UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Online optimization, reinforcement learning and their applications"

Prof. E. Veronica BELMEGA

Université Gustave Eiffel (UGE), CNRS, LIGM – France

E-mail address: veronica.belmega@esiee.fr

Short Abstract: This graduate course is focused on the study of online optimization and reinforcement learning applied to wireless and mobile mobile networks (IoT, 5G). Such networks may vary rapidly over time, potentially in an unpredictable and non-stochastic way because of ad-hoc user connectivity and behavior, and, hence traditional methods based on static (classic) or stochastic optimization and game theory are no longer suited. Instead, online optimization can be exploited to derive efficient algorithms, with theoretical guarantees in terms of no regret, that solve optimization problems where no assumptions can be made on the underlying temporal dynamics governing the network and, hence, the objective function to be optimized.

Course Contents in brief:

- Iterative online process based on strictly causal feedback information

- Regret measure: definition, no-regret property, intuition, links with static (classic) and stochastic optimal solutions

- Link with multi-armed bandits from reinforcement learning (UCB, epsilon-greedy, EXP3 algorithms)

- First-order online algorithms: online gradient descent, online mirror descent, and their theoretical guarantees in terms of no-regret and regret decay rates

- Applications in wireless communications: beam-alignment in mmWave networks, energy-efficient NOMA power allocation, resource optimisation in IoT networks…

- *Beyond wireless*: online metric learning for multimedia indexing, online matrix completion for movie ratings, universal filtering, etc.

- Tradeoff between performance (regret decay) vs. required feedback information:

- o   Feedback reduction: imperfect gradient feedback (stochastic gradient estimation), zeroth order methods (gradient estimation based on one value of the objective function)

- o   Second order online descent methods

- **Lab practice** (4 hours): implement and evaluate several multi-armed bandit algorithms to solve an outage minimization problem in a two-user adaptive NOMA system without any CSIT/CDIT, but relying solely on a single bit of feedback

Total number of lecture hours: The 16-hour course will be split into 12 hours for lecture and a 4-hour lab practice in MatLab or Python.

References:

[1] S. Shalev-Shwartz (2011). "*Online learning and online convex optimization*". Foundations and trends in Machine Learning, 4(2), 107-194.

[2] **E.V. Belmega**, P. Mertikopoulos, and R. Negrel, "*Online convex optimization in wireless networks and beyond: The feedback - performance trade-off*", **invited paper at** RAWNET intl. workshop in conjunction with WiOpt, Turin, Italy, Sep. 2022

[3] H. El Hassani, A. Savard, and **E.V. Belmega**, "*Adaptive NOMA in time-varying wireless networks with no CSIT/CDIT relying on a 1-bit feedback*", IEEE Wireless Commun. Lett., vol. 10, no. 4, pp. 750-754, Apr. 2021

CV of the Teacher

E. Veronica Belmega received the Engineer Degree (M.Sc.) from the University Politehnica of Bucharest, Romania, in 2007. In 2005-2006, she studied applied mathematics at Ecole Polytechnique, Palaiseau, France within the International Socrates/Erasmus Exchange Program. She obtained the M.Sc. and Ph.D. from the Université Paris-Sud 11, France, in 2007 and 2010. In 2010-2011, she was a post-doctoral researcher in a joint project between Princeton University, USA and Supélec, France. She was a visiting researcher *(délégation complete)* at Inria, Grenoble, between 2015 - 2017. She was an Associate Professor (MCF HDR) with ENSEA graduate school between 2011 - 2022 and **Deputy Director** of ETIS research lab between 2020 - 2022, Cergy, France. She received her HDR habilitation degree from the Université de Cergy-Pontoise, France in 2019. Since May 2022, she is a **Full Professor** at the Université Gustave Eiffel (ESIEE Paris) and LIGM research lab, Marne-la-Vallée, France. She has co-authored over 80 papers in international venues on convex and online optimization, game theory and machine learning applied to wireless communications and power networks.

Awards and distinctions:

- 2023-2027 **PI** and **Correspondent** for UGE/ESIEE Paris (via CNRS) of the **PEPR 5G** project (300k euro for UGE/ESIEE Paris)

- 2023 - **Best paper award** at ICL-GNSS international conference

- 2019-2024 **PI** and **Scientific Coordinator** of the International PRCI ANR - FAPESP research project: ELIOT - Emerging Technologies in IoT (390k euro for the ANR French partner, ETIS research lab)

- **Top 5 papers** award at IEEE Transactions on Smart Grids in 2022

- **CY Alliance** award: For women and science in 2021

- Spotlight talk at ICLR, 8th Intl. Conf on Learning Representations, 2020

- **IEEE Senior Member** since 2020

- **Prix L'Oréal**: French National Fellowship - L'Oréal France - UNESCO - French Academy of Science in 2009

Professional service:

- **Tutorials Chair** at the ISWCS'24 international conference

- **Area Editor** for the IEEE Transactions on Machine Learning in Communications and Networking since Sep. 2022

- Co-lead **Guest Editor** for the IEEE IoT Magazine, Special Issue: *Pervasive, Efficient and Smart Signal Processing for IoT* in 2022

- Executive Editor for the Transactions on Emerging Telecommunications Technologies (ETT) between Jul. 2016 - Feb. 2020, distinguished **Top Editor** for 2016-2017

- Co-organizer: 2020 Special session at NETGCOOP, Cargese, Corsica; 2014 International workshop WNC3 at WiOpt, Hammamet, Tunisia etc.

Further details available at: https://sites.google.com/site/evbelmega

---

Final Exam: At the end of the lab work a written report will be required. The lab report will be graded. A particular importance will be given to the interpretation and analysis of the obtained results.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

27/05/2024 – 8h-12h

28/05/2024 – 8h-12h

29/05/2024 – 8h-12h

30/05/2024 – 8h-12h