ERCIM fellowship Programme

Final scientific report

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Host Organisation	Norwegian University of Science and Technology, Trondheim
Scientific coordinator	Marta Molinas

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The field of affective computing deals with computational systems that are designed to understand the effects of human emotions. Human actions, decisions, interpersonal interactions, and health are influenced by their emotional states. It is possible to provide improved assistance to humans with automated emotion detection methods, which can also improve human-to-machine interactions. These methods can also play a crucial role in healthcare facilities, teaching-learning scenarios, entertainment, and gaming. The electroencephalogram (EEG) signals can be very useful for the development of the automated emotion recognition techniques as EEG signals and human emotions are found to be correlated [1]. Therefore, the objective of my postdoctoral work is to develop an emotion decoder algorithm that can identify the different kinds of human emotions using EEG signals. The development of the automated emotion detection techniques involves, data collection, preprocessing of the collected data, representation of information using suitable features, and finally needs the training of the classification models with features to make it enable for decision making. During the fellowship, I was involved in the following activities.

1. Evaluation of the emotion decoder algorithms on the publicly available dataset namely, SEED [2] and DEAP [3] datasets.
2. Developing the protocol for the recording of the EEG signals corresponding to the different human emotions in collaboration with researchers from Human Sleep Lab, University of Tsukuba, Japan.
3. Supervision of master students in two different projects.

In the first part, I worked on the different machine learning and deep learning algorithms for human emotion detection and test their performance on the two publicly available datasets SEED and DEAP. These two datasets are recorded in different ways. The SEED dataset consists of the EEG signals corresponding to the discrete labels of human emotions namely, positive, negative, and neutral. However, the DEAP dataset consists of the EEG signals related to the continuous two-dimensional scale of human emotions namely, valance and arousal. In this work, the preprocessed EEG signals of these datasets are first decomposed into different EEG rhythms such as, theta, delta, alpha, beta, and gamma which are further segmented into 1-second epochs. In total, there are 3394 and 2400 epochs for SEED and DEAP datasets, respectively. The differential entropy (DE) feature is explored with a multilayer perceptron (MLP) and convolution neural network (CNN) for emotion recognition. DE feature is computed from each epoch and for all EEG rhythms. The classification performance is tested with 5-fold cross-validation method. For the SEED dataset, the MLP-based algorithm (MLPA) achieved 86.8% accuracy of classification. For the DEAP dataset, MLPA has shown 94.25% and 93.39% accuracy for high versus low arousal (HA/LA) classes and high versus low valence (HV/LV) classes, respectively. Further, we transformed the 1-dimensional DE feature into a 2-dimensional DE feature as per the electrode placement over the scalp. In this way, spatial information can be utilized for emotion detection. The CNN-based algorithm (CNNA) with 2-dimensional DE features yielded 93.81% accuracy for the SEED dataset. The performance is significantly improved with CNNA than that of MLNA for the SEED dataset. However, for the DEAP dataset, we do not see any significant improvement with the CNNA as compared to the MLNA. It should be noted that SEED dataset contains 62 channels of EEG recordings as compared to the 32 channels of EEG recordings of the DEAP dataset. Hence, we can infer that spatial information is more meaningful when the EEG recordings have performed with a large number of channels. With a smaller number of EEG channels, the spatial information is not able to significantly improve emotion detection accuracy. These results can be further improved with a suitable channel selection approach.

In the other part of the work, I was involved in the designing of the protocol for the recording of EEG signals for developing the emotion decoder algorithms. The protocols are as follows. A total of 52 trials are performed for each participant. The time duration of each trial is 111 seconds. In each trial, a video clip of 40 seconds duration is shown to the participant to elicit the emotion. There are a total of 52 video clips related to different emotions which are categorized on the two-dimensional emotion scale valence and arousal. After watching the video clip, the participant needs to rate it on a two-dimensional emotion scale in the range of 1 to 9 for both valence and arousal. Under these protocols, the EEG signals of the 3 subjects are recorded. The recording has been performed at the Human Sleep Lab, University of Tsukuba, Japan. Our proposed algorithms for emotion recognition also have shown good performance on these three subjects' EEG data. The classification accuracies for the three subjects are found to be 92.74%, 91.63%, and 91.01%, respectively for HV/LV classes. For HA/LA classes, the three subjects have shown 93.4%, 96.6%, and 92.02% accuracy, respectively.

Other than this work, I was also involved in the supervision of the master students' projects. I was involved in two different projects, one group has worked on emotion detection methodologies using EEG signals, and the other has worked on the automated monitoring of human mental health using EEG and phonocardiogram (PCG) signals.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Published work:

1. **M. Kumar**, M. Molinas, Human emotion recognition from EEG signals: model evaluation in DEAP and SEED datasets, 21st International Conference of the Italian Association for Artificial Intelligence, December 2022, Udine, Italy.

Pending work:

2. R. Lu, E.C.S. Neverlien, **M. Kumar**, M. Molinas, EEG-based automatic emotion recognition using machine learning (Abstract submitted to 10th International BCI Meeting for review), https://bcisociety.org/bci-meeting/.

3. E.C.S. Neverlien, R. Lu, **M. Kumar**, M. Molinas, Decoding emotions from EEG responses elicited by videos using machine learning techniques on two datasets (Submitted to 45 Annual International Conference of the IEEE Engineering in Medicine & Biology Society for review.)

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. 21st International Conference of the Italian Association for Artificial Intelligence, December 2022, Udine, Italy. (I attended the conference and gave an oral presentation on *Human emotion recognition from EEG signals: model evaluation in DEAP and SEED datasets*)

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Place: SIGIPRO Lab, Simula, Oslo
Duration: 12th December 2022 to 16th December 2022
Hosting Professor: Prof. Baltasar Beferull-Lozano

I visited SIGIPRO lab during the fellowship. The REP visit was very fruitful. First, I presented my work on the human emotion recognition using EEG signals. Researchers of the SIGIPRO lab also presented their work very well. Their work was related to the online learning. They used various sensors' current and past data to predict the future value of a particular sensor. The EEG data is also collected from the various scalp sensors. Hence, their work has a huge potential to be explored in my research area. They also provided very valuable suggestions for my future research. We also discussed the opportunity of the research collaboration in the near future.

References

[1] D. Sammler, M. Grigutsch, T. Fritz, S. Koelsch, Music and emotion: electrophysiological correlates of the processing of pleasant and unpleasant music, Psychophysiology, vol. 44, pp. 293-304, 2007.

[2] W.-L. Zheng and B.-L. Lu, "Investigating critical frequency bands and channels for EEG-based emotion recognition with deep neural networks," IEEE Transactions on Autonomous Mental Development, vol. 7, no. 3, pp. 162–175, 2015

[3] S. Koelstra et al., "DEAP: a database for emotion analysis using physiological signals," IEEE Transactions on Affective Computing, vol. 3, no. 1, pp. 18–31, 2012.