PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

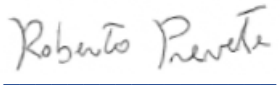
PhD Student: Salvatore Giugliano

Cycle: XXXV

Training and Research Activities Report

Academic year: 2020-21 - PhD Year: Second

Tutor: Prof. Roberto Prevete



Co-Tutor: Francesco Isgrò

Date: October 21, 2021

1. Information:

- **PhD student:** Salvatore Giugliano **PhD Cycle:** XXXV
- **DR number:** DR994201
- **Date of birth:** 20/08/1986
- **Master Science degree:** Computer Science (cum laude) **University:** Università degli Studi di Napoli "Federico II"
- **Scholarship type:** no scholarship
- **Tutor:** Roberto Prevete
- **Co-tutor:** Francesco Isgrò

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Robot Manipulation and Control	Seminar	2.5	0.5	17/11/20	Bruno Siciliano	Y
Data Driven Transformation in WINDTRE through Managers voice VII Antonio Picariello Lectures on Data Science Flora Amato	Seminar	2	0.4	16/12/20	Flora Amato	Y
Cybercrime and e-evidence: the criminal justice response	Seminar	2	0.4	20/1/21	Matteo Lucchetti	Y
The era of Industry 4.0: new frontiers in business model innovation	Seminar	1	0.2	3/2/21	Marco Balzano	Y
Machine learning: Causality lost in translation	Seminar	1.5	0.3	10/2/21	Edwin A. Valentijn	Y
Approaches to Graph Machine Learning	Seminar	1	0.2	17/2/21	Miroslav Cepek	Y
Data science for patient records analysis	Ad hoc course	12	2.5	10-17-24/2/21, 3-17-18/3/21	Marcello Cinque	Y
Visual Interaction and Communication in Data Science	Seminar	2	0.4	3/3/21	Marco Quartulli	Y
Robo Ludens: A game design taxonomy for human-robot interaction	Seminar	1	0.2	5/3/21	John Edison Muñoz Cardona	Y

Matrix Analysis for Signal Processing with MATLAB Examples	Ad hoc course	10	2	10/5/21	Prof. Augusto Aubry, Dr. Vincenzo Carotenuto, Prof. Antonio De Maio	Y
Ethics of quantification	Seminar	2	0.4	26/5/21	Andrea Saltelli	Y
Real-Time Embedded Systems for I4.0 and IIoT	Ad hoc course	12	2.5	22/7/21	Prof. Marcello Cinque & Alessandro Cilardo	Y
L'esposizione ai campi elettromagnetici generati dal sistema 5G	Seminar	4	0.8	16/7/21	Sara Adda, Daniele Franci, Settimio Pavoncello	N
SAE 2021 - Big4small, Data Science Methodology Transfer: Big to Small.	Seminar	4	0.4	24/9/21	Prof. Edwin Valentjin	N

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1		**0.9**	**8**		**8.9**
Bimonth 2		**1.1**	**9**		**10.1**
Bimonth 3	**2.5**	**0.6**	**7**		**10.1**
Bimonth 4	**2**	**0.4**	**8**		**10.4**
Bimonth 5	**2.5**	**0.8**	**7**		**10.3**
Bimonth 6		**0.4**	**9**		**9.4**
Total	**7**	**4.2**	**48**		**59.2**
Expected	**10**	**5**	**45**	**0**	**60**

3. Research activity:

The research topic is "Analysis and interpretation of EEG signals with Machine Learning techniques". During this second year of PhD, I analyzed the state of the art of EEG signals with Machine Learning techniques. I worked on two applications of EEG signals: engagement classification from EEG data for the AVATEA project, and SSVEP detection from EEG data. Other research activities I have studied and worked on are Transfer Learning (TL) on EEG data and eXplainable Artificial Intelligence (XAI).

- **Analysis and interpretation of EEG signals**
  EEG (Electroencephalographic) signals are not easy to interpret. They have a lot of noise, vary significantly between individuals and, even for the same person, change substantially over time. Artificial intelligence and machine learning are used to process and classify data.
  - Engagement classification (AVATEA project)
    The term engagement means the level of involvement of an individual under three main aspects: cognitive, emotional, and behavioural. Through the EEG waves, it is possible to quantify the level of engagement of a person. These waves are collected through a helmet equipped with a variable number of non-invasive electrodes placed on the surface of the head. The main difficulty and challenge of these data was their imbalance by class, and by session. Then, data balancing techniques were used on the training set.

Using and comparing different machine learning techniques such as k-NN, SVM, and ANN, it was possible to obtain good results in terms of cognitive and emotional engagement.

- SSVEP detection
  The EEG signals of the SSVEP type (Steady State Visually Evoked Potential) are signals that are taken from the occipital region of the user's scalp: when the user observes a light stimulus that flashes at a certain frequency (typically in the range 3-75 Hz , with an optimal range between 8 and 15 Hz), a signal is generated having a spectral component at the same frequency as the observed stimulus (in many users the generation of a second and third harmonic is also evident).
  Therefore, by analyzing the EEG signal taken, it is possible through appropriate processing strategies to trace the light stimulus that the user observed, turning it into a command to be given to the target (in this case, the Robot). Work done on this data proposes a highly wearable single-channel BCI based on SSVEP signal detection. Two ML-based algorithms were implemented to improve SSVEP detection performance, in terms of classification accuracy and temporal response. Experimental results on four datasets show a significant improvement in performance. In particular, the combined use of features in both the time domain and the frequency domain helps to mitigate performance. This results in greater discrimination between classes and, therefore, in an improvement in system performance, without a significant increase in computational complexity.

- **Transfer Learning on EEG data**
  TL can be defined as “take a model trained on a large dataset and transfer its knowledge to another dataset”. Two scenarios usually apply: (1) Finetuning, initialize the network with a pretrained network, like the one that is trained on ImageNet 1000 dataset. Rest of the training looks as usual; (2) Fixed feature extractor, freeze the weights for all the network except that of the final fully connected layer. This last fully connected layer is replaced with a new one with random weights and only this layer is trained.
  - SEED Dataset
    Transfer learning is usually applied to domains of the same type. For example, a model is trained on an image dataset and the knowledge, i.e., the weights of the trained network, is transferred to a different image dataset. Applying the TF starting from a pre-trained model on images (ImageNet 1000 Dataset for example) and transferring the knowledge on an EEG signal dataset such as SEED is really a challenge.
    The EEG data is conveniently transformed into images to become the input of the pre-trained network. Several experiments were carried out: using both the RAW data and the extracted features made available by the SEED dataset; inter-subjective and intra-subjective strategies; finetuning and fixed feature extractor scenarios. These trials are still ongoing.

- **XAI**
  XAI refers to the principle of making the operation of artificial intelligence and its results understandable to the user. Mainly, in literature, two types of XAI methods can be distinguished: agnostic (or black-box) methods which are independent of the machine learning model to be explained and white-box methods which instead have access to the structure of the model to be interpreted. Another possible distinction between XAI methods is the level (low or

middle) of the features to be explained. Low-level feature approaches allow for an explanation of a model's output in terms of low-level features such as pixels in an image classification problem. A popular method based on this approach is Layer-wise Relevance Propagation (LRP), which maps a relevance value to each pixel of the image as an explanation of the model's output. Relevance values are shown on a heatmap. This method is also a typical example of a white-box approach.

- Hierarchically organized Middle Level Features
  A current line of XAI research attempts to alleviate the weakness of low-level approaches by constructing explanations in terms of input characteristics that represent more salient and understandable input properties for a user, which we call Middle-Level input Features (MLF). Furthermore, another interesting approach is to consider hierarchically organized explanations. My work team and I investigated the possibility of combining both MLFs and hierarchical organizations. The potential benefits of providing explanations in terms of hierarchically organized MLFs are based on the ability to exhibit explanations at a different granularity of interacting MLFs. We have experimentally tested our approach on two datasets and the results look encouraging.

4. Research products:

Paper in preparation

- "Enhancement of SSVEP detection for wearable Brain-Computer Interfaces by means of Machine Learning and Convolutional Neural Networks", Andrea Apicella, Pasquale Arpaia, Egidio De Benedetto, Nicola Donato, Luigi Duraccio, Salvatore Giugliano, Roberto Prevete.

Paper accepted

- "High-wearable EEG-Based transducer for Engagement Detection in Pediatric Rehabilitation", Andrea Apicella, Pasquale Arpaia, Salvatore Giugliano, Giovanna Mastrati. Nicola Moccaldi, Brain-Computer Interfaces.

Conference paper submitted

- "Explanations in terms of Hierarchically organised Middle Level Features", Andrea Apicella, Salvatore Giugliano, Francesco Isgrò and Roberto Prevete, AIxIA2021 (20th International Conference of the Italian Association for Artificial Intelligence).

Conference paper published

- "A general approach to compute the relevance of middle-level input features", Apicella, A., Giugliano, S., Isgrò, F., & Prevete, R. (2021, January), In International Conference on Pattern Recognition (pp. 189-203). Springer, Cham.

5. Conferences and seminars attended

During my secondo PhD year, I did not participate to any conference.

6. Periods abroad and/or in international research institutions

Study stay abroad in telework mode, from 30/6/21 to 30/9/21 at the Superior Technical Institute of the University of Lisbon, Group of Instituto de Engenharia de Sistemas and Computadores: Investigação e Desenvolvimento em Lisboa (INESC-ID), Lisbon, Portugal.
The overseas supervision was by Prof. Pedro Silva Girão, who holds the role of full professor at the aforementioned institution. The study and research activity involved the analysis and interpretation of EEG signals using Machine Learning techniques.

7. Tutorship

During my second PhD year, I did not make any tutorship activity.

8. Plan for year three

Activities planned for the third year include:

- Research activities
  - Conclude the paper on the SSVEP paradigm
  - The ATENA project (at Villa delle Ginestre clinic)
    - Classification of burnout states to support the early diagnosis of autistic children (using EEG, ECG, EMG signals)
  - Domain Adaptation/Generalization on EEG data
- Draft topic of the thesis
  - Deep learning for the classification of EEG signals