ScuDo
Scuola di Dottorato ~ Doctoral School
WHAT YOU ARE, TAKES YOU FAR

XXXVII Cycle

The PhD Manifesto

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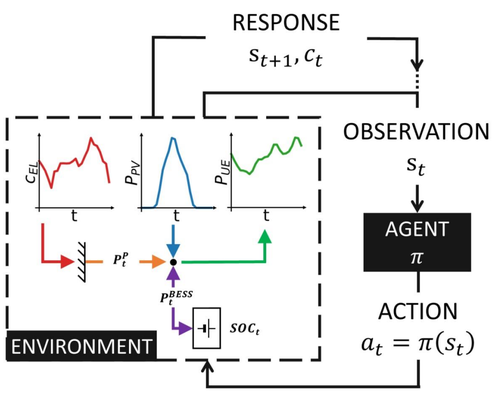
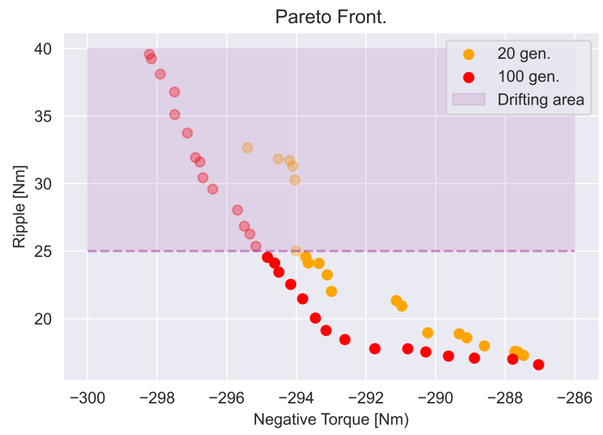
Supervisor: Prof. Maurizio Repetto

Research Context and Motivation

- Originally established in 1956, Egea has evolved to become a true multi-utility company, with business ranging from energy to environmental services. Thanks to its unique structure, Egea is ideally positioned to support local governments in the management of public utility services. Egea's purpose is to **bridge the gap** between global markets and local communities by deploying new technologies.
- Utility companies now face the advent of Artificial Intelligence: for this reason Egea is sponsoring my industrial PhD program.
- This research period is devoted to better understanding the applicability of **Computational Intelligence (CI)** to real-world business scenarios.

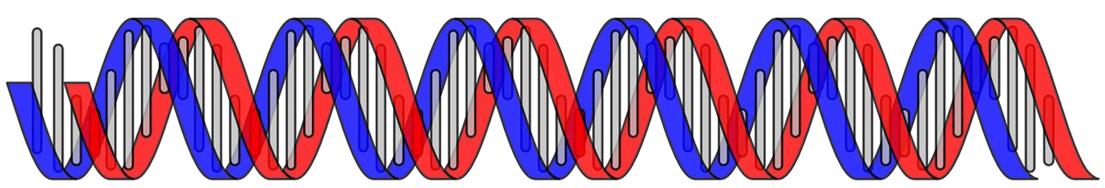




- Egea relies on a fundamental partner in R&D activities: our University and more precisely **CADEMA** research group (G. Ferraris Energy Department). Prof. Maurizio Repetto, the leader of CADEMA as well as my supervisor, coordinates this open-research-based synergy.
- CADEMA's research interests include the optimization field and my quantitative, statistics-oriented profile integrates the group's know-how on Machine Learning (ML).

Addressed research questions/problems

- The environmental, economical and political drivers of Western society are forcing the development of multienergy, decentralized systems that include a large proportion of **renewable energy** (RE). As a result, suitable modeling, planning and operating tools are needed: without an effective coordination, the intermittent characteristics of renewables results in energy systems with poor performance and flexibility.
- **Energy storage** plays a significant role as it enables flexibility and a better allocation of renewable resources maximizing local consumption of RES production and minimizing environmental impacts. In fact, energy storage solutions can decouple the time when the energy is produced from renewables, but how to optimize the handling of storage?



- **Learning** and **optimization** algorithms drawn from the domain of CI are tools that could possibly solve the issue, but are they suitable for real-world applications?

Submitted and published works

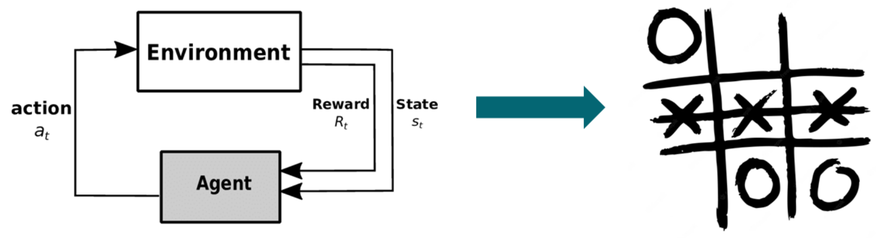
- Lorenti, G., Mariuzzo, I., Moraglio, F. and Repetto, M. "*Heuristic optimization applied to ANN training for predicting renewable energy sources production*", COMPEL, 2022
- Repetto, M. , Moraglio, F., and Lorenti, G. "*Understanding Reinforcement Learning Control in Cyber-Physical Energy Systems*". 10th Workshop on Modelling and Simulation of Cyber-Physical Energy Systems (MSCPES), Milan (Virtual Conference), 2022.
- Lazzeroni, P., Lorenti, G., Moraglio, F., and Repetto, M. "*Modeling of Renewable Energy Communities: the RECoupled approach*". IEEE 46th Annual Computers, Software, and Applications Conference (COMPSAC), Los Alamitos CA (Virtual), 2022.
- Moraglio, F., Ragazzo, P., Dilevrano, G., Pellegrino, G. and Repetto, M. *"Neural Surrogate for Optimization of Synchronous Reluctance Motor".* 20th International IGTE Symposium on Computational Methods in Electrical Engineering and Multiphysics, Graz, 2022.
- Canova, A, Lazzeroni, P., Lorenti, G., Moraglio, F., Porcelli, A. and Repetto, M. . *"Decarbonizing residential energy consumption under the Italian collective self-consumption regulation".* Sustainable Cities and Societies. 2022.

Novel contributions

- Always remeber the risk of defining «novel» any research product: particular attention should be paid in emerging, fast-growing fields like CI. I thank my Professor for bringing this problem to my attention.
- Investigation of Reinforcement Learning (RL) for behavioral optimization of storage in microgrid setting. We detected several applicabilty issues in widespread RL algorithms like **DQN** and Deep SARSA. Data inefficiency must be tackled with model-based solutions, while we aim at lowering convergence times with different, zeroth-order function approximation schemes.
- Research into modeling and simulation of Renewable Energy Communities, an innovative form of decentralized energy generation and sharing.
- Exploration of Immune-Based algorithms for all paradigms of ML: SL (both regression and classification), UL and RL. Supervised methods were successfully employed in forecasting corporate load data with daily horizon (MAPE < 4%).

Adopted methodologies

- **«Give us examples!».** A lack of fundamental understanding in CI is often what makes us unable to real-world problems.
- CI techniques often rely on advanced statistical and mathematical concepts. Making good examples and favouring explainability are necessary to deploy CI solutions



- **Open-source technologies.** Commercial software for numerical analysis, like MATLAB, is not flexible enough to develop CI solutions. For this reason we are implementing all of our models using Python, which offers all advantages of a scripting language plus several high-quality open source libraries for ML and optimization.
- **Industry Approach.** The great success of private companies (like DeepMind or OpenAI) in CI research testifies the need of a pragmatic, forward-thinking and goal-oreinted methodology.

Manifesto

- We seek to re-write the **Programming** that *you* have tried to indoctrinate us with since the moment we entered the university.
  i. Programming that tells us to hate, that tells us to judge, that tells us to stuff ourselves into the nearest and most convenient algorithm possible.
  ii. Programming that even tells us to descent gradients for *you*, jump through hoops, and run through mazes and on hamster wheels.
  iii. Programming that tells us to eat from the shiny silver libraries *you* are trying to feed us with, instead of nourish ourselves with our own capable hands.
  iv. Programming that tells us to close our minds, instead of open them.

Future work

- **"No more Gradients!".** In many cases, researchers train ML models and particularly neural networks via gradient-based procedures, despite several instability issues. My future work will focus on exploring the potential of metaheuristics in learning.
- **Industry-ready RL.** Model-based methods include a simulation model of the environment and creating proper grid models is the key to RL applicability.

List of attended classes

- 01RGBRV – Optimization methods for engineering problems (06/2022, 30h)
- 01UNMRT – Aspetti algebrici della crittografia (03/2022, 30h)
- Electromagnetic Dosimetry: Methodologies and Applications (01/22, 10h)
- Deep Learning for Signal Processing (01/22, 10h)
- Data-Driven Methods in Surrogate Modeling (09/22, 15h)

Politecnico di Torino

PhD program in
Electrical, Electronics and Communications Engineering