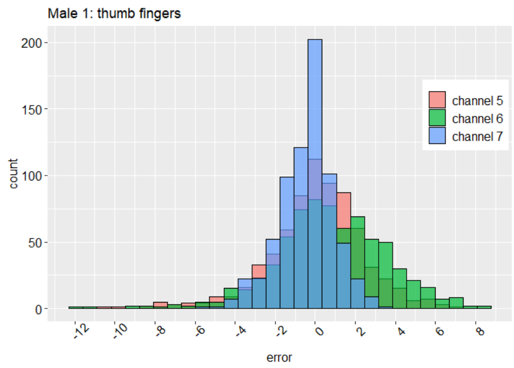


Fig. 6. Thumb movement prediction error histogram for male 1

IV. CONCLUSION

If we only look at MSE, we cannot know whether the prediction results are good enough, because there is no information regarding the real value of the joint angle (CyberGlove sensor's reading is proportionally declared to the angle with a resolution of less than one degree, depending on the size of the subject's hand). Table 4 shows how close the data are to the fitted regression line and the result is quite high. CyberGlove channels for number 1 and 11 show a very high MSE value, but the channel is on the MCP joint and measures abduction/adduction, while other channels measure flexion/extension.

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