DEEP LEARNING
- COURSE INTRODUCTION -

Corsi di Laurea in Informatica,
Ing. Gestionale, Ing. Informatica, Ing. di Internet
(a.a. 2023-2024)

Roberto Basili

Objectives

- Methods for the accurate access and processing of the information distributed in Web sources

- Foundations:
  - Advaced models of *Machine Learning* and *Deep Learning*
    - *Statistical Learning Theory*
    - *Kernel Machines*
    - *Artificial Neural Networks e Deep Learning*
  - Natural Language Inference, Text Search and Classification
    - DL-based Natural Language Processing

- Applications:
  - Multimedia Data Mining: Machine Vision & Data Analytics
  - *Opinion* Mining & Sentiment Analysis
  - *Textual Inference, Semantic Search*, Question Answering
  - Fake News Detection, Data Journalism

Organization

Section I: **Advanced Machine Learning & Deep Learning**

Intro ML. Supervised & Unsupervised Learning

Statistical Learning Theory & Kernel-based learning.

Support Vector Machines.

Deep Learning with Neural Networks.

Image Processing with Deep Learning Architectures

Section II: **Neural Language Processing & Generative AI**

Neural Models for Language Processing. Large Language Models.

Prompting and Instruction Tuning.

- Section III: **Deep Learning Applications**
  - Visual Object Recognition and Automatic Image Captioning
  - Information Extraction. Fake News Detection.
  - Sentiment Analysis, Brand Reputation Analysis and Marketing.

Lessons

- Foundational aspects
  - Paradigms and Methods for Machine Learning
  - Optimization: *Feature Selection*, *Dimensionality Reduction*, *Statistical Learning Theory*
  - Deep Learning paradigms and methods
  - Complex Models for Web Data Management
- Laboratory Lessons
  - Introduction to technologies, systems and tools
    - ML and DL software, NLP software, Ml frameworks, Prompt Engineering
  - Final Project
    - Advanced Analytics applications
    - ML for IR and knowledge discovery
    - Natural Language Processing applications (e.g. Visual QA)

Target

- Master Degree in Computer Science (o Comp.Eng., Aut. Eng., ICT Eng., Business Eng.)
- Prerequisites:
  - Elements of Calculus (Analisi Matematica) and Geometry
  - Basic Knowledge of Logic and KR methods
  - Probabiliy Theory and Statistics
  - Data and Knowledge Base management systems
- Some Topics are *shared* with other courses:
  - *Machine Learning* (G. Gambosi)
  - *Information Retrieval* (D. Croce)
  - *Natural Language Processing* (F.M. Zanzotto)

Timetable

- **Monday 14:00 - 16:00** AULA C10
  Macroarea di Ingegneria

- **Wednesday 9:30 - 11:30** AULA B16
  Macroarea di Ingegneria

- **Thursday 9:30 - 11:30** AULA C12   Macroarea
  di Ingegneria

Meeting with Students:

every Thursday after the lesson or,

on individual sessions *on-line* (on the MS Teams channel)

Course MS Teams & Web page

- Didattica Web (Corso di Laurea in Informatica)
- URL:
- **http://sag.art.uniroma2.it/didattica/basili/DL_24_25/**

- MS: Teams: **BASILI-8067802-DEEP_LEARNING**
- Link: Deep Learning 24-25 on MS Teams

Course Official Web Page

Esci dai Frame

Deep Learning (a.a. 2024/25, ex Web Mining and Retrieval)
Semester Second

List of Files on the Page

Content Summary

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5. Slides of the lessons NEW
6. Projects and Exercises NEW

NEW **News**

URL: http://sag.art.uniroma2.it/didattica/basili/DL_24_25/

Textbooks

- Ian Goodfellow, Yoshua Bengio and Aaron Courville, Deep Learning, MIT press, 2016.
- Gerhard Paaß and Sven Giesselbach, Foundation Models for Natural Language Processing, Springer Nature, https://link.springer.com/book/9783031231896.
- Mor Harchol-Balter, Introduction to Probability for Computing, Cambridge University Press, 2024
- Teacher notes distributed during the course.
- Complementary Materials:
  - Pattern Recognition and Data Mining, C. Bishop, 2006.
  - Papers and tutorial:
    - Scientific Papers
    - Lesson slides: http://sag.uniroma2.it/basili/didattica/DL_22_23/

Overview of the syllabus

DEEP LEARNING, a.a. a.a. 2023-24 (1st Ed.)		
Moduli	**Argomenti**	**Lezioni**
Introduction to the basic elements of ML	Introduction to ML algorithmics. Probability and Similarity Metrics. Classification using basic algorithms.	Introduction to WM&R.
		Introduction to ML. Supervised vs. Unsupervised Methods. Probabilstic and Generative Methods
		Discriminative Methods: the role of metric spaces. Metrics and semantic similarity.
Probabilistic View on DL Problems and methods	Generative Language Models. HMMs	Probabilistic Language Modeling, HMM.
From PAC learnability to SVM	PAC learnability. VC-dimension. SVMs. Kernel methods	PAC Learnability. Perceptron
		SVM. Hard Margin.
		Soft margin SVM. The notion of Kernels.
		Polynomial and RBF Kernels. Sequence & Tree Kernels.
Neural Networks and Deep Learning	Semi-supervised learning: ensemble methods, active learning, EM. On-line learning: Passive-Aggressive. Deep Neural netork architectures.	From neural networks to deep learning: perceptrons and MLP
		Deep Learning over MLPs.
		Convolutional Neural Networks: Adopting Convolutional Neural Networks on images, ….
		Recurrent Neural Networks
		Neural Language Models: Probabilistic Language Modeling, HMM.
		Neural Language Models: Bengio et al model
		Attention Mechanisms and Trasformers
Fondational Models, Neural Learning in NLP	Word Embeddings with NNs. Large Language Models. Autoregressive Decoders. 0 and Few Shot learning. Prompting.	Encoder and Decoder Architectures. Decoder Only Architectures.
		Large Scale Neural Language Models.
		From fine-tuning to instruction learning
		Prompting LLMs
		0-shot, few-shot learning
		Richiami ai metodi di Elaborazione del Linguaggio Naturale: il TAL
		Wordspaces. Word Embeddings through Neural Networks.
		Machine Learning for: Natural Language Inference
Social Media Analytics (*)	IR in Social Media. Community detection. User profiling and Recommending. Sentiment and Emotion Analysis.	Opinion Mining e Sentiment Analysis: the task
		OM & SA: Twitter as a case study
		Fake News Detection: FEVER and other stories

Exams: modalities

- *Two ways of attending the Course*
  - *FULL (9 ETC credits)*
    - *Informatica, Laurea Tecnologie di Internet*
  - *LIGHT (6 crediti)*
    - *Laurea Ing. Informatica, Automatica e Gestionale*

LIGHT Exam

- One **MidTerm** is organized during the semester
  - Two tests
    - MidTerm1, Date: End of April
    - MidTerm2, Date: End of the Course (mid June)
- Two **Final Tests** at the end of the Semester
  - Final Test 1, Date: **same** as MidTerm2
  - Final Test 2, Date: mid July
- Oral session: not mandatory, i.e. only on request
- Program Section: I, II

- It is possible (not mandatory) to carry out a software development or experimental project (e.g. Testing ML models on domain specific datasets, Design and Develop a Data-driven Web application) or an *in depth* study of a selected advaced topic

FULL Exam

- One **MidTerm** is organized during the semester
  - Two tests
    - MidTerm1, Date: End of April
    - MidTerm2, Date: End of the Course (mid June)
- Two **Final Tests** at the end of the Semester
  - Final Test 1, Date: **same** as MidTerm2
  - Final Test 2, Date: mid July
- Oral session: not mandatory, i.e. only on request

- Mandatory a software development or experimental project or the in depth study of an advaced topic
- Program Section: I, II e III

Project activity

- A in depth study of an advanced topic
  - Selection of the specific focus of the study
  - Survey of the recent literature
  - Dedicated meetings (different from the lesson),
  - Final report
  - Final presentation of the study (end of the Course)

- Project (max 2/3 people)
  - Project *topic* assignment
  - Dedicated meetings (different from the lesson)
  - Development of the experimental system and short presentation
  - Exam: Discussion of the project + Demo

Examples of Final Projects

- **Opinion Recognition/Tracking and Brand Reputation Analysis**. Riconoscimento e tracking di opinioni in social networks sulla base di descrizioni tematiche
- **Multimedia Search Engine**. Enterprise search for picture and video repositories. Fake News Detection.
- **Automatic Metadata creator**. Titolazione automatica di immagini e video

- **Graph Neural Networks**. Algoritmi graph-based per machine learning e ragionamento automatico.
- **Zero-Shot Learning for domain specific classification in GenAI systems**
- Adaptation of LLMs for specific tasks and domains (e.g. *medicine, fintech, security*).
- **RAG based reasoning in GenAI**. Chain-of-Thought techniques, LLM agents

Questions?
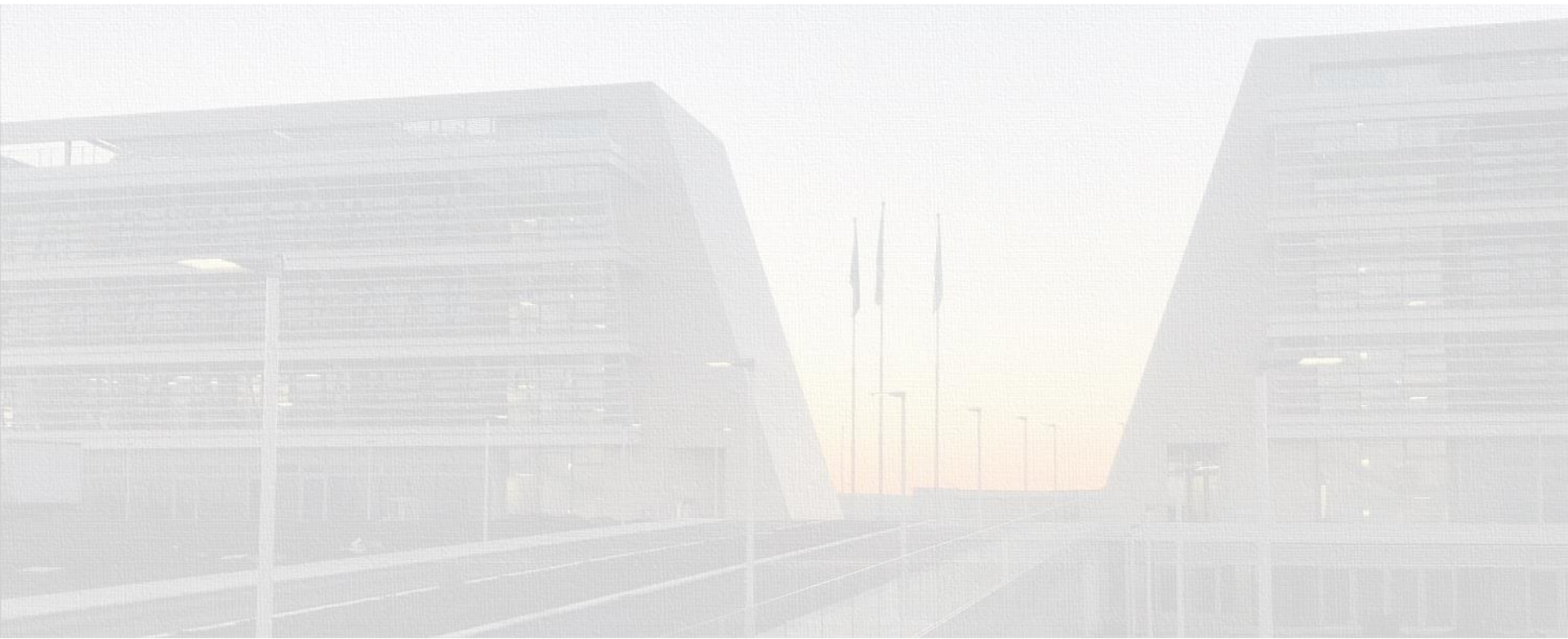
Action List

- Please register to the Course on Delphi :
  - URL: https://delphi.uniroma2.it/totem/jsp/

- Please use the field Note» to communicate your Laurea Degree and the number of ECTS foreseen by your curriculum

- **Regularly** access the Teams channel and the Course Web page for:
  - Slides and teaching materials (*in progress*)
  - Timetables and Scheduling changes
  - Laboratory and Project Topics