Person-Independent sEMG Gesture Recognition Using LSTM Networks for Human-Computer Interaction

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Final: Guided Research

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Human Computer Interfaces (HCI)

- Hands as “natural” HCI
- Hands gestures are hard to detect
- Common approaches:
  - Computer vision
  - Electromyography (EMG)

Figure 1: EMG Needles [6]

Myo Armband

- Surface Electromyography (sEMG)
- 8 sEMG sensors (200 Hz)
- IMU (50 Hz)
- Bluethooth, SDK

- But data is very noisy/inaccurate
- Possible to interpret the data by hand?

Figure 2: Myo armband [7]

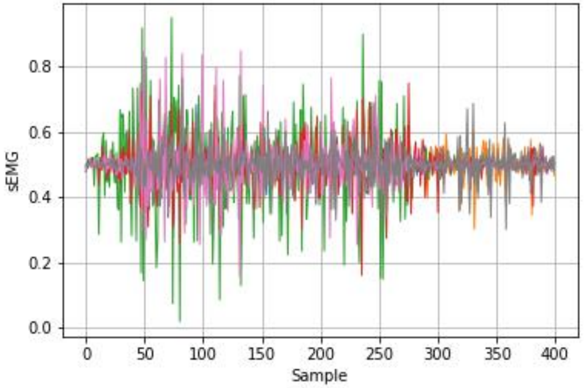


Figure 3: sEMG data from Myo

Data Recording

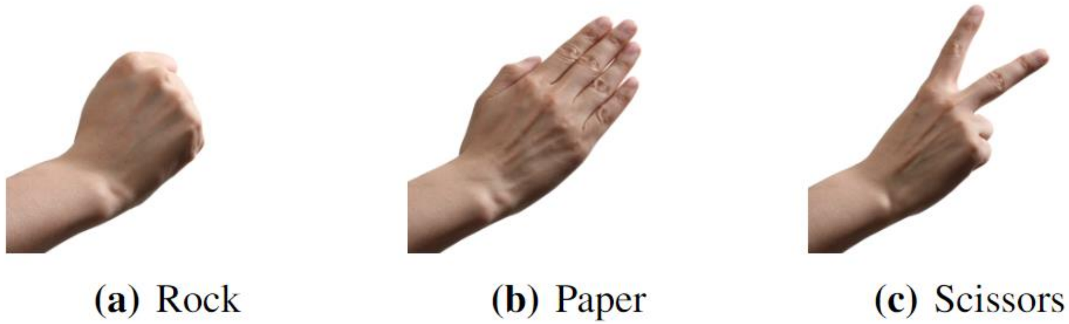


Figure 4: Gestures used [8]

- Python GUI application
- One gesture: 2 seconds = 400 samples
- 30 gestures per iteration
- 3 iterations per session
- 13 subjects, aged 18-58 years (4 female, 9 men)

Preprocessing: Padding, Normalization

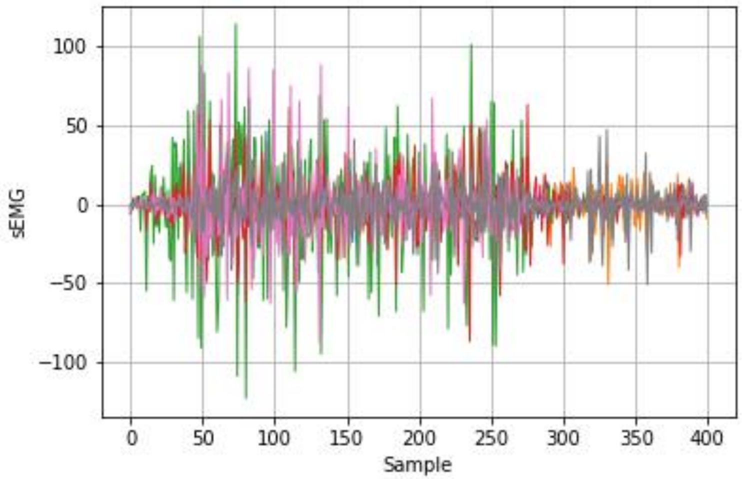


Figure 5: Raw data of 8 sensors

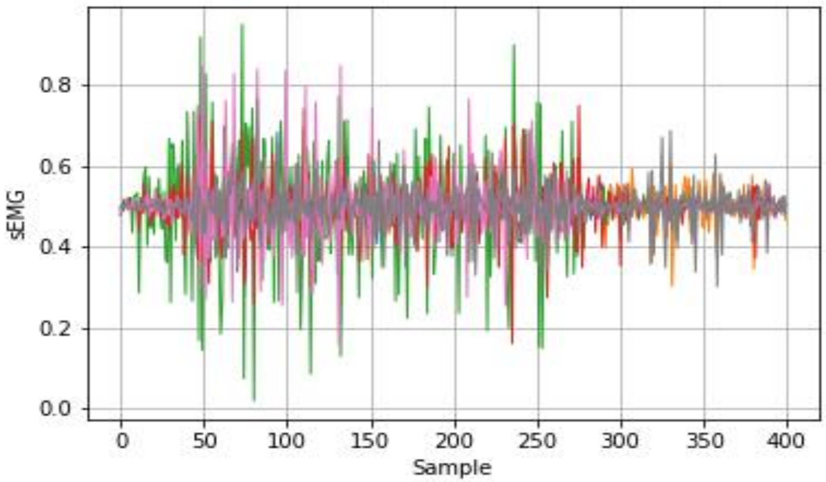


Figure 6: Padded, normalized

Preprocessing: Moving Average, Filtering

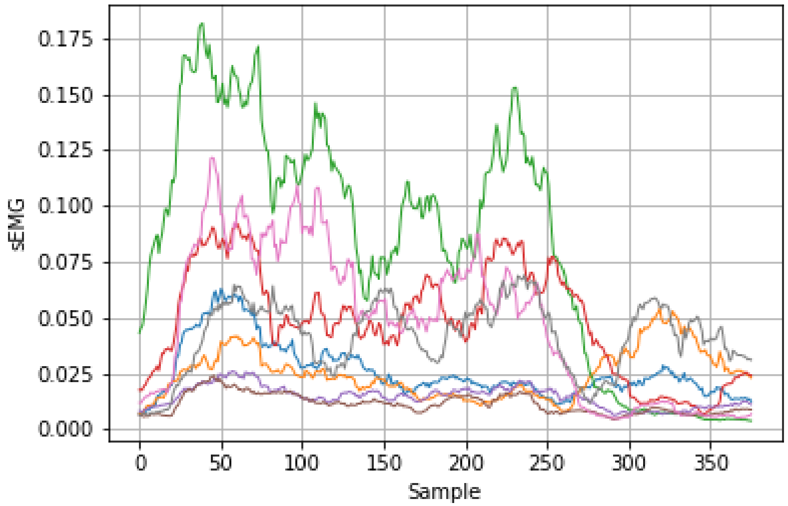


Figure 7: Rectified, moving average of n=25

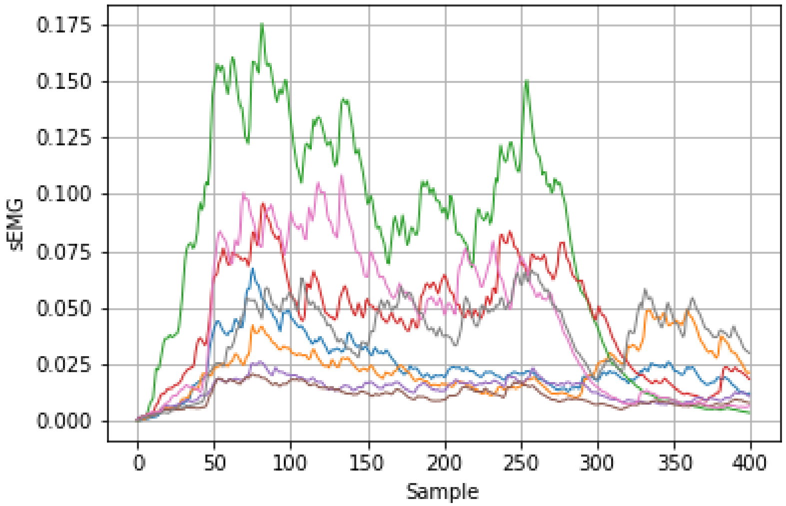


Figure 8: Butterworth filter

Detecting gestures by hand

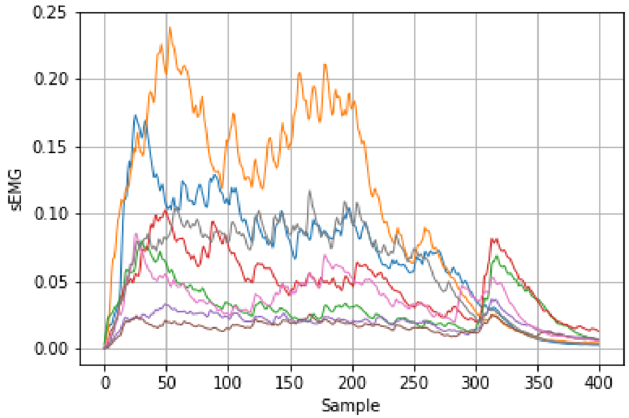


Figure 9: A rock gesture

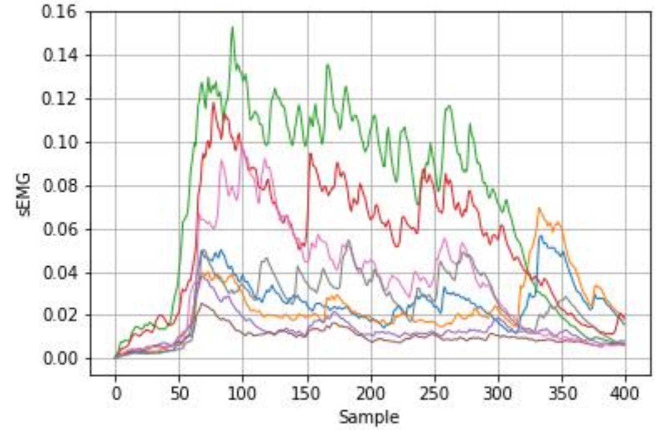


Figure 10: A paper gesture

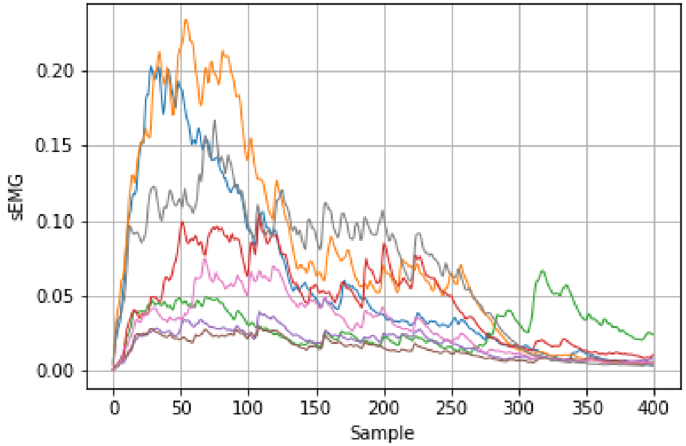


Figure 11: Guess the gesture!

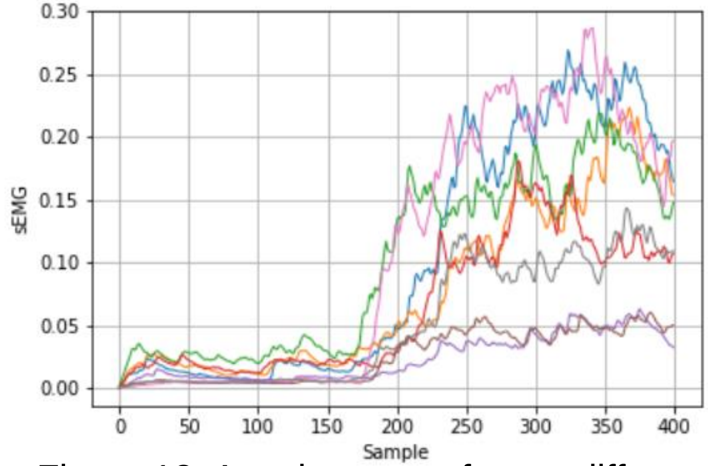


Figure 12: A rock gesture from a different person

Long Short-Term Memory (LSTM)

- Translation of muscle activity to gestures
- Defining time-based thresholds

- Neural Networks (NN): ability to optimize to unknown functions

- LSTM are a type of Recurrent Neural Network (RNN) [1]
- Can learn long-term dependencies in sequence prediction problems

Generalization vs Specialization

- Problems
  - Data will vary significantly from person to person [2,3]
  - And also from session to session (armband placement)
- Learn features that make up the essence of the gesture
- Generalization: Work well on new persons, trained with data from different persons
- Specialization: Work very well on one single person, trained with data from one person

Transfer Learning

- Adapt a NN to a different but related problem
- Adding layers on top to “translate” the data
- Needs little more data and training time

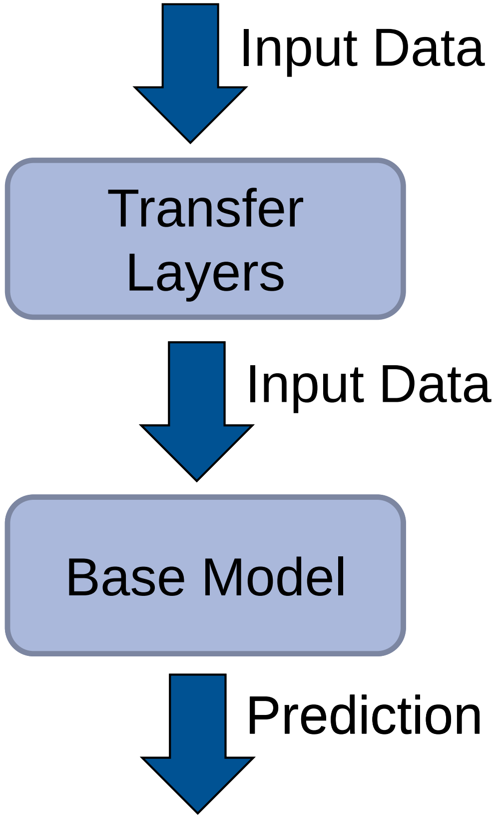


Figure 13: Architecture sketch

Base Model: Architecture

- Based on model by Cedric Fromm [4]
- Tuned with Hyperparameter Optimization

Hyperparameter	Type	Values	Chosen Value
Batch size	Integer	[10 – 100]	55
LSTM units	Integer	[1 – 600]	250
LSTM recurrent dropout	Float	[0 – 0.5]	0.55
LSTM dropout	Float	[0 – 0.5]	0.45
Additional LSTM layers	Integer	[0 – 2]	1
Hidden units	Integer	[50 – 300]	80
Hidden activation function	Categorial	Sigmoid, Relu, Tanh	Sigmoid
Dropout	Float	[0 – 0.5]	0.60
Optimizer	Categorial	Adam, NAdam, RMSprop, SGD	NAdam

Figure 14: Hyperparameters

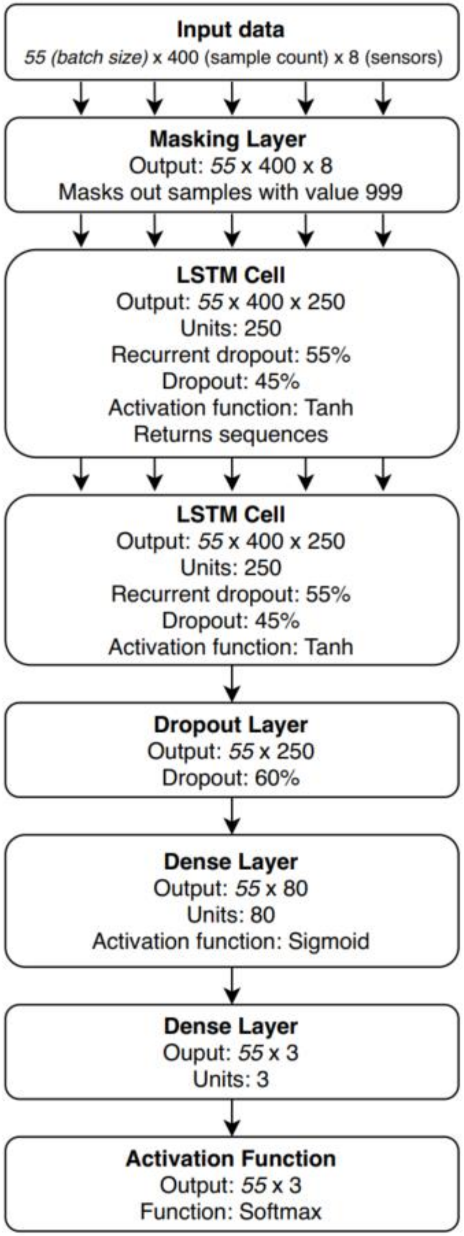


Figure 15: Base model architecture

Base Model: Training

- Training sets
  - **10sub**: 3 iterations from 10 subjects
  - **5sub**: 6 iterations from 5 subjects
  - **1sub**: 30 iterations from 1 subject
- Accuracies
  - Test Set Accuracy (**TSA**)
  - Session-Independent Accuracy (**SIA**)
  - Person-Independent Accuracy (**PIA**)

Dataset	TSA	SIA	PIA
10sub	0.852	0.678	**0.656**
5sub	0.852	**0.700**	0.645
1sub	**0.974**	0.234	0.333

Figure 16: Base model accuracies

Transfer Learning: Model

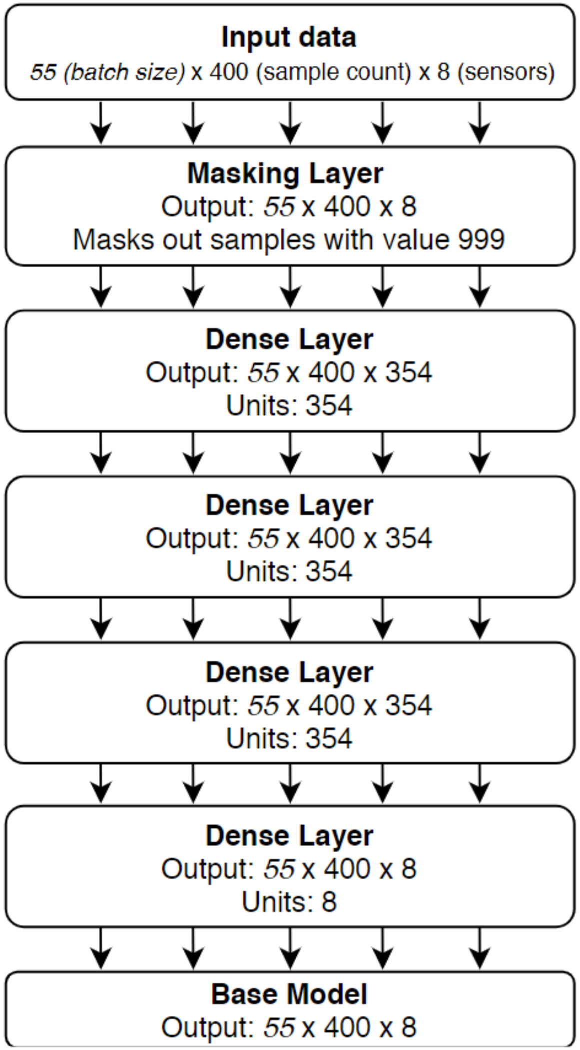
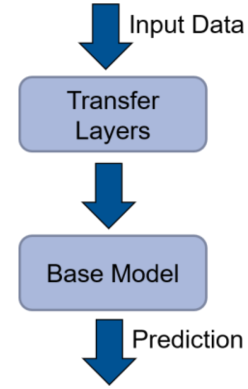


Figure 18: Transfer model architecture

- Add 3 dense layers
- Base model weights are locked



Hyperparameter	Type	Values	Chosen Value
Batch size	Integer	$[5 - 100]$	55
Dense layer count	Integer	$[1 - 3]$	3
Dense units	Integer	$[10 - 500]$	350
Optimizer	Categorial	Adam, NAdam, RM-Sprop, SGD	NAdam

Figure 17: TL hyperparameters

Transfer Learning: Results

Dataset	TSA	SIA	PIA
10sub	1.000	**0.983**	0.500
5sub	1.000	0.950	0.656
1sub	1.000	0.967	0.400

Figure 19: TL accuracies

Dataset	TSA	SIA	PIA
10sub	0.852	0.678	**0.656**
5sub	0.852	**0.700**	0.645
1sub	**0.974**	0.234	0.333

Figure 16: Base model accuracies

TSA: Test Set Accuracy
SIA: Session-Independent Accuracy
PIA: Person-Independent Accuracy

Usage as HCI Interface

- Requirements
  - Short training time
  - Few training data
  - Inference in real-time (sliding window)
- Not possible with base model
- TL recording time: ~4 minutes
- TL training time: ~8 minutes (GTX 1080)
- Real-time inference: ~0.2 seconds

Further Work

- More extensive testing with more subjects/data
- Improve base model accuracy (like [4])
- Use more gestures
- Improve recording by better timing
- Implement actual HCI application
- Use two Myo armbands
- Use the built-in IMU (yields better results [5])
- Reduce training time/amount of data of TL layers

Conclusion

- sEMG is convenient but challenging
- Build a base model with transfer layers
- Use hyperparameter optimization
- Inference possible in real-time
- TL setup takes ~15 minutes
- Approach fit for long-term usage

Sources

- [1] Hochreiter, S.; Schmidhuber, J. (1997): Long short-term memory. In *Neural computation* 9 (8), pp. 1735–1780. DOI: 10.1162/neco.1997.9.8.1735.
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