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Mind Controlled Bionic Arm with Sense of Touch [8 class version]

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Protocol status: In development
We are still developing and optimizing this protocol

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Disclaimer

This is a ongoing project, so lot of changes are variation in results are to be expected!

Abstract

Advancements in bionic technology are transforming the possibilities for restoring hand function in individuals with amputations or paralysis. This paper introduces a cost-effective bionic arm design that leverages mind-controlled functionality and integrates a sense of touch to replicate natural hand movements. The system utilizes a non-invasive EEG-based control mechanism, enabling users to operate the arm using brain signals processed into PWM commands for servo motor control of the bionic arm. Additionally, the design incorporates a touch sensor (tactile feedback) in the gripper, offering sensory feedback to enhance user safety and dexterity.
The proposed bionic arm prioritizes three essential features:
1. Integrated Sensory Feedback: Providing users with a tactile experience to mimic the sense of touch (signals directly going to the brain). This capability is crucial for safe object manipulation by arm and preventing injuries
2. Mind-Control Potential: Harnessing EEG signals for seamless, thought-driven operation.
3. Non-Invasive Nature: Ensuring user comfort by avoiding invasive surgical procedures.
This novel approach aims to deliver an intuitive, natural, and efficient solution for restoring complex hand functions.

Downloading of Datasets from Internet & Arranging them in a Proper Format

1 Please acquire the data associated with the following datasets::

Dataset	
MILimbEEG: An EEG Signals Dataset based on Upper and Lower Limb	NAME
https://data.mendeley.com/datasets/x8psbz3f6x/2	LINK

Dataset	
Supporting data for "EEG datasets for motor imagery brain comput	NAME
https://gigadb.org/dataset/100295	LINK

2 Extract it and keep the 2 datasets into 2 seperate folder
In the ***MILimbEEG dataset*** run the following python file (it will sort the data into 8 different categories)
https://github.com/Dhruvacube/Mind-Control-Bionic-Arm/tree/main/datasets/datasourceDatasets/MILimbEEG%20An%20EEG%20Signals%20Dataset%20based%20on%20Upper%20and%20Lower%20Limb%20Task%20During%20the%20Execution%20of%20Motor%20and%20Motorimagery%20Tasks

Command

MindLimbEEG data sorter in python (Windows 11)

```
from pathlib import Path
import pandas as pd

task_dict = {1: 'BEO', 2: 'CLH', 3: 'CRH', 4: 'DLF', 5: 'PLF', 6:
'DRF', 7: 'PRF', 8: 'Rest'}
task_var_dict = {1: 0, 2: 0, 3: 0, 4: 0, 5: 0, 6: 0, 7: 0, 8: 0}
folders_list = [Path(f'./S{i}') for i in range(1,60+1)]

for j in range(60):
    for k in [i for i in folders_list[j].glob('*.csv')]:
        for h in k.parts[1]:
            if h in ('M', 'I'):
                next_index: int = (k.parts[1].index('M' if h == 'M'
else 'I')) + 1
                task_var_dict[int(k.parts[1][next_index])] += 1

                df = pd.read_csv(k)
                df = df.drop(df.columns[0], axis=1)
                df.to_csv(f'./{task_dict[int(k.parts[1]
[next_index])]}/{task_dict[int(k.parts[1]
[next_index])]}_{task_var_dict[int(k.parts[1][next_index])]}.csv',
index=False, header=False)

print(f'BEO: {task_var_dict[1]}\nCLH: {task_var_dict[2]}\nCRH:
{task_var_dict[3]}\nDLF: {task_var_dict[4]}\nPLF:
{task_var_dict[5]}\nDRF: {task_var_dict[6]}\nPRF:
{task_var_dict[7]}\nRest: {task_var_dict[8]}')
```

Categories this python file sorts into:
- Recording a Baseline with Eyes Open (BEO) without any task command: only once at the beginning of each run.
- Closing Left Hand (CLH): five times per run.
- Closing Right Hand (CRH): five times per run.
- Dorsal flexion of Left Foot (DLF): five times per run.
- Plantar flexion of Left Foot (PLF): five times per run.
- Dorsal flexion of Right Foot (DRF): five times per run.

- Plantar flexion of Right Foot (PRF): five times per run.
- Resting in between tasks (Rest): after each task.

Now, similarly goto the ***GigadbEEG dataset*** folder and run the following python file: https://github.com/Dhruvacube/Mind-Control-Bionic-Arm/tree/main/datasets/datasourceDatasets/GigaDb

Command

GigaDB class Sorter (Windows 11)

```
# Data to extract
# - movement_left
# - movement_right
# - imagery_left
# - imagery_right
# - rest

# next is nose
# - noise
# It is a 5x1 cell array in matlab

import scipy.io
import pandas as pd


for i in range(1, 53):
    mat = scipy.io.loadmat(f's{i}.mat')
    mat_eeg = mat['eeg']

    for j in range(0, 5):
        df_noise = pd.DataFrame(mat_eeg['noise'][0,0][j,0])
        df_noise.to_csv(f'noise/noise_{i}_{j}.csv', index=False,
header=False)
        print(f'noise/noise_{i}_{j}.csv')

    df_movement_left = pd.DataFrame(mat_eeg['movement_left'][0, 0])
    # df_movement_left =
df_movement_left.drop(labels=df_movement_left.columns[0], axis=1)

    df_movement_right = pd.DataFrame(mat_eeg['movement_right'][0, 0])
    # df_movement_right =
df_movement_right.drop(df_movement_right.columns[0], axis=1)

    df_imagery_left = pd.DataFrame(mat_eeg['imagery_left'][0, 0])
    # df_imagery_left =
df_imagery_left.drop(df_imagery_left.columns[0], axis=1)

    df_imagery_right = pd.DataFrame(mat_eeg['imagery_right'][0, 0])
    # df_imagery_right =
df_imagery_right.drop(df_imagery_right.columns[0], axis=1)
```

```
    df_rest = pd.DataFrame(mat_eeg['rest'][0, 0])
    # df_rest = df_rest.drop(df_rest.columns[0], axis=1)

    df_movement_left.to_csv(f'movement_left/movement_left_{i}.csv',
index=False, header=False)
    print(f'movement_left/movement_left_{i}.csv')


df_movement_right.to_csv(f'movement_right/movement_right_{i}.csv',
index=False, header=False)
    print(f'movement_right/movement_right_{i}.csv')

    df_imagery_left.to_csv(f'imagery_left/imagery_left_{i}.csv',
index=False, header=False)
    print(f'imagery_left/imagery_left_{i}.csv')

    df_imagery_right.to_csv(f'imagery_right/imagery_right_{i}.csv',
index=False, header=False)
    print(f'imagery_right/imagery_right_{i}.csv')

    df_rest.to_csv(f'rest/rest_{i}.csv', index=False, header=False)
    print(f'rest/rest_{i}.csv')
```

Note

In GigaDB for this case we will take only the Rest class data

In this ***GigaDB dataset*** take the segregated **Rest data** and mixed with the ***MindLimb*** **Rest data.**

Conversion to Audio Files (single channels) from CSV Files

3 In the sorted data run the following python file to get it segregated into different channels and convert it into ***audio file in .wav format***

Command

CSV to Single Channel Audio File Converter (Windows 11)

```
import pandas as pd
import soundfile as sf
import os

fs = 125 # sampling frequency
destinationFolder = "./audioFiles/"
sourceFolder = "./orderedDatasets/"

for root, dirs, files in os.walk(sourceFolder):
    if len(files) > 0:
        classCurrent = root[len(sourceFolder):]
        try:
            os.makedirs(destinationFolder + classCurrent)
        except Exception as e:
            pass
        for file in files:
            df: pd.DataFrame =
pd.read_csv(sourceFolder+classCurrent+'/'+file, header=None)
            columns = list(df.columns)
            for column in columns:
                sf.write(destinationFolder + classCurrent + '/' +
file[:-4] + '_' + str(column) + '.wav', df[column], fs)
```

Training of Model (Transfer Learning from Yamnet)

4 Now open up the **MATLAB** and run the following file to train the ***yamnet*** for our *specific use case* and then test it and generate the confusion matrix.

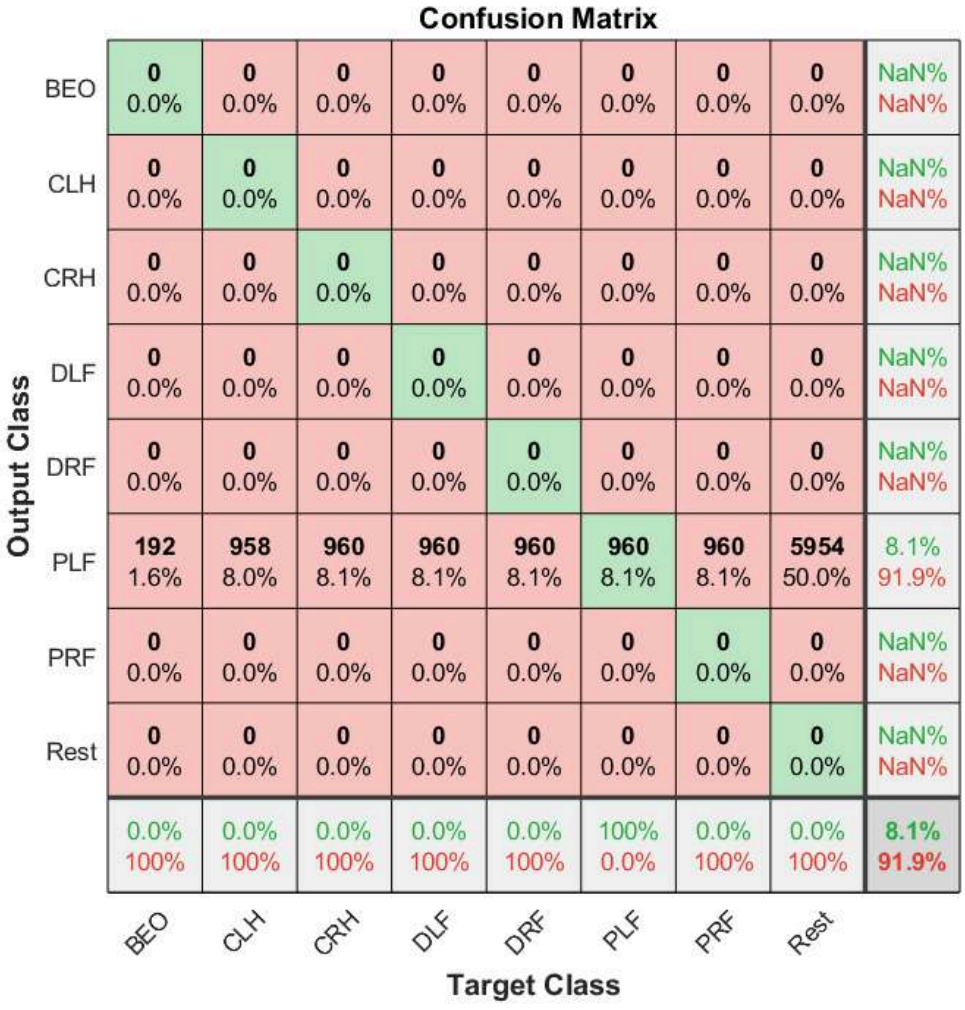
Take the supporting files from here: **https://github.com/Dhruvacube/Mind-Control-Bionic-Arm/**

Command

Model Training and Testing (Transfer Learning from Yamnet) (Windows 11)

```
%start from here
addpath(fullfile('yamnet'))
fs = 125; %since sampled at 125Hz

adsSource = audioDatastore("D:\projects\Research\Mind Control Bionic
Arm\datasets\audioFiles\",IncludeSubfolders=true,LabelSource="folderna
mes",FileExtensions=[".wav"]);
[adsTrain,adsValidation,adsTest] =
splitEachLabel(adsSource,0.7,0.2,0.1,"randomized");

trainLabels = adsTrain.Labels;
classNames = unique(adsTrain.Labels);
numClasses = numel(classNames);
testLabels  = adsTest.Labels;

net = audioPretrainedNetwork("yamnet",NumClasses=numClasses);

% Extract features using YAMNet
adsTrain = transform(adsTrain,@audioPreprocess, "IncludeInfo",true);
adsValidation = transform(adsValidation,@audioPreprocess,
"IncludeInfo",true);
adsTest = transform(adsTest,@audioPreprocess, "IncludeInfo",true);


miniBatchSize = 128;
validationFrequency = floor(numel(trainLabels)/miniBatchSize);
options = trainingOptions('sgdm', ...
    InitialLearnRate=3e-4, ...
    MaxEpochs=2, ...
    MiniBatchSize=miniBatchSize, ...
    Shuffle="every-epoch", ...
    Plots="training-progress", ...
    Metrics="accuracy", ...
    Verbose=false, ...
    LearnRateSchedule="exponential", ...
    ValidationData=adsValidation, ...
    ValidationFrequency=validationFrequency, ...
    ExecutionEnvironment="parallel-auto");

net = trainnet(adsTrain,net,"crossentropy",options);
```

```
YTest = minibatchpredict(net,adsTest);
YTestFinal = scores2label(YTest,classNames);
plotconfusion(testLabels,YTestFinal);

[C,order] = confusionmat(testLabels,YTestFinal);
stats = statsOfMeasure(C, 1);
```



Confusion Matrix of the Trained Model

Protocol references

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Citations

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