



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee_{PhD}
information technology
electrical engineering



Sarah Adamo

Implementation of AI solutions for medicine and telemedicine

Tutor: Prof. Mario Cesarelli

Cycle: XXXVII

Year: Third

Candidate's information

- MSc Degree in Biomedical Engineering @ DIETI – Federico II
 - *Thesis: “Machine Learning to predict rehabilitative outcomes in post-stroke patients”*
- Ph.D. Fellowship founded by Consortium GARR
 - *Starting date: 01/11/2021 (Ended in March 2023)*
 - *Host Institution: IRCCS Maugeri, Telese Terme (BN)*
- Research group:
 - UNINA Bioengineering Research Group;
 - Maugeri Bioengineering Unit.

Summary of study activities

- 6 ad hoc PhD courses a 3 MSc Courses:
 - Using Deep Learning Properly
 - Ultra High Field Magnetic Resonance Imaging
 - Statistical data analysis for science and engineering research
 - Big Data Architecture and Analytics
 - Data Science for Patient Records Analysis
 - Interaction control in surgical and rehabilitation robotics
 - Biomedical Instrumentation and Photonics Laboratory for medicine
 - Advanced biomedical instrumentation
- Research and study on machine learning in medicine and telemedicine in several diseases

Research area: AI in healthcare (1/2)

- Artificial Intelligence (AI) as a precious support for scientific progress in healthcare
- The human body: a source of heterogeneous data
 - *Clinical, anamnestic and demographic data*
 - *Biosignals*
- Every biological process can be outlined as model
- Smart devices have simplified data acquisition and patients monitoring

Research area: AI in healthcare (2/2)

AI can be successfully employed for:

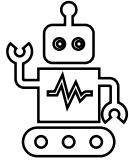
Early diagnosis, treatment of diseases and rehabilitation

Telemonitoring and remote assistance of chronic diseases

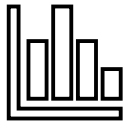


CLINICAL DECISION MAKING

Research results



Implementation of Machine Learning (ML) algorithms able to predict in terms of **Accuracy, Sensitivity, AUCROC** employing datasets collected from patients with chronic and/or disabling diseases



Definition of **predictive** indexes related to rehabilitation outcomes and/or early diagnosis



Identification of the most important parameters that can predict **exacerbations of pathological conditions**, suggesting an intervention before an acute event occurs

Products

[P1]	Adamo, S. ; Ambrosino, P.; Ricciardi, C.; Accardo, M.; Mosella, M.; Cesarelli, M.; d'Addio, G.; Maniscalco, M. A Machine Learning Approach to Predict the Rehabilitation Outcome in Convalescent COVID-19 Patients. <i>J. Pers. Med.</i> 2022, 12, 328. https://doi.org/10.3390/jpm12030328
[P2]	D'Amato, M., Ambrosino, P., Simioli, F., Adamo, S. , Stanziola, A. A., D'Addio, G., ... & Maniscalco, M. (2022). A machine learning approach to characterize patients with asthma exacerbation attending an acute care setting. <i>European Journal of Internal Medicine</i> .
[P3]	Amboni, M., Ricciardi, C., Adamo, S. , Nicolai, E., Volzone, A., Erro, R., Cuoco, S., Cesarelli, G., Basso, L., D 'Addio, G., Salvatore, M., Pace, L., Barone, P. (2022, Accepted). Machine learning can predict Mild Cognitive Impairment in Parkinson disease. <i>Frontiers in Neurology</i> .
[C1]	Adamo, S. , Ricciardi, C., Ambrosino, P., Maniscalco, M., Biancardi, A., Cesarelli, G., Donisi, L. & D'Addio, G. (2022, June). Unsupervised Machine Learning to Identify Convalescent COVID-19 Phenotypes. In 2022 IEEE International Symposium on Medical Measurements and Applications (MeMeA).
[P4]	Donisi, L., Ricciardi, C., Cesarelli, G., Coccia, A., Amitrano, F., Adamo, S. , & D'Addio, G. (2022). Bidimensional and Tridimensional Poincaré Maps in Cardiology: A Multiclass Machine Learning Study. <i>Electronics</i> , 11(3), 448. https://doi.org/10.3390/electronics11030448

Products

[P5]	Cesarelli, G., Petrelli, R., Adamo, S. , Monce, O., Ricciardi, C., Cristallo, E., ... & Cesarelli, M. (2023). A Managerial Approach to Investigate Fall Risk in a Rehabilitation Hospital. <i>Applied Sciences</i> , 13(13), 7847.
[P6]	Cappiello, A., Abate, F., Adamo, S. , Tepedino, M. F., Donisi, L., Ricciardi, C., ... & Picillo, M. (2024). Direct Current Stimulation of Prefrontal Cortex Is Not Effective in Progressive Supranuclear Palsy: A Randomized Trial. <i>Movement Disorders</i> .
[P7]	Clemente, F., Amato, F., Adamo, S. , Russo, M., Angelone, F., Ponsiglione, A. M., & Romano, M. (2024). Circuitual modelling in muscle tissue impedance measurements. <i>Heliyon</i> , 10(7).
[C2]	Ponsiglione, A. M., Donisi, L., Adamo, S. , Tedesco, A., Ricciardi, C., Romano, M., & Amato, F. (2022, November). A Sensitivity Analysis of Symbolic Dynamics indices for Fetal Heart Rate Monitoring. In <i>2022 E-Health and Bioengineering Conference (EHB)</i> (pp. 01-04). IEEE.

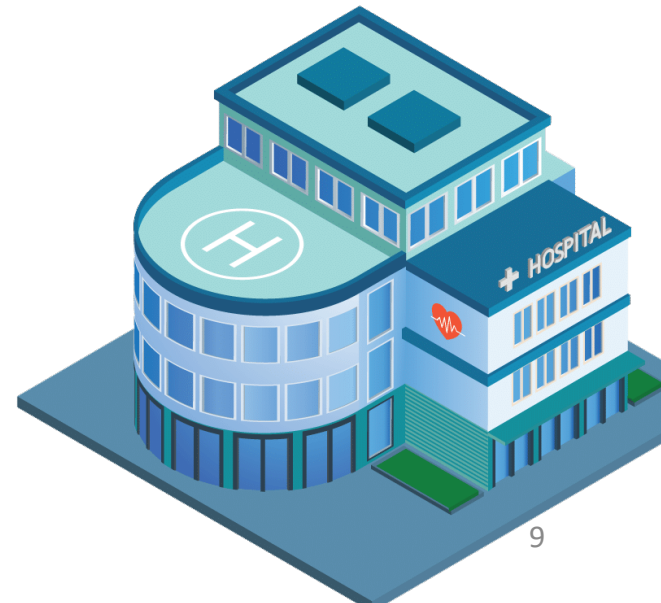
PhD Thesis background (1/2)

Pathologies and diseases:

- ⊕ Need for an early diagnosis to be better managed
- ⊕ Present development and behaviors that can be better studied through models that outline pathways and correlations
- ⊕ Need a protocol based on focused outcomes for an appropriate treatment both in the acute phase and in rehabilitation



Machine Learning (ML) algorithms can be employed for building models to help the understanding of diseases



PhD Thesis background (2/2)

Telemedicine and medical remote assistance:



Patients with chronic disease are more exposed to acute events and require constant monitoring



Telemedicine can be crucial since patients can be assisted from their own home



An effective way to collect huge amount of data...



...used as input for Machine Learning (ML) algorithms



PhD Thesis: Problem



Which are the main parameters able to...

- Predict an acute event?
- Differentiate clinical phenotypes?

ML algorithms to identify



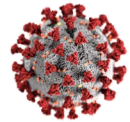
- ✓ Indexes for early diagnosis
- ✓ Clinical phenotypes in the disease behavior
- ✓ Predictive outcomes for the rehabilitation

PhD thesis: Problem

MAIN CASE STUDIES

1

COVID-19 disease and post-acute COVID-19 rehabilitation



2

Asthma disease and asthma exacerbations



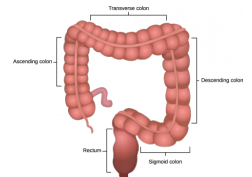
3

Parkinson's disease (PD)



4

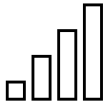
Colorectal carcinoma (CRC) disease



PhD Thesis: Methodology



Data acquisition and processing



Feature selection



- Unsupervised ML (clustering, silhouette coefficient);
- Supervised ML (classification, 2 or more classes)



Feature Importance



Validation of results (hold-out, cross-validation)



Application of the results to real approaches

PhD Thesis: Results (1/4)

Long-term COVID19 rehabilitation

- 6 Minute Walking Test as good predictive outcome
- Supervised ML, 3 classes of improvement
- DLCO and FEV1 as main parameters to predict rehabilitation outcome
 - Accuracy 83.7%

COVID19 phenotypes

- Clustering basing on hematochemical parameters
- Unsupervised ML, 2 phenotypes
- Silhouette coefficient 0.85
 - D-Dimer as most discriminant parameter

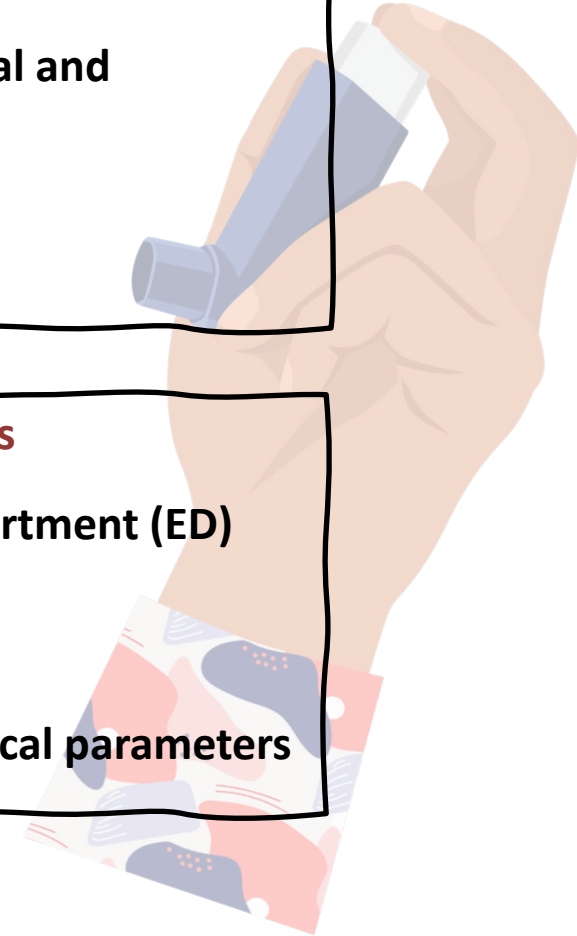
PhD Thesis: Results (2/4)

Step 1. Identification of a threshold for Asthmatic patients

- Unsupervised ML to identify 2 phenotypes basing on clinical and respiratory parameters
- Eosinophil count as main discriminating parameter
- Threshold value 370 cells/ μL

Step 2. Prediction of Asthma exacerbations among phenotypes

- Prediction of exacerbations and access to Emergency Department (ED)
- Supervised ML, 2 classes
- Accuracy 98.5%
- Smoker history and Nasal Polyposis as most important clinical parameters



PhD Thesis: Results (3/4)

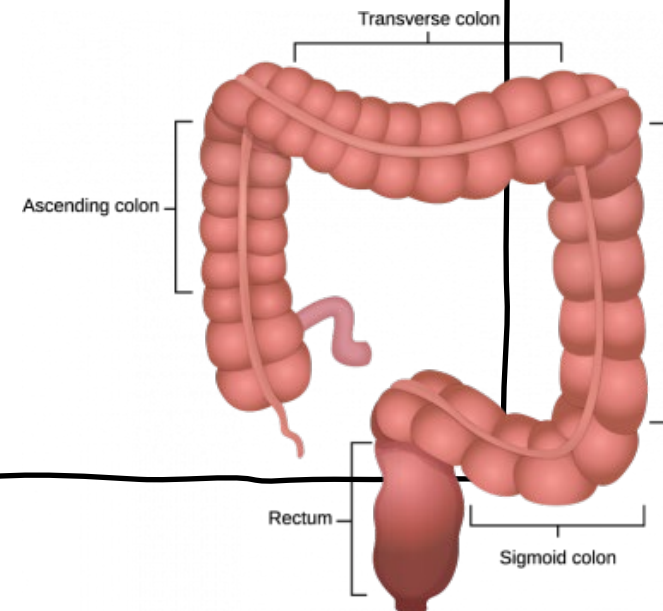
Prediction of Mild Cognitive Impairment (MCI) in PD

- **2 ML models:**
 - **One dataset with clinical variables + gait analysis variables**
 - **One dataset with most important variables of the previous model + amyloid PET imaging variables**
- **ML model based on gait analysis variables demonstrated good results in the MCI prediction (Accuracy 80%)**
- **Age, dynamic instability and reduced step length as main predictors of MCI in patients affected by PD**
- **Amyloid PET imaging variables did not show good results in the prediction of MCI**

PhD Thesis: Results (4/4)

Early diagnosis in Colorectal Cancer

- Identification of a subset of 3 clinical parameters able to predict the diagnosis of cancer
- Supervised ML, 2 classes
- Estimation of thresholds for the most important parameters:
 - Leucine = $177.4 \mu\text{mol/L}$
 - Isoleucine = $96.4 \mu\text{mol/L}$
 - Valine = $278.5 \mu\text{mol/L}$
- Accuracy 94.4 %



PhD Thesis conclusions



Implementation of AI solutions



Prediction of clinical outcomes



Supporting clinical decision making



More improvements
Less healthcare management costs



Essential Assistance Levels (LEA) in non-urbanized area



Better Quality of Life for all patients

Thanks for the attention!

