MUSCLE CLASSIFICATION VIA HYBRID CNN-LSTM ARCHITECTURE FROM SURFACE EMG SIGNALS

HYBRID MODEL VS CNN AND LSTM ALONE

The present document compares 3 architectures for the task of muscle classification from SEMG data: our hybrid model (CNN+LSTM) against CNN alone, and LSTM alone. The training setup, the metrics employed, as well as the results obtained from each of the evaluated architectures are presented in the following sections.

Training Setup

The previously mentioned architectures are trained over 200 epochs, using batches of 1024 samples at a time in form of TensorFlow Records. The selected loss function is the categorical cross entropy, which is an ideal loss function for the multiclass classification task that the model is addressing. Moreover, the accuracy is stored through the epochs as it is a relevant metric in classification. Adaptive Moment Estimation (ADAM) is used as optimizer with a fixed learning rate of 0.001.

Note that some of the hyperparameters defined in the architecture of the model are determined through empirical manual tuning. A total of 49648 samples are used for the training step, while 12464 samples are used for the first validation scenario (new bursts from seen subjects) and 7664 samples for the second validation scenario (new bursts from unseen subject, meaning the leave-one-out subject). Random weight initialization was used for the three architectures.

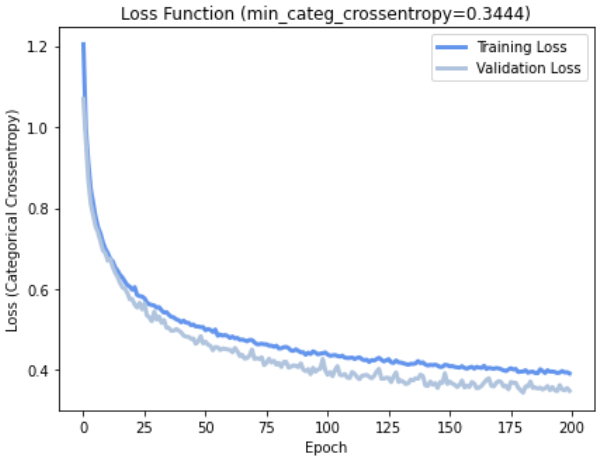
Evaluation Metrics

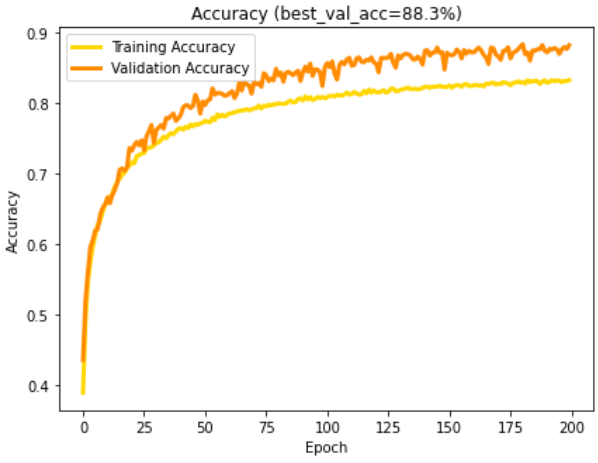
The metrics for evaluating the performance of each of the architectures are:

- Precision
- Recall
- F-Score
- Accuracy

CNN ONLY

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
cnn_layer_1 (Conv1D)         (None, 500, 32)           192
_________________________________________________________________
leaky_re_lu_20 (LeakyReLU)   (None, 500, 32)           0
_________________________________________________________________
max_pooling1d_10 (MaxPooling (None, 250, 32)           0
_________________________________________________________________
dropout_20 (Dropout)         (None, 250, 32)           0
_________________________________________________________________
cnn_layer_2 (Conv1D)         (None, 250, 64)           14400
_________________________________________________________________
leaky_re_lu_21 (LeakyReLU)   (None, 250, 64)           0
_________________________________________________________________
max_pooling1d_11 (MaxPooling (None, 125, 64)           0
_________________________________________________________________
dropout_21 (Dropout)         (None, 125, 64)           0
_________________________________________________________________
dense_15 (Dense)             (None, 125, 50)           3250
_________________________________________________________________
leaky_re_lu_22 (LeakyReLU)   (None, 125, 50)           0
_________________________________________________________________
dropout_22 (Dropout)         (None, 125, 50)           0
_________________________________________________________________
dense_16 (Dense)             (None, 125, 15)           765
_________________________________________________________________
leaky_re_lu_23 (LeakyReLU)   (None, 125, 15)           0
_________________________________________________________________
dropout_23 (Dropout)         (None, 125, 15)           0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1875)              0
_________________________________________________________________
dense_17 (Dense)             (None, 4)                 7504
=================================================================
Total params: 26,111
Trainable params: 26,111
Non-trainable params: 0
```





Confusion Matrix: Intrapersonal Validation

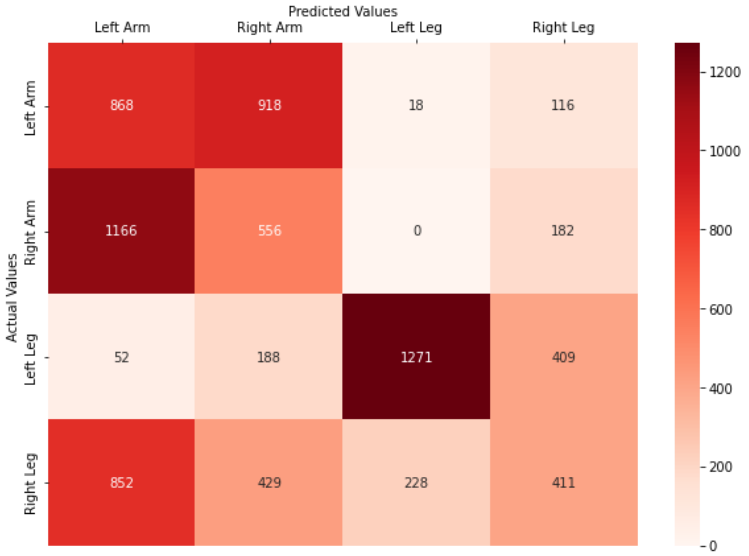
precision: [0.885 0.929 0.86 0.865]

recall: [0.934 0.89 0.864 0.85]

fscore: [0.909 0.909 0.862 0.857]

accuracy: 0.88

Confusion Matrix: Interpersonal Validation (Leave-One-Out)



precision: [0.295 0.266 0.838 0.368]

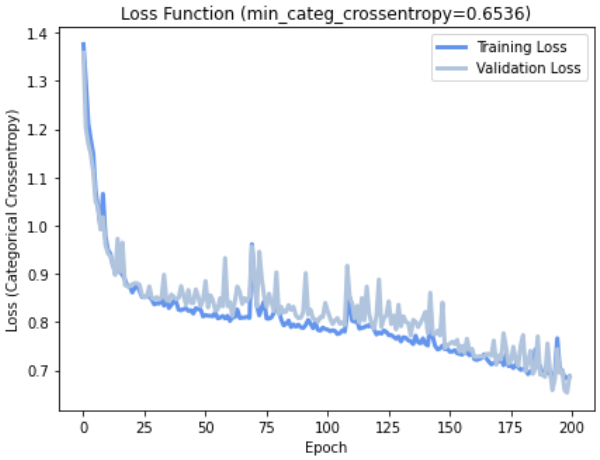
recall: [0.452 0.292 0.662 0.214]

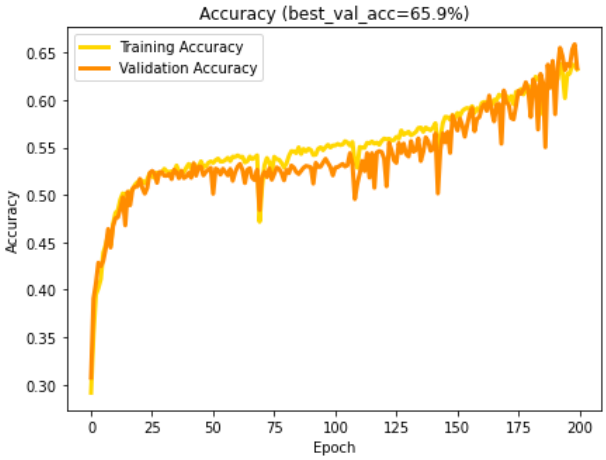
fscore: [0.357 0.278 0.74 0.271]

accuracy: 0.40

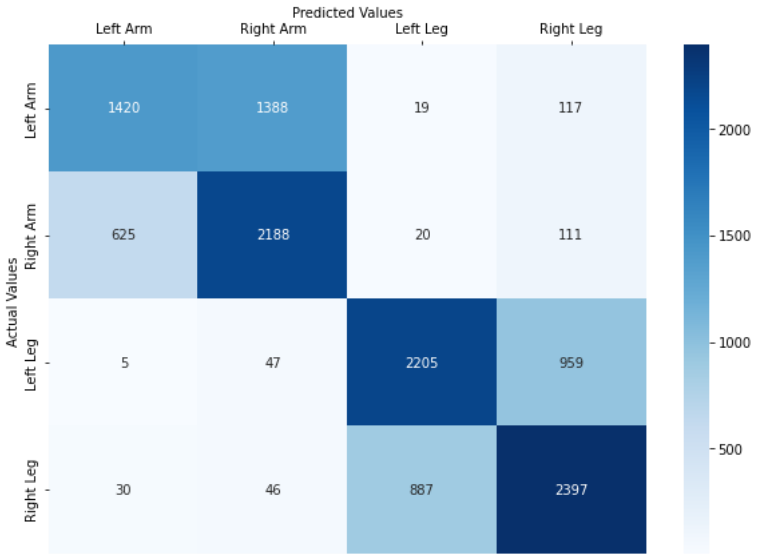
LSTM ONLY

```
Model: "sequential_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_21 (Dense)             (None, 500, 50)           100
_________________________________________________________________
leaky_re_lu_26 (LeakyReLU)   (None, 500, 50)           0
_________________________________________________________________
dropout_26 (Dropout)         (None, 500, 50)           0
_________________________________________________________________
lstm_2 (LSTM)                (None, 30)                9720
_________________________________________________________________
dense_22 (Dense)             (None, 15)                465
_________________________________________________________________
leaky_re_lu_27 (LeakyReLU)   (None, 15)                0
_________________________________________________________________
dropout_27 (Dropout)         (None, 15)                0
_________________________________________________________________
dense_23 (Dense)             (None, 4)                 64
=================================================================
Total params: 10,349
Trainable params: 10,349
Non-trainable params: 0
```





Confusion Matrix: Intrapersonal Validation



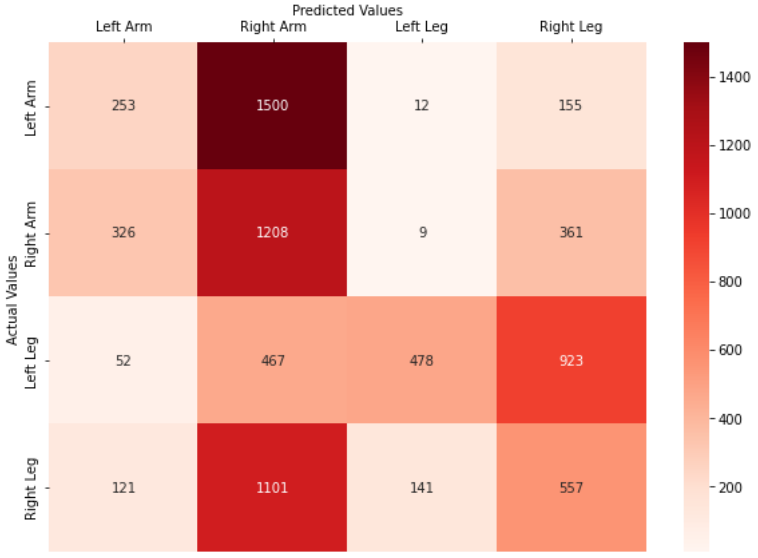
precision: [0.683 0.596 0.704 0.669]

recall: [0.482 0.743 0.686 0.713]

fscore: [0.565 0.662 0.695 0.69]

accuracy: 0.66

Confusion Matrix: Interpersonal Validation (Leave-One-Out)



precision: [0.336 0.283 0.747 0.279]

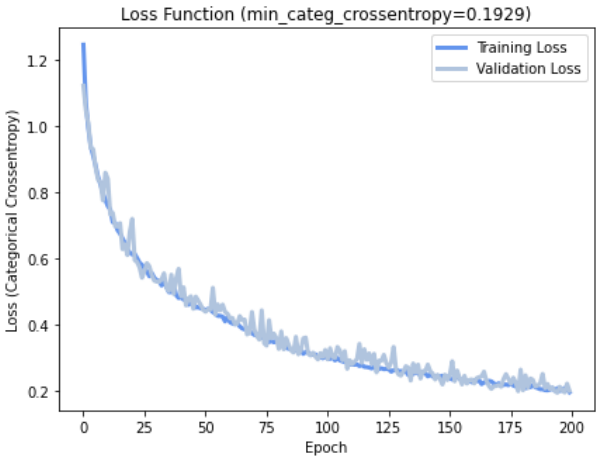
recall: [0.132 0.634 0.249 0.29]

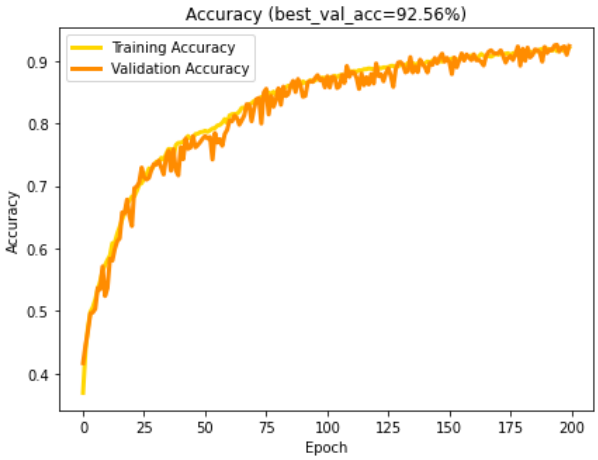
fscore: [0.189 0.391 0.373 0.284]

accuracy: 0.33

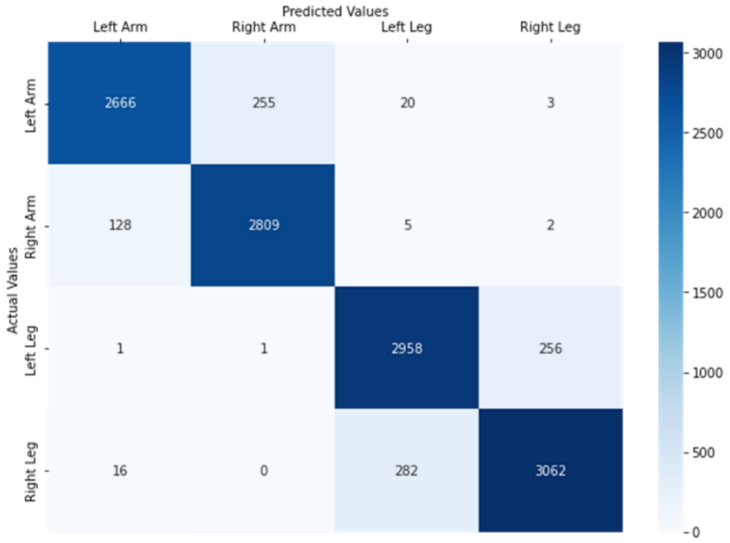
HYBRID MODEL: CNN + LSTM

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
cnn_layer_1 (Conv1D)         (None, 500, 32)           192
_________________________________________________________________
leaky_re_lu_8 (LeakyReLU)    (None, 500, 32)           0
_________________________________________________________________
max_pooling1d_4 (MaxPooling1 (None, 250, 32)           0
_________________________________________________________________
dropout_6 (Dropout)          (None, 250, 32)           0
_________________________________________________________________
cnn_layer_2 (Conv1D)         (None, 250, 64)           14400
_________________________________________________________________
leaky_re_lu_9 (LeakyReLU)    (None, 250, 64)           0
_________________________________________________________________
max_pooling1d_5 (MaxPooling1 (None, 125, 64)           0
_________________________________________________________________
dropout_7 (Dropout)          (None, 125, 64)           0
_________________________________________________________________
dense_6 (Dense)              (None, 125, 50)           3250
_________________________________________________________________
leaky_re_lu_10 (LeakyReLU)   (None, 125, 50)           0
_________________________________________________________________
dropout_8 (Dropout)          (None, 125, 50)           0
_________________________________________________________________
lstm_2 (LSTM)                (None, 30)                9720
_________________________________________________________________
dense_7 (Dense)              (None, 15)                465
_________________________________________________________________
leaky_re_lu_11 (LeakyReLU)   (None, 15)                0
_________________________________________________________________
dense_8 (Dense)              (None, 4)                 64
=================================================================
Total params: 28,091
Trainable params: 28,091
Non-trainable params: 0
```



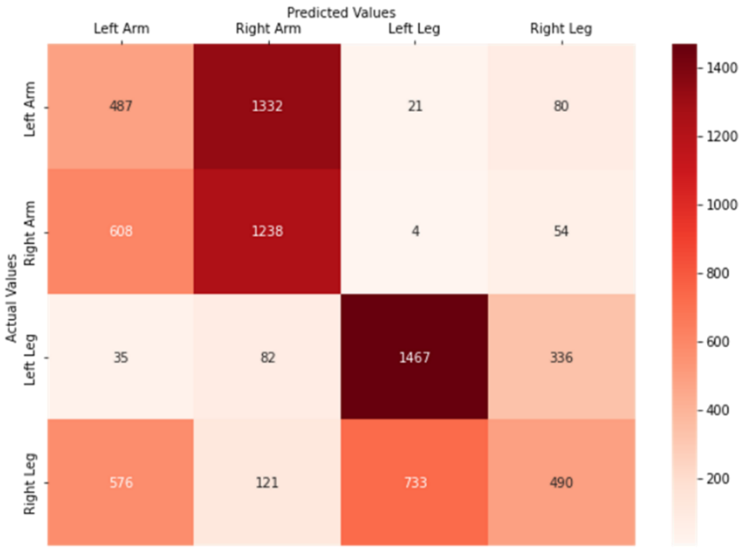


Confusion Matrix: Intrapersonal Validation



precision: [0.948 0.916 0.906 0.921]
recall: [0.926 0.954 0.92 0.911]
fscore: [0.926 0.935 0.913 0.916]
accuracy: 0.92

Confusion Matrix: Interpersonal Validation (Leave-One-Out)



precision: [0.285 0.446 0.659 0.51]
recall: [0.254 0.65 0.764 0.255]
fscore: [0.269 0.529 0.708 0.34]
accuracy: 0.48