UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Advanced Artificial Intelligence, Machine Learning and Deep Learning

2627-1-F9103Q009

Aims

Recent developments in Artificial Intelligence and Machine Learning have changed how we work and live by assuming a significant role in the industry, education, and, more generally, in today's culture. This course provides students with advanced techniques for designing intelligent systems, understanding model behavior, learning effective representations, transferring knowledge across tasks, and reasoning with modern neural architectures. The course combines theoretical foundations with practical applications.

Contents

The course is organized around four main themes:

1. **Explainable Artificial Intelligence (XAI)**: understanding, interpreting, and explaining the decisions of modern machine learning models.
2. **Representation Learning**: learning effective data representations through embeddings, deep neural models, and graph-based approaches.
3. **Attention and Knowledge Representation**: processing information through attention mechanisms and representing structured knowledge to support reasoning and intelligent decision-making.
4. **Transfer and Continual Learning**: reusing and adapting learned knowledge across tasks, domains, and time to improve learning efficiency, generalization, and knowledge retention.

Detailed program

A) Explainable Artificial Intelligence (XAI)

- Interpretability and explainability
- Foundations and motivations of XAI
- Post-hoc explanation methods
- LIME (Local Interpretable Model-Agnostic Explanations)
- Feature attribution and saliency-based explanations
- Local and global explanations

B) Representation Learning

- Neural embeddings and latent spaces
- Principles of representation learning
- Skip-Gram and word embedding models
- Graph representation learning
- Introduction to Knowledge Graphs
- Knowledge graph embeddings

C) Attention and Knowledge-Based Reasoning

- Knowledge representation and reasoning
- Translational embedding models for knowledge graphs
- Attention mechanisms
- Query-Key-Value framework
- Attention in modern AI systems and Transformers

D) Transfer Learning and Continual Learning

- Foundations of transfer learning
- Inductive transfer learning
- Transductive transfer learning
- Unsupervised transfer learning
- Domain adaptation and domain alignment
- Representation transfer
- Practical applications of transfer learning
- Introduction to continual and lifelong learning
- Catastrophic forgetting and the stability-plasticity dilemma
- Regularization-based continual learning methods
- Knowledge distillation approaches for continual learning
- Evaluation of knowledge transfer, retention, and forgetting

Prerequisites

Most of the prerequisites will be briefly recalled in classes. However, basic knowledge of Linear algebra, Calculus, and Probability are warmly recommended. Basic programming skills are fundamentals. Python programming language is strongly recommended.

Teaching form

Lectures introduce the main concepts, models, and algorithms. Practical sessions and laboratories allow students to apply the techniques discussed in class through guided exercises and small projects. Active participation in both lectures and labs is strongly encouraged.

Textbook and teaching resource

A) Suggested texts (Specialized papers and further resources will be provided during the course)

- Zhang, Aston, et al. "Dive into deep learning." arXiv preprint arXiv:2106.11342 (2021).
- Murphy, Kevin P. Machine learning: a probabilistic perspective. MIT press, 2012.
- Heaton, Jeff. "Ian Goodfellow, Yoshua Bengio, and Aaron Courville: Deep learning." (2017).
- Russell, Stuart J. Artificial intelligence a modern approach. Pearson Education, Inc., 2010. (and subsequent editions)

Semester

Second

Assessment method

The final grade will be based on:

- **Project assignment and interview**: evaluation of the ability to apply course concepts, implement and analyze AI methods, interpret results, and discuss methodological choices.
- **Written examination**: theoretical questions and exercises covering the main course topics, assessing conceptual understanding, problem-solving ability, and knowledge of the presented techniques.

Office hours

By appointment.

Sustainable Development Goals

QUALITY EDUCATION