Myoelectric Control in a Virtual Reality Environment

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Abstract

This MSc thesis deals initially with the development of a Convolutional Neural Network for the recognition of hand movements through surface electromuscular signals. It also focuses on developing an application in a Virtual Reality environment in which the user's goal is to win by making the right gesture depending on the object he has to grab each time. MindRove armband, an array 1x8 of electrodes was placed on the user's forearm for data acquisition and a Convolutional Neural Network was developed for gesture recognition based on EMG signals. The network was built based on data publicly available on the Ninapro-project's website in the Database 1. To achieve satisfactory recognition, we used only 6 out of the 52 movements of NinaPro Database 1 and we provided an inter-subject analysis. Afterwards, we deal with the construction of a Virtual Reality application in Unity where the movements performed with the MindRove must be recognized, to increase the score every time the user makes the right move, after some action is performed in the scene. Our goal was to test the Neural Network's results in real-time and make a VR application for rehabilitation purposes or to collect Electromyography data in an online way.

Data

- We focus on the 8 + 2 sensors (bias, ref) of MindRove armband, that are equally spaced around the forearm.
- NinaPro Database 1 (52 movements) was used for training the Neural Network for gesture recognition
- 6 out of 52 movements were used (those with the highest success rate)

Large Diameter Grasp (30) | Small Diameter Grasp (31) | Medium Wrap (34) | Stick Grasp (37) | Power Sphere Grasp (39) | Power Disk Grasp (49)

Figure 1: The 6 Movements out of 52 of NinaPro Database 1.

Pre-Processing

NinaPro Database 1 pre-processing methods:

- Smoothing: 5th order Butterworth low-pass filter with 1Hz cut-off frequency
- Data Augmentation: Sliding window of 150ms length with 60% overlapping
- Min-Max Normalization

The data we collect from MindRove armband are raw surface EMG data, which are noisy and non-stationary. As a result, some basic signal processing methods are used:

- Transform raw sEMG values to real values: Multiply values with

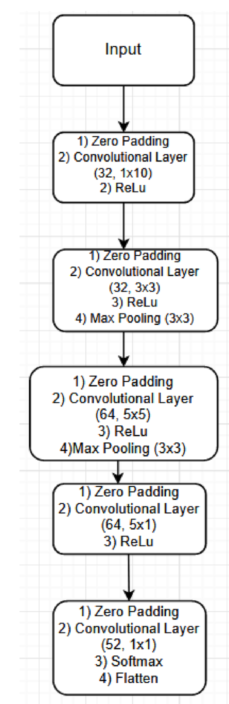
$$LSB = 0.0045 * 10^{-6}$$

- Anti-aliasing filter: 1st order Butterworth low-pass with 50Hz cut-off frequency and Downsampling
- Min-Max Normalization

Convolutional Neural Network

The arcitecture of the Convolutional Neural Network:

- Input 15×8×1 (height = length of sliding window × width = number of MindRove's EMG channels/electrodes × depth)
- 4 hidden layers with ReLU activation functions and an output layer with Softmax activation function
- Output 1 x 6 containing the probability of each movement



Epochs	0.1, 0.01, 0.001	30
Batch size	32, 64, 128	128
Dropout rate	0, 0.1, 0.2, 0.3	0.2

Figure 2: CNN's Epochs, Batch size and Dropout rate.

Development of Virtual Reality Application

We developed a Virtual Reality application in Unity environment, using Unity 2019.3.14f1 version. We included Barracuda Unity's package, to integrate the Convolutional Neural Network model into the Unity platform and we had to export our CNN model in an .onnx format to import it as a Unity's asset. We created Input, Output and Worker tensors to execute the model with real-time data taken from the MindRove armband and collect the result in a 1x6 vector (output), from which we choose the biggest probability as the movement that the user performs. The input of this model are the raw surface Electromyography (sEMG data) collected from the MindRove armband online, in the Unity VR application.

The environment of this application was also developed. The user has to move spawning objects (6 objects corresponding to the 6 movements the CNN recognizes: bottle, stick, glass, pen, ball, CD) to the correct hole / position, by performing the right gesture, while wearing the MindRove armband around their forearm. Depending on the movement the network recognizes, the corresponding object is moved to the correct position and the user's score is increased. Hand animations were also created, for the user to understand better what movement they perform and the network recognizes.

The goal of the application is for the user to perform all the 6 movements correctly and place all the objects to the correct hole (position). Then the application restarts and the score is set to zero again.

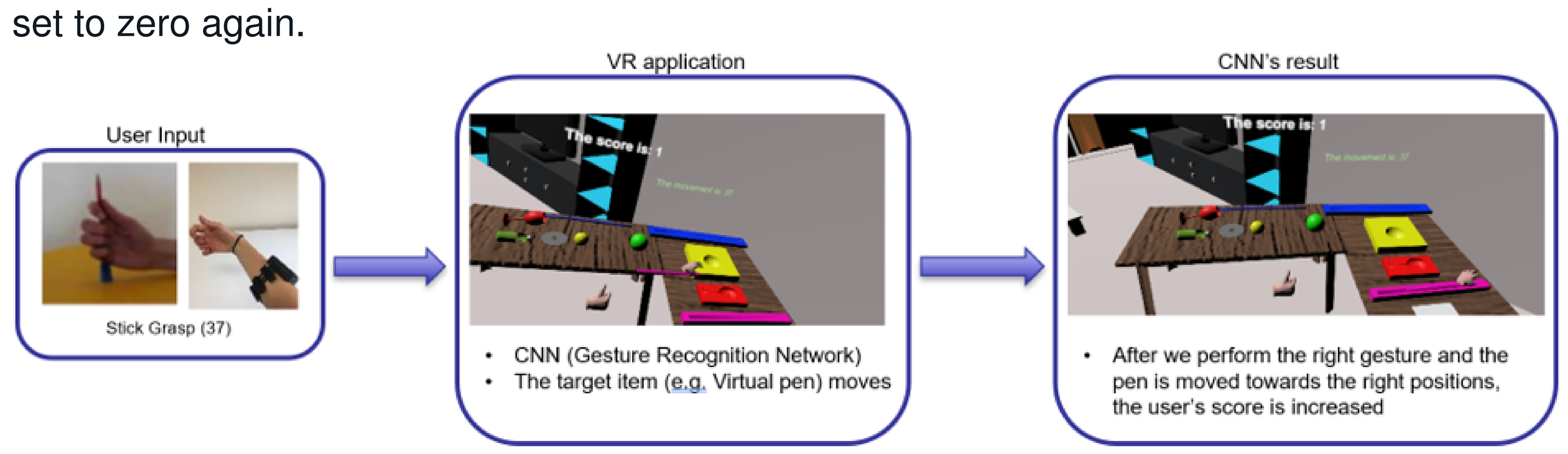


Figure 3: Application overview.

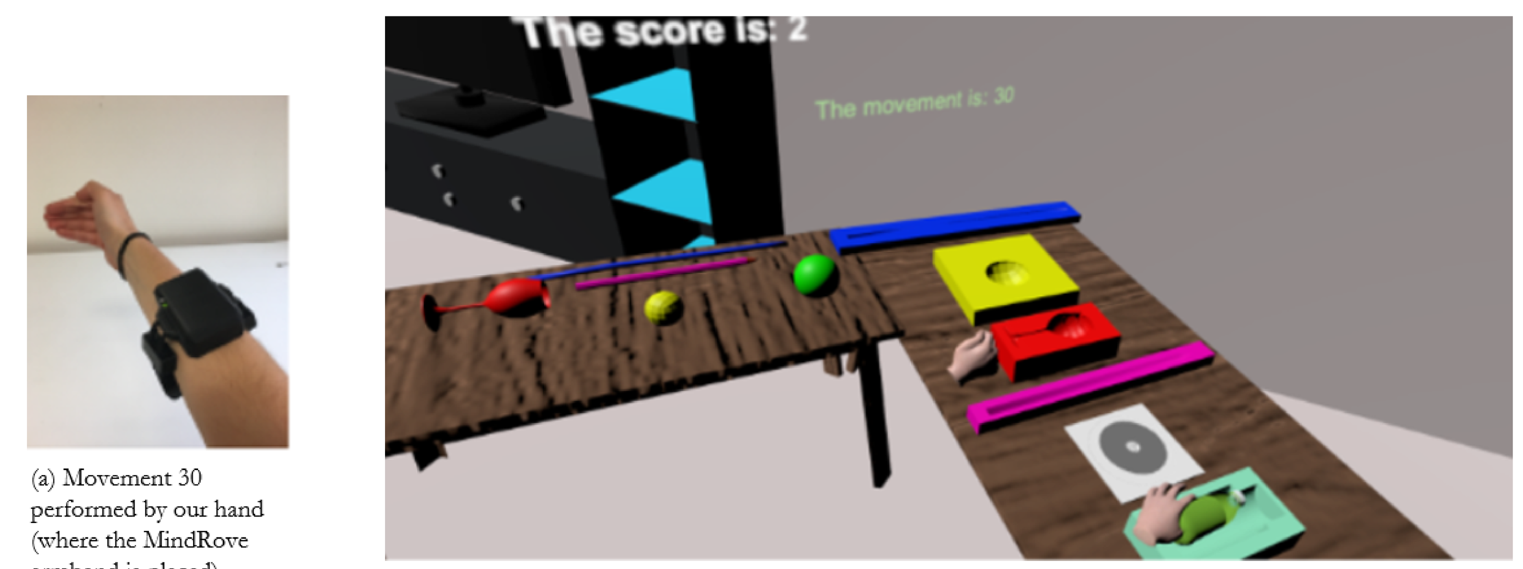
Results

Results of the Convolutional Neural Network:

- CNN shows an accuracy rate of 80 ± 2.36%
- Better than other research with inter-subjects evaluation scheme
- Worse than other approaches with an intra-subject evaluation scheme, because in this case we have a smaller signal covariance

Results of the entire application:

- The user performs one movement out of the 6 that the model recognizes, while having the MindRove armband placed on their forearm
- The CNN model recognizes the performed movement with an 80% accuracy
- The object that correspond to the performed movement (e.g. bottle for movement 30 of NinaPro database) is moved to the correct position
- The user's score is increased



(a) Movement 30 performed by our hand (where the MindRove armband is placed) simultaneously

(b) Movement 30 and bottle's transfer to the correct position

Figure 3: User performs movement 30 of NinaPro DB1 and the bottle is moved to the correct position.

Conclusions

- Construction of a Convolutional Neural Network for recognition of hand movements
- CNN accuracy: 80 ± 2.36% (performance comparable to other inter-subject approach models)
- Development of a Virtual Reality application with online collection of data from the armband

Future Directions

- Expand this application with more recognized gestures and more complex tasks for the users
- Carry out urveys to measure the user-experience
- Include interaction with more input modalities such as speech recognition and eye-tracking

Acknowledgements

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