Leveraging synthetic subject invariant EEG signals for zero calibration BCI

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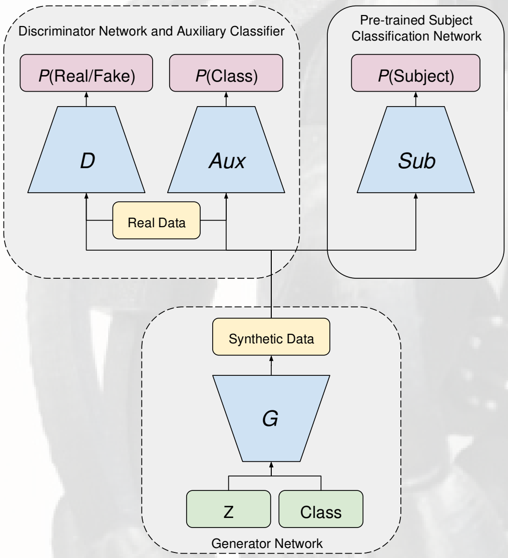
Issue:

The requirement of calibration stage especially for cross-subject EEG signals for SSVEP-based BCI application.

Approach:

Generate **realistic synthetic EEG** signals that **eliminate subject-specific features** to boost **SSVEP classification** performance for **unseen subject** via **Subject Invariant SSVEP GAN (SIS-GAN).**



Our Subject Invariant SSVEP Generative Adversarial Network. The Generator (G) produces data with subject-specific information removed (Sub) that can fool the Discriminator (D) and is classified as a certain frequency (Aux).

The subject invariant loss component:

$$L_S = \arg\max_{\hat{y}} S(\hat{y}|x),$$

The overall training objective:

$$L = L_D + \lambda_a L_A + \lambda_s L_S$$

Contribution:

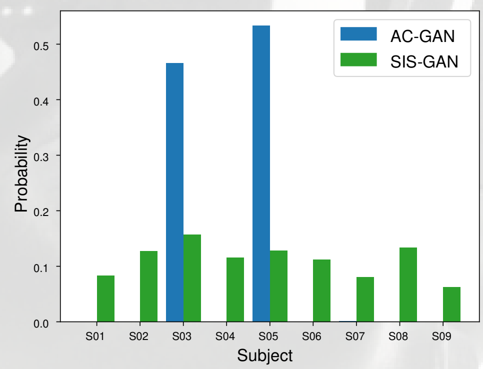
Generating subject-invariant synthetic data which can be used for training to enhance unseen subject classification.

Unseen Subject	Real data	Augmentated Training Data		Synthetic Training Data	
		AC-GAN	SIS-GAN	AC-GAN	SIS-GAN
01	0.576 ± 0.055	0.534 ± 0.042	0.550 ± 0.028	0.617 ± 0.023	**0.665 ± 0.017**
02	0.705 ± 0.009	0.711 ± 0.023	0.709 ± 0.032	0.619 ± 0.053	**0.714 ± 0.009**
03	0.687 ± 0.016	0.688 ± 0.032	**0.732 ± 0.021**	0.604 ± 0.025	0.717 ± 0.006
04	0.656 ± 0.010	0.581 ± 0.023	0.600 ± 0.028	0.627 ± 0.162	**0.667 ± 0.012**
05	0.682 ± 0.027	0.694 ± 0.024	0.711 ± 0.026	0.380 ± 0.029	**0.768 ± 0.080**
06	0.757 ± 0.045	0.710 ± 0.068	0.727 ± 0.032	0.627 ± 0.162	**0.815 ± 0.029**
07	0.905 ± 0.005	0.940 ± 0.009	**0.943 ± 0.014**	0.588 ± 0.155	0.911 ± 0.025
08	0.447 ± 0.046	0.426 ± 0.038	0.378 ± 0.046	0.343 ± 0.030	**0.485 ± 0.018**
09	0.778 ± 0.012	0.807 ± 0.018	**0.814 ± 0.023**	0.710 ± 0.048	0.780 ± 0.009
Mean	0.688 ± 0.125	0.677 ± 0.146	0.685 ± 0.155	0.543 ± 0.150	**0.725 ± 0.113**

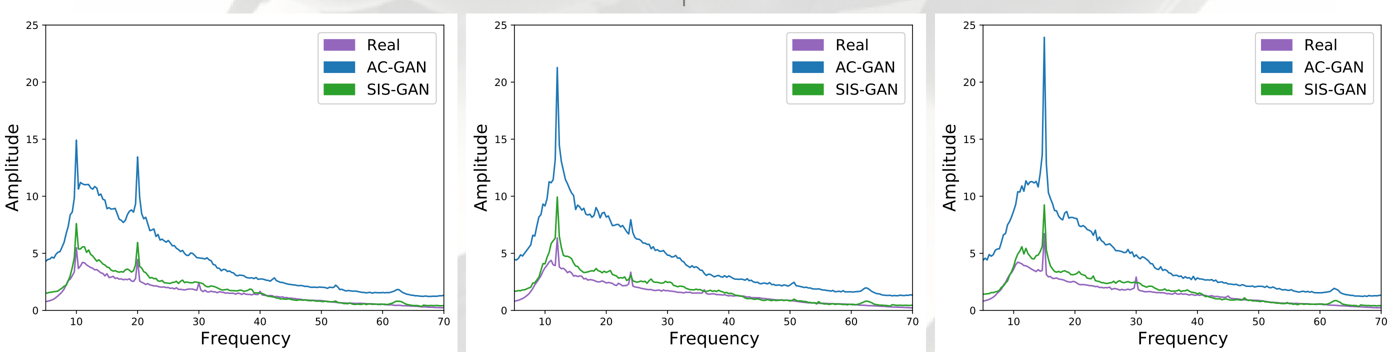
Mean accuracy with standard deviation when classifying SSVEP for unseen subject on offline dataset.

Subject	Realdata	Augmentated Training Data		Synthetic Training Data	
		AC-GAN	SIS-GAN	AC-GAN	SIS-GAN
T01	0.736± 0.066	0.742± 0.071	0.756± 0.103	0.695± 0.100	**0.845± 0.019**
T02	0.508± 0.072	0.542± 0.062	0.592± 0.052	0.488± 0.083	**0.675± 0.016**
T03	0.240± 0.039	0.277± 0.067	0.303± 0.057	0.310± 0.060	**0.453± 0.017**
Mean	0.495± 0.211	0.520± 0.202	0.550± 0.201	0.498± 0.177	**0.660± 0.161**

Mean accuracy with standard deviation for cross-task when classifying SSVEP on online subject dataset.



Softmax probability values taken from the pre-trained subject-biometric classification network for the generated data. A low consistent value distributed across all subjects is best as it indicates the subject-biometric classification network is unable to find discriminative features.



(a) SSVEP Signal at 10Hz. (b) SSVEP Signal at 12Hz. (c) SSVEP Signal at 15Hz.

Comparing Fast-Fourier Transforms (FFT) of real and synthetic data from all the generative models.

Conclusion:

- successfully **generate new synthetic** SSVEP-based dry-EEG signals via **SIS-GAN**
- creation of **subject-invariant** data **removing subject-specific features** whilst **preserving the SSVEP frequencies**
- improvement of **unseen subjects generalisation** when performing **zero-calibration classification** by training only on synthetic signals.

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