ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	Alejandro Antonio Torres-García
Nationality	Mexican
Name of the *Host Organisation*	Norwegian University of Science and Technology (NTNU)
First Name / family name of the *Scientific Coordinator*	Marta Molinas
Period of the fellowship	01/03/2019 to 29/02/2020

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my stay at NTNU, the main activities were focused on the analysis and classification of EEG signals recorded during color exposure. Despite there exists some evidence about differences between colors following an event-related potentials (ERP) approach [1], -which is based on the averaging of the EEG signals for each color and all subjects-, its automatic discrimination for controlling devices has been only approached in [2]. Even though they recorded the EEG signals from 7 subjects using a 4-channel EEG cap (P1, P2, O1, and O2) whose frequency sampling is 256Hz., their outcomes were overestimated due to the use of the same information during the training and testing. Besides, looking for a wearable design, it is unclear what performance could be achieved without this overestimation and using dry electrodes.

For approaching this problem, we have scheduled two scenarios of analysis (offline and online) for our project. In the offline analysis, we will assess the feasibility of a color-based BCI using pre-recorded signals, whereas in the online we will work on how to recognize the target activity from the idle states and to control an automatized door using online EEG signals. Both analyses imply the application of algorithms for artifact

removal, signal processing, machine learning, and their parameters' optimization. Specifically, we assessed in feature extraction stage two techniques, discrete wavelet transform (DWT) and empirical mode decomposition (EMD). Whereas in the classification stage, we analyzed 4 classifiers Naive Bayes, K-nearest neighbors, support vector machine (SVM) and Random Forest (RF), getting the best preliminary results with SVM and RF.

For the offline scenario, the first advances are described here. Looking for solving the drawbacks in [2] and assuring an independence of our results from a specific dataset, we designed a protocol to record the responses to the color exposure, resulting in an additional dataset composed of the EEG signals belonging to 18 subjects (more than in [2]) and 30 trials per class for each subject (52 trials in [2]). The EEG signals were recorded using a gTec Sahara device and the analyzed channel locations were FP1, FP2, AF3, AF4, P03, P04, O1 and O2. These locations were selected based on the related works [1,2]. Our dataset was recorded in a dark room and following the next protocol timeline per each trial: a 2-seconds gray screen with a fixation cross for indicating the subjects to pay attention, a 3-seconds screen with the target color's exposure, and a short and randomized pause screen (1-2 seconds). The average performances for RGB classification were 37.64% (RF and DWT-based features) using the previous dataset [2] and 37.5% (EMD-based features and SVM) in our dataset. We observed that the performances were subject-dependent in both datasets regardless of their sizes. In some subjects, their performances overcame 40%, which is higher than the chance level for 3 classes. These outcomes make necessary more research looking for providing more evidence on RGB classification, especially, it is necessary to collect more instances for each color aiming to enhance the machine learning performances.

Whereas looking for providing a first attempt towards an online scenario, we have analyzed if a machine learning algorithm can distinguish between the target colors (seen as a single class) and idle state using the dataset recorded in [1] and ours. This was done since the method should be able to discriminate between these activities in an online scenario. In this case, the best average accuracies were 98.76% (SVM and EMD-based features) for the previous dataset, and 92.5% (RF and EMD-based features) and 94.6% (SVM and EMD-based features) using two different types of idles states (break-related and attention-related epochs) in our dataset. This suggests that a machine learning algorithm can accurately recognize between both classes, regardless of the dataset analyzed. A second step is to design a method based on short windows for a fast detection of the target colors and idle states looking for the implementation of an online BCI based on color exposure. As a third step, this project considers evaluating a real scenario for controlling an automatized door for which the interface to control the door's actions and to convert the algorithm outputs will be developed.

Besides that, I presented the lecture on Wavelet in the course of **Adaptive Data Analysis: Theory and Applications** [1]**.** In the same course, I was the external examiner for the students' projects.

In addition, I co-supervised the master thesis entitled **"Supervised learning for classification of EEG signals evoked by visual exposure to RGB colors"** [3] and the following two NTNU Specialization projects of the Master of Science in Cybernetics and Robotics.

- Towards a method for onset detection in color-based BCI by Thomas Nakken Larsen.
- An assessment of the impact of the number of instances on the recognition of the RGB colors by Robin Kleiven.

Also, I contributed to our lab with ideas and the initial advisoring for the application of the *Evolutionary Multi-Objective Algorithms* such as NSGA-II on channel selection problems like in [4].

Last, I promoted the collaboration between NTNU and INAOE from Mexico, getting the signature of a collaboration agreement whose first activity will be the creation of a dataset of EEG signals for color exposure recognition.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Conference Papers

1. Discriminating between color exposure and idle state using EEG signals for BCI application. A. A. Torres-García and M. Molinas. International Conference on e-Health and Bioengineering (IEEE EHB 2019), pp. ?-?. Iasi, Romania, November 21-23, 2019. Paper (in press).
2. Analyzing the Recognition of Color Exposure and Imagined Color from EEG signals. A. A. Torres-García and M. Molinas. International Conference on BioInformatics and BioEngineering (IEEE BIBE 2019), pp. ?-?. Athens, Greece, October 28-31, 2019. Paper (in press).
3. Assessing the impact of idle state type on the identification of RGB color exposure for BCI. A A Torres-García, L. A. Moctezuma, and M. Molinas. In: BIOSTEC 2020. Valletta, Malta: SciTePress, Feb. 24–26, 2020, pp. 187–194. ISBN: 978-989-758-398-8.

[1] https://www.itk.ntnu.no/emner/fordypning/TTK7

Peer Reviewed Abstract

1. Towards a BCI based on Color Exposure Recognition. 4th HBP Student Conference "On Interdisciplinary Brain Research". 4th HBP Student Conference "On Interdisciplinary Brain Research". Pisa, Italy. January 21-23, 2020.
2. David versus Goliath: Low-density EEG unravels its power through adaptive signal analysis - Flex-EEG. A. A. Torres-García, L. Moctezuma and M. Molinas. 4th HBP Student Conference "On Interdisciplinary Brain Research". Pisa, Italy. January 21-23, 2020.

As work in progress, we have two book chapter in the book entitled **"Biosignal Processing and Classification Using Computational Learning and Intelligence"**. The chapters are,

- "Feature Extraction"
- "Pre-processing"

III – ATTENDED SEMINARS, WORKSHOPS, CONFERENCES

I attended the following conferences

1. International Conference on e-Health and Bioengineering (IEEE EHB 2019). Iasi, Romania, November 21-23, 2019.
2. International Conference on BioInformatics and BioEngineering (IEEE BIBE 2019). Athens, Greece, October 28-31, 2019.
3. 13th International Conference on Bio-inspired Systems and Signal Processing (BIOSIGNALS 2020). Valletta, Malta, February 24-26, 2020.
4. 4th HBP Student Conference "On Interdisciplinary Brain Research". Pisa, Italy. January 21-23, 2020.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Prof. Fabien lotte at INRIA Bordeaux, France. From September 19 to 30. During the research exchange, we focused on the assessment of algorithms for classifying small datasets applied to the RGB color recognition.

REFERENCES

[1] Forder, L., Bosten, J., He, X., & Franklin, A. (2017). A neural signature of the unique hues. Scientific reports, 7, 42364.

[2] Rasheed, S. (2011). Recognition of primary colours in electroencephalograph signals using support vector machines. PhD thesis, Università degli Studi di Milano, 2011.

[3] Åsly, S. H. (2019). Supervised learning for classification of EEG signals evoked by visual exposure to RGB colors (Master's thesis, NTNU).

[4] Torres-García, A. A., Reyes-García, C. A., Villaseñor-Pineda, L., & García-Aguilar, G. (2016). Implementing a fuzzy inference system in a multi-objective EEG channel selection model for imagined speech classification. *Expert Systems with Applications*, *59*, 1-12.