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EEG Data for Emotive Response to Robot Facial Expressions

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1. DATASET DESCRIPTION

This dataset consists of EEG recorded during visual human-robot interaction from 10 healthy participants to investigate the emotive response in EEG to different robot facial expressions. Participants observed four different facial expressions (angry, happy, sad and surprised along with neutral expression) displayed by the social robot Miko on its digital screen. EEG was recorded from 16 unipolar channels in frontal, central, temporal, parietal, and occipital locations. During each trial, an emotion stimulus was displayed for approximately 4s followed by 4s break during which the Miko robot displayed neutral expression and blinked regularly. Emotions were displayed in random order. Total of 240 EEG trials were recorded from each participant with 60 trials per emotion. The dataset provides raw minimally filtered EEG along with cleaned EEG with artefacts removal using ICA with sampling frequency of 128 Hz, and corresponding stimulus onset markers.

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2. METHODS

2.1 Participants

EEG was recorded from 10 healthy participants (22-29 years, 1 female and 9 male). The ethical approval for the study was obtained from Imperial College London Research Ethics Committee and all participants gave their informed written consent.

2.2. Experimental Paradigm

The aim of this experiment was to study the emotive responses in EEG to different facial expressions of the social robot Miko and characterise visual human-robot interaction. EEG was recorded while participants observed changing expressions of Miko. Social robot Miko was placed on a desk in front of the participant. EEG responses to four emotions Angry, Happy, Sad and Surprised along with neutral expression as shown in Fig.1 were recorded. During each EEG trial, Miko displayed the emotion for 4 s followed by a break of 4 s (during which it displayed neutral expression and blinked regularly). Order of emotions displayed was randomised. A camera co-registered with EEG recorded Miko expressions simultaneously, which was later used to extract timings of emotion stimulus onset. Please note that the video was recorded with 30 FPS leading to in identification of stimulus onset within ±33.33 ms of the actual onset. Further details on are given Wairagkar et al. (2021), *IEEE IoT J*, https://doi.org/10.1109/JIOT.2021.3097592.

Fig. 1. Miko robot facial expressions

2.3. Data Recording

EEG was recorded using TMSi Porti amplifier and EEG cap with passive electrodes. 16 unipolar channels of EEG were recorded from the locations Fp1, Fpz, Fp2, F3, Fz, and F4 (frontal), C3, Cz, and C4 (central), T7 and T8 (temporal), P3, Pz, P4, and Poz (Parietal), and Oz (occipital) according to the 10-20 international system (channel locations file is provided). Channel AFz was used as common ground. EEG was recorded at 2048 Hz and downsampled to 128 Hz. In total 60 EEG trials were recorded for each of the four emotions for each participant. The recording was divided into 6 runs with 10 trials of each emotion in random order within each run (total 40 trials per run).

2.4. Pre-Processing and Artefacts Removal

Pre-processing and artefacts removal was done in MATLAB 2020a and EEGLAB 2020 as follows:

- **Resampling:** EEG was downsampled to 128 Hz
- **Filtering and DC offset removal:** EEG was filtered between 0.5 - 60Hz using 4th order zero-phase shift band-pass Butterworth filter (MATLAB functions *butter* and *filtfilt*) to remove DC offset and high frequency noise. Additionally, baseline was removed to centre the EEG by subtracting the mean from each run.
- **Power line noise removal:** Powerline was removed using band-stop filter between 49.5-50.5Hz using same filter as above.
- **Artefacts removal using ICA:** Artefacts were removed using Independent Component Analysis from EEGLAB using Infomax ICA algorithm. Independent components with artefacts were identified and removed manually and EEG was reconstructed.

3. DATA FILES DESCRIPTION

The dataset consists of separate MATLAB (*.mat) files for ten participants names as `P1, P2, … P10`. Data for each participant is stored in MATLAB struct. The format of each struct is as follows:

`P1.EEG(1)` - there are 6 runs of EEG for each participant `P1.EEG(1)` to `P1.EEG(6)`

`P1.EEG(1).raw` – *[channels x times]* contains raw (non-artefacts removed) EEG filtered between 0.5 to 60Hz and power line noise removed, Fs =128 Hz.

`P1.EEG(1).clean` – *[channels x times]* contains clean EEG with artefacts removed using ICA, filtered between 0.5 to 60Hz and power line noise removed, Fs = 128Hz.

`P1.EEG(1).stimuli` – struct with emotion stimulus onset index and its type.

`P1.EEG(1).stimuli.index` – *[1x num_stimulus]* contains indices of stimulus onset for that EEG run.

`P1.EEG(1).stimuli.emotion` – *[1x num_stimulus]* contains types of stimuli corresponding to stimulus index (1 - Angry, 2 - Happy, 3 - Sad, 4 - Surprised).

`P1.unmixing_matrix` – *[components x channels]* unmixing matrix computed from ICA, can be used to obtain independent components from EEG.

`P1.rejected_IC` – *[1x num_components_rejected]* array containing indices of independent components that were removed due to artefacts to obtain clean EEG.

`P1.Fs` – sampling frequency (128 Hz).

`P1.channels` – cell containing strings with channel names for 16 channels in order.

`P1.bandpass_cutoff_Hz` – cutoff frequencies for band-pass filter used for raw and clean EEG (0.5 - 60 Hz).

`P1.notch_cutoff_Hz` – cutoff frequencies for band-stop filter used for raw and clean EEG to remove power line noise (49.5 - 50.5 Hz).

`P1.stimuli_key` – keys for emotion stimuli used in `P1.EEG(1).stimuli.emotion` (1 - Angry, 2 - Happy, 3 - Sad, 4 - Surprised).

Order of 16 unipolar channels:

Fp1	Fpz	Fp2	F3	Fz	F4	C3	Cz	C4	T7	T8	P3	Pz	P4	POz	Oz
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Example MATLAB commands:

- Example 1: Obtain raw and clean EEG for participant 1, run 1

```
>> rawEEG = P1.EEG(1).raw;
>> cleanEEG = P1.EEG(1).clean;
```

- Example 2: Segment a single run of EEG into individual trials from -0.5 s to 1 s of stimulus onset

```
>> seg_start = P1.Fs/2;    % -0.5s
   seg_end = P1.Fs;        % 1s

   cnt = 1;
   run = 1;
   for tr = 1:length(P1.EEG(run).stimuli.index)
       ind = P1.EEG(run).stimuli.index(tr);

       % Segment EEG -seg_start (-0.5s) to +seg_end (1s) from stimulus onset
       EEG(cnt,:,:)= P1.EEG(run).clean(:,ind-seg_start:ind+seg_end);
       cnt = cnt+1;
    end
```

- Example 3: Segment a single run of EEG into individual trials from -0.5 s to 1 s of stimulus onset only for emotion happy

```
>> seg_start = P1.Fs/2;
   seg_end = P1.Fs;
   cnt = 1;
   run = 1;
   for tr = 1:length(P1.EEG(run).stimuli.index)
       ind = P1.EEG(run).stimuli.index(tr);
```

```
      % Check if stimulus is Happy
      if P1.EEG(run).stimuli.emotion(tr) == 2
         EEG(cnt,:,:)= P1.EEG(run).clean(:,ind-seg_start:ind+seg_end);
         cnt = cnt+1;
      end
   end
```

- Example 4: Plot channel Cz of a single EEG trial 3 for stimulus ‘happy’ from above

```
>> time=(-seg_start:seg_end)*(1000/Fs);
>> plot(time, squeeze(EEG(3,8,:)),'linewidth',1)
>> xlabel ('Time(s), Stimulus onset at 0s'); ylabel('Amplitude (\muV)')
```

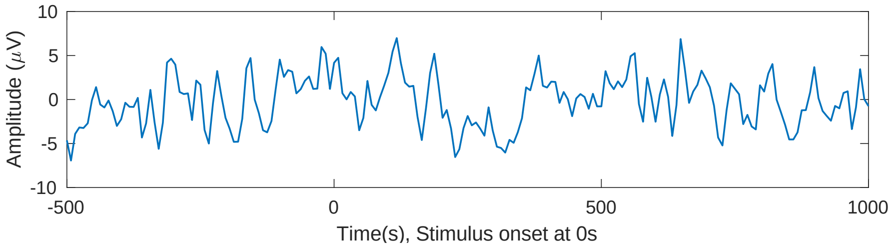

Fig. 2. Plot of single EEG trial for P1, run 1 from channel Cz

- Example 5: Obtain independent components from raw EEG, remove artefactual components, and reconstruct EEG (which is equivalent of clean EEG)

```
>> % Get independent components
   independent_components = P1.unmixing_matrix * P1.EEG(1).raw;

   % Make artefactual components 0
   independent_components(P1.rejected_IC,:) = 0;

   % Get mixing matrix - pseudoinverse of unmixing matrix
   mixing_matrix = pinv(P1.unmixing_matrix);

   % Obtain artefacts removed clean EEG which is same as P1.EEG(1).clean
   cleanEEG = mixing_matrix * independent_components;
```

Note:

- P4 has 7 runs, some participants have 38-39 trials in each some of the runs
- Please use `loadmat` from `scipy.io` to import the data in Python