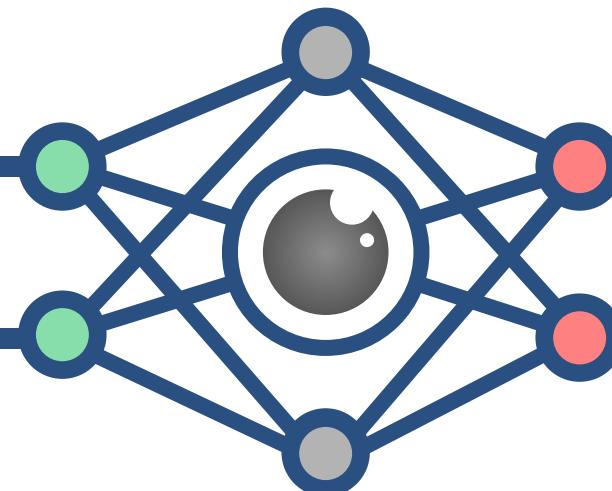


CS3485

# Deep Learning for Computer Vision



*Lec 1:* Introduction to Computer Vision

# Course Staff

- **Instructor:** Jeova Farias Sales Rocha Neto (can call me Jeova or Prof. Farias)
  - Email: [j.farias@bowdoin.edu](mailto:j.farias@bowdoin.edu)
  - Office Hours: Mon & Wed 4:30-5:30pm at Searles 121 (or by appointment or **just come by!**)
- **Instructor Bio:**
  - PhD, Computer Engineering. (Brown University),
  - MSc, Applied Math (Brown University), CS (University of Nice, France).
- **Research interests:**
  - Statistical Machine Learning and Discrete Optimization,
  - Image Processing and Computer Vision.
  - More recently: Unsupervised Deep Learning.
  - *Contact me if you are interested in research in the field!*



# Learning Objectives

- At the end of the course, the students are expected to:
  - a. Understand what **Computer Vision** is and how it's been applied in the industry and academia.
  - b. Know what neural networks are and how that led to the development of **Deep Learning**.
  - c. Have a concise knowledge of how Deep Learning has developed over the years and the problems it brought solutions to.
  - d. Have enough working skills on **PyTorch** to develop Deep Learning applications for, and more broadly than, Computer Vision.
  - e. Be able to read and understand the **recent literature** in Deep Learning and Computer Vision and present their content to a wider audience.



# What you can expect from this course

- You can expect **organized lectures and assignments**. (OBS: Some lectures may not cover the whole 1.5 hours).
- I expect you to participate in our **in-class activities** and be kind to your peers' questions.
- Prerequisites:
  - In this course, we'll use **math** in some classes, especially calculus and linear algebra, so I assume you understand these math basics.
  - However, more importantly: **feel free to ask questions about these topics!** It's ok if you forgot some of these things or never learned them well. I'll try my best not to help you on them too.
- We'll go through the very basics of Deep Learning, so, for those who may already know some stuff: **be patient** (and also contribute to the class, if possible).
- Some classes will **have faster pace** than others. Let me know if they are too fast, tho!
- Most modern Deep Learning literature is **still being written**, and it is not concise, so We may use for different sources other than the textbook as we go.

# Hardware for Deep Learning

- One big disadvantage when doing/teaching Deep Learning: it requires expensive hardware, i.e., Graphics Processing Units (GPUs).
- **Google Colab** is an option for codes in class, homeworks and your final project:
  - Uses Python notebooks (.ipynb).
  - It is free for anyone with a GDrive account,
  - Provides GPUs for us to run our codes on,
- One problem: in the free accounts, it may stop providing GPU access after a lot of usage on it.
- We can also use Bowdoin's HPC, but we'll leave it only for projects, for now.
- If you are interested in using it anyway, I'll write the instructions on how to.

## Google Colaboratory



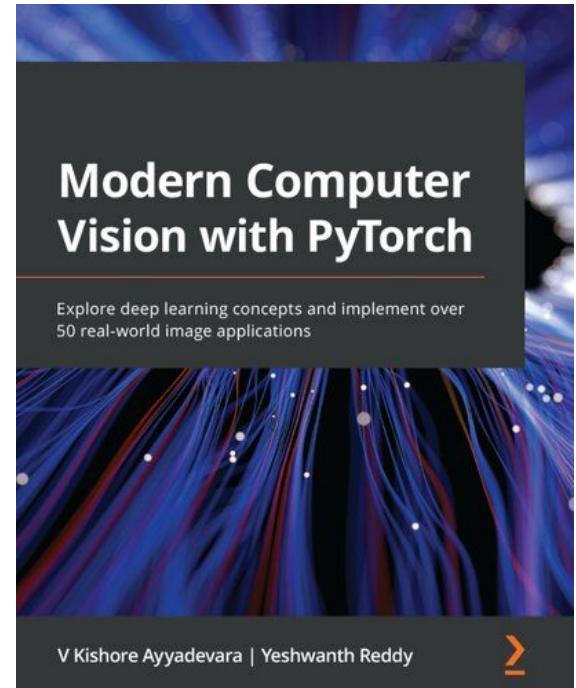
# Textbook

- It is hard to find a textbook for this course: the field changes **extremely fast**.
- However, the book we will most use in this course is:

***Modern Computer Vision with PyTorch***, by V Kishore Ayyadevara and Yeshwanth Reddy. Packt Publishing Ltd, 2020.

It's not an academic book, more like a "hands-on" learning material.

- Most of the code will be inspired from it.
- For the theory, use the slides + (potential) papers I'll send to you.



# Our Website

- We have a website for our course! It's [jeovafarias.github.io/Bowdoin-CS3485-F23](https://jeovafarias.github.io/Bowdoin-CS3485-F23).
- In it, you shall find:
  - The lecture slides + useful code and papers we discuss in each class;
  - The links to the assignment instructions (their submission will still be via Canvas)
  - The schedule of lectures, exams, breaks and review sessions;
  - Info on the final project.
  - The course syllabus and other materials.
- Despite having a website, we may still use canvas for some activities. Details TBD.



## Course Description

Computer Vision has become ubiquitous in our society, image searches to self-driving cars. On the other hand, Deep learning has shaken the world of artificial intelligence in the recent years. Most of these developments greatly advanced the performance of state-of-the-art visual recognition systems, which put Computer Vision in the epicenter of most technological progress from the past decade. In this context, this course aims at providing a consistent exploration of how deep learning started to its most recent achievements, always using Computer Vision tasks as their main application, historically or practically. During the course, we'll also understand many of the main computer vision problems and use them as cases for the introduction of various deep learning related problems. Finally, this course hope to give students working knowledge of PyTorch, one of the main deep learning frameworks, and prepare them to future industrial and academic careers in the field.

## Pre-requisites

Basics of Multivariate Calculus and Linear Algebra.

## Instructor



Jeova Farias

## Course Details

### When/Where:

Mondays and Wednesdays from 11:45a to 1:10p at Searles 126 and at this Zoom link (available when asked)

### Office Hours:

Monday and Wednesday from 4:30-5:30p at Searles 121.

# Final grade

- **Homework** (also called *labs*) **(30 %)**:
  - Released on Mondays after class, 6-7 total, every 1 to 2 weeks with 1 to 2 weeks to submit.
  - You'll be given **4 late days for the semester** (budget your days wisely!).
  - Deliverables will be reports **in Latex** (or else, for 80% of the grade), starting from Lab 2.  
Suggestion: Use [Overleaf](#) for starting off with Latex (more on it in our website).
  - (*Tentative*) Students will pair-up in each lab. *I may change this strategy later.*
- **Exams** **(30 %)**:
  - Two exams (15% each), on October/4th and November/20th. *Dates may change, if needed.*
- **Final Project** **(30 %)**:
  - **Theme**: anything that deep learning as a solver **or** a review of two or more papers with code.
  - **Deliverables**: a proposal (due by **October/20th**), code and presentation. **Teams**: 2-4 people.
  - (*Tentative*) The 2nd to last week of the semester will be just for project work, **no classes!**
- **Participation** **(10 %)**:
  - Includes attendance and participation in class.

# Final thoughts

- **What counts as participation?**
  - **Asking** and **answering** questions in class (very important!)
  - Actively participating in in-class activities.
  - Attending office hours.
  - Sending me emails with questions, etc.
  - Basically, if I can see that you are actively making effort to learn the content.
- The lectures will be primarily **in person**, but I can live stream them if *any student* (even if just one) needs it (just let me know a few hours before it).
- The all of this info (as a PDF) is on our **Syllabus**.
  - **Make sure to read it! It is our rule book here.**
  - The website also has this data.

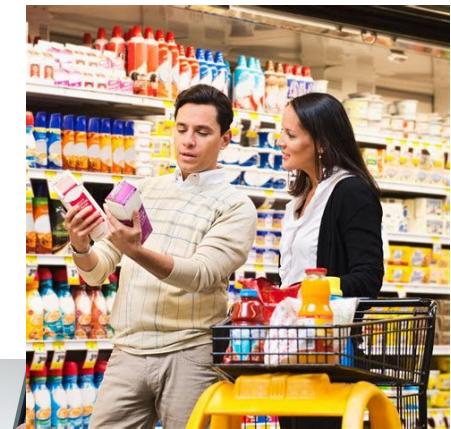
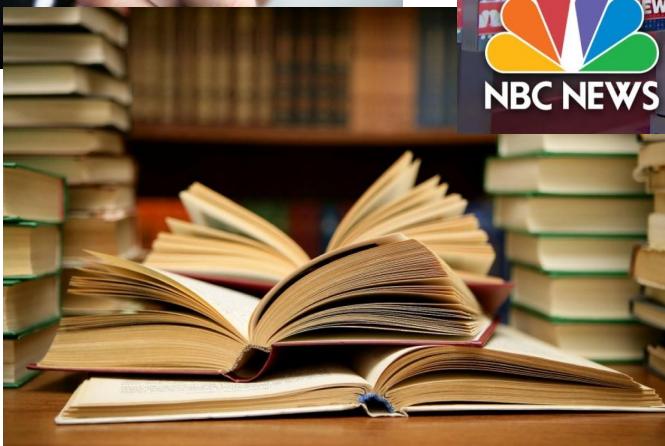
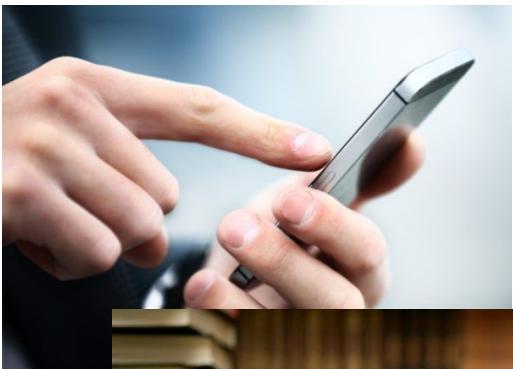


# Some little good news

- **My wife is expecting!** Her due date is Nov/1st.
- For the lectures scheduled around the due date, we may either:
  - (*Most likely*) Have them online.
  - (*Likely*) Reschedule them by shifting all courses “forward” one lecture, therefore using the dates from the “free” week reserved for the final project. These classes will then be “extra”/not covered in our 2nd exam.
  - (*Unlikely*) Shift lectures and cancel the last ones. In this case, I’ll make myself available to teach them outside of lecture hours to those who are interested.
- We’ll play it by ear as things develop.

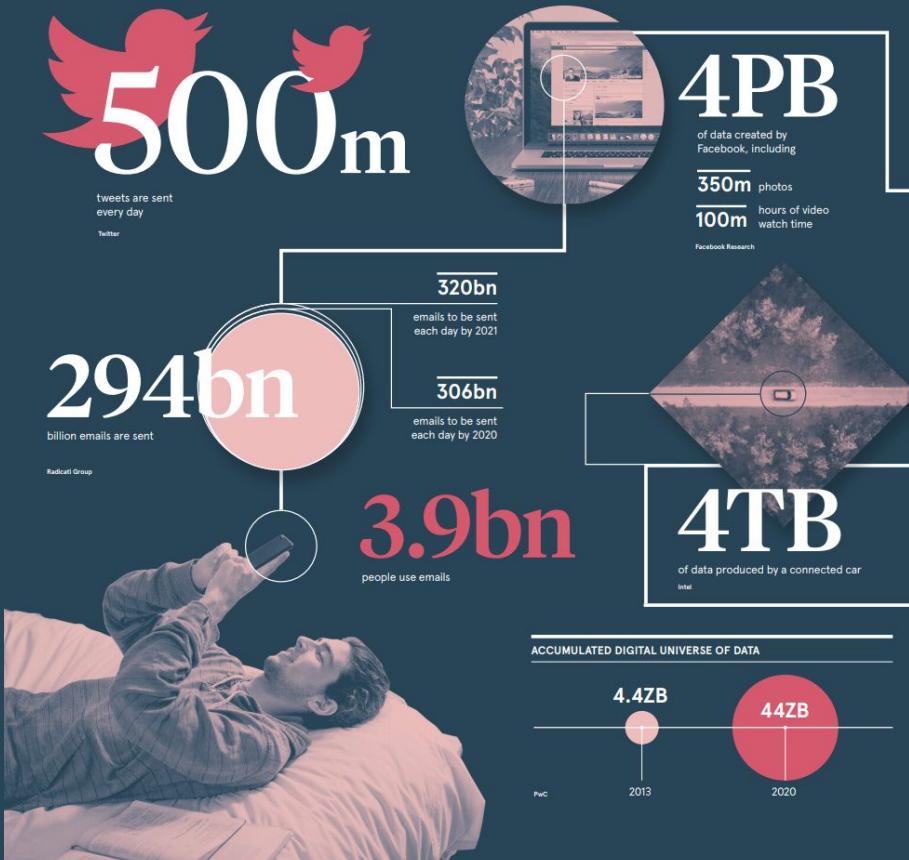


# *Let's get started:* Data and the modern world



# A DAY IN DATA

The exponential growth of data is undisputed, but the numbers behind this explosion – fuelled by internet of things and the use of connected devices – are hard to comprehend, particularly when looked at in the context of one day

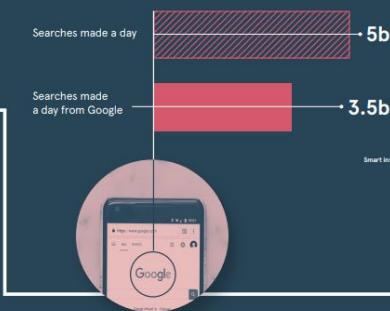


## DEMYSTIFYING DATA UNITS

From the more familiar ‘bit’ or ‘megabyte’, larger units of measurement are more frequently being used to explain the masses of data

Unit	Value	Size
b	0 or 1	1/8 of a byte
B	byte	1 byte
KB	kilobyte	1,000 bytes
MB	megabyte	1,000 <sup>3</sup> bytes
GB	gigabyte	1,000 <sup>6</sup> bytes
TB	terabyte	1,000 <sup>12</sup> bytes
PB	petabyte	1,000 <sup>15</sup> bytes
EB	exabyte	1,000 <sup>18</sup> bytes
ZB	zettabyte	1,000 <sup>21</sup> bytes
YB	yottabyte	1,000 <sup>24</sup> bytes

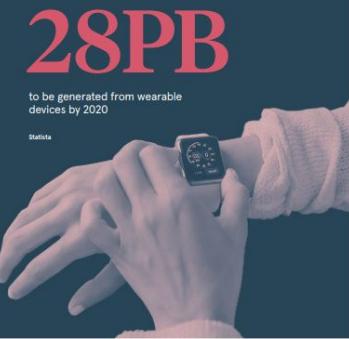
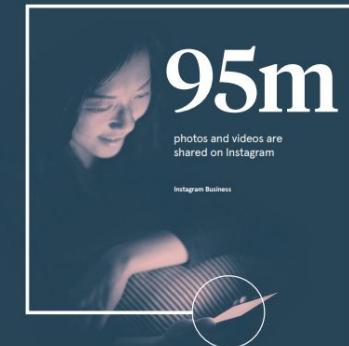
\*A lowercase “b” is used as an abbreviation for bits, while an uppercase “B” represents bytes.



# 463EB

of data will be created every day by 2025

idc



# The richest data

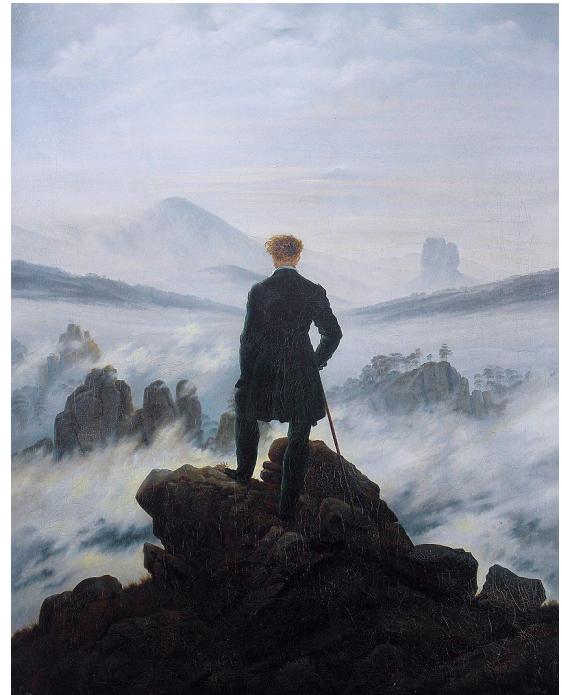
- Arguably, the visual data (image and videos) is the **richest** among all types of data!
- In a simple image, we have so much information:



1. A couple is drinking wine during the day.
2. The man has a beard, long hair and is wearing a white shirt.
3. The woman also has long hair and is wearing a typical French cap.
4. They seem in love with each other.

*What else?*

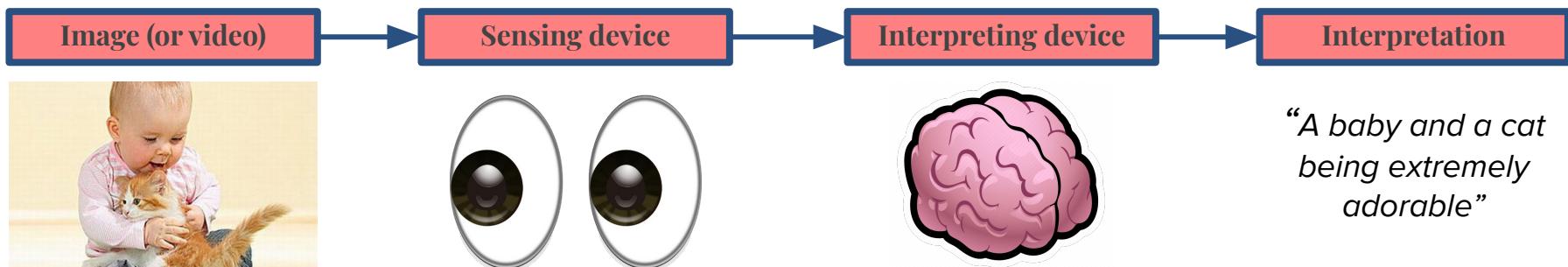
- The visual data is so rich that, we perceive **up to 80%** of all impressions by means of our sight.
- **The vision system is our main door to the world!**



Caspar David Friedrich's [Wanderer above the Sea of Fog](#) (1817)

# (Oversimplified) Vision pipeline

- In simple terms, our visual system proceeds as following when it sees an image:



- And it works very well: on average, we only need 150ms to detect whether there is an animal in a picture!

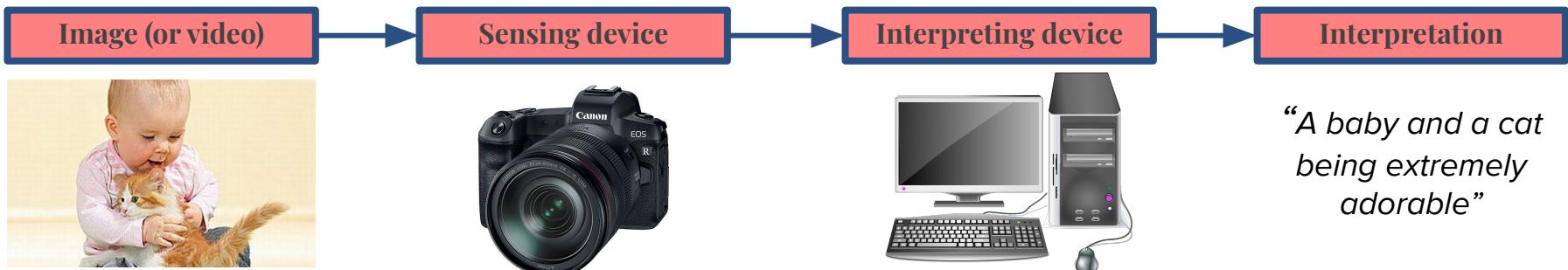


# Computer Vision

- As Computer Scientists, we aim to do Computer Vision:

Computer Vision (CV) is the study of how computers can gain high-level understanding from **visual data**, such as images and videos.

- Here, we seek to **understand and automate** tasks proper to the human visual system.
- **Our desire pipeline is:**



- Computer Vision is then about **finding the right algorithms** for the interpreting device.

# Easy peasy

- At first, Computer Vision seems like an easy problem to solve: “we *humans do it so easily since we were children*”!
- It seemed so easy that its study started with an MIT undergraduate **summer project** in 1966.
- The goal was very modest: find a model that rightly mimics our visual system.
- Unfortunately (or fortunately!) vision is a much harder problem to solve, and one summer wasn’t enough time.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
PROJECT MAC

Artificial Intelligence Group  
Vision Memo. No. 100.

July 7, 1966

## THE SUMMER VISION PROJECT

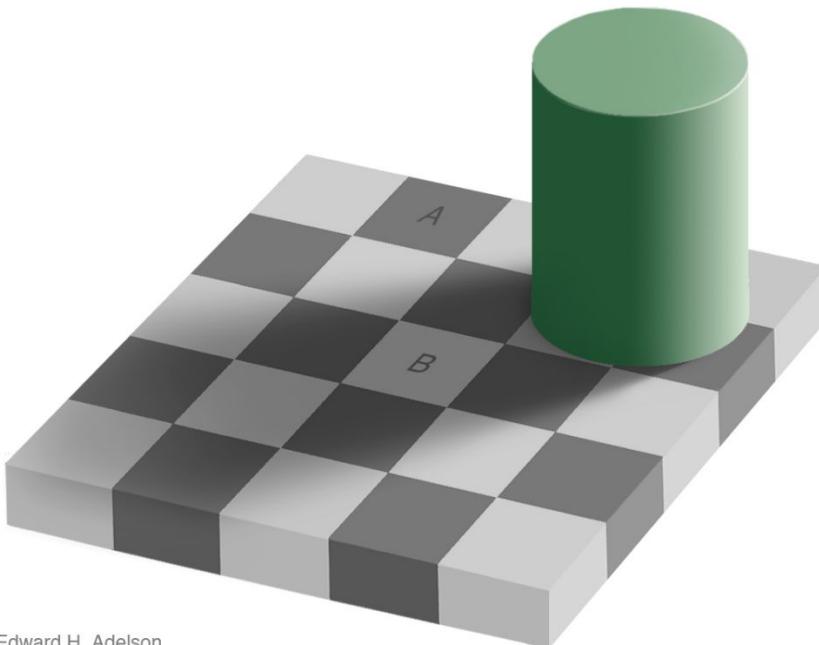
Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system.

The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".

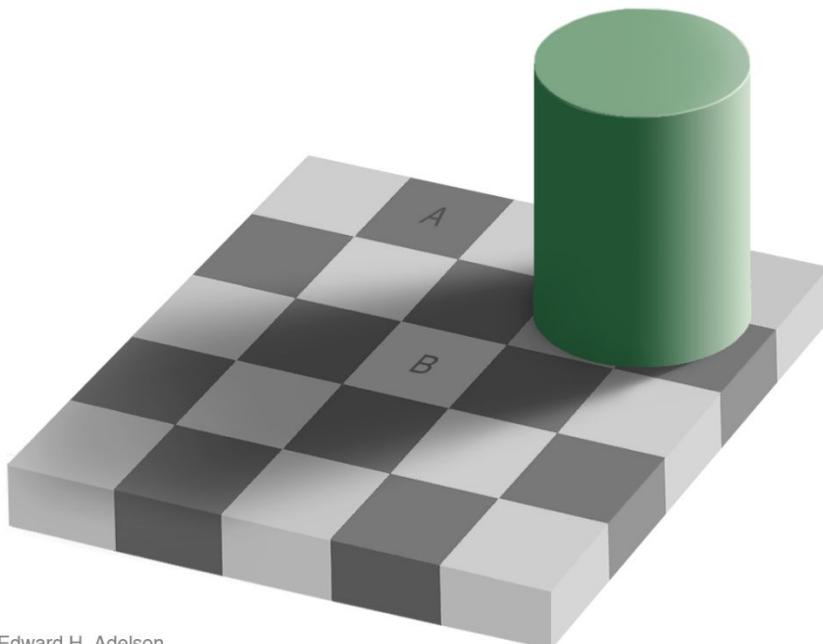
# Example of why vision is complicated

- Which region is darker in the image below, A or B?

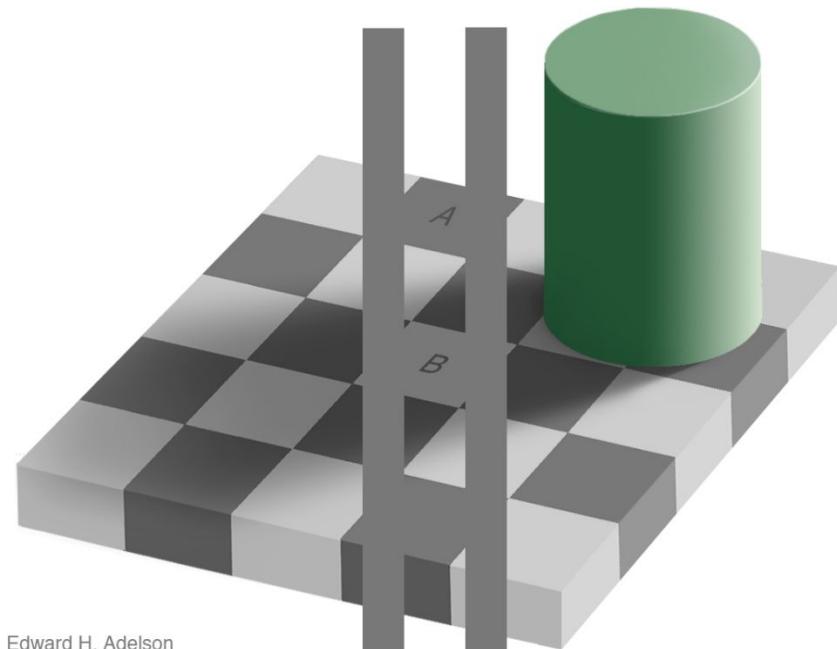


# Example of why vision is complicated

- Believe it or not, but A and B are of the same shade of gray!



Edward H. Adelson



Edward H. Adelson

# Exercise (*In pairs*)

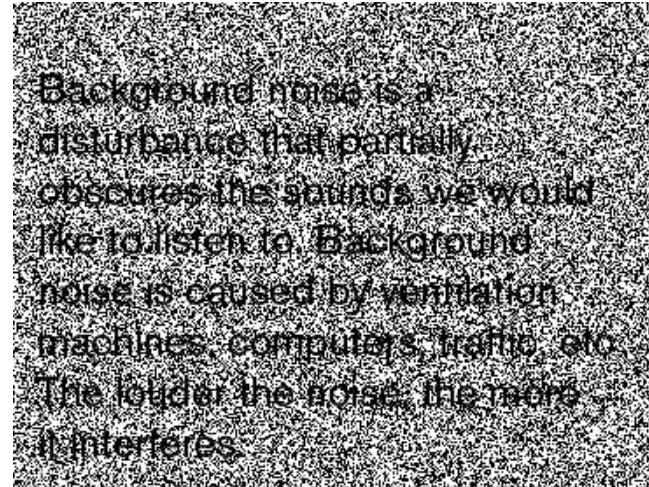
- Answer the questions for the following images:



How many objects are there in this image?



Which object is the largest? What color is the sky?



What is written in the above image?

# Why vision is complicated

- Computer Vision is hard for many reasons, like:
  - **Our visual system is limited in some tasks:**
    - Our vision is prone to illusions that lead to misinterpretation of certain phenomena.
    - That raises the question of whether we want to necessarily mimic it using CV.
  - **Many vision problems are ambiguous:**
    - There is usually not an objective solution for some problems, as they may depend on human subjective reasoning.
    - That makes the modeling of those problems harder.
  - **Images remove important aspects of the observed scene:**
    - Usually the distance from the camera to the objects is unavailable, making the distance between the objects in a scene wrong.
    - Also, some color information may not match to what the real scene's colors are.
  - **The sensing device is imperfect, and the images are noisy:**
    - It is usually impossible to capture a real world scene without adding noise to it.

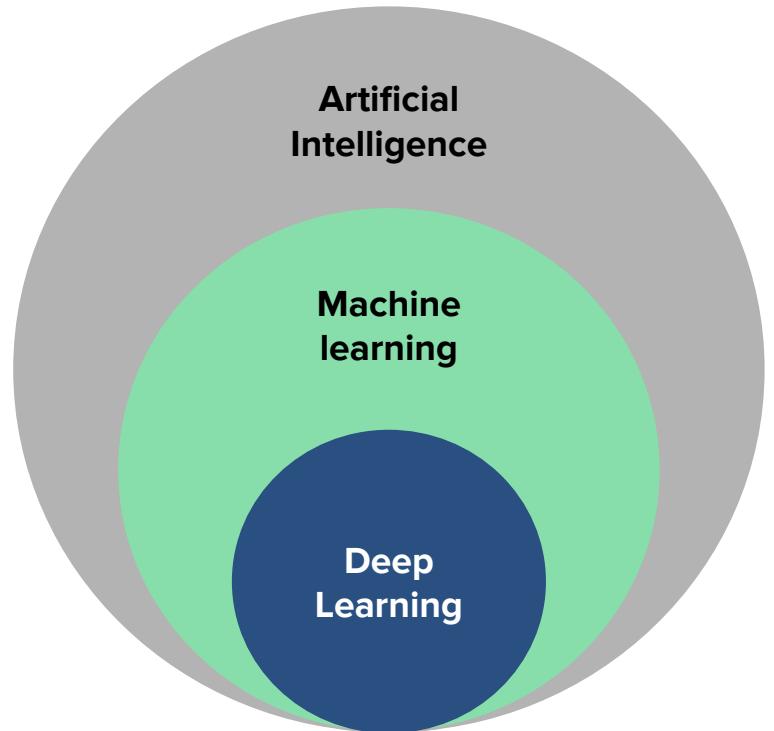
# Why is Computer Vision so Important Now

- Despite these issues, technology is progressed at an exponential pace and computer vision solutions found numerous applications in modern society.
- This is due to the following factors:
  - **Computing Power:** Hardware designed for computer vision has become cheaper, faster, better and easily accessible.
  - **Big Data:** Availability of large training data sets due to mobile technology with built-in cameras saturating the world with photos and videos
  - **Open Source:** Availability of new algorithmic frameworks that can take advantage of hardware and software capabilities



# Deep Learning and Computer Vision

- Largely, the great success of Computer Vision is due to recent use of **Deep Learning** as an “algorithmic framework” (the interpreting device).
- Based on Neural Networks, it a **supervised learning model** inspired by the way the brain propagates information.
- It was initially mainly used for image classification, it has been extended to **regression** and even **unsupervised tasks**.
- In fact, it has been extended to solve problems way beyond Computer Vision!



# Deep Learning in the news

## Deep learning helps predict traffic crashes before they happen

A deep model was trained on historical crash data, road maps, satellite imagery, and GPS to enable high-resolution crash maps that could lead to safer roads.

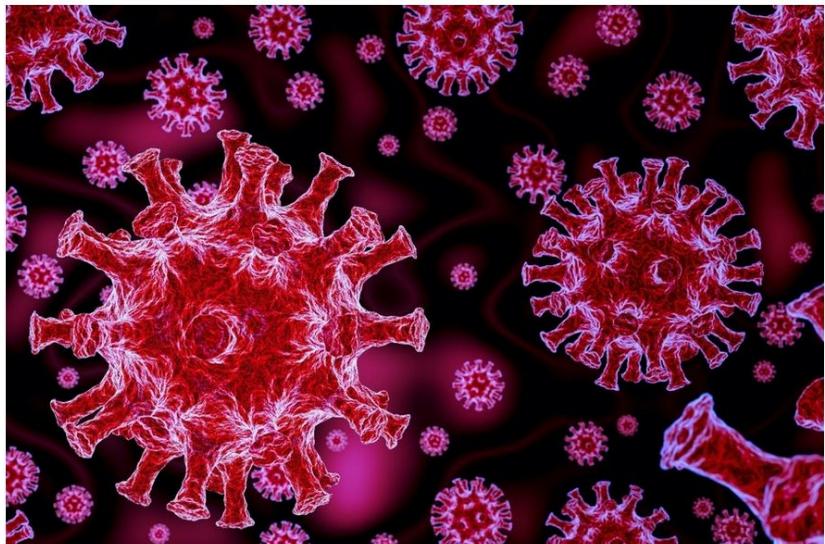
Rachel Gordon | MIT CSAIL  
October 12, 2021



## Deep learning helps predict new drug combinations to fight Covid-19

Neural network identifies synergistic drug blends for treating viruses like SARS-CoV-2.

Rachel Gordon | MIT CSAIL  
September 24, 2021



# Deep Learning in the news

## Deep learning of quantum entanglement from incomplete measurements

DOMINIK KOUTNÝ , LAIA GINÉS , MAGDALENA MOCZAŁA-DUSANOWSKA , SVEN HÖFLING , CHRISTIAN SCHNEIDER, ANA PREDOJEVIĆ , AND MIROSLAV JEŽEK  [Authors Info & Affiliations](#)

SCIENCE ADVANCES • 19 Jul 2023 • Vol 9, Issue 29 • DOI: 10.1126/sciadv.add7131

**Machine learning refines earthquake detection capabilities**  
New methodology enables the detection of ground deformation automatically at a global scale

Date: November 11, 2021

## Study finds ChatGPT boosts worker productivity for some writing tasks

A new report by MIT researchers highlights the potential of generative AI to help workers with certain writing assignments.

Zach Winn | MIT News Office  
July 14, 2023

 OCTOBER 27, 2021

## Discovering exoplanets using artificial intelligence

by University of Geneva

# How to do Deep Learning

- Over the years, many libraries in Python were implemented for developing applications using deep learning.
- Currently, the most famous ones (both open-sourced) are:

## Tensorflow



**TensorFlow**

- Created in 2015 by Google Brain department (Version 2.0 launched in 2019).
- Steep learning curve.
- Usually used in pair with Keras, an easy interface for it
- Large community, many tutorials.
- Use to be DL's main library.

## Pytorch



**PyTorch**

- Developed in 2016 by Facebook's AI Research lab.
- Based on a library called Torch, written in Lua,
- Highly "Pythonic", easy to learn.
- Gives you more control.
- Small (but growing) community.
- Research preferable library.

- In our course, we'll use **PyTorch**, and we'll have a lecture solely on it.

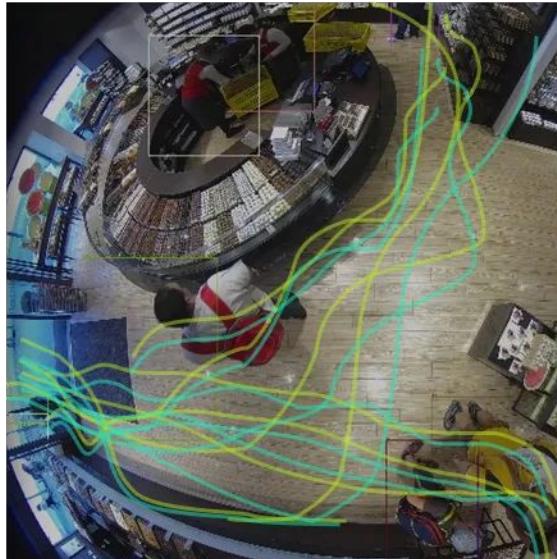
# Applications of Computer Vision

- **Shopping** will never be the same without Computer Vision!

Cashierless Shopping



Customer tracking and Flow



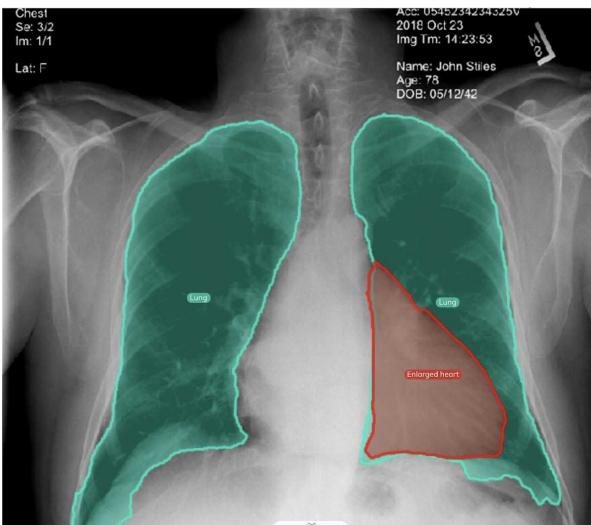
Gaze detection



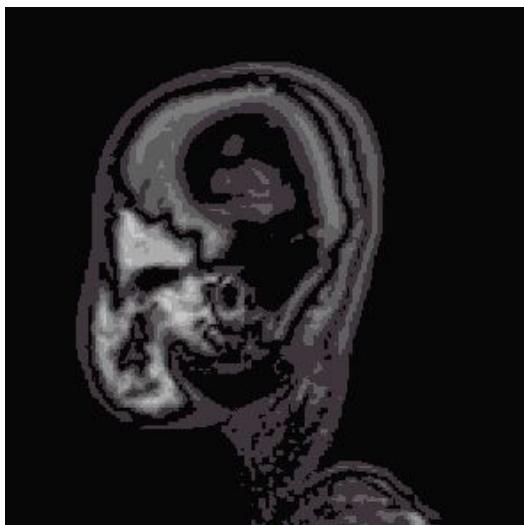
# Applications of Computer Vision

- Without the Computer Vision, **healthcare** professionals would forced to spend hours manually analyzing patient data.

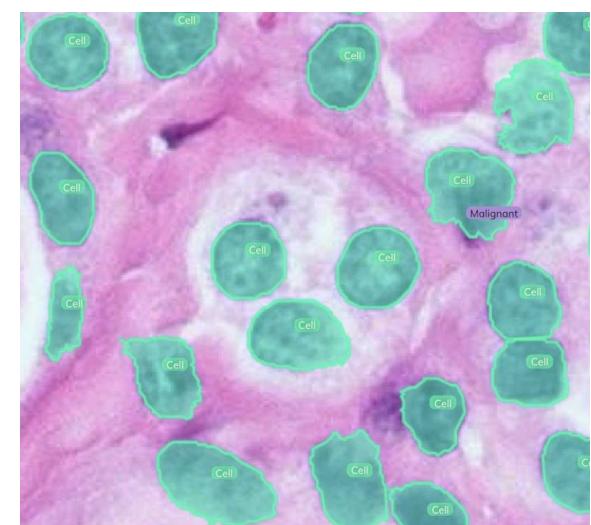
X-Ray image segmentation



MRI understanding



Pathology detection



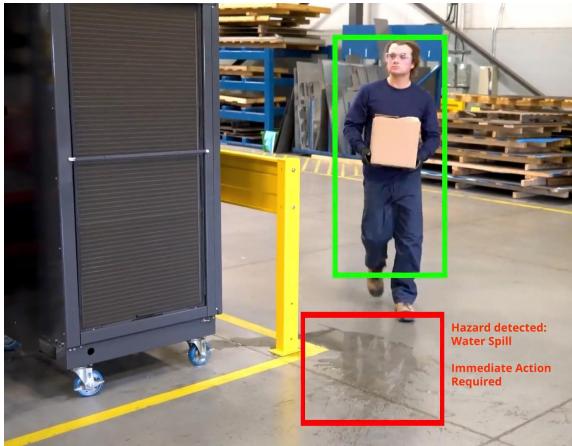
# Applications of Computer Vision

- Computer vision enables many possibilities in **security and surveillance!**

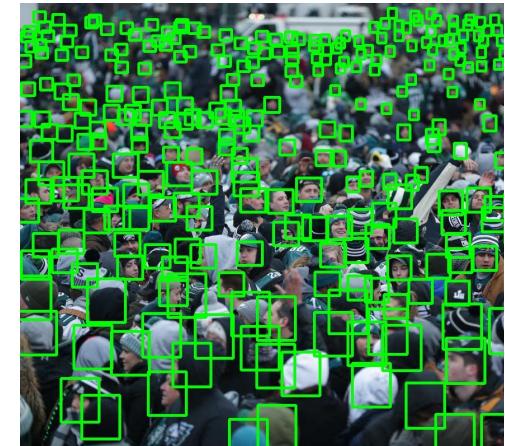
Face Recognition



Hazard Detection



Crowd Counting/Control



- Good news for public safety: helping police and first responders more easily spot crimes and accidents.

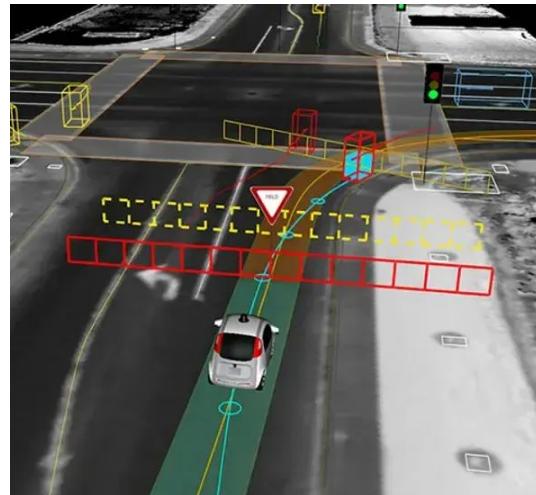
# Applications of Computer Vision

- The future of **self-driving cars** depends on Computer Vision:

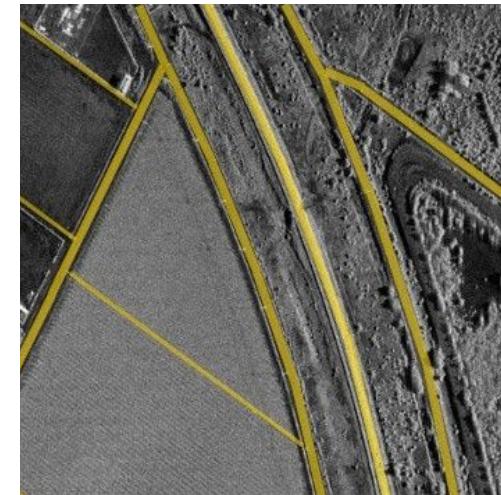
## Car and pedestrian detection



## Trajectory Planning



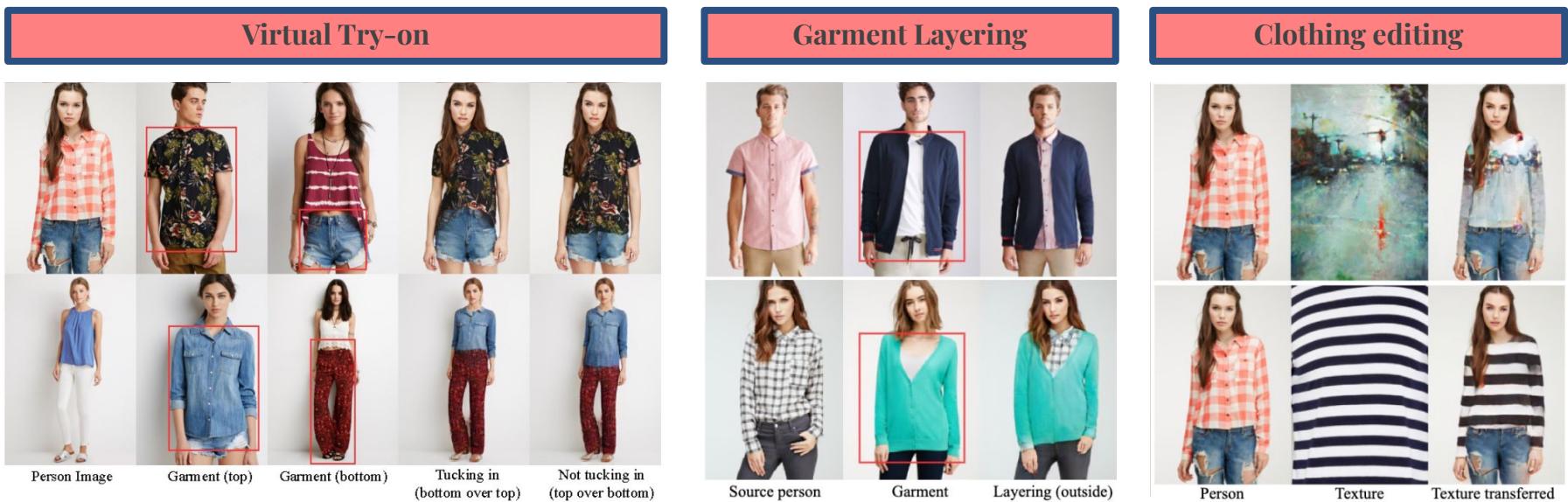
## Road Detection



- And this all is already implemented on Tesla cars.

# Applications of Computer Vision

- Also, many applications in the **fashion** industry:



Source and more: [cuiayu.github.io/dressing-in-order/](http://cuiayu.github.io/dressing-in-order/)

# Applications of Computer Vision

- And it has overflowed the **digital art** industry recently!

Style Transfer

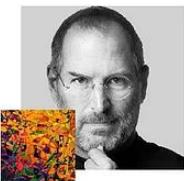


Image Generation by Prompt

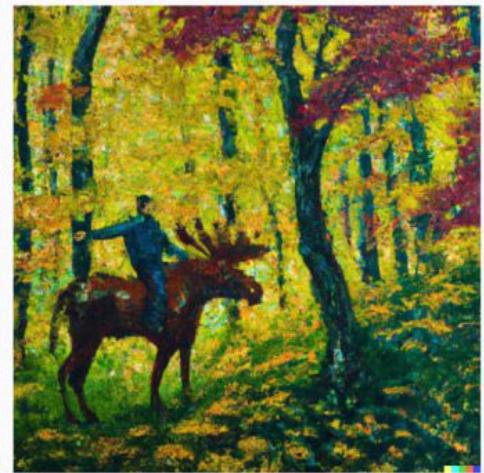
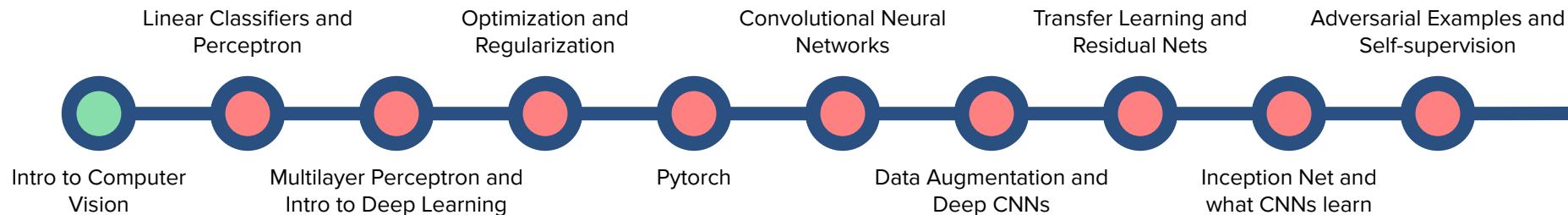


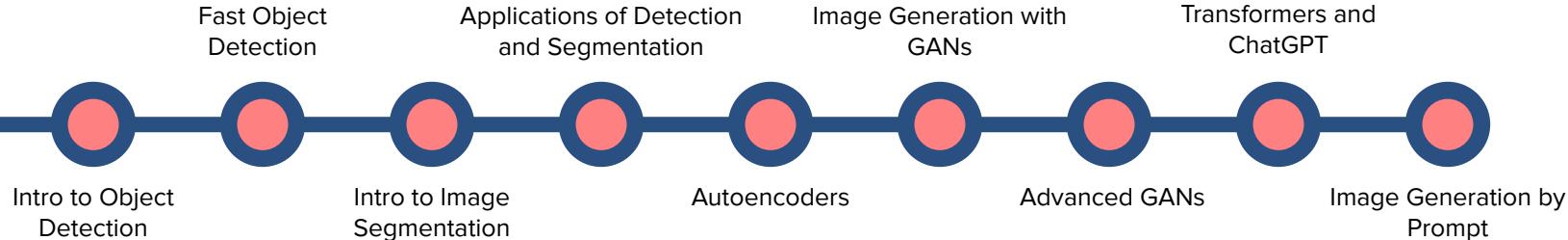
Image generated with the prompt: "an impressionist oil painting of a Canadian man riding a moose through a forest of maple trees"

# (Tentative) Lecture Roadmap

## Basics of Deep Learning



## Computer Vision Tasks



# *Video: The Deep Learning Revolution*

