Project clarification

Short version

Scientific developments

We propose a new model. It reveals dependencies between mind state and body state. These states form mind and body trajectories in low-dimensional spaces. We construct these spaces with the new Riemannian state space model. We find a part of the EEG signal that describes the quality of meditation and use it as privileged information for a model that evaluates mindfulness (attention) with the IMU signal.

De-Risking

We use stable signal processing models, we use open-source data to select the initial structure of ML models. we use a limited dataset of collected data to fine-tune the model parameters and check the main hypothesis: there exists a dependency between brain and body states in meditation behaviour.

Extended version

New scientific/engineering technical developments that support enabling the innovation

The challenge is to create a model, that establishes dependencies between EEG signals and the body position during the meditation state. The EEG is a superposition of signals generated by several intracranial sources. The problem is to discover the necessary group of signals in the absence of voluntary body motion. To make this discovery, the authors propose a new model selection technique. It selects an optimal model from the class of Convergent Cross-Mapping models. (The known alternatives are the canonical correlation analysis and cross-attention model.) We compute the Lipschitz constant that connects volumes of participant state trajectory clusters in both state spaces: mind state and body state. We check the hypothesis if there is a dependency between mind space and body state exists for a certain class of behavior (phase of meditation). The Lipschitz constant indicates the proportions of the trajectory cluster volumes in both spaces. The trick is to construct low-dimensional [descriptive] spaces both for the mind and the body states. For the EEG part, we propose a new Riemannian model in their state-space representation. For the IMU part, we use the multivariate Singular Spectrum Decomposition model. We combine these two models with the Cross-Convergence Mapping. We select a model that discovers and proves [fails to reject] that dependency.

de-risking the highest risk elements that would indicate strong potential for scale up and commercialization

To make the desired engineering system and run a computational experiment the authors use open-source datasets: 1) meditation EEG datasets, and 2) periodic synchronous EEG-IMU datasets [see the list below]. Also, a dataset from the limited group of experienced and inexperienced participants will be collected to tune the model with given classes of behavior.

Quality criteria for model optimization

We select models and their structures using available open-source datasets. The following quality criteria are to be applied.

1. EEG filtering, spectrogram (pre-defined hyperparameters, grid search of structure)
2. EEG metric space construction (covariance, or recommended metrics)
3. EEG state space model (reconstruction accuracy criterion, dimensionality reduction)
4. IMU filtering (pre-defined hyperparameters)
5. IMU state space model (reconstruction accuracy criterion, dimensionality reduction)
6. EEG-IMU clustering model (intra and cross-cluster distance, given class of behavior)
7. Cross-Convergence Mapping (minimum of Lipschitz constant criterion)

Useful databases EEG, EG-IMU

EEG meditation study. This meditation experiment contains 24 subjects. Subjects were meditating and were interrupted about every 2 minutes to indicate their level of concentration and mind wandering. The scientific article (see Reference) contains all methodological details. 4.3 GB https://nemar.org/dataexplorer/detail?dataset_id=ds001787

BIDS formatted EEG meditation experiment data. This meditation experiment contains 24 subjects. Subjects were meditating and were interrupted about every 2 minutes to indicate their level of concentration and mind wandering. The scientific article (see Reference file) contains all methodological details. 4.6 GB, 4.5 GB https://zenodo.org/records/2536267

EEG Dataset for '**Immediate effects of short-term meditation on sensorimotor rhythm-based brain–computer interface performance**'. This database includes the de-identified EEG data from 37 healthy individuals who participated in a brain-computer

interface (BCI) study. All but one subject underwent 2 sessions of BCI experiments that involved controlling a computer cursor to move in one-dimensional space using their "intent". EEG data were recorded with 62 electrodes. In addition to the EEG data, behavioral data including the online success rate and results of BCI cursor control are also included. 52.8 GB
https://figshare.com/articles/dataset/EEG_Dataset_for_Immediate_effects_of_short-term_meditation_on_sensorimotor_rhythm-based_brain_computer_interface_performance_/21644429

Human EEG Dataset for Brain-Computer Interface and Meditation. This database includes the de-identified EEG data from 62 healthy individuals who participated in a brain-computer interface (BCI) study. All subjects underwent 7-11 sessions of BCI training which involves controlling a computer cursor to move in one-dimensional and two-dimensional spaces using subject's "intent". EEG data were recorded with 62 electrodes. In addition to the EEG data, behavioral data including the online success rate of BCI cursor control are also included. 351.01 GB
https://figshare.com/articles/dataset/Human_EEG_Dataset_for_Brain-Computer_Interface_and_Meditation/13123148

These datasets contain quasiperiodic data along with relaxing behavior data.

Mind in motion young adults walking over uneven terrain. Our dataset contains high-density, dual-layer electroencephalography (EEG), neck electromyography (EMG), inertial measurement unit (IMU) acceleration, ground reaction forces, head model constructed from T1 structural MR images from 32 participants walking over uneven terrain and at different speeds. 50.5 GB
https://nemar.org/dataexplorer/detail?dataset_id=ds004625
https://openneuro.org/datasets/ds004625/versions/1.0.2/download

Real-world table tennis. Our dataset contains high-density, dual-layer electroencephalography (EEG), neck electromyography (EMG), inertial measurement unit (IMU) acceleration, T1 structural MR images, and video data from 25 participants playing real-world table tennis. Participants played 60 minutes of table tennis (in total) with a ball machine and a human player, with an additional 10 minutes of standing baseline. For 17 of the participants, we also include video data of all trials.
https://openneuro.org/datasets/ds004505/versions/1.0.4

Dataset of electrophysiological signals (EEG, ECG, EMG) during **Music therapy with adult burn patients** in the Intensive Care Unit. Electrophysiological measures were

taken from a subset of 9 participants in the intervention group. (To correlate pain, anxiety, and depression levels with electrophysiological signals) 599.5MB https://openneuro.org/datasets/ds004840/versions/1.0.1

Eric Todd. 60 EEG channels and 4 EOG channels were recorded at a sampling rate of 100 Hz from the Brain Products actiCap. 4.38 GB
https://figshare.com/articles/dataset/EEG_and_IMU_data/22233079

See also.

DEAPdataset. We present a multimodal dataset for the analysis of human affective states. The electroencephalogram (EEG) and peripheral physiological signals of 32 participants were recorded as each watched 40 one-minute-long excerpts of music videos. 2.9 GB https://www.eecs.qmul.ac.uk/mmv/datasets/deap/

ECG, EEG and IMU data for **local motion artifact removal** 1 participant, IMU attached to each electrode! 8 GB https://figshare.manchester.ac.uk/articles/dataset/ECG_EEG_and_IMU_data_for_local_motion_artefact_removal/13626395/1

Appendix

Useful tables

Data_Sheet_2_A Critical Analysis on Characterizing the Meditation Experience Through the Electroencephalogram.PDF
https://figshare.com/articles/dataset/Data_Sheet_2_A_Critical_Analysis_on_Characterizing_the_Meditation_Experience_Through_the_Electroencephalogram_PDF/12777392

Table_2_Report from a Tibetan Monastery: EEG neural correlates of concentrative and analytical meditation.XLSX Dataset posted on 2024-05-02 in Frontiers
https://figshare.com/articles/dataset/Table_2_Report_from_a_Tibetan_Monastery_EEG_neural_correlates_of_concentrative_and_analytical_meditation_XLSX/25739796

Link to search https://figshare.com/search?q=IMU%2C%20EEG%2C%20meditation

Experience (no data)

Brainvision. We integrate EEG with fMRI, fNIRS, TMS, tDCS/tACS, MEG, and eye-tracking. We offer both wired and wireless EEG solutions with a variety of electrode technologies, including active, dry, passive gel, and sponge-saltwater, that are ideal for a wide range of cognitive neuroscience applications. https://brainvision.com/

Muse. At-home biofeedback training. Using EEG-data and Machine Learning to control games https://choosemuse.com/ https://github.com/baljo/Muse-EEG/

Bitbrain. Innovative devices and software tools for real-time monitoring of EEG, biosignals (ExG, GSR, RESP, TEMP, etc.), movement activity (EMG, IMUs, etc.) and eye-tracking (screen-based and mobile).
https://www.bitbrain.com/neurotechnology-products

Jhourney. Life-changing meditative bliss used to take thousands of hours to learn. We teach it in a week. https://www.jhourney.io (questionable meditation start-up)

Labeling System with EEG, EMG, and IMU for Visual Training of Autonomous Vehicles https://dergipark.org.tr/en/download/article-file/843034 no data no code