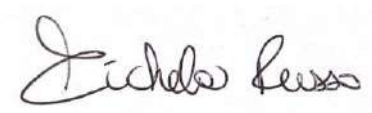
PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Michela Russo

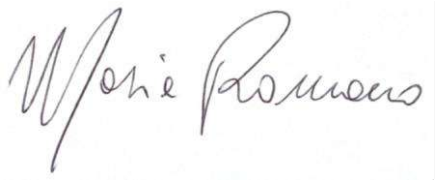
Cycle: XXXVII

Artificial Intelligence & Gait Analysis for Neurological Diseases

Year: First



Tutor: prof. Maria Romano



Date: October 31, 2022

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXVII **Author: MICHELA RUSSO**

1. Information:

- **PhD student: Michela Russo**
- **DR number: DR995854**
- **Date of birth: 19/04/1995**
- **Master Science degree: Biomedical Engineering**
- **University: University of Naples FEDERICO II**
- **Doctoral Cycle: XXXVII**
- **Scholarship type: *UNINA***
- **Tutor: Prof. Maria Romano**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Cybersecurity-AKKA	Seminar	2	0.4	3/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	**Y**
Vehicular Hacking AKKA	Seminar	1.5	0.3	3/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	**Y**
Possible Quantum Machine Learning Approaches in HEP	Seminar	2	0.4	12/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	**Y**
Connecting to the dots-Splunk	Seminar	2	0.4	26/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	**Y**
From present to future in digital healthcare	Seminar	2	0.4	29/11/2021	Prof. Paolo Gargiulo	**N**
Single cell omics leverage Machine Learning to dissect tumour microenvironment and cancer immune editing	Seminar	2	0.4	2/12/2021	Prof. Anna Corazza	**Y**

Ultra-High Field Magnetic Resonance Imaging	Course	15	3	Jan 17th 2022 – Jan 31th 2022	Prof. Ruello	**Y**
The learning landscape in deep neural networks and its exploitation by learning algorithms	Seminar	1.5	0.3	21.1.2022	Prof. Riccardo Zecchina	**N**
Systems biology as a compass to understand tumour-immune interactions in humans	Seminar	1.5	0.3	2.2.2022	Davide Bedognetti	**N**
Computational analysis of cancer genomes	Seminar	1.5	0.3	16.2.2022	Prof. Nùria Lòpez-Bigas	**N**
Can a Text-to-Speech engine generate human sentiments?	Seminar	1.5	0.3	28/02/2022	Prof. V.K.Gurbani,	**N**
Towards a Political Philosophy of AI	Seminar	2	0.4	11/04/2022	Mark Coeckelbergh	**N**
Explainable Natural Language Inference	Seminar	1	0.2	13/04/2022	Prof. Francesco Cutugno	**Y**
An Introduction to Deep Learning for Natural Language Processing	Seminar	1	0.2	13/04/2022	Prof. Francesco Cutugno	**Y**
Using Delays for Control	Seminar	1	0.2	21/04/2022	Prof. Stefania Santini	**N**
Towards AI-Driven Cancer Precision Medicine	Seminar	1.5	0.3	22/04/2022	Prof. Olivier Elemento	**N**
Assessing postural control and motion sickness using electrophysiological signals	Seminar	2	0.4	26/04/2022	Prof. Paolo Gargiulo	**N**
Population and medical genomics applications to human traits and diseases	Seminar	1	0.2	29/04/2022	Prof. Nicole Soranzo	**N**
Statistical Data Analysis for Science and Engineering	Course	20	4	22-24-29-31/03, 05-07/04/2022	Prof. Pietrantuono Roberto	**Y**

Big Data Architecture & Analytics	Course	25	5	06-08-22-27-29/04-06-11/05/2022	Prof. Sperlì Giancarlo	**Y**
Symbiotic Control of Wearable Soft Suits for human motion assistance and augmentation	Seminar	2	0.4	20/05/2022	Prof. Fanny Ficuciello	**Y**
Probing and infusion biomedical knowledge for pre-trained language models	Seminar	2	0.4	7/06/2022	Prof Francesco Cotugno	**N**
Data Science for Patient Records Analysis	Course	15	3	15/06 - 14/07/2022	Prof Marcello Cinque	**Y**
Imprenditorialità accademica	Course	20	4	26/05 – 14/07/2022	Prof. Pierluigi Rippa	**Y**
New paradigms for 3D modelling and surgical planning	Seminar	2	0.2	13/10/2022	Prof. Paolo Gargiulo	**N**
Machine Learning for Science and Engineering Research	Course	20	5	20-21-22-23-24-27-28-29-30/06 - 01/07/2022	Proff. A. Corazza, F. Isgrò, R. Prevete, C. Sansone, G. Pezzulo	**Y**

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**	**2.3**	**6**	**0**	**8.3**
Bimonth 2	**3**	**1.2**	**6**	**0**	**10.2**
Bimonth 3	**0**	**1.9**	**7**	**0**	**8.9**
Bimonth 4	**9**	**0.8**	**7**	**0**	**16.8**
Bimonth 5	**7**	**0**	**8**	**0**	**15**
Bimonth 6	**5**	**0.2**	**4**	**0**	**9.2**
Total	**24**	**6.4**	**38**	**0**	**68.4**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

During my first year of Ph.D. course, I carried out two main research activities within my Ph.D. topic: first, "Gait Analysis and Machine Learning tools to investigate the interplay between gait and neuropsychiatric symptoms in Parkinson's Disease", and second, "Postural analysis to distinguish the Parkinsonism". Moreover, I had the opportunity to carry out a research activity off-topic of my research field, namely "Simulation, Artificial Intelligence and Bioimaging".

- **Gait Analysis and Machine Learning tools to investigate the interplay between gait and neuropsychiatric symptoms in Parkinson's Disease.**

Parkinson's Disease (PD) is a progressive and disabling disorder. PD clinical picture is characterized by a combination of motor (bradykinesia, resting tremor, rigidity, and stability impairment) and non-motor symptoms (cognitive decline, psychosis, autonomic symptoms, etc.) that worsen as the disease progresses. Among non-motor symptoms, neuropsychiatric impairments, including cognitive impairment, depression, psychosis, apathy, are associated with worse quality of life, can significantly contribute to patient disability and even increase mortality [1]-[2].
Neuropsychiatric non-motor symptoms and gait in PD appear being closely related in a complex pattern. Gait is no longer considered as an automatic task, but an activity requiring multiple cognitive skills [3], as a consequence, gait has been considered a reliable surrogate biomarker of cognitive decline in PD [4]. In addition, affective symptoms, like depression and anxiety and psychotic symptoms [5]-[6], have been associated with gait dysfunction and instability in PD. Indeed, the relationship between neuropsychiatric symptoms and gait is quite complex, thus reflecting, at least to some extent, the progression of the neurodegenerative process involving non-dopaminergic networks and posterior cortical areas. The diagnosis of PD is based on neurological examination. This assessment includes imaging tests and the use of international evaluation scales, such as Unified Parkinson's Disease Rating Scale (UPDRS) and Hoehn & Yahr Scale (H&Y). However, in an effort to improve PD management and move towards a quantitative assessment and recognition of PD motor and non-motor symptoms, the gait analysis is a well-established tool for the systematic examination of the way a person walks. It may be conducted either for clinical purposes or for research. In the institute of care and scientific research, the gait analysis has been used for diagnosis, assessment, or for monitoring the results of treatment and is included in the clinical medical record.
The aim of my study was to employ spatial and temporal features obtained through gait analysis to find differences in patients with and without non-motor mental symptoms through a univariate statistical analysis and ML algorithms.
A traditional statistical analysis was carried out: the U-test of Mann-Whitney was used to compare numerical variables of gait, while the differences in the distribution of categorical variables were assessed by the chi-square test. The statistical significance was set at $p < 0.05$. The computation was supported by the Statistical Package for the Social Sciences (IBM SPSS v. 26). Then, a ML evaluation was performed through MATLAB (R2020b). The findings support the idea that PD patients with non-motor mental symptoms as compared with PD patients without display a worse gait pattern, mainly characterized by increased slowness and dynamic instability. A possible future development could be analysing larger samples stratified for symptoms, i.e., cognitive impairment, affective symptoms, psychotic disorders, impulse control disorders.

- **Postural analysis to distinguish the Parkinsonism.**

Gait and balance dysfunctions represent a major motor symptom in PD and are even more prominent in patients with atypical Parkinsonisms (e.g. Progressive Supranuclear Palsy (PSP)). In addition, a dysfunction on gait and balance control during daily activities, like standing or walking, increases the probability of unexpected falls [7], [8]. Clinical tests and evaluation scales (such as: Unified Parkinson's Disease Rating Scale (UPDRS)) are used for the assessment of postural instability. Adding a quantitative analysis through instruments (such as force plates, stabilograms, clinical posturography and wearable sensors) allowed to make careful screening and timely diagnosis, along with effective intervention, to prevent any complication of falls [9]. The combination of qualitative and quantitative analysis could help the clinicians distinguish the different Parkinsonisms, especially in the first stage of disease. In this field, I conducted my second research activity. The aim of my study was to investigate the role of stabilometric analysis and sway variables to differentiate PD and PSP patients in the early stage of disease, respectively. The data were recorded, with regular acquisitions, in the laboratory of motion analysis of A.O.U. San Giovanni di Dio e Ruggi d'Aragona, in Salerno. A traditional statistical analysis with the U-test of Mann-Whitney was carried out. The computation was supported by the Statistical Package for the Social Sciences (IBM SPSS v. 26) and a ML evaluation was performed through MATLAB (R2020b). The present findings indicate that atypical parkinsonism as compared with typical parkinsonism patients exhibited increased measures of medio-lateral instability and that ML algorithms have been implemented successfully in Parkinsonisms using the sway features to identify some hallmark symptoms.

- **Simulation, Artificial Intelligence and Bioimaging.**

Medical imaging is an invaluable resource in medicine as it enables to peer inside the human body and provides scientists and physicians with a wealth of information indispensable for understanding, modelling, diagnosis, and treatment of diseases. Artificial intelligence, especially deep learning (DL) approaches, was investigated for various biomedical image reconstruction problems and medical image analysis. However, DL techniques require large training-image datasets. For this reason, many techniques of simulation data (as data augmentation) and synthetic images (from phantoms or anatomic structure models) are implemented to generate a huge amount of data.

In this field, I dealt with a systematic review on Scopus, PubMed and Web of Science with the scope to investigate the link between "Simulation, Artificial Intelligence and Bioimaging".

4. Research products:

- Michela Russo, Marianna Amboni, Antonio Volzone, Gianluca Ricciardelli, Giuseppe Cesarelli, Alfonso Maria Ponsiglione, Paolo Barone, Maria Romano and Carlo Ricciardi - **Interplay Between Gait and Neuropsychiatric Symptoms in Parkinson's Disease.** Article published to **"European Journal of Translational Myology and Mobility Medicine", 2022 -** DOI: 10.4081/ejtm.2022.10463

- M. Russo, C. Ricciardi, M. Amboni, M. Picillo, G. Ricciardelli, F. Abate, M.F. Tepedino, M.C. Calabrese, M. Cesarelli, M. Romano - **Postural control in Parkinsonisms during a short static sway.** Abstract in journal published to **"Gait & Posture**", 2022- https://doi.org/10.1016/j.gaitpost.2022.09.022 (NOT indexed in Scopus or ISI Web of Science)

- M. Russo, C. Ricciardi, M. Amboni, M. Picillo, G. Ricciardelli, F. Abate, M.F. Tepedino, M.C. Calabrese, M. Cesarelli, M. Romano - **Performing a short sway to distinguish Parkinsonisms –** Conference paper accepted to **''IEEE International conference on Metrology for extended reality, artificial intelligence and neural engineering''**

5. Conferences and seminars attended

22° Annual Congress of "Società Italiana Di Analisi Del Movimento In Clinica (SIAMOC)"; 5-8 October 2022, Bari.

I presented an abstract**: Postural control in Parkinsonisms during a short static sway**

I attended the following lectures:

Magister Lecturer: "Il Costo Di Essere Bipedi" Prof. P.Barone, AOU San Giovanni e Ruggi Clinica Neurologica.

Magister Lecturer: "Modellistica Computazionale Caratterizzazione Sperimentale E Controllo Di Attuatori Liberi E Riabilitazione Robotica" Prof. F. Amato, Università degli studi di Napoli Federico II.

Magister Lecturer: "Le Nuove Tecnologie Di Analisi Del Movimento Per La Terapia Occupazionale E L'ergonomia" Dott.ssa M. Panigazzi, Istituto Maugeri IRCCS Pavia.

Magister Lecturer: "L'analisi Del Movimento: Ponte Tra Ricerca E Assistenza Nella Clinica Ortopedica Dei Pazienti Fragili" Prof. B. Moretti, Università degli studi di Bari Aldo Moro.

IEEE International conference on Metrology for extended reality, artificial intelligence and neural engineering (2022IEEEMetroXRAINE); 26-28 October 2022, Roma.

I presented a conference paper: **Performing a short sway to distinguish Parkinsonisms**

I attended the following lectures:

Magister Lecturer: "How to characterize human cognition using extended reality and cognitive neuroscience: the concept of Extended Reality-based Behavioral Biomarkers (XRBB)" Mariano Alcañiz, University Of Valencia, Spain.

Magister Lecturer: "Movement decoding from non-invasive EEG: a chance for the spinal cord injured?" Gernot Müller-Putz, Graz University Of Technology.

Magister Lecturer: "The Future of AI and IA" Jim Spohrer, International Society Of Service Innovation Professionals.

Magister Lecturer: "Design and deployment of interoperable deeply quantized neural networks for in-sensor and micro-controller computing" Davide Denaro, STMICROELECTRONICS.

Magister Lecturer: "Real-Time EEG Streaming with Helmate" Marco Nalin, ab medica.

I attended the following contest:

- NEURAL DATA PROCESSING CONTEST applied by AB MEDICA.

Awards:

The best performance of classification on EEG datasets acquired through the Helmate headset provided by ab medica at Neural Data Processing Contest.

6. Activity abroad:

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

7. Tutorship

During my first year of Ph.D., I did not do tutorship activities.

References

[1] P. Barone *et al.*, «The PRIAMO study: A multicenter assessment of nonmotor symptoms and their impact on quality of life in Parkinson's disease», *Mov Disord*, vol. 24, n. 11, pagg. 1641–1649, ago. 2009, doi: 10.1002/mds.22643.
[2] M. Amboni, P. Barone, e J. M. Hausdorff, «Cognitive contributions to gait and falls: evidence and implications», *Mov Disord*, vol. 28, n. 11, pagg. 1520–1533, set. 2013, doi: 10.1002/mds.25674.
[3] M. A. Hely, W. G. J. Reid, M. A. Adena, G. M. Halliday, e J. G. L. Morris, «The Sydney multicenter study of Parkinson's disease: the inevitability of dementia at 20 years», *Mov Disord*, vol. 23, n. 6, pagg. 837–844, apr. 2008, doi: 10.1002/mds.21956.
[4] B. Mollenhauer, L. Rochester, A. Chen-Plotkin, e D. Brooks, «What can biomarkers tell us about cognition in Parkinson's disease?», *Mov Disord*, vol. 29, n. 5, pagg. 622–633, apr. 2014, doi: 10.1002/mds.25846.
[5] L. Avanzino, G. Lagravinese, G. Abbruzzese, e E. Pelosin, «Relationships between gait and emotion in Parkinson's disease: A narrative review», *Gait Posture*, vol. 65, pagg. 57–64, set. 2018, doi: 10.1016/j.gaitpost.2018.06.171.
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[7] J. C. Steele, J. C. Richardson, e J. Olszewski, «Progressive Supranuclear Palsy. A Heterogeneous Degeneration Involving The Brain Stem, Basal Ganglia And Cerebellum With Vertical Gaze And Pseudobulbar Palsy, Nuchal Dystonia And DementiA», *Arch Neurol*, vol. 10, pagg. 333–359, apr. 1964, doi: 10.1001/archneur.1964.00460160003001.
[8] S. D. Kim, N. E. Allen, C. G. Canning, e V. S. C. Fung, «Postural Instability in Patients with Parkinson's Disease», *CNS Drugs*, vol. 27, n. 2, pagg. 97–112, feb. 2013, doi: 10.1007/s40263-012-0012-3.
[9] B. Palakurthi e S. P. Burugupally, «Postural Instability in Parkinson's Disease: A Review», *Brain Sciences*, vol. 9, n. 9, Art. n. 9, set. 2019, doi: 10.3390/brainsci9090239.