Harvard Extension School
HARVARD DIVISION OF CONTINUING EDUCATION

CSCI E-89
Deep Learning

Fall Term 2025

Full syllabus displayed to registered students only

Course Information

CRN: 16392
Section Number: 1
Format: Flexible Attendance Web Conference
Credit Status: Undergraduate, Graduate, Noncredit
Credit Hours: 4

Class Meetings: Fridays, September 5-December 20, 6:30pm-8:30pm

Course Description: In this course, students master the most important neural network and deep learning concepts and techniques and start applying them productively in modern artificial intelligence (AI) workplace. Deep learning is the primary technique for data analysis and the solution for many complex problems in natural sciences, linguistics, and engineering. We use deep learning for image classification, manipulation, and generation; speech recognition and synthesis; natural language translation; sound and music manipulation and generation; and navigation of self-driving cars. Students master several key deep learning architectures, such as convolutional neural networks (CNNs), long short-term memory networks (LSTMs), autoencoders (AEs), variational autoencoders (VAEs), generative adversarial networks (GANs), transformers with attention, and graph neural networks (GNNs). Students master the most essential skills for the efficient use of large language model (LLM)-based applications such as ChatGPT and DALL*E. The course starts with a review of the theoretical foundations of neural networks approach to machine learning including auto-differentiation and back-propagation. The emphasis is on practical applications of deep learning APIs Keras (a package within

TensorFlow 2.x framework) and PyTorch.

Prerequisites: Proficiency with Python. We assume no familiarity with Linux and introduce all essential Linux features and commands. Students need access to a computer with a 64-bit operating system and at least 8 GB of RAM. Having a machine with NVIDIA card is a plus but not required. All complex examples given as assignments could be run on Google Collaboratory.

Instructor Information & Office Hours

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Section Meetings

Optional online section takes place every Saturday at 1 PM EST. Zoom session is recorded and posted on the Canvas site in the folder for every week. Online sections discuss key practical code elements mentioned in the class or in homework assignment for this week. Students are encouraged toanswer and discuss any course related issues.

Course Goals / Learning Outcomes

Students will master the most important neural network and deep learning concepts, techniques and architectures for productive use in modern AI workplace. This includes detailed and practical mastery of Keras and PyTorch on CNNs, Auto-Encoders and VAE, GNNs, Transformers, and Large Language Models (LLMs).

Mode of Attendance & Participation Policy

This is a flexible attendance course, which means you can choose to: (1) attend class live over Zoom (synchronous option); or (2) watch the class recording afterward (asynchronous option). You do not need to commit to the same mode of attendance for the whole semester.

If you are attending live over Zoom:

- **Select "Zoom" in the Canvas course website to join class meetings**

Please arrive on time. You should attend Zoom meetings with a functional web-camera and microphone, prepared with materials needed, to engage thoughtfully, and with your camera on. You may turn off your camera for occasional interruptions or momentarily for privacy.

You will also need the most up-to-date Zoom client installed on your computer to join class. Please participate from a safe and appropriate environment with appropriate clothing for class. Participating while traveling or in a car is not permitted. In addition, please do not join class via mobile phone or web browser.

If you are participating asynchronously:

You are expected to watch the class recording, available in Canvas, and complete any assignments before the next live class meets.

Please be sure to review important information on **Student Policies and Conduct**.

Assignments & Grading

Assignments

Practically every class will be followed by a homework assignment. The first assignment will be used to assess readiness of each enrolled student in the course. Grades on the solutions for the class assignments constitute approximately 80% of the final grade. 5% of the grade is assigned based on class participation and/or participation in online assistance and discussion forum. 15% of the grade is earned through the final project. Final projects will be assigned before the 7th lecture. For the final project, you will produce a paper (10+ pages of MS Word text, 10+ PowerPoint Slides, a working demo, 15 minutes YouTube video with your detailed exposition about the project and a brief 2 minute YouTube video to be presented to the whole class.

Grading

80% Assignments / Problem Sets / Group Projects - **DUE: Next Saturday**

5% Class participation and participation in online discussions,

15% Final Exam / Paper / Project - **DUE: 12/10/2025**

95% or higher cumulative grade on all assignments, class participation and the final project gives student an A as the final grade in the course. 90-94.99% gives student an A-, 85-89.99% a B+, 80-84.99% a B, 75-79.9% a B-, etc.

See [Grades & Grading System] for additional information.

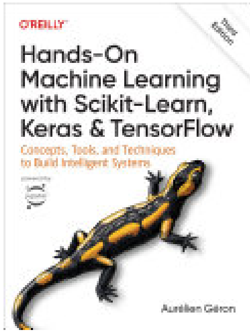
Graduate Credit Requirements

Students can take this course for graduate credit as well as undergraduate credit; see "Credit Status" under Course Information, above. All full credit students are given the same asignments.

Course Materials

Deep Learning
ISBN: 978-0262035613
Authors: Ian Goodfellow, Yoshua Bengio, Aaron Courville
An introduction to a broad range of topics in deep learning, covering mathematical and conceptual background, deep learning techniques used in industry, and research perspectives.
Publisher: The MIT Press
Publication Date: November 18, 2016
Edition: 1st

Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow
ISBN: 9781098122478
Authors: Aurélien Géron

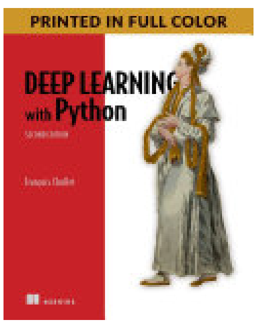


Through a recent series of breakthroughs, deep learning has boosted the entire field of machine learning. Now, even programmers who know close to nothing about this technology can use simple, efficient tools to implement programs capable of learning from data. This bestselling book uses concrete examples, minimal theory, and production-ready Python frameworks (Scikit-Learn, Keras, and TensorFlow) to help you gain an intuitive understanding of the concepts and tools for building intelligent systems.

Publisher: "O'Reilly Media, Inc."

Publication Date: 2022-10-04

Edition: 3rd



Deep Learning with Python, Second Edition

ISBN: 9781617296864

Authors: Francois Chollet, François Chollet

Deep Learning with Python introduces the field of deep learning using the Python language and the powerful Keras library. You'll learn directly from the creator of Keras, François Chollet, building your understanding through intuitive explanations and practical examples. Updated from the original bestseller with over 50% new content, this second edition includes new chapters, cutting-edge innovations, and coverage of the very latest deep learning tools. You'll explore challenging concepts and practice with applications in computer vision, natural-language processing, and generative models. By the time you finish, you'll have the knowledge and hands-on skills to apply deep learning in your own projects.

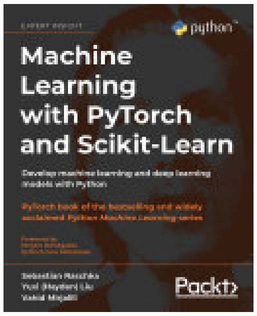
Publisher: Simon and Schuster

Publication Date: 2021-12-21

Machine Learning with PyTorch and Scikit-Learn

ISBN: 9781801816380

Authors: Sebastian Raschka, Yuxi (Hayden) Liu, Vahid Mirjalili



This book of the bestselling and widely acclaimed Python Machine Learning series is a comprehensive guide to machine and deep learning using PyTorch s simple to code framework. Purchase of the print or Kindle book includes a free eBook in PDF format. Key Features Learn applied machine learning with a solid foundation in theory Clear, intuitive explanations take you deep into the theory and practice of Python machine learning Fully updated and expanded to cover PyTorch, transformers, XGBoost, graph neural networks, and best practices anded to cover the latest trends in deep learning, including graph neural networks and large-scale transformers used for natural language processing (NLP).

Publisher: Packt Publishing Ltd

Publication Date: 2022-02-25

Community Charter

By enrolling in courses offered by the Harvard University Division of Continuing Education (DCE), individuals agree to abide by our community standards to promote a culture of trust, cooperation, mutual understanding, and learning.

Members of the DCE community, including students, faculty, and staff, are expected to treat each other with dignity and communicate respectfully and appropriately across all channels. When using social media or other forms of communication designed to reach members of the public, no one should repeat an oral or written statement made in class in a way that would identify the person who made the statement.

Our commitment to academic integrity and excellence includes holding ourselves accountable for our actions. Violations of these community standards may result in disciplinary actions. DCE adheres to all University-wide policies that address discrimination, bullying, and harassment. Resources including the Office for Gender Equity and the Harvard Ombuds Office are available to assist community members with concerns.

Academic Integrity Policy

You are responsible for understanding Harvard Extension School policies on Academic Integrity and how to use sources responsibly. Violations of academic integrity are taken very seriously. Visit Using Sources Effectively and Responsibly and the Harvard Guide to Using Sources to review important information on academic citation rules.

AI Technologies Policy

We expect that all work students submit for this course will be their own. In instances when collaborative work is assigned, we expect for the assignment to list all team members who participated. **We specifically forbid the use of ChatGPT or any other generative artificial intelligence (GAI) tools at all stages of the work process, including preliminary ones**. Violations of this policy will be considered academic misconduct. We draw your attention to the fact that different classes at Harvard could implement different AI policies, and it is the student's responsibility to conform to expectations for each course.

Writing Code

While it may be common practice in non-academic settings to adapt code examples found online or in texts, this is not the case in academia. In particular, you should never copy code produced as coursework by other students, whether in the current term or a previous term; nor may you provide work for other students to use. Copying code from another student or any other source is a form of academic dishonesty, as is deriving a program substantially from the work of another.

Writing code is similar to academic writing in that when you use or adapt code developed by someone else as part of your assigned coursework, you must cite your source. Paraphrasing without proper citation is just as dishonest with programming as it is with prose. A program can be considered plagiarized even though no single line is identical to any line of the source.

Accessibility Services Policy

The Division of Continuing Education (DCE) is committed to providing an accessible academic community. The Accessibility Services Office (ASO) is responsible for providing accommodations to students with disabilities. Students must request accommodations or adjustments through the ASO. Instructors cannot grant accommodation requests without prior ASO approval. It is imperative to be in touch with the ASO as soon as possible to avoid delays in the provision of accommodation.

DCE takes student privacy seriously. Any medical documentation should be provided directly to the ASO if a substantial accommodation is required. If you miss class due to a short-term illness, notify your instructor and/or TA but do not include a doctor's note. Course staff will not request, accept, or review doctor's notes or other medical documentation. For more information, email accessibility@extension.harvard.edu.

Publishing or Distributing Course Materials Policy

Students may not post, publish, sell, or otherwise distribute course materials without the written permission of the course instructor. Such materials include, but are not limited to, the following: lecture notes, lecture slides, video, or audio recordings, assignments, problem sets, examinations, other students' work, and answer keys. Students who sell, post, publish, or distribute course materials without written permission, whether for the purposes of soliciting answers or otherwise, may be subject to disciplinary action, up to and including requirement to withdraw. Further, students may not make video or audio recordings of class sessions for their own use without written permission of the instructor.

Canvas Access After End of Term

The Canvas website for this course will remain available to enrolled students for a limited time after the course concludes. **You are encouraged to download coursework and materials you wish to keep *before* the term ends.** See Course Formats & Required Technology for additional information on Canvas access.

Class Meeting Schedule

September 5: Class 1: **Introduction to Neural Networks and Deep Learning,**

We briefly review several key examples from physiology and neurology motivating basic concepts and patterns in Neural Networks (NNs) and introduce a basic model of the neural network loss function optimization

September 12: Class 2: **Gradient Descent and Back Propagation**

We introduce the gradient descent, auto-differentiation, and backpropagation the algorithms which make large scale NNs feasible.

September 19: Class 3: **Keras**

We introduce Keras, the development framework for Deep Learning Networks with its key elements: Loss Functions, Regularization, Sequential and Functional Models and others. We present detailed architecture and patterns for building models in Keras. Initially we discuss fully connected or "dense" networks.

September 26: Class 4: **Convolutional Neural Networks (CNNs)**

Starting from physiological models and an analysis of the computational efficiency of fully connected networks we introduce CNNs. We also learn how to determine the number of trainable parameters of various layers in CNN Models.

October 3: Class 5: **Visualizing Feature Maps of CNN Layers, Locating Objects in Images**

We learn how to monitor the evolution of layer's (network's) parameters as NN evolves through the optimization and observe the distributions of values of those parameters in optimized NNs. Those observations provide a deep insight in the nature of NN data processing.

October 10: Class 6: **Transfer Learning, Fine Tuning, Augmentation**

Transfer Learning, Fine Tuning, and Data Augmentation are three most frequently used techniques for training networks on restricted data sets and the increasing the precision of Deep Learning analysis.

October 17: Class 7: **Autoencoders, Variational Autoencoders and Manifold Hypothesis**

We learn that NNs behave as if they are searching for a minimal representation of any object. We "discover" embedded vector representations of words in texts. We also understand VAEs, an extension of the autoencoders which allows generation of "higher quality" images and other objects.

October 24: Class 8: Natural Language Processing (NLP), Doc2Vec like API-s and Large Language Models (LLMs). Deep Learning (DL) and LLMs provide sophisticated tools for analysis and representation of text. We introduce and demonstrate the most important applications of DL techniques in NLP.

October 31: Class 9: **Analysis and Transcription of Speech**

We learn how to encode human speech and present it as a time series of codes. Subsequently, we learn how to use such representations to train DL networks to transcribe speech into text.

November 7: Class 10: **Sequence Analysis, Seq2Seq Models and Machine Translation**

Using LSMTs, we demonstrate an ability to predict next value in a sequence, ability to perform machine (automated) translations of texts from one to another language and other sequence related tasks.

November 14: Class 11: **Transformers**

Transformer technology is at the core of LLMs. We will demonstrate the capacity of transformer-based systems (LLMs) to generate sensible text and perform many other linguistic and graphical tasks.

November 21: Class 12: **Large Language Models (LLMs)**

Large Language Models (LLMs) are redefining artificial intelligence. We will review the basic architecture and capabilities of several flavors of LLMs.

November 28: NO CLASS (Thanksgiving Break)

December 5: Class 13: G**enerative Adversarial Networks (GANs)**

GANs are special networks that act as generators of objects such as speech, text, and images.

December 12: Class 14: **Graphs Neural Networks (GNNs)**

We extend the convolution idea to the graph domain. We learn about characteristics of graphs and define the Graph Convolution and GNNs.

December 19: The Final Project Presentations

Every student in the class will present his final project.

Final Exam

This final project is an individual effort. Every student will implement one project.

The purpose of the final project is for every student in the class to learn a new Deep Learning technology or a use case not covered in the lectures and help the rest of the class gain additional knowledge. Students will write the final project report as a tutorial. All project materials including all code will be made available to the entire class. No proprietary code or code should be included. A student can not do a project and then refuse to share the code. Pojects should be delivered using Keras, TensorFlow, JAX or Pytorch APIs.

Every student may propose hers or his own topic. Such topic must be approved by the professors. Reuse of topics and materials from other classes at Harvard Extension or other schools is not acceptable.

Topics proposed by the teaching staff will be assigned in an on-line auction. The auction allows 2 individuals to sign up for each topic. The auction is on the first come, first served basis. For the auction, we use an online tool called Signup Genius.