Special Topics in Data Science and Machine Learning: A Self Learners Resource Guide - (Work IN PROGRESS)

February 3, 2022

Contents

1 Introduction

1.1 Primary Objective

- Provide data science and ML practitioners the resources necessary to learn new topics of interest in a self contained manner

1.2 Structure

Provide resources, course materials, and suggested strategies/paths for learning intermediate to advanced topics for data science and Ml
NOTE: This document is meant to be used as a guide. Not all courses and linked videos are needed nor meant to be covered. For beginners it is highly advised to seek the guidance of an expert or working data science professional prior to beginning the courses. This is mean to be a fully self contained guide, however it is not perfect, and sometimes assumed prior knowledge might have been overlooked (although I try hard to avoid this).

2 Topics and Learning Tracks

2.1 Computer Vision

- 0.0 Introduction to Computer Vision and Image Processing
  Description: Computer Vision is one of the most exciting fields in Machine Learning and AI. It has applications in many industries, such as self-driving cars, robotics, augmented reality, and much more. In this beginner-friendly course, you will understand computer vision and learn about its various applications across many industries. This is a hands-on course and involves several labs and exercises. Labs will combine Jupyter Labs and Computer Vision Learning Studio (CV Studio), a free learning tool for computer vision. CV Studio allows you to upload, train, and test your own custom image classifier and detection models. At the end of the course, you will create your own computer vision web app and deploy it to the Cloud.
  As part of this course, you will utilize Python, Pillow, and OpenCV for basic image processing and perform image classification and object detection.
  Resources:
  Prerequisites: This course does not require any prior Machine Learning or Computer Vision experience. However, some knowledge of the Python programming language and high school math is necessary.
- 1.0 Introduction to Computer Vision
  Alternate page
  Description: This class is a general introduction to computer vision. It covers standard techniques in image processing like filtering, edge detection, stereo, flow, etc. (old-school vision), as well as newer, machine-learning based computer vision.
  Resources: Full semester lecture videos, homework assignments, lectures notes, jupyter notebooks, and more.
  Prerequisites: Some Data Structures and Parallelism
- 1.1 Computer Vision (CMU 16-385)
  Description: This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems.
  Resources: Full semester lecture videos, homework assignments, lectures notes, jupyter notebooks, and more.
  Prerequisites: This course requires familiarity with linear algebra, calculus, basic probability, as well as programming. In particular, the following courses serve as prerequisite: Applied Matrix Methods/Applied Linear Algebra, Multivariable Calculus,Object oriented programming.
- 1.2 Machine Learning for Computer Vision
  Description: This course covers advanced machine learning methods allowing for so-called "structured prediction". The goal is to make multiple predictions that interact in a nontrivial way; and we take these interactions into account both during training and at test time. One example would be a method that accepts a

video as input and that outputs a set of trajectories, one for each target. The number of targets is not known beforehand and can change throughout the sequence. Another example is the problem of learning a policy for making good sequential decisions (e.g. in autonomous agents). Here, we need to anticipate the effect of decisions made earlier.
Contents:

- undirected probabilistic graphical models
- deep neural networks
- reinforcement learning

Resources: Full semester lecture videos, homework assignments, lectures notes*, and more.
Prerequisites: The most important prerequisite: interest in a steep learning curve. Modern machine learning builds on a broad range of ideas and techniques, and you will face many of them in the lecture and exercises. Participants should have a working knowledge of one or more of the following:

- basic machine learning / pattern recognition
- basic computer vision
- optimization

The following are strictly required:

- multivariable calculus
- linear algebra: linear system of equations, eigenproblems
- probability theory: multivariate random variables
- basic python programming skills, or advanced programming skills in any modern language

• 1.3. Autonomous Vision Lectures - Computer Vision (University of Tubingen)
Description: This course will provide an introduction to computer vision, with topics including image formation, camera models, camera calibration, feature detection and matching, motion estimation, geometry reconstruction, object detection and tracking, and scene understanding. Applications include building 3D maps, creating virtual avatars, image search, organizing photo collections, human computer interaction, video surveillance, self-driving cars, robotics, virtual and augmented reality, simulation, medical imaging, and mobile computer vision. Modern computer vision relies heavily on machine learning in particular deep learning and graphical models. The tutorials will deepen the understanding of deep neural networks by implementing and applying them in Python and PyTorch. A strong emphasis of this course is on 3D vision.
Prerequisites: This course assumes prior knowledge of deep learning and introduces the basic concepts of graphical models and structured prediction where needed.It assumed students have a working knowledge in the following:

- Basic Computer Science skills: Variables, functions, loops, classes, algorithms
- Basic Python and PyTorch coding skills
- Basic Math skills: Linear algebra, probability and information theory (eg. Math for ML lecture)
- a recommended refresher is to read Chapters 1-4 of:Deep Learning Book
- Experience with Deep Learning (eg., through participation in Deep Learning lecture

Resources: Full semester lecture videos, homework assignments, lectures notes*, and more.

*The accompanying lecture notes are of extremely high quality

• 1.4 Advanced Computer Vision with TensorFlow
Description: The DeepLearning.AI TensorFlow: Advanced Techniques Specialization introduces the features of TensorFlow that provide learners with more control over their model architecture and tools that help them create and train advanced ML models. This Specialization is for early and mid-career software and machine learning engineers with a foundational understanding of TensorFlow who are looking to expand their knowledge and skill set by learning advanced TensorFlow features to build powerful models.
In this course, you will:

- Explore image classification, image segmentation, object localization, and object detection. Apply transfer learning to object localization and detection.
- Apply object detection models such as regional-CNN and ResNet-50, customize existing models, and build your own models to detect, localize, and label your own rubber duck images.

- Implement image segmentation using variations of the fully convolutional network (FCN) including U-Net and d) Mask-RCNN to identify and detect numbers, pets, zombies, and more.
- Identify which parts of an image are being used by your model to make its predictions using class activation maps and saliency maps and apply these ML interpretation methods to inspect and improve the design of a famous network, AlexNet.

- 1.5 Convolutional Neural Networks for Visual Recognition (Standford CS231n)
  Description: Computer Vision has become ubiquitous in our society, with applications in search, image understanding, apps, mapping, medicine, drones, and self-driving cars. Core to many of these applications are visual recognition tasks such as image classification, localization and detection. Recent developments in neural network (aka "deep learning") approaches have greatly advanced the performance of these state-of-the-art visual recognition systems. This course is a deep dive into details of the deep learning architectures with a focus on learning end-to-end models for these tasks, particularly image classification. During the 10-week course, students will learn to implement, train and debug their own neural networks and gain a detailed understanding of cutting-edge research in computer vision. The final assignment will involve training a multi-million parameter convolutional neural network and applying it on the largest image classification dataset (ImageNet). We will focus on teaching how to set up the problem of image recognition, the learning algorithms (e.g. backpropagation), practical engineering tricks for training and fine-tuning the networks and guide the students through hands-on assignments and a final course project. Much of the background and materials of this course will be drawn from the ImageNet Challenge.
  Prerequisites:
  - Proficiency in Python, high-level familiarity in C/C++ All class assignments will be in Python (and use numpy) (we provide a tutorial here for those who aren't as familiar with Python), but some of the deep learning libraries we may look at later in the class are written in C++. If you have a lot of programming experience but in a different language (e.g. C/C++/Matlab/Javascript) you will probably be fine.
  - College Calculus, Linear Algebra: You should be comfortable taking derivatives and understanding matrix vector operations and notation.
  - Basic Probability and Statistics: You should know basics of probabilities, gaussian distributions, mean, standard deviation, etc.
  - Equivalent knowledge of Introductory Machine Learning: We will be formulating cost functions, taking derivatives and performing optimization with gradient descent.

- 1.5 Deep Learning for Computer Vision (U Michigan)
  Description: The first half of the course will cover the fundamental components that drive modern deep learning systems for computer vision:
  - Linear classifiers
  - Stochastic gradient descent
  - Fully-connected networks
  - Convolutional networks
  - Recurrent networks

  In the second half of the course we will discuss applications of deep learning to different problems in computer vision, as well as more emerging topics. During this second half the tone of the course will shift slightly towards a seminar: we will omit some details of the systems we discuss, instead focusing on the core concepts behind those applications. We will touch topics such as:
  - Attention and transformers
  - Object detection
  - Image segmentation
  - Video classification
  - Generative models (GANs, VAEs, autoregressive models)

  Resources: Full semester lecture videos, homework assignments, lectures notes, jupyter notebooks, and more.
  Prerequisites: .
  - Programming: You should be comfortable programming in Python. You should be familiar with algorithms and data structures at the level of EECS 281 or equivalent. Familiarity with numpy or similar frameworks for numeric programming will be helpful but is not strictly required.

- Probability: You should have been exposed to probability distributions, random variables, expectations, etc. at the level of EECS 401, MATH 425, or equivalent.
- Vector Calculus: You will need to compute gradients of vector-valued functions, so you should be comfortable doing so.
- Machine Learning: Some familiarity with machine learning (at the level of EECS 445 or equivalent) will be helpful but not required; we will review important concepts that are needed for this course.

• 1.6 Computer Vision 3: Detection, Segmentation and Tracking
Description: This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems.
Resources: Full semester lecture videos, homework assignments, lectures notes, jupyter notebooks, and more.
Prerequisites: .

- Introduction to Deep Learning (I2DL) (IN2346)
- Strong mathematical background: Linear algebra and calculus.
- Previous knowledge of Python is mandatory.
- Previous knowledge of PyTorch is highly recommended.

A. Additional and Related Courses

• A.0 Introduction to Augmented Reality and ARCore
Description: This class will teach you the fundamentals of augmented reality (AR), and how to build an AR experience using ARCore. This course will break down complex AR concepts to make them easy to understand, while also sharing expert tips and knowledge from Daydream's ARCore team.
Through the four week course, you'll learn:

- How to identify different types of AR experiences
- Tools and platforms used in the AR landscape
- What makes AR feel "real"
- Popular use cases for AR
- How to create an AR use flow
- How AR experiences work
- Tools like Google Poly and Unity to build AR experiences
- Next steps to start building an AR experience using ARCore and other tools

Prerequisites: The course is great for beginners who are just getting started with AR or ARCore.

2.2 Deep Learning

• 2.2 Deep Learning
Description: This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems.
Resources: Full semester lecture videos, homework assignments, lectures notes, jupyter notebooks, and more.