High-Level Computer Vision
SS 2024

Tutorial 1

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Max Planck Institute for Informatics, Saarland Informatics Campus

April 14, 2025

Outline

- **Tutorial Organization**
- Assignment 1 Discussion
- Python Tutorial

TAs

Amin Parchami

Nhi Pham

Mostafa Abdelgawad

Sophia Wiedmann

Contacting TAs

Online:

- For questions of general interest (e.g. about assignments): Forum
  - https://cms.sic.saarland/hlcvss25/forum/
  - Ask in the appropriate topic forum
- For other questions: E-mail
  - hlcv-ss25@mpi-inf.mpg.de
  - Visible to all TAs
  - **Please avoid emailing us individually!**

In-Person:

- During Tutorials: Mondays 10:15 AM - 12:00 PM, **E1.5 002**
- Office Hours: Tuesdays 10:00 AM - 11:00 AM, **E1.4 629**

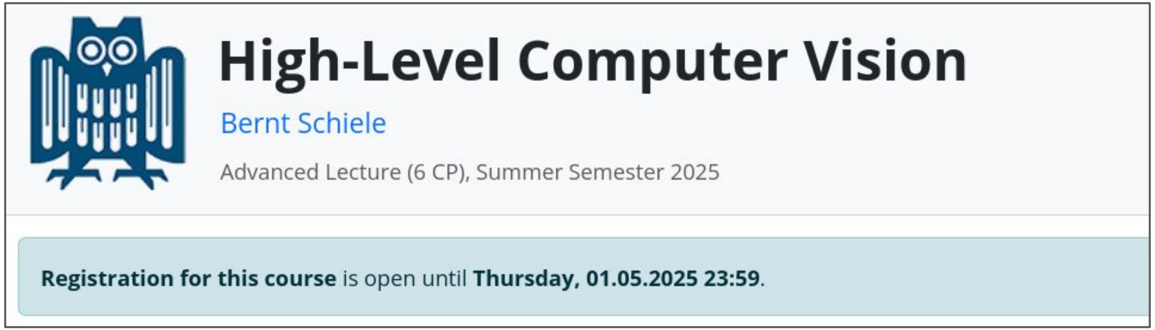
Tutorials

- On Mondays 10:15 AM - 12:00 PM, at **E1.5 002**
- For:
  - Discussing assignment problems
  - Introductions to tools useful for the course (e.g. PyTorch)
  - Answering questions
  - Help with assignments

- Agenda for each tutorial will be announced in the CMS

- Not held every week (will be announced in the CMS each week)

Course Page: CMS



High-Level Computer Vision

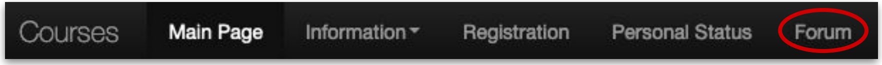
Bernt Schiele

Advanced Lecture (6 CP), Summer Semester 2025

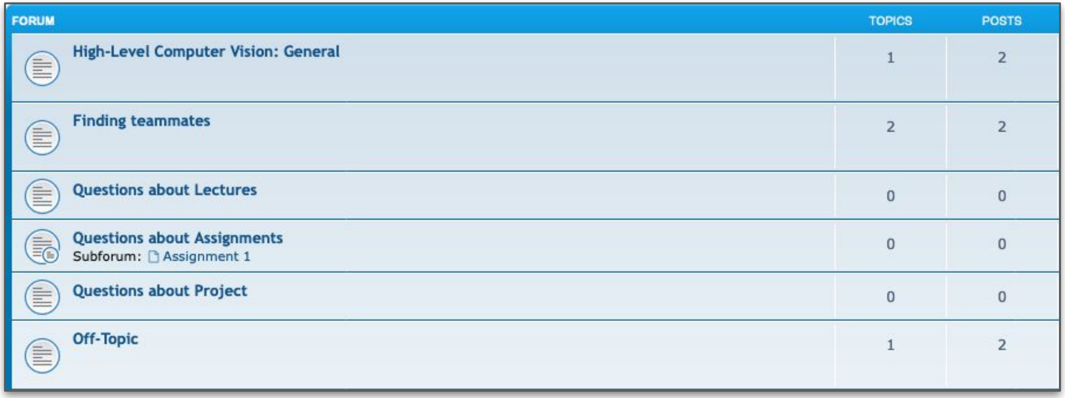
Registration for this course is open until **Thursday, 01.05.2025 23:59**.

- Register at https://cms.sic.saarland/hlcvss25 by **May 1st, 2025**
- For:
  - Announcements
  - Course Materials (e.g. slides, project instructions, old lecture videos)
  - Some submissions
  - User-specific information (e.g. access tokens for servers, exam time slots)

For Questions and Discussion: Forum

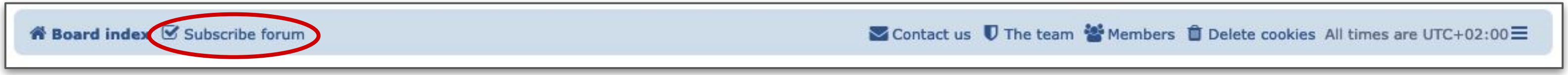


- Ask questions in the appropriate forum
- Separate subforum for each assignment



FORUM	TOPICS	POSTS
High-Level Computer Vision: General	1	2
Finding teammates	2	2
Questions about Lectures	0	0
Questions about Assignments Subforum: Assignment 1	0	0
Questions about Project	0	0
Off-Topic	1	2

- If you want notifications (optional):



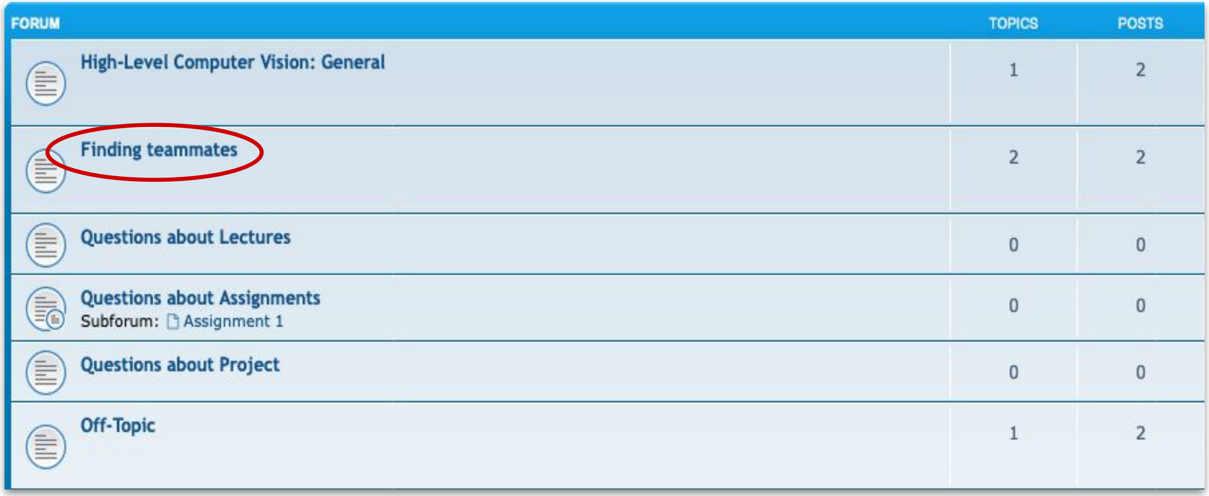
Overview of Evaluation

- Three mandatory assignments:
  - ***First:*** basic feature extraction, object identification, and image classification
- Final Project (in-person presentation + short report)
- Written Exam

- >50% on assignments and project mandatory to participate in the exam.
- Up to 1 grade improvement if you do well on (Assignment+Project)

Assignments

- Usually published on Mondays
- Deadline usually in 2 weeks
- To be submitted in teams of two
- Can use the forum to find teammates:



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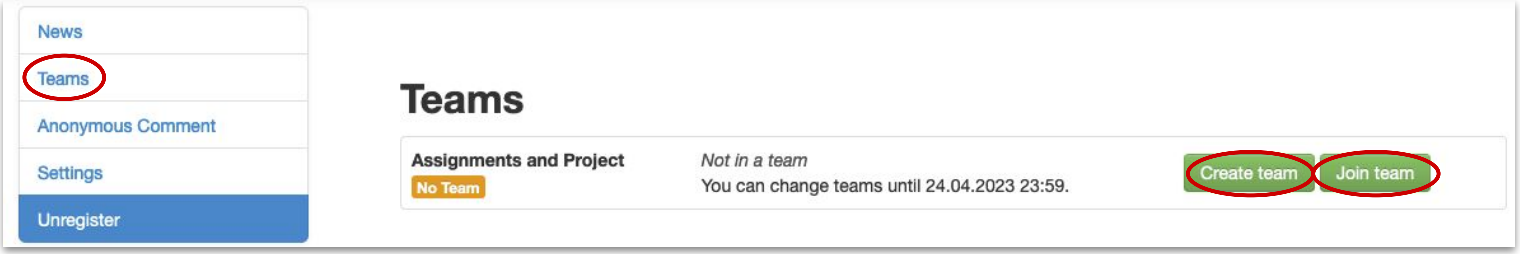
Off-Topic	1	2

Registering teams in CMS

Deadline: May 1st, 2024

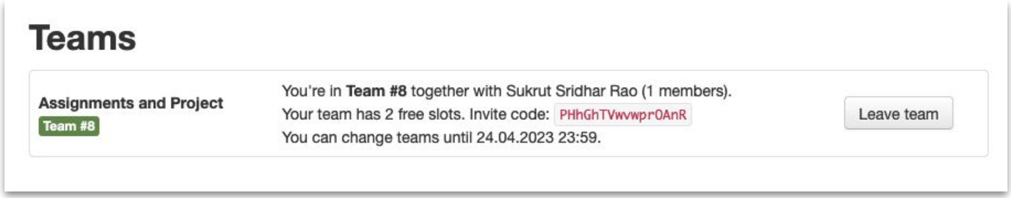


Teams

Assignments and Project
No Team

Not in a team
You can change teams until 24.04.2023 23:59.

1. Creating a team:

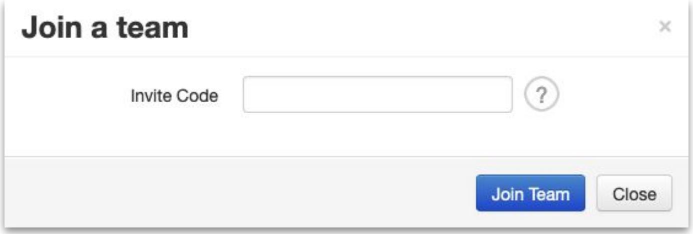


Teams

Assignments and Project
Team #8

You're in **Team #8** together with Sukrut Sridhar Rao (1 members).
Your team has 2 free slots. Invite code: `PHhGhTVwvwprOAnR`
You can change teams until 24.04.2023 23:59.

2. Joining a team:



Join a team

Invite Code

Projects

- Structure:
  - Proposal
  - Final presentation: 15-min talk
  - Final report: 4-5 pages
- Time: ~1-1.5 months
- After the assignments
- Topic can be as per your choice. You'll receive feedback on the Proposal

Sample Projects

- Age Recognition
- Other recognition tasks....
- Image retrieval for 3D objects
- Object retrieval in videos, on a mobile phone
- Person re-identification
- Image and video segmentation
- Detection and segmentation
- Domain Adaptation
- Explainability and Interpretability
- Image generation tasks (GANs, conditional generation, style transfer)

Computing Resources (GPUs)

- Access to university GPU servers will be provided
  - One account per team
  - Likely starting from Assignment 3

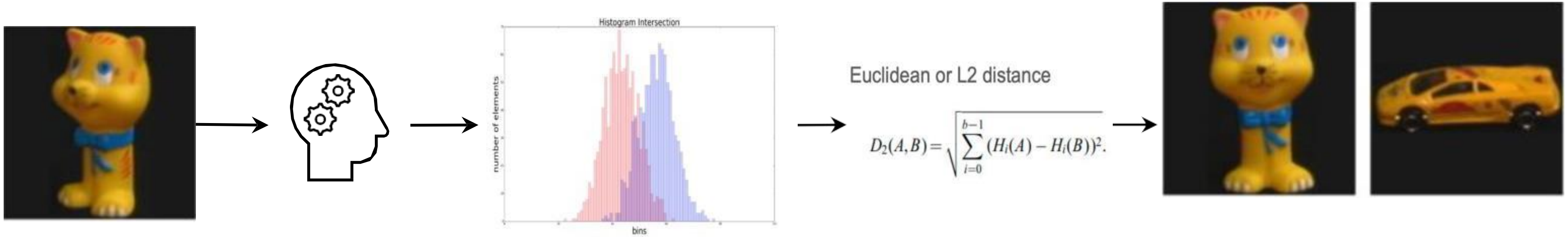
Additional options:

- Google Colab (https://colab.research.google.com/)
- Your own resources (e.g. personal laptop)

Outline

- Course Organization
- **Assignment 1 Discussion**
- Python Tutorial

Assignment 1



Euclidean or L2 distance

$$D_2(A,B)=\sqrt{\sum_{i=0}^{b-1}(H_i(A)-H_i(B))^2}.$$

Feature Engineering ***Distance Metrics***

Assignment 1

Goal: getting familiar with Python & doing small and easy image processing tasks

Part 1

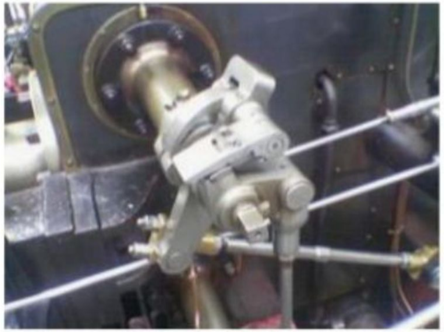
- Q1: Image filtering
- Q2: Image representations and histogram distances
- Q3: Object identification
- Q4: Performance evaluation

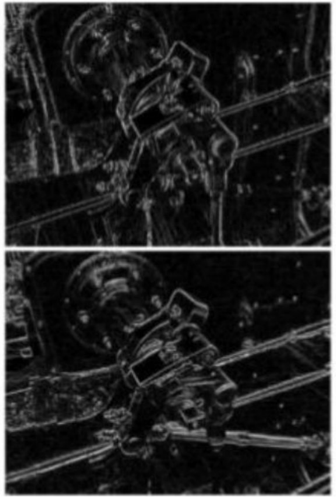
Part 2

- Image classification

Q1: Image filtering

Goal: implementing an edge detector using the derivative of the Gaussian filter

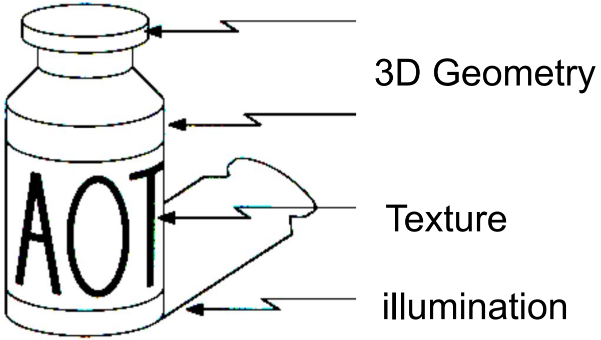




Edges along the x axis

Edges along the y axis

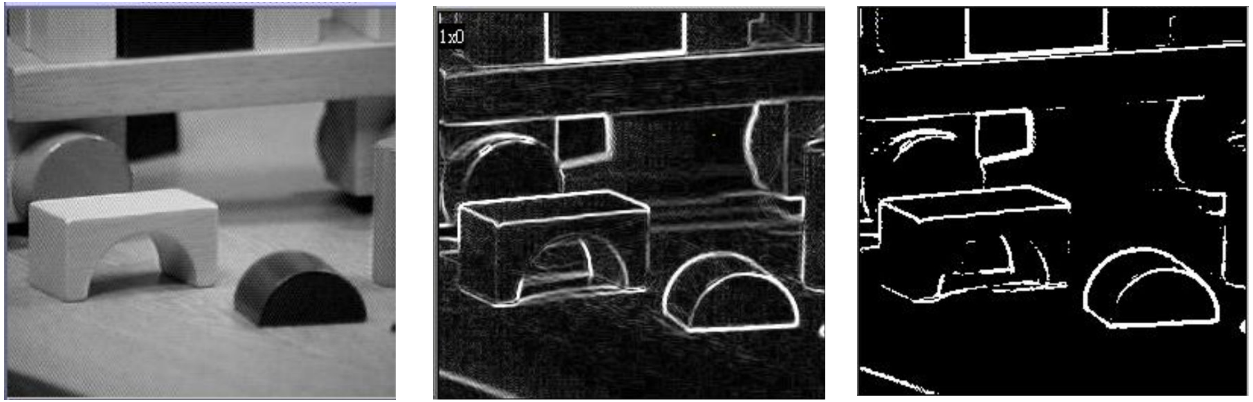
Q1-Detour: Why Edges?



3D Geometry

Texture

illumination

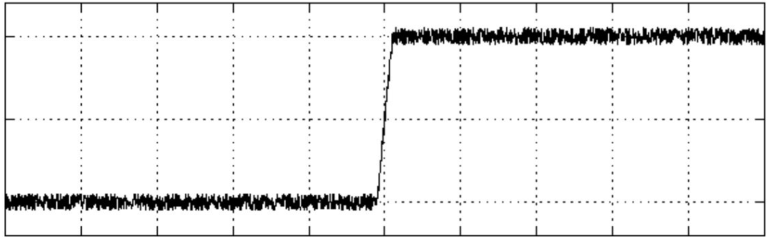


Seem to cover *interesting* locations

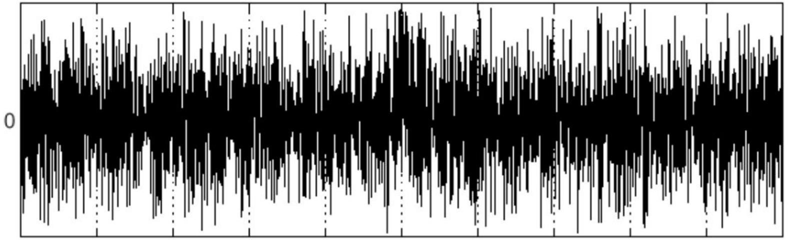
Images taken from Udacity slides.

Q1-Detour: One Problem: Noise!

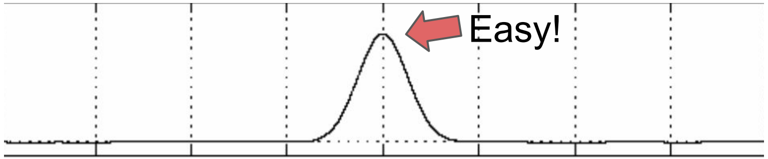
Original input



Derivative



Where’s the edge !?



Wish it was like this!

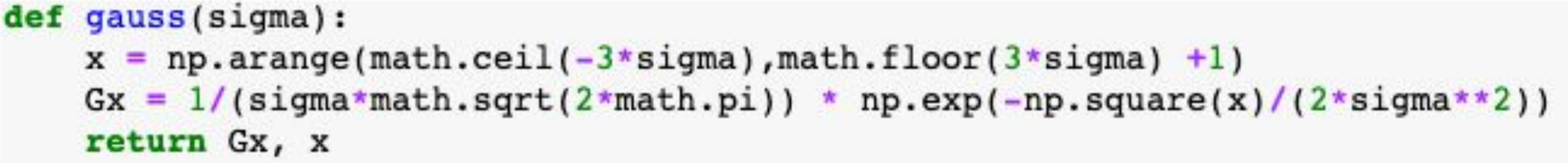
Images taken from Udacity slides.

Q1.1: 1D Gaussian distribution

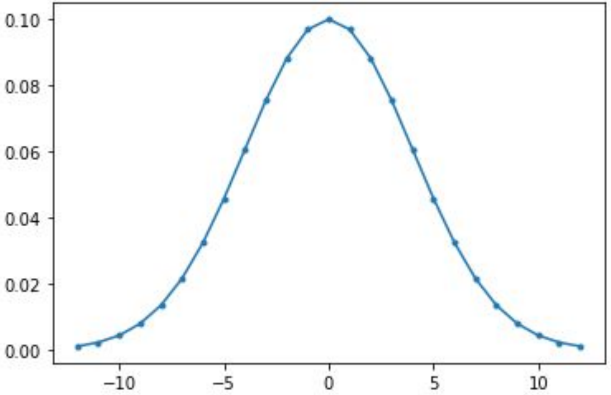
Q1.1 Implement a method that computes the values of a 1-D Gaussian for a given variance σ^2. The method should also give a vector of values on which the Gaussian filter is defined: integer values on the interval $[-3\sigma, 3\sigma]$.

$$G = \frac{1}{\sqrt{2\pi\sigma}}\exp(-\frac{x^2}{2\sigma^2}).$$

mean = 0



```
def gauss(sigma):
    x = np.arange(math.ceil(-3*sigma),math.floor(3*sigma) +1)
    Gx = 1/(sigma*math.sqrt(2*math.pi)) * np.exp(-np.square(x)/(2*sigma**2))
    return Gx, x
```



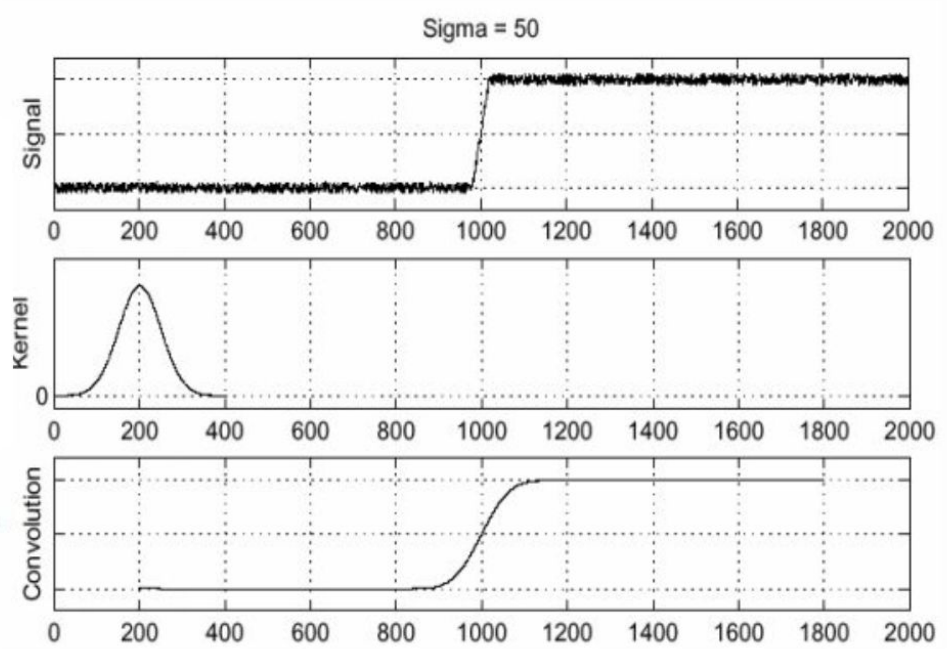
Q1.2: 2D Gaussian filtering

Convolution operation (1D)

Convolution: $G = H * F$

$$G[i,j] = \sum_{u=-k}^{k} \sum_{v=-k}^{k} \boxed{H[u,v]} F[i-u, j-v]$$

Kernel



Q1.2: 2D Gaussian filtering

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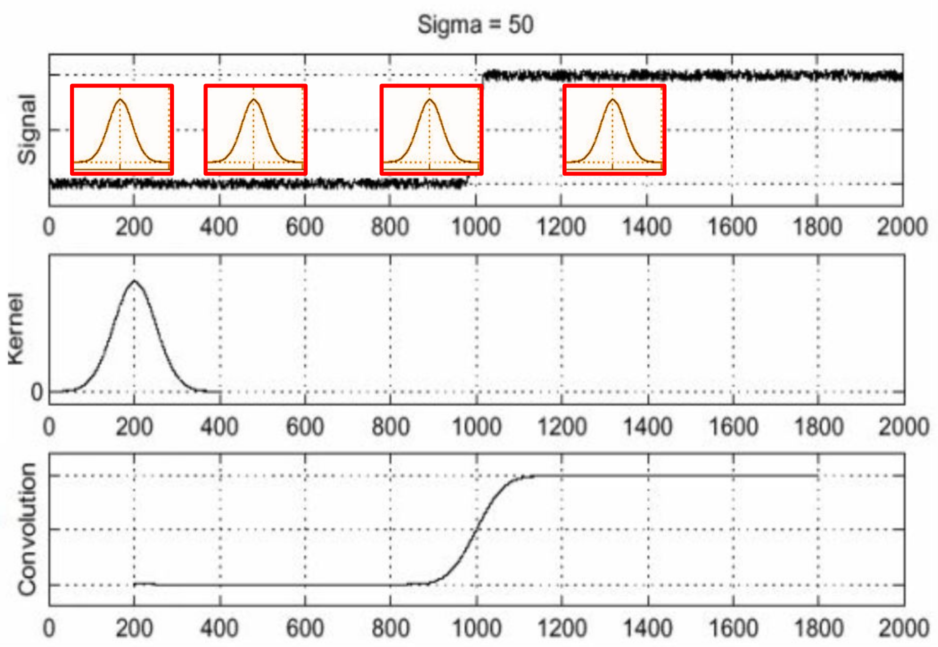
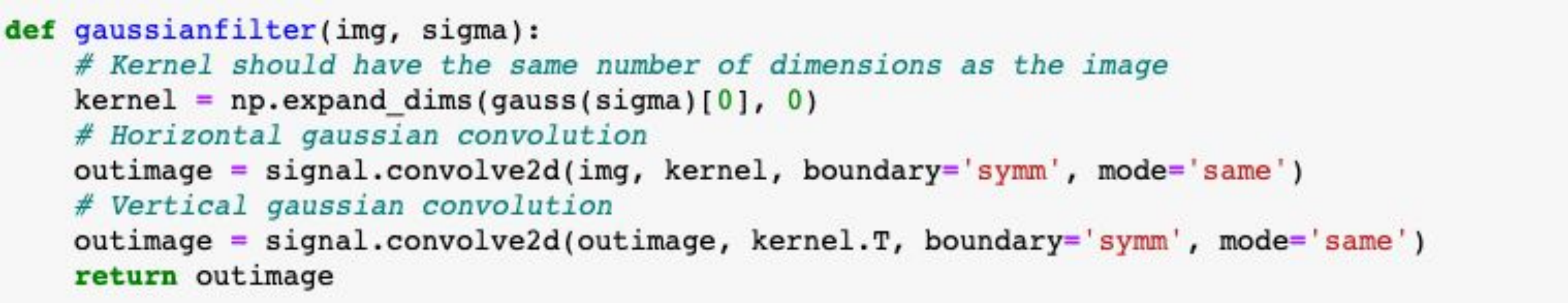


Q1.2: 2D Gaussian filtering

Separability of the Gaussian filter

$$\begin{aligned} G_\sigma(x, y) &= \frac{1}{2\pi\sigma^2} \exp^{-\frac{x^2 + y^2}{2\sigma^2}} \\ &= \left(\frac{1}{\sqrt{2\pi}\sigma} \exp^{-\frac{x^2}{2\sigma^2}} \right) \left(\frac{1}{\sqrt{2\pi}\sigma} \exp^{-\frac{y^2}{2\sigma^2}} \right) \end{aligned}$$

Q1.2: 2D Gaussian filtering



```python
def gaussianfilter(img, sigma):
    # Kernel should have the same number of dimensions as the image
    kernel = np.expand_dims(gauss(sigma)[0], 0)
    # Horizontal gaussian convolution
    outimage = signal.convolve2d(img, kernel, boundary='symm', mode='same')
    # Vertical gaussian convolution
    outimage = signal.convolve2d(outimage, kernel.T, boundary='symm', mode='same')
    return outimage
```

So we’ve got a pipeline!

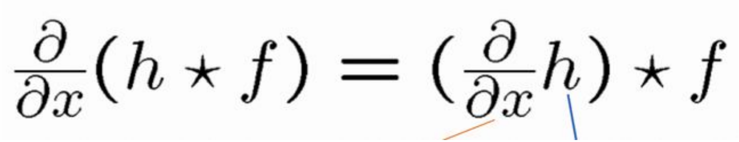
The smoothing operator (i.e what we just implemented!)

$$\frac{\partial}{\partial x}(h \star f)$$

The derivative (i.e edge-finding operator)

-1/2	0	+1/2

So we’ve got a pipeline!

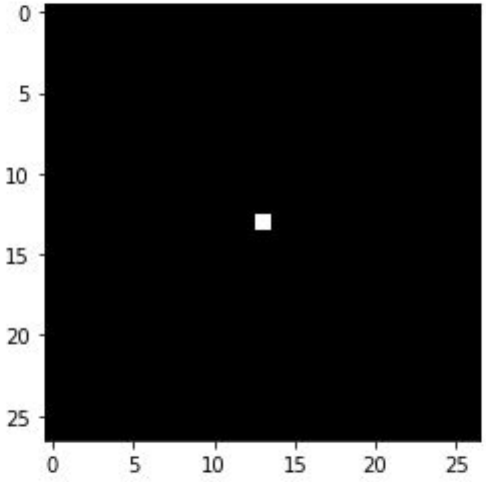


$$\frac{\partial}{\partial x}(h \star f) = (\frac{\partial}{\partial x}h) \star f$$

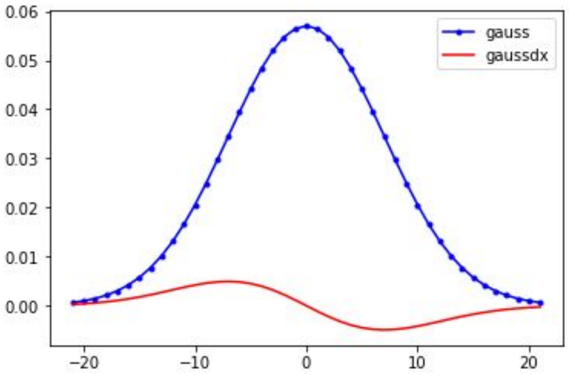
Due to **associativity of convolution,** we can take derivative of the Gaussian kernel and apply convolution on image (time consuming) only once with the final kernel.

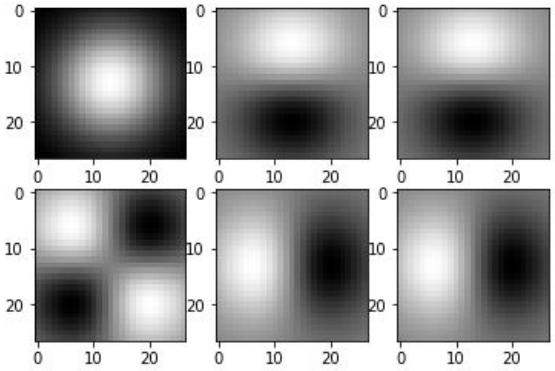
Hence we need, ***derivative of the Gaussian.***

Q1.3: 1D Gaussian derivative



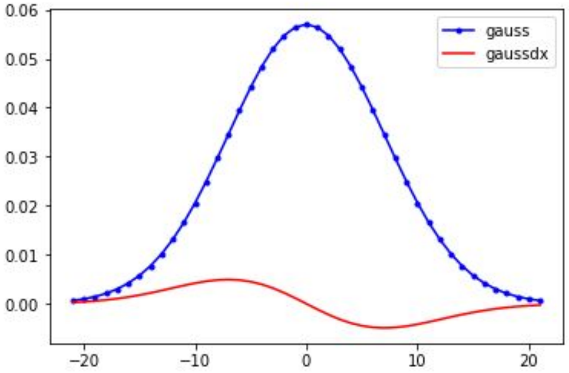
Input signal

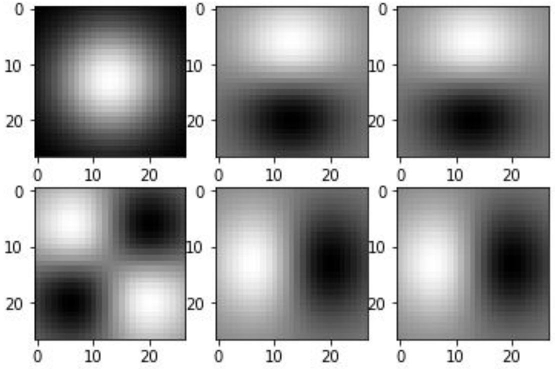




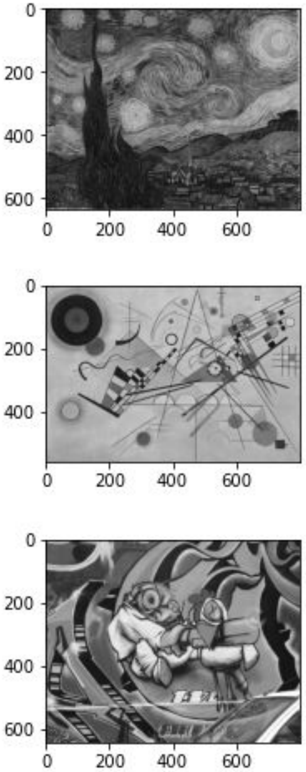
Q1.3: 1D Gaussian derivative

Convolving this kernel is same as smoothing first and then taking the derivative

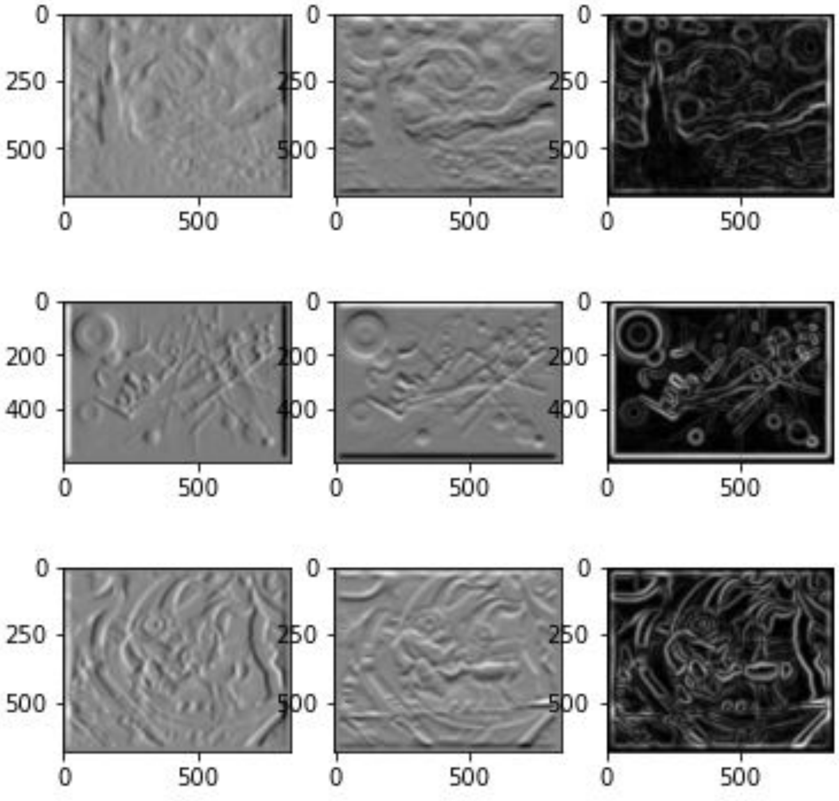




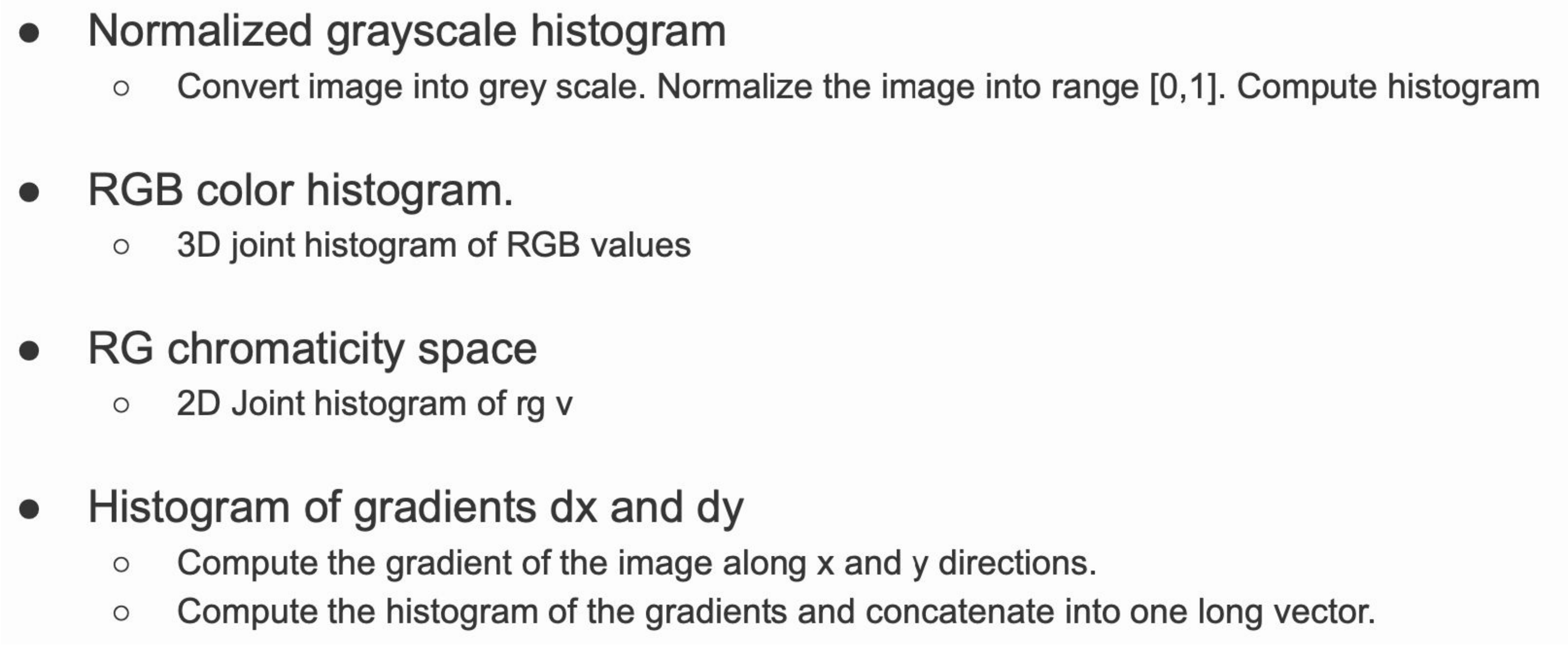
Q1.4: 2D Gaussian derivative



Apply the kernel



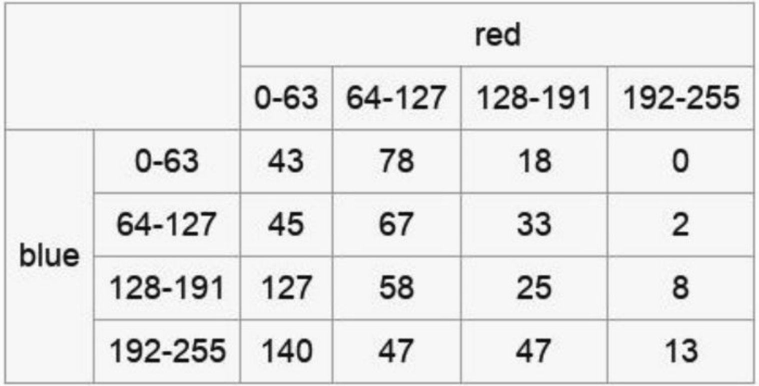
Q2: Image representations and histogram distances



- Normalized grayscale histogram
  - Convert image into grey scale. Normalize the image into range [0,1]. Compute histogram
- RGB color histogram.
  - 3D joint histogram of RGB values
- RG chromaticity space
  - 2D Joint histogram of rg v
- Histogram of gradients dx and dy
  - Compute the gradient of the image along x and y directions.
  - Compute the histogram of the gradients and concatenate into one long vector.

RGB histogram

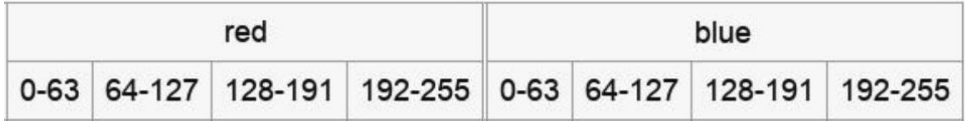
- Compute 3D histogram for RGB color combinations.
- For input **n** bin, discretize each channel into these bin indexes.
- Map bin indexes into **n**^{3} number of bins. Illustration of the process in 2D



		red			
		0-63	64-127	128-191	192-255
blue	0-63	43	78	18	0
	64-127	45	67	33	2
	128-191	127	58	25	8
	192-255	140	47	47	13

RGB histogram

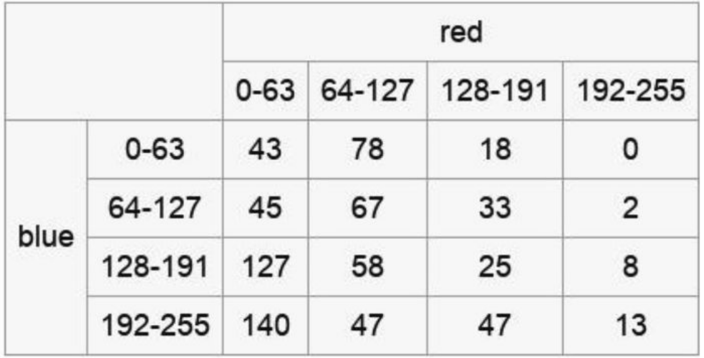
*2*n Histogram*



red				blue			
0-63	64-127	128-191	192-255	0-63	64-127	128-191	192-255

<u>Don’t</u> do this

n^2 Histogram



		red			
		0-63	64-127	128-191	192-255
blue	0-63	43	78	18	0
	64-127	45	67	33	2
	128-191	127	58	25	8
	192-255	140	47	47	13

Do this
(for 3 colors → n^3)

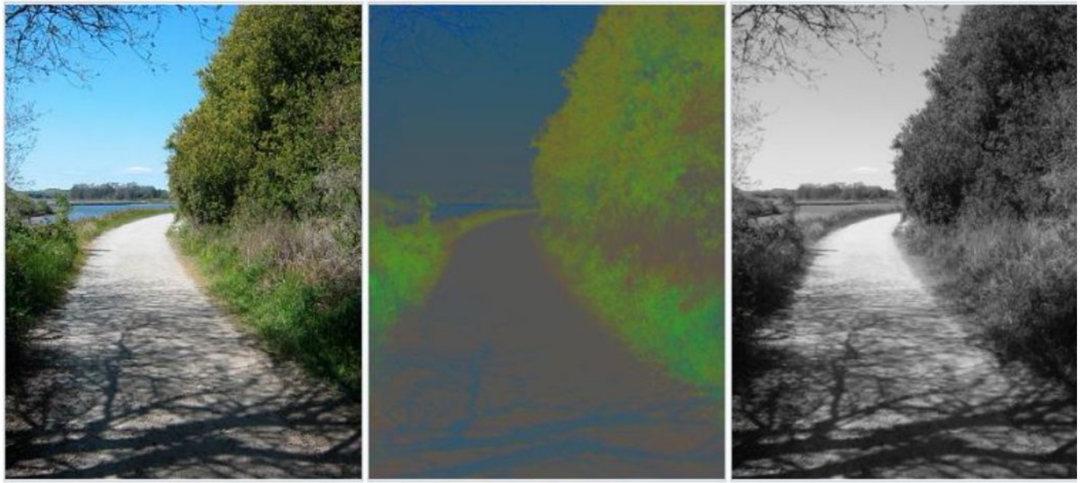
RG histogram- 2D histogram on chromaticity image

$$r = \frac{R}{R+G+B}$$

$$g = \frac{G}{R+G+B}$$

$$b = \frac{B}{R+G+B}$$

$$r+g+b=1$$

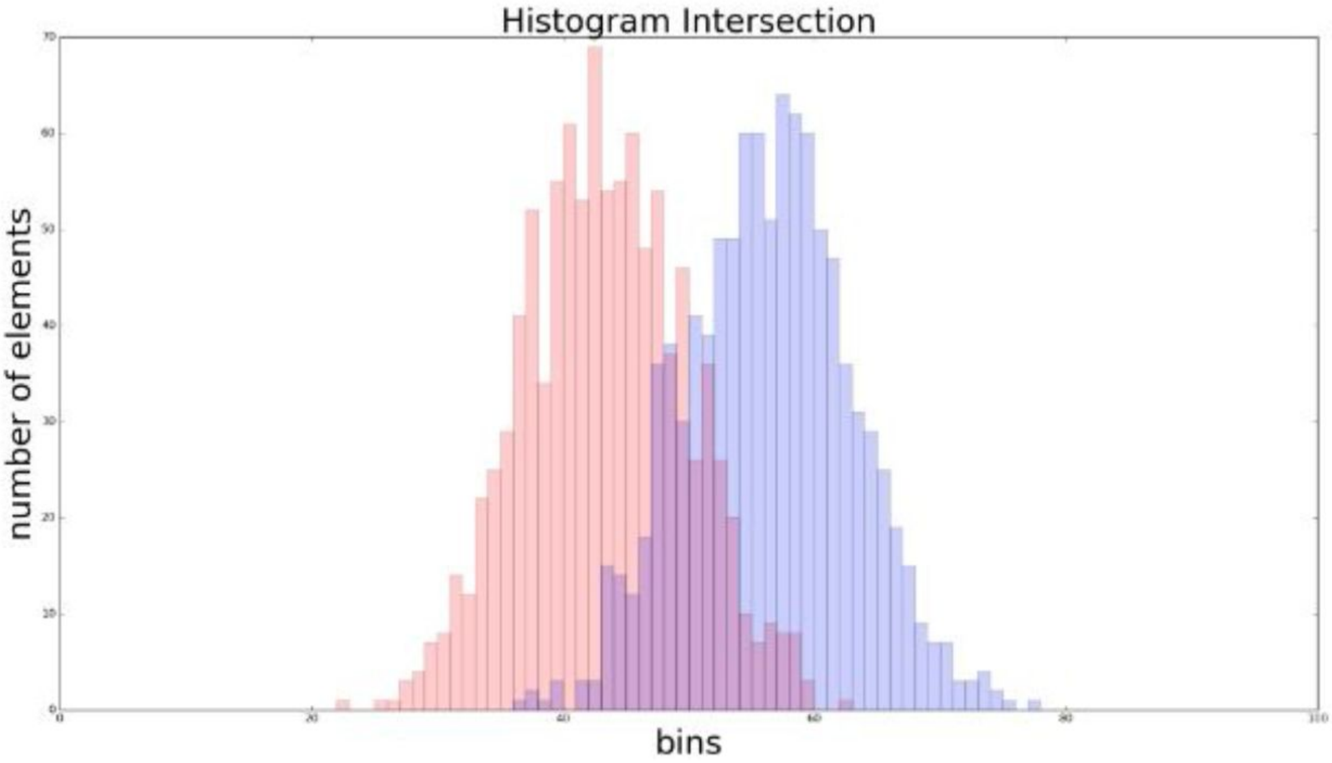


RGB image

rg - chromaticity

greyscale image

Histogram distances



Histogram distances

- City-block or L1 distance

$$D_1(A,B)=\sum_{i=0}^{b-1}|H_i(A)-H_i(B)|.$$

- Euclidean or L2 distance

$$D_2(A,B)=\sqrt{\sum_{i=0}^{b-1}(H_i(A)-H_i(B))^2.}$$

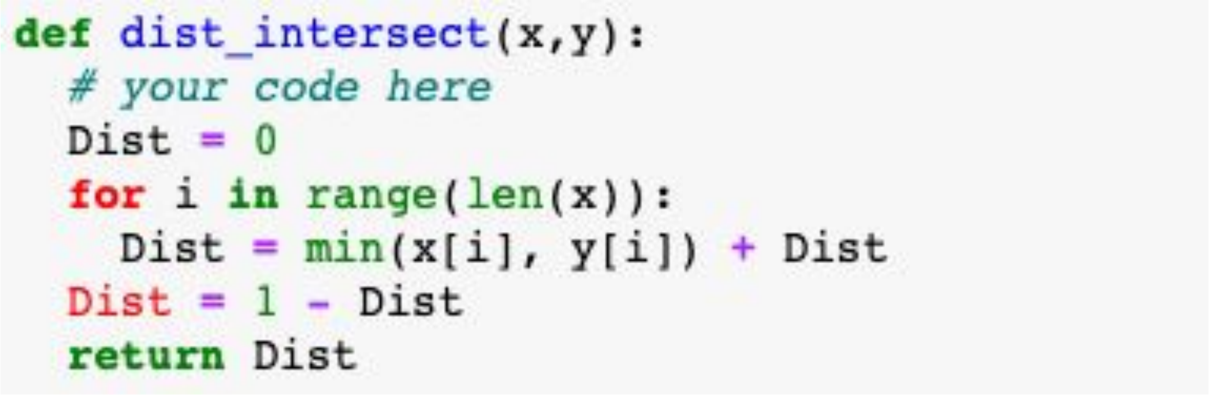
- Intersection distance

$$D_3(A,B)=n-\sum_{i=0}^{b-1}\min(H_i(A),H_i(B)).$$

- Chi -squared distance

$$D_4\,(A,B)=\sum_{i=0}^{b-1}\frac{(H_i(A)-H_i(B))^2}{H_i(A)+H_i(B)}$$

Intersection distance

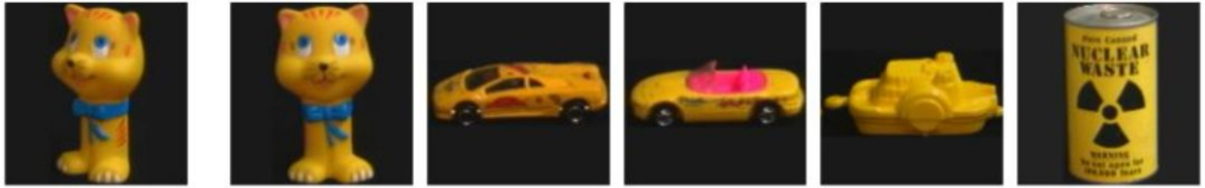


```
def dist_intersect(x,y):
  # your code here
  Dist = 0
  for i in range(len(x)):
    Dist = min(x[i], y[i]) + Dist
  Dist = 1 - Dist
  return Dist
```

Q3: Object identification

- Using this space (in this case the histogram space), one can perform several recognition tasks - e.g. identification.

- In this question you will use various histogram features and metrics from to find the best matching image from the database for a given query image.



(a) (b)

Q4: Performance evaluation

How to compare models?

1. Compare a single number
    a. E.g. Accuracy, top-k Accuracy
    b. *Easy* to Compare, but ***might be misleading*** in some cases ***(e.g ?)***

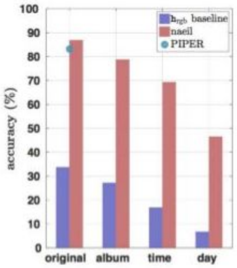


Figure 4. Recognition accuracy across different experimental setups on the test data.

Accuracy (Oh, ICCV'15)

Q4: Performance evaluation

How to compare models?

1. Compare a single number
   a. E.g. Accuracy, top-k Accuracy
   b. ***Easy*** to Compare, but ***might be misleading*** in some cases (e.g imbalanced data)

2. Compare Curves
   a. Precision-Recall curve, ROC curve

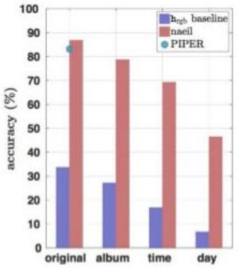
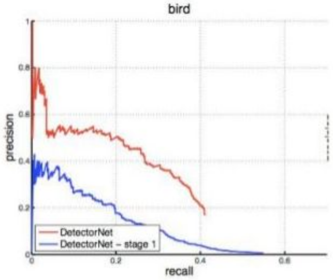
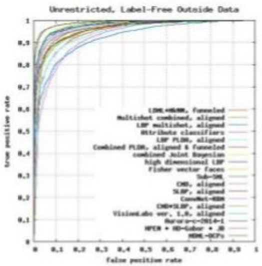


Figure 4. Recognition accuracy across different experimental setups on the test data.

Accuracy (Oh, ICCV'15)

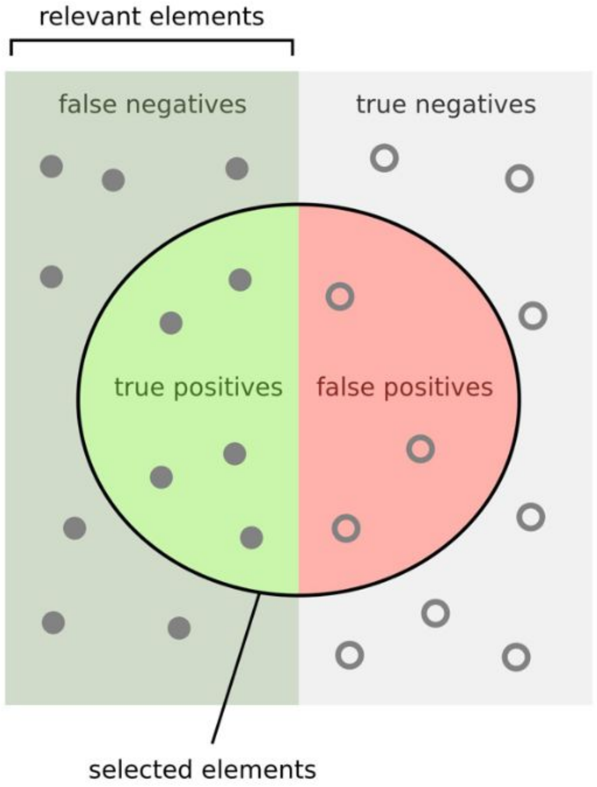


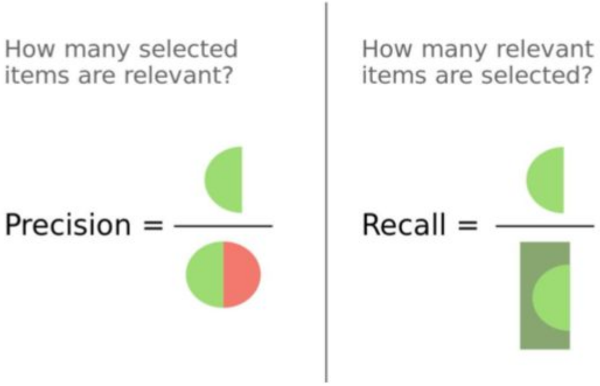
Precision-Recall (Szegedy, NIPS'13)



ROC (LFW Face verification)

Precision and recall

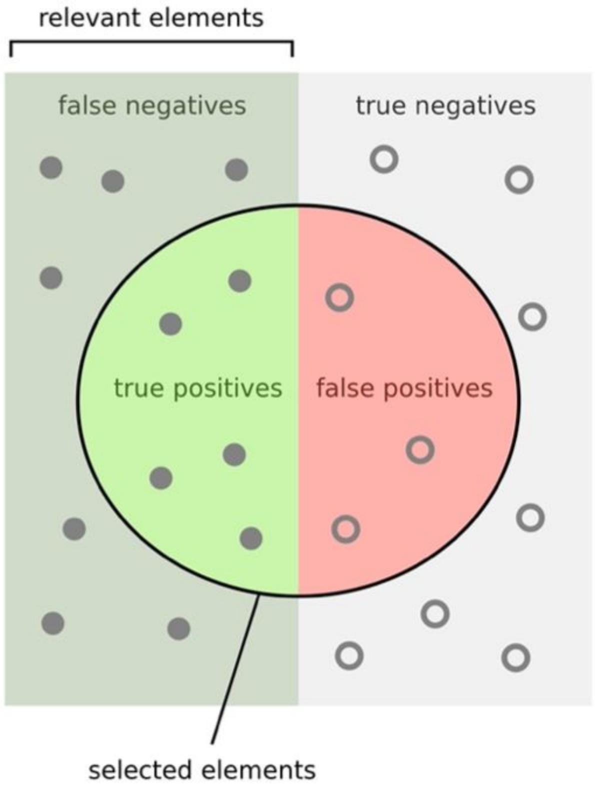



How many selected items are relevant?
Precision =
How many relevant items are selected?
Recall =

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

Accuracy



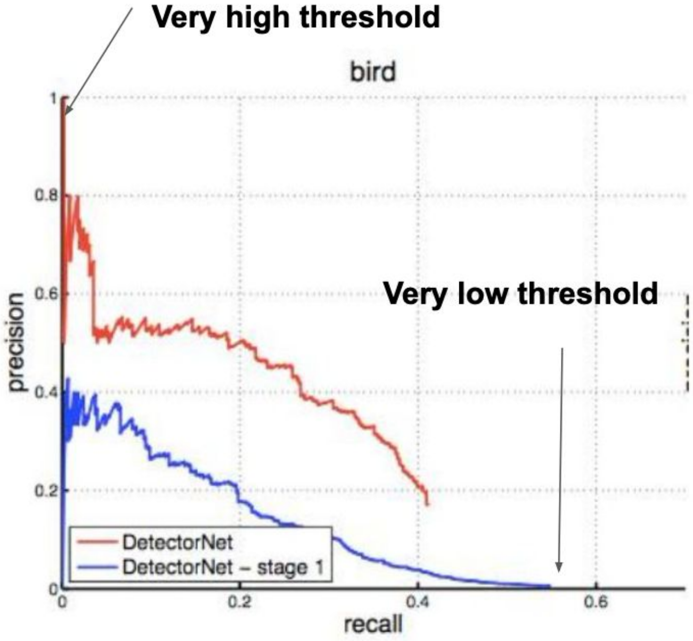
$$\text{Accuracy} = \frac{\text{\#Correct Predictions}}{\text{\#Total Examples}}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

Precision-Recall curve

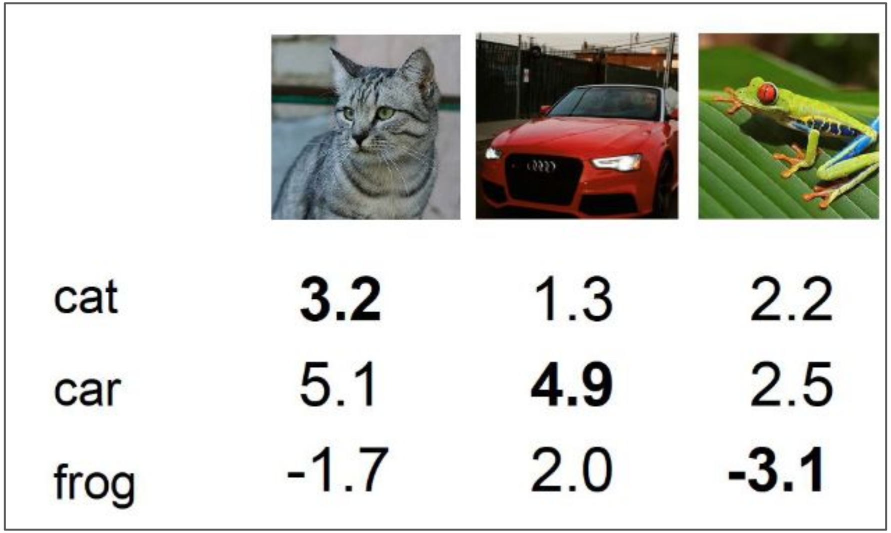
- Usually model output is continuous value. Binary decision is made by thresholding this value P(match|x,y) > **threshold**

- Different thresholds lead to different operating points.
- Precision recall curve allows us to compare models independent of the threshold



One could also try to sum up the plot by computing the Area Under the Curve (AUC), named ***Average Precision*** for the PR curve.

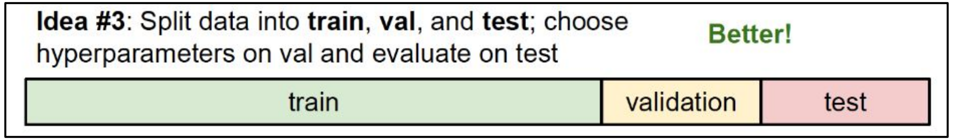
Part 2 - Image Classification



cat	**3.2**	1.3	2.2
car	5.1	**4.9**	2.5
frog	-1.7	2.0	**-3.1**

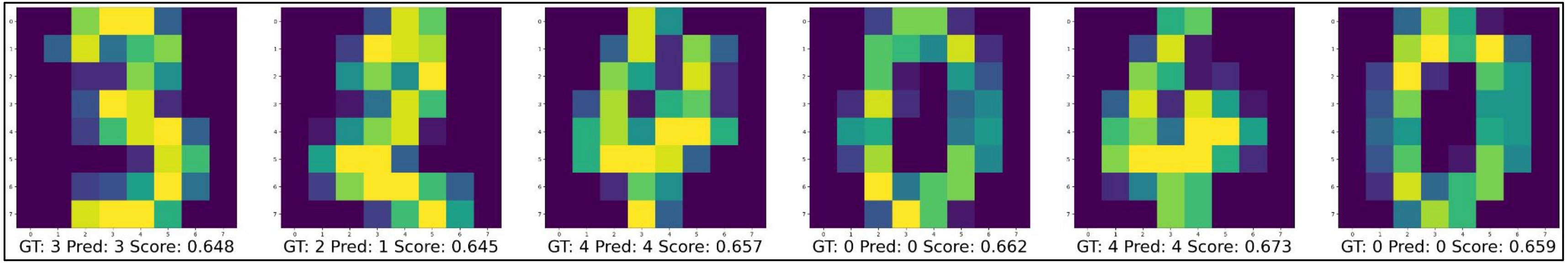
Will be released after Wednesday Lecture :)

Part 2 - Image Classification



Idea #3: Split data into **train**, **val**, and **test**; choose hyperparameters on val and evaluate on test

Better!



GT: 3 Pred: 3 Score: 0.648 GT: 2 Pred: 1 Score: 0.645 GT: 4 Pred: 4 Score: 0.657 GT: 0 Pred: 0 Score: 0.662 GT: 4 Pred: 4 Score: 0.673 GT: 0 Pred: 0 Score: 0.659

Will be released after Wednesday Lecture :)

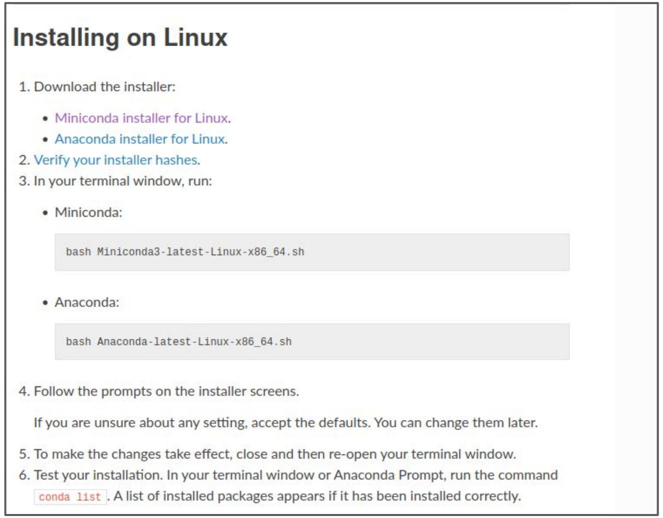
Submission

- Please make sure your notebooks runs out-of-the-box.

Outline

- Course Organization
- Assignment 1 Discussion
- **Python Tutorial**

Install Conda



Installing on Linux

1. Download the installer:
   - Miniconda installer for Linux.
   - Anaconda installer for Linux.
2. Verify your installer hashes.
3. In your terminal window, run:
   - Miniconda:

     ```
     bash Miniconda3-latest-Linux-x86_64.sh
     ```

   - Anaconda:

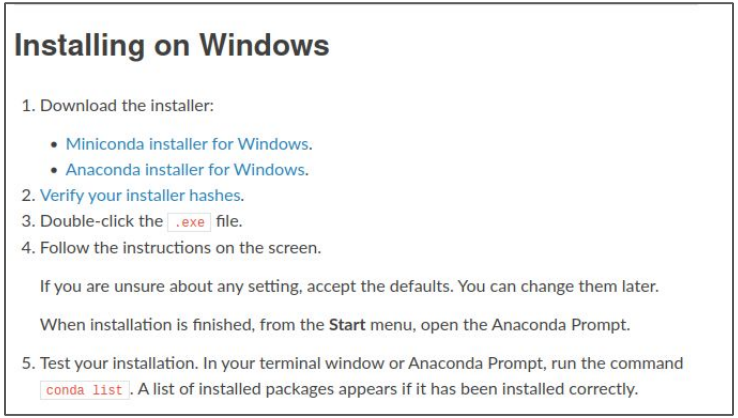
     ```
     bash Anaconda-latest-Linux-x86_64.sh
     ```

4. Follow the prompts on the installer screens.

   If you are unsure about any setting, accept the defaults. You can change them later.

5. To make the changes take effect, close and then re-open your terminal window.
6. Test your installation. In your terminal window or Anaconda Prompt, run the command `conda list`. A list of installed packages appears if it has been installed correctly.

here



Installing on Windows

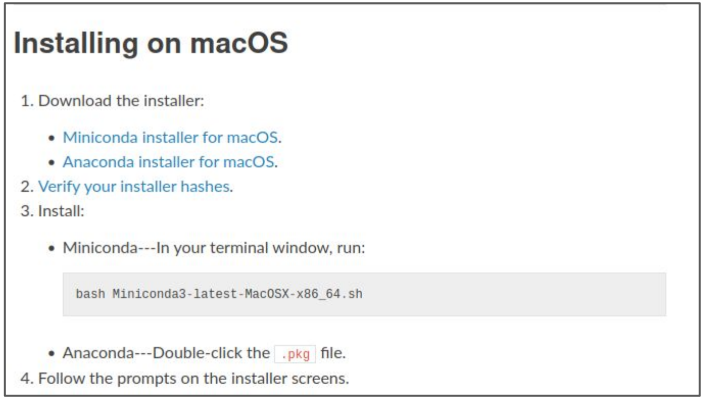
1. Download the installer:
   - Miniconda installer for Windows.
   - Anaconda installer for Windows.
2. Verify your installer hashes.
3. Double-click the `.exe` file.
4. Follow the instructions on the screen.

   If you are unsure about any setting, accept the defaults. You can change them later.

   When installation is finished, from the **Start** menu, open the Anaconda Prompt.

5. Test your installation. In your terminal window or Anaconda Prompt, run the command `conda list`. A list of installed packages appears if it has been installed correctly.

here



Installing on macOS

1. Download the installer:
   - Miniconda installer for macOS.
   - Anaconda installer for macOS.
2. Verify your installer hashes.
3. Install:
   - Miniconda---In your terminal window, run:

     ```
     bash Miniconda3-latest-MacOSX-x86_64.sh
     ```

   - Anaconda---Double-click the `.pkg` file.
4. Follow the prompts on the installer screens.

here

First Step: Set up the environment

- Create your environment
  - conda create --name MyEnvName
- View the available environments
  - conda info --envs

- Activate your environment
  - conda activate MyEnvName

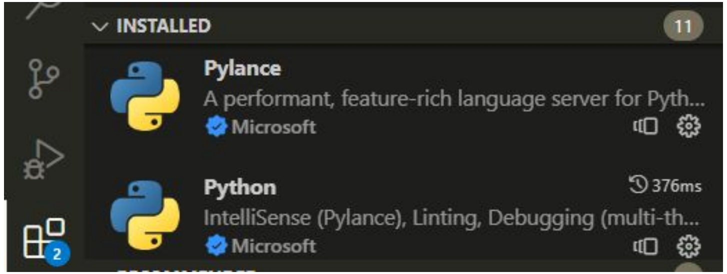
- Install Required Packages

  Only if you have GPU

  - conda install jupyter numpy pytorch torchvision torchaudio pytorch-cuda=11.7 -c pytorch -c nvidia
  - conda install matplotlib -c conda-forge
  - Sometimes you might have to install some packages with pip instead
    - pip install …

- Now you need to select this created environment for your Python interpreter.

Install these two extensions if using VSCode



INSTALLED 11

Pylance
A performant, feature-rich language server for Pyth...
Microsoft

Python 376ms
IntelliSense (Pylance), Linting, Debugging (multi-th...
Microsoft

Hit Ctrl/CMD + Shift + P and search for “Python: select interpreter”

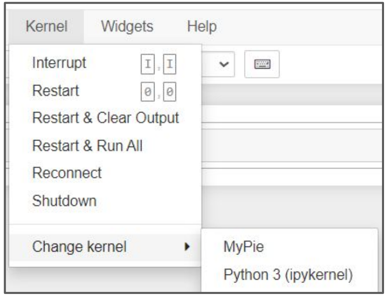
Select the conda environment that you just created!

You need ipykernel (in your conda env) to run Notebooks.

With your conda environment activated, type in:

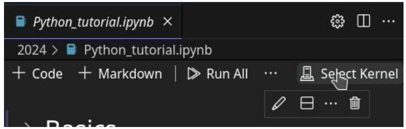
```
conda install ipykernel

python -m ipykernel install --user --name MyEnvName \
--display-name "MyEnvName"
```



browser

Select the kernel
in the notebook.



VSCode

Interactive Tutorial