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

PhD Student: Jessica Centracchio

Cycle: XXXV

Training and Research Activities Report

Year: First

Jessica Centracchio

Tutor: prof. Paolo Bifulco

Paolo Bifulco

Date: October 21, 2020

1. Information:

- **PhD student: Jessica Centracchio**
- **DR number: 993886**
- **Date of birth: 21 September 1994**
- **Master Science degree: Biomedical Engineering**
- **University: University of Naples “Federico II”**
- **Doctoral Cycle: XXXV**
- **Scholarship type: *UNINA***
- **Tutor: Prof. Paolo Bifulco**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
“Marked point processes for object detection and tracking in high resolution images: application to remote sensing data”	Seminar	1	0.2	02.12.19	Prof. G. Scarpa	Y
“Intelligenza Artificiale ed Etica: la ricerca in IA alla prova delle sfide etiche”	Ad hoc course	6	1.2	06.12.2019	Prof. R. Prevete	Y
“Scientific Programming and Visualization with Python”	Ad hoc course	10	2	04.03.2020 and 06.03.2020	Prof. A. Botta	Y
“Computational Biology: Large scale data analysis to understand the molecular bases of human diseases”	Seminar	1	0.2	09.04.2020	Prof. M. Ceccarelli	Y
“Elettromagnetismo e Salute”	Seminar	1	0.2	09.04.2020	Prof. R. Massa	N
BCI & NEUROTECHNOLOGY SPRING SCHOOL 2020 https://www.gtec.at/spring-school-2020/	External seminar	30	6	20.04.2020 – 24.04.2020	g.tec medical engineering GmbH (AT)	Y
“Innovation Management, entrepreneurship and intellectual property”	Ad hoc course	18	5	23.04.2020 – 05.06.2020	Prof. P. Rippa	Y
“La programmazione europea e la ricerca. Nuovi scenari della	Seminar	2	0.4	13.05.2020	Prof. F. Ammirati	N

programmazione europea dopo il 2020. La gestione di un progetto di ricerca”						
“Noninvasive Mapping of Electrical Properties using MRI”	Seminar	1.5	0.3	13.06.2020	Prof. G. Ruello	Y
“Machine Learning”	Ad hoc course	20	4	06.07.2020 – 17.07.2020	Prof. C. Sansone	Y
“Strategic Orientation for STEM Research & Writing”	Ad hoc course	21	3.6	16.07.2020 – 01.10.2020	Chie Shin Fraser	Y
“Computer Interface for Biological Systems”	MSc course U1593 ING-INF/06	II semester	6	14.10.2020	Prof. P. Bifulco	Y
Study on intracranial electrodes localization in CT volumes	Research		15.5	01.11.2019 – 31.10.2020		
Study on EEG signals analysis for epileptic seizures prediction	Research		6	01.02.2020 – 31.08.2020		
Study on localization of electrodes for Deep Brain Stimulation	Research		5.5	07.02.2019 – 15.05.2020		
Study on Data Mining	Research		3	01.02.2020 – 30.06.2020		
Study on Forcecardiography	Research		3	01.09.2020 – 31.10.2020		
Assistant for the BSc Course “Elaborazione dei segnali e dei dati biomedici”	Tutorship	40	1.6	01.02.2020 – 31.10.2020	Prof. F. Amato	

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	1.2	0.2	1.5	0	2.9
Bimonth 2	0	0	7	0.2	7.2
Bimonth 3	2	6.4	7	0.2	15.6
Bimonth 4	5	0.7	7	0.4	13.1
Bimonth 5	4	0	5.5	0.4	9.9
Bimonth 6	9.6	0	5	0.4	15
Total	21.8	7.3	33	1.6	63.7
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

3. Research activity:

Innovative bioengineering methods for diagnosis and monitoring

During my first year of Ph.D. course I carried out two research activities within my research field, namely “ECoG electrodes recognition in CT images” and “Analysis and monitoring of heart mechanical activity via force sensors”.

- **ECoG electrodes recognition in CT images**

People with focal epilepsy, refractory to anti-seizure medications, could be considered for surgery. The surgical treatment consists in the resection of the Epileptogenic Zone (EZ), defined as the site of the beginning of the epileptic seizures, and its successful outcome depends on accurate localization of this area [1]. From a clinical point of view, this allows excluding eloquent areas, which are responsible for vital functionalities, also avoiding deficits to patient and minimizing brain volume resection. Generally, the localization is achieved by combining neuroimaging techniques with non-invasive electrophysiological recordings, such as ElectroEncephaloGraphy (EEG). In many cases, non-invasive presurgical work-up is not sufficient to identify this area and intracranial investigations are carried out, such as ElectroCorticoGraphy (ECoG) [2]. Patients undergo a craniotomy for the implantation of subdural electrodes. A precise localization of electrodes position onto the cerebral cortex is required with the aim of carefully defining the anatomical boundaries of the seizure onset zone [3]. Electrodes are usually recognized manually or by processing Computed Tomography (CT) images, by using simple image thresholding [3-10]. Manual methods are very time-consuming, user-dependent and prone to inaccuracy. On the contrary, the mere CT image thresholding method is not able to recognize all the electrodes and to completely exclude other metallic objects, such as wires, tooth fillings, intracranial clips, splinters, stitches, screws, hearing aids or intracranial stents. Hence, manual intervention is often required to adjust the data.
My work aimed to develop a new, automated method, based on shape analysis, for ECoG electrodes recognition in CT volumes. Head CT scans of 24 patients undergoing epilepsy surgery were provided by IRCCS Neuromed (Pozzilli, Italy) and were included in this study. Before the acquisition of CT scans, patients underwent a craniotomy and ECoG electrodes were placed on the brain surface. Each

electrode consists of a round platinum-iridium disc, with a 4 mm diameter and a thickness of about 0.5 mm. Electrodes are arranged in strips or grids within a flexible sheet and are connected to the recording device via cables. Grids also included a platinum marker to identify the electrode numbered as 1.
Raw CT images were submitted to a Metal Deletion Technique to suppress metal artifacts. Afterward, the CT volumes were re-sampled by using a cubic interpolation in order to obtain a cubic voxel of 0.5 mm size. After the preprocessing phase, a thresholding on radiodensity values (Hounsfield Units, HU) was performed. ECoG electrodes and other metal objects were detected for HU greater than 2400. Then, only the 6-connected voxels were kept. Since a large part of wires and stitches were placed outside the skull, a binary head mask was applied to exclude them. Afterward, a shape analysis was carried out to separate electrodes from other metallic objects inside the head. For each cluster of voxels, six geometric features were computed, namely Volume, Primary axis length, Secondary axis length, Tertiary axis length, Circularity, and Cylinder-similarity. The electrodes have the shape of a flattened cylinder, whereas segments of threads or sutures have an elongated and potentially curved shape. A distinct database was provided for each patient, with rows corresponding to potential electrode objects within the CT volume, and composed by a collection of the six geometric features and the assigned class. Two classes were considered: “electrode” and “non-electrode”. The “electrode” class was assigned to the actual electrodes, while the non-electrode class was assigned to all the other detected metal objects. A Linear Discriminant Analysis (LDA) algorithm was used for model training and data classification. Classification performances were assessed by applying the 10-fold cross validation on each of the 24 patients’ databases and on the combined database (devised by joining all patients’ databases), reaching respectively a 98.08% mean classification accuracy across all patients and a 95.47% classification accuracy on the combined database.
The proposed algorithm allows efficient automated localization of the ECoG electrodes, without the need for manual intervention by the operator and can be easily integrated into software suites, that manage the whole preoperative analysis process.
Furthermore, I carried out a bibliographic research on scientific literature about the challenging problem of epileptic seizure prediction via the analysis of EEG or intracranial EEG (iEEG) signals. Thanks to the collaboration with IRCCS Neuromed, I also experienced using a software for the localization of electrodes for Deep Brain Stimulation (DBS), implanted on patients affected by Parkinson disease.

- **Analysis and monitoring of heart mechanical activity via force sensors**

In my first year of PhD course, I also joined a research activity aimed at investigating a novel non-invasive technique to analyze and monitor the mechanical activity of the heart via force sensors. Since the 19th century, the study of cardiac mechanics has been pursued through the recording of mechanical vibrations induced onto the chest wall by the beating heart [11-13]. Nowadays, the most widespread technique to acquire such mechanical signals is Seismocardiography (SCG), which measures the accelerations of the chest wall via small MEMS accelerometers and is mainly used to detect abnormal heart valves behavior, as well as some arrhythmias [14-16].
Recently, the research group I joined for my PhD presented the novel Forcecardiography (FCG) technique, which is based on force sensors and proved capable to acquire mechanical signals from the chest wall with a richer informational content than SCG [17]. In particular, a novel low-frequency component, not visible in SCG signals, showed up in FCG recordings and seemed to be related to the filling and emptying of the heart. This suggested its potential use in enabling a long-term, non-invasive

monitoring of stroke volume variations. Usually, FCG recordings have been acquired during apnoea conditions, so as to avoid potential motion artifacts caused by respiration. However, it is clear that a long-term monitoring cannot rely on apnoeas recordings only, therefore I participated in experimental activities aimed at assessing the performances of FCG also during breathing. The preliminary results show that the FCG sensors are able to monitor at the same time both respiratory and cardiac activity with high accuracy, thus proving as valid, unobtrusive, cheap and lightweight devices for long-term patient monitoring.
Further analyses will focus on assessing the relationship between certain FCG signal features and stroke volume variations, e.g. during controlled experiments involving physical exercises.

4. Research products:

a. scientific papers:

i. J. Centracchio, A. Sarno, D. Esposito, E. Andreozzi, L. Pavone, G. Di Gennaro, M. Bartolo, V. Esposito, R. Morace, S. Casciato, P. Bifulco. **Efficient Automated Localization of ECoG Electrodes in CT Images Via Shape Analysis**. Submitted to International Journal of Computer Assisted Radiology and Surgery (INT J CARS).

5. Conferences and seminars attended

During my first year of Ph.D., I did not attend conferences or seminars.

6. Activity abroad:

During my first year of Ph.D., I did not spend time aboard.

7. Tutorship

Assistant for the BSc course of “Elaborazione dei segnali e dei dati biomedici” (40 hours), held by Prof. Francesco Amato.

8. References

[1] Rosenow F, Lüders H (2001) Presurgical evaluation of epilepsy. Brain 124:1683–1700.

[2] Jayakar P, Gotman J, Harvey AS, et al (2016) Diagnostic utility of invasive EEG for epilepsy surgery: Indications, modalities, and techniques. Epilepsia 57:1735–1747.

[3] Taimouri V, Akhondi-Asl A, Tomas-Fernandez X, et al (2014) Electrode localization for planning surgical resection of the epileptogenic zone in pediatric epilepsy. Int J Comput Assist Radiol Surg 9:91–105.

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[15] Jain, P.K.; Tiwari, A.K.; Chourasia, V.S. (2016) Performance analysis of seismocardiography for heart sound signal recording in noisy scenarios. J. Med. Eng. Technol., 40, 106–118.

[16] Taebi, A.; Solar, B.E.; Bomar, A.J.; Sandler, R.H.; Mansy, H.A. (2019) Recent Advances in Seismocardiography. Vibration, 2, 5.

[17] Andreozzi, E.; Fratini, A.; Esposito, D.; Naik, G.; Polley, C.; Gargiulo, G.D.; Bifulco, P. (2020) Forcecardiography: A Novel Technique to Measure Heart Mechanical Vibrations onto the Chest Wall. Sensors, 20, 3885.