UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

PHD IN INFORMATION AND COMMUNICATION TECHNOLOGY FOR HEALTH

Module Title:

"Metrology and Machine Learning

for Brain Computer Interfaces"

Lecturer: Prof. Pasquale Arpaia

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CV: Pasquale Arpaia took Master Degree and PhD in Electrical Engineering at University of Napoli Federico II (Italy), where he is full professor of Instrumentation and Measurements. He is Director of the Interdepartmental Center for Research on Management and Innovation of Health (CIRMIS), Head of the Instrumentation and Measurement for Particle Accelerators Laboratory (IMPALab) and the Augmented Reality for Health Monitoring Laboratory (ARHeMlab). He is Team Leader at European Organization for Nuclear Research (CERN) and head of the Hi-Tech Academic FabLab Unina DIETI and Chairman of the Stage Project of the University Federico II. He was also professor at University of Sannio, associate at Institutes of Engines and Biomedical Engineering of CNR, and now of INFN Section of Naples.

He is Associate Editor of the Institute of Physics Journal of Instrumentation, Elsevier Journal Computer Standards & Interfaces, MDPI Instruments, and in the past also of IEEE Transactions on Electronics Packaging and Manufacturing. He was Editor at Momentum Press of the Book Collection "Emerging Technologies in Measurements, Instrumentation, and Sensors". In last years, he was scientific responsible of more than 30 awarded research projects in cooperation with industry, with related patents and international licences, and funded 4 academic spin off companies. He acted as scientific evaluator in several international research call panels. He continuously serves as organizing and scientific committee member in IEEE and IMEKO Conferences. He is plenary speaker in several scientific conferences.

His main research interests include instrumentation and measurement for magnets, advanced materials, beam, superconductors, power converters. and cryogenics of particle accelerators, biomedical instrumentation, Augmented Reality, Brain Computer Interfaces, evolutionary diagnostics, distributed measurement systems, ADC modelling and testing. In these fields, he published 3 books, several book chapters, and about 350 scientific papers in journals and national and international conference proceedings. His PhD students were awarded in 2006, 2010, 2020, and 2022 at IEEE I2MTC, as well as in 2016 and 2012, 2018 at IMEKO TC-10 and World Conferences, respectively..

Lecturer: Prof. Selina Christin Wriessnegger

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CV: Selina C. Wriessnegger received her M.S. degree in Psychology at the Karl-Franzens University in Graz Austria in 2000. In 2005 she received her PhD in Cognitive Neuroscience from the Max-Planck-Institute for Human Cognitive and Brain Sciences and the Ludwig-Maximillians-University, Munich, Germany. During her PhD she was for one year visiting researcher at IRCCS Santa Lucia Foundation, Department of Neuromotor Physiology, in Rome, Italy. Since 2020 she is Associate

Professor and deputy head of the Institute of Neural Engineering, Graz University of Technology, Austria.

Her main research areas are the Neural correlates of motor imagery, the development of passive Brain-Computer Interfaces (BCI) for healthy users, the fusion of BCI technology with VR (virtual reality) environments and affective computing. To address the related scientific questions, different neuroimaging methods like EEG, fMRI and fNIRS together with physiological parameters (GSR, ECG) are used to investigate brain activity and networks of higher-level cognition in different modalities. For example, the development of an adaptive, real-time learning environment based on the mental states of the users is currently under investigation. Another research area, called "affective computing" deals with emotion detection from neurophysiological data with deep learning methods. This highly interdisciplinary research fields require a close cooperation with other disciplines like psychology, biomedical engineering, medicine, and computer science. Therefore, our research outcome contributes to various disciplines like biomedical engineering, psychology, neuroimaging, neurophysiology and clinical science of different levels of knowledge.

University: University Federico II of Naples

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CV: Andrea Apicella received the M.S. degree in computer science and the Ph.D. degree in mathematics and computer science from the University of Naples Federico II, Italy, in 2014 and 2019, respectively. He is currently a Researcher with the Department of Information Technology and Electrical Engineering, University of Naples Federico II. His current research interests include artificial intelligence methods and explainable artificial intelligence (XAI) approaches for explaining the AI system's decisions.

Antonio Esposito, PhD

University of Naples Federico II

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CV: Antonio Esposito received the MSc degree in Electronic Engineering at the University of Naples Federico II in 2017 and the PhD in Metrology at Politecnico di Torino in 2022. His main research activities focus on the measurement of electroencephalographic signals in wearable brain-computer interfaces. He has been working with visually evoked potentials and motor imagery. He participated in the development of a BCI prototype for industry and healthcare applications and he also studies extended reality applications exploiting either evoked or spontaneous brain activity.

Lecturer: Antonio Gilardi PhD

University: Stanford University

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CV: Antonio Gilardi received the MSc degree in Electronic Engineering at the University of Naples Federico II in 2017 and the Ph.D. degree in electronics with the Department of Electrical Engineering and Information Technology at the University of Naples Federico II, collaborating with the European Organization for Nuclear Research (CERN), Geneva, Switzerland.

He was with the Hadron Synchrotron Collective effects in the Beam Department, CERN, where he worked on modeling new devices to dampen parasitic resonances. Following, he obtained a post-doc at Lawrence Berkeley National Laboratory (LBNL), California, USA. There, his research was focused on developing laser combining and control for future LPA applications. Currently, he is following a tenure track staff position as an engineer at Stanford University, working on the photon side of the free electron laser accelerator.

Lecturer: Nicola Moccaldi PhD

University: Università del Salento - Università Federico II

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CV: Nicola Moccaldi received the M.S. degree in Communication Science at the University of Salerno, the M.Sc. degree in Electronic Engineering and the Ph.D. in Information Technologies and Electrical Engineering at the University of Naples Federico II. He is the responsible of *Passive Brain Computer Interface* research line of Augmented Reality for Health Monitoring Laboratory (ARHeMLab) of Federico II University of Naples. He conducts studies based on the use of electroencephalography to measure emotion, attention, stress and engagement.

Dates and Locations

Date	Hours	Room	Lecturer
13/09/22	14.00-16.00	**Teams link**	**Pasquale Arpaia**
13/09/22	16.00 -18.00	**Teams link**	**Antonio Gilardi**
15/09/22	10.00 -12.00	**Meeting room (4.19), 4th floor**	**Antonio Esposito**
20/09/22	10.00 -12.00	**Meeting room (4.19), 4th floor**	**Andrea Apicella**
22/09/22	10.00 -12.00	**Meeting room (4.19), 4th floor**	**Nicola Moccaldi**
27/09/22	10.00 -12.00	**Meeting room (4.19), 4th floor**	**Antonio Esposito**
10/10/22	10.00 -12.00	**Teams link**	**Selina Christin Wriessnegger**

Contents

I Lesson – Wearable EEG-based instrumentation for Brain-Computer Interfaces
- **History, taxonomy, architectures**
- **Noninvasive measurement of neural phenomena**
- **Design of daily-life Brain Computer Interfaces**
- **Channel minimization strategies**
- **Characterization of low-cost EEG instrumentation**
- **Cybersecurity and privacy issues**

II Lesson - Fundamentals of metrology for BCI
- **Metrological characteristics**
- **Experimental design**
- **Statistical testing**
- **Machine Learning introduction**
- **Use case application**

III Lesson - Signal acquisition for BCI
- **Sampling and errors**
- **Hardware for Analog Digital Converters**
- **Truncation error**
- **Use case application**

IV Lesson - Introduction to Machine Learning
- **Traditional machine learning approaches**
- **Artificial Neural Networks (ANN)**
- **Fully connected neural network**
- **Convolutional neural networks**
- **Validation methods**
- **Use case application**

V Lesson - Uncertainty management in passive BCI measurement
- **Uncertainty sources: the role of the model uncertainty and the intrinsic uncertainty of the measurands**
- **Experimental reproducibility issues: stimuli standardization and sensitivity**
- **Reference measurement systems**
- **Instrumental reproducibility and generalization**
- **Use case application**

VI Lesson - Active BCI instrumentation
- **fundamentals of neurophysiology in active BCI**
- **hardware and software for acquisition and neurofeedback**
- **processing approach**
- **experimental results**
- **use case application**

VII Lesson - New frontiers of BCI: the experience of the Institute of Neural Engineering Laboratory of Brain-Computer Interfaces at Graz University of Technology
- **Clinical application of BCI-based motor Neuroprosthetics**
- **Neuroadaptive Systems and mental state detection**

ECTS Credits TBD

Notes

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