

Irene Uriarte, Martin Garenfeld, Oliver Damsgaard, Simon Bruun. Aalborg University, School of Medicine and Health

## AIM

The aim for this project are expressed in the following two hypotheses:

- Simultaneous and proportional control of two DOF's of the wrist in different limb positions, can be achieved through the use of linear regression as control system.
- Combining surface EMG and IMU's can minimize the limb position effect when using regression as control system.

## METHODS

Surface EMG data was collected from four able-bodied subjects. Subjects were instructed to performed four different hand gestures. This study only focus on two DOF, which are, flexion and extension, radial and ulnar deviation of the wrist. sEMG signals were recorded with Myo armband, positioned on the right forearm of the subjects while standing.

The sEMG was recorded by eight channels in a frequency range 0-200Hz. IMU data was recorded using the buildt in accelerometer in the Myo armband. sEMG data were filtered through a second-order Butterworth high-pass filter, with cutoff frequency  $f_c=10\text{Hz}$ .

Features are extracted using a sliding-window of 40 samples with an overlapping of the 50%. Two time domain features are extracted; Mean absolute value (MAV) and logarithmic variance. MAV represent the amplitude of the signal. It is defined as the average of the absolute values of the sEMG signal:

$$MAV = \frac{1}{N} \sum_{i=1}^N |x_i| \quad (1)$$

where  $N$  is the length of the signal, and  $x_i$  is the signal of  $i$  samples. The logarithmic variance is a nonlinear transformation of the variance applied to

$$\log(\sigma^2) = \log\left(\frac{\sum_{i=1}^N (x_i - \mu)^2}{N}\right) \quad (2)$$

where  $N$  is the length of the signal,  $x_i$  is the  $i^{th}$  sample of the signal and  $\mu$  is the mean. PCA is applied to qualitatively determine the separability of the feature data. Data is evaluated for differences in feature data clusters and significant outliers. If the feature clusters are distinguishable from each other and have no significant outliers, the data is of high quality and will be used to train the regressors. Only the first three principal components identified through PCA will be used to train the regressors. The regressors are implemented through simple linear regression:

$$Y = \alpha + \beta X + \epsilon \quad (3)$$

where  $Y$  is the dependent variable or response,  $X$  is the independent variable or the predictor,  $\beta$  is the regression coefficient or the slope, and  $\alpha$  is the Y intercept (predicted value of  $Y$  at  $X = 0$ ),  $\epsilon$  is the error. The regressor accuracy of control is tested qualitatively through superimposition of the output of the regressors build for each feature onto the actual data for the intensities of the movements. The regressor accuracy is quantitatively tested through a target reaching task measuring time to reach 16 targets. The scores are compared through statistical t-test, comparing scores between limb positions and between only using sEMG data and including IMU data.

All data processing is performed in Matlab (2017).

## INTRODUCTION

The development of EMG controlled prosthetics have advanced greatly in recent years. More complex prosthetics are demanded and more advanced control methods has been developed. Most control methods so far has utilized pattern recognition which only enables control of one degree of freedom at a time. Most studies have conducted tests in only one limb position, not considering the limb position effect on EMG signals. [1] This study aims to overcome the limb position effect by combining EMG with inertial information in the training sessions of the regressor to obtain simultaneous and proportional control of EMG prosthesis.

## OFFLINE RESULTS

Results of the superimposition of the regressor outputs on the estimated data.

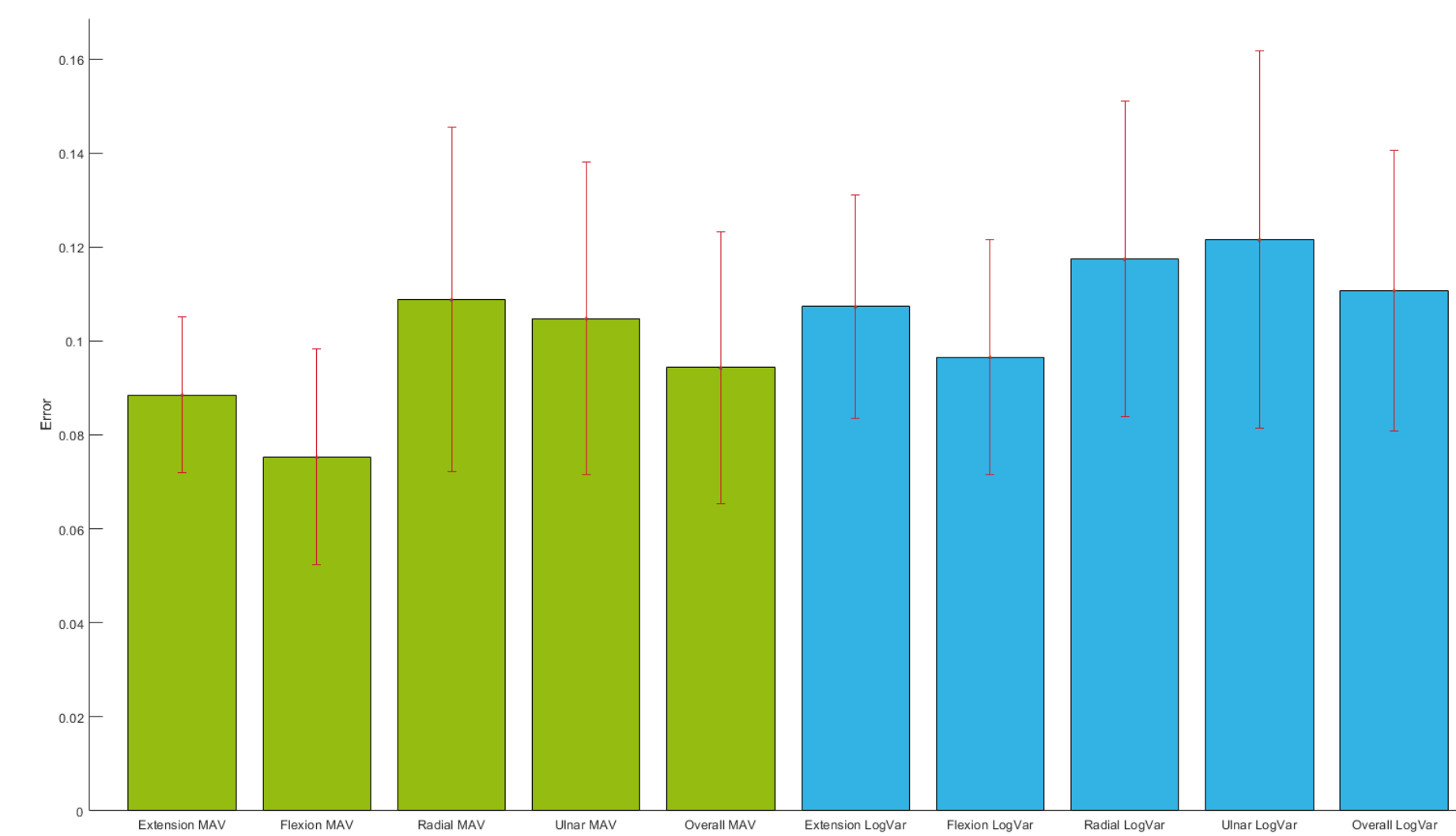


Figure 3: Superimposition of data.

The results for the offline test of accuracy of the regressors of both test and training data. This test determines if the training of the regressors have over- or under-fitted to the training data.

Feature	Overall mean error	Highest mean error
MAV	$0.0943 \pm 0.0290$	$0.1088 \pm 0.0366$
Log-Var	$0.1107 \pm 0.0298$	$0.1216 \pm 0.0402$

Table 1: RMSE of training data

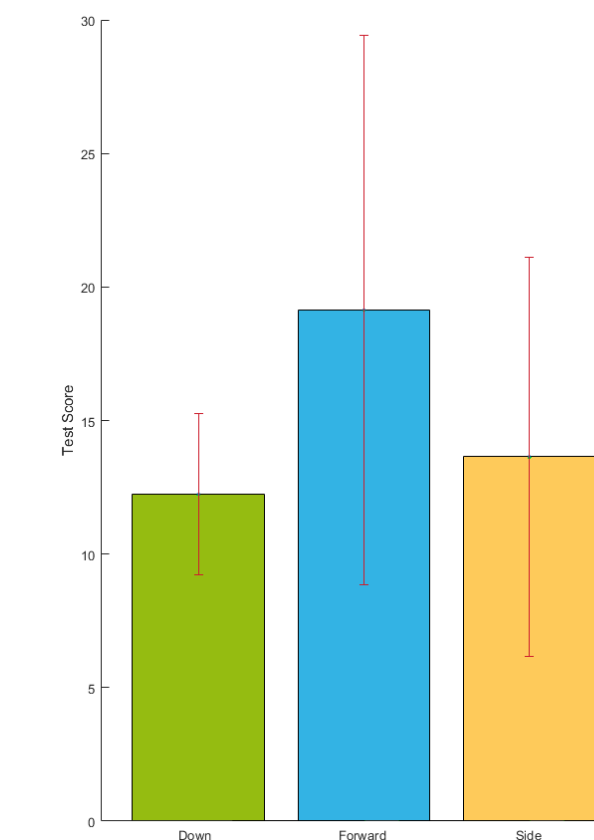
\*\*\* maybe put some text here to devide the tables \*\*\*

Feature	Overall mean error	Highest mean error
MAV	?? ± ??	?? ± ??
Log-Var	?? ± ??	?? ± ??

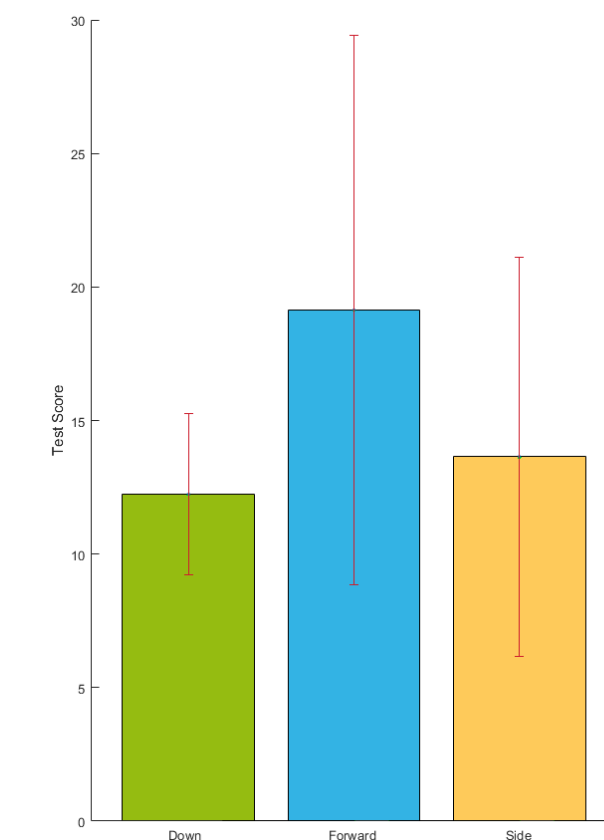
Table 2: RMSE of test data

## ONLINE RESULTS

Results for the online test of regressor accuracy and control. The test is performed in a modified Fitts' Law test of reaching targets. The score is calculated as the relation between time and number of targets reached.



**Figure 1:** The mean test score among four subjects when using regressors trained with Log-Var excluding IMU information

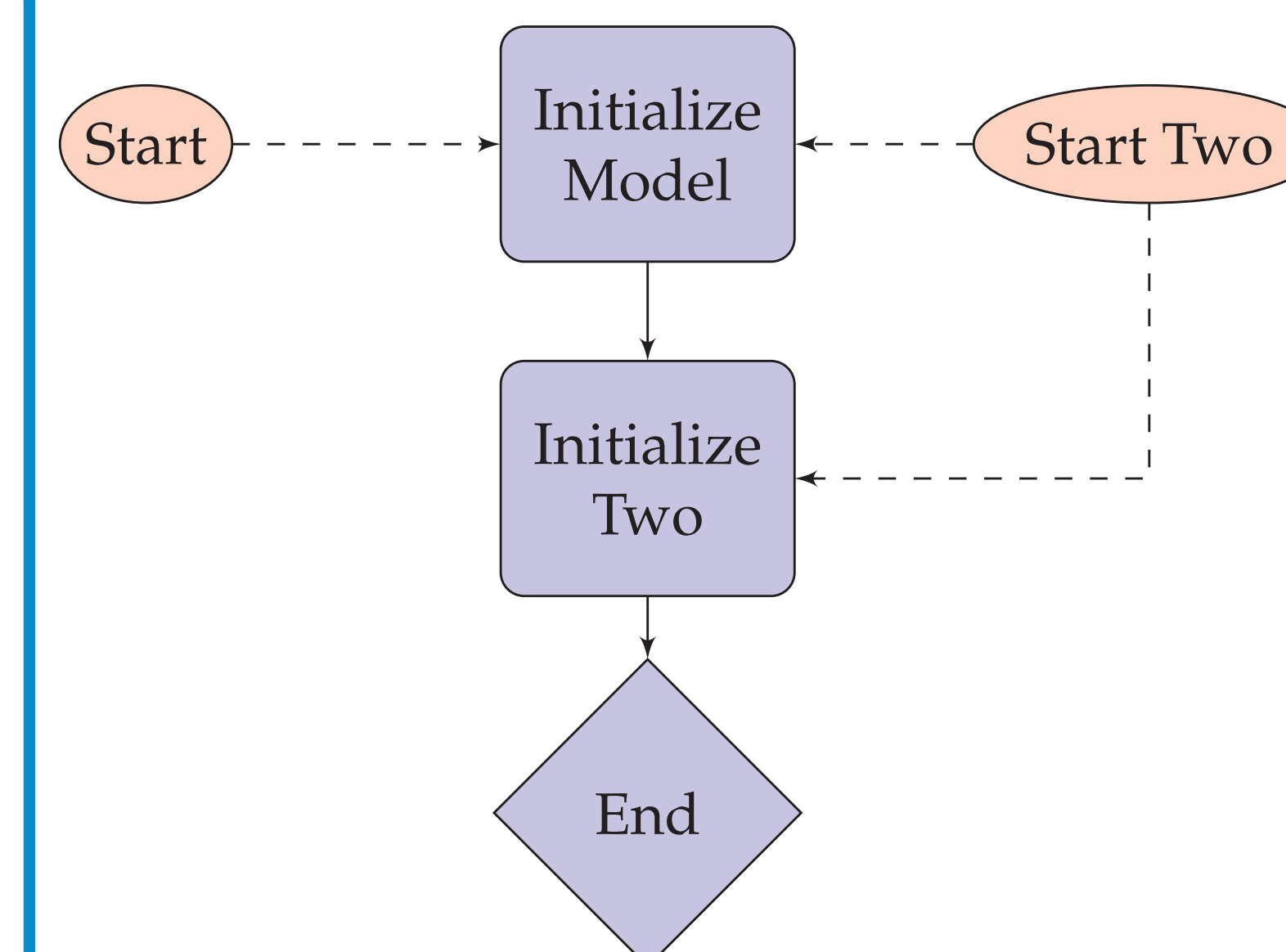


**Figure 2:** The mean test score among four subjects when using regressors trained with Log-Var excluding IMU information

```
*** text ***
```

placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder  
text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder  
placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder  
text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text.  
placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder text. placeholder  
text. placeholder text. placeholder text. placeholder text. placeholder text.

## CONCLUSION



- Pellentesque eget orci eros. Fusce ultricies, tellus et pellen-  
tesque fringilla, ante massa luctus libero, quis tristique pu-  
rus urna nec nibh. Phasellus fermentum rutrum elementum.  
Nam quis justo lectus.
- Vestibulum sem ante, hendrerit a gravida ac, blandit quis  
magna.
- Donec sem metus, facilisis at condimentum eget, vehicula ut  
massa. Morbi consequat, diam sed convallis tincidunt, arcu  
nunc.
- Nunc at convallis urna. isus ante. Pellentesque condimen-  
tum dui. Etiam sagittis purus non tellus tempor volutpat.  
Donec et dui non massa tristique adipiscing.

## REFERENCES

- [1] Anders Fougner, Erik Scheme, Adrian D.C. Chan, Kevin Englehart, and Øyvind Stavdahl. Resolving the limb position effect in myoelectric pattern recognition. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 19, 2011.
- [2] J. M. Smith and A. B. Jones. *Book Title*. Publisher, 7th edition, 2012.
- [3] A. B. Jones and J. M. Smith. Article Title. *Journal title*, 13(52):123–456, March 2013.

## CONTACT INFORMATION

**Web** [www.smh.aau.dk](http://www.smh.aau.dk)

**Email** 17gr7404@hst.aau.dk