UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Probabilistic Neural Networks and Uncertainty Quantification"

Prof. Claudia Caudai and Giulio Del Corso

Istituto di Scienza e Tecnologie dell'Informazione "Alessandro Faedo"

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Short Abstract:

With the advent of modern machine learning and deep learning techniques, the field of mathematical modelling has become increasingly saturated with powerful and effective models. However, most deep learning models have two major problems: the need for very large datasets (thousands to millions data) and the tendency to produce overconfident solutions. Probabilistic deep learning is thus emerging as a powerful support tool in the development of machine learning models, allowing the user to interpret results more realistically and providing an assessment of the risk of error related to the models' output (Trustworthy AI). This aspect is particularly important in many fields of application, such as medicine, biology, law, engineering, astronomy, etc.

This PhD course explores the most popular state-of-the-art models of probabilistic deep learning. In particular, Bayesian networks, probabilistic Ensembles and post-hoc techniques for integrating a pre-existing model with reliability estimates at near-zero computational cost are introduced.

Course Contents in brief:

- Introduction to types of uncertainty: epistemic and aleatoric
- From determinist to probabilistc networks
- Intrusive approach: Bayesian Neural Networks and Ensemble Learning
- Non-intrusive approach: MC-Dropount and Trust score
- From theory to practice: implement probabilistic networks on real world data

Total # of hours of lecture: 20

References:

[1] Hullermeier, E., Waegeman, W.: Aleatoric and epistemic uncertainty in machine learning: an introduction to concepts and methods. Machine Learning 110, 457 – 506 (2019). URL https://api.semanticscholar.org/CorpusID:216465307

[2] He, W., Jiang, Z.: A comprehensive survey on uncertainty quantification for deep learning (2023). URL https://api.semanticscholar.org/CorpusID:257219242

CV of the Teacher: Claudia Caudia

Claudia Caudai received the MS degree in Mathematics in 2003 and the PhD degree in Biomedical Engineering in 2009, both from the University of Pisa. In the past she has worked on the modeling of ECG signals and neural and neuroglial messages in the human brain, on the assessment of compliance and stiffness of biological and artificial muscles, on the modeling of molecular and macromolecular movements, and on the inference of the 3D chromatin conformation in the nucleus. From 2013 she works as a researcher at the Institute of Information Science and technologies at the CNR of Pisa. In the last years her activity concerns the study of Bayesian techniques for modeling and multivariate analysis of heterogeneous biological signals and the study of Deep Learning techniques for medical imaging diagnostics. Her research interests include mathematical modeling, statistics, bioinformatics, biology, genomics and proteomics.

CV of the Teacher: Giulio Del Corso

Giulio Del Corso is an applied mathematician (MS degree cum laude in Mathematics, University of Pisa and Ph.D. degree cum laude in Applied Mathematics, GSSI-Gran Sasso Science Institute). From 2023 he is a postdoctoral fellow at the Institute for Information Science and Technologies at the National Research Council (CNR) of Italy.
His research interests are mainly focused on mathematical modeling, probabilistic machine learning, uncertainty quantification, and trustworthy AI. A secondary focus of his research is the probabilistic modeling of the human heart and the integration of machine learning models to obtain efficient approximations of error propagation.

Final Exam: Oral test and discussion

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

Schedule:

Day1 – February 4, 2025, h. 9:00-13:00 (4 hours)

Day2 – February 6, 2025, h. 9:00-13:00 (4 hours)

Day3 – February 11, 2025, h. 9:00-13:00 (4 hours)

Day4 – February 13, 2025, h. 9:00-13:00 (4 hours)

Day5 – February 18, 2025, h. 9:00-13:00 (4 hours)