UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Geometric Deep Learning for Engineering Applications"

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Short Abstract: Geometric Deep Learning (GDL) is an emerging interdisciplinary field that combines the power of deep neural networks with geometric and topological methods to tackle complex learning tasks. This Ph.D. course offers a comprehensive exploration of the principles, theories, and applications of GDL, providing students with the necessary tools to understand and contribute to this exciting research area.

The course begins with an introduction to the fundamentals of deep learning, including neural networks, optimization, and training algorithms. From there, we delve into the world of geometry, exploring foundational concepts such as graphs and geometric transformations. We investigate how geometry can be seamlessly integrated with deep learning techniques to enhance the understanding and analysis of structured data.

In addition to theoretical knowledge, the course incorporates hands-on practical sessions where students gain experience with implementing and applying GDL algorithms/models with the Pytorch and the Pytorch Geometric libraries.

By the end of this course, students will have a comprehensive understanding of geometric deep learning, enabling them to apply cutting-edge techniques to a wide range of domains. They will be equipped with the knowledge and skills necessary to conduct original research, contribute to the development of novel algorithms, and advance the frontiers of GDL.

Course Contents in Brief:

- Logistic Regression for Neural Networks
- A brief introduction to Neural Networks
- Graph Convolutional Networks
- Message-Passing Neural Networks
- Pytorch/Pytorch Geometric

Total # of hours of lecture: 20 hours.

References:

[1] Kipf, Thomas N., and Max Welling. "Semi-supervised classification with graph convolutional networks." *arXiv preprint arXiv:1609.02907* (2016).

[2] Veličković, Petar, et al. "Graph attention networks." arXiv preprint arXiv:1710.10903 (2017).

[3] Ying, Chengxuan, et al. "Do transformers really perform badly for graph representation?." Advances in Neural Information Processing Systems 34 (2021): 28877-28888.

CV of the Teacher

Giovanni Trappolini is an assistant professor at the Department of Computer Engineering of the Sapienza University of Rome. He is a member of the RSTLess Research Group led by Professor Fabrizio Silvestri. He received his Ph.D. in Machine Learning in 2022 and was awarded the title of Sapienza's honor student. His research interests lie at the intersection of geometric and multimodal deep learning, with a particular focus on graph learning.

Final Exam: Project-Based.

Room and Schedule

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

Schedule:

Day 1 – 9-13. Intro to Logistic Regression for neural networks and to the Pytorch Python library.

Day 2 – 9-13. A Brief Introduction to Neural and Convolutional Networks. Applications and implementation.

Day 3 – 9-13. Combining Feature-based and Geometric-based information in neural models. Graph Neural Networks.

Day 4 – 9-13. Extending the Graph Neural Networks: Message-Passing Neural Networks.

Day 5 – 9-13. Applications of MPNN in engineering.