Assignment 4
Introduction

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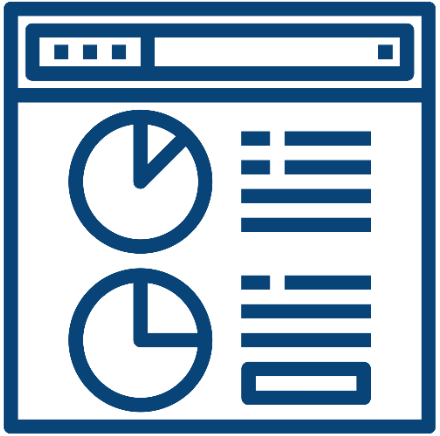
Deep Learning Exercise

Chair of Explainable Machine Learning (xAI)

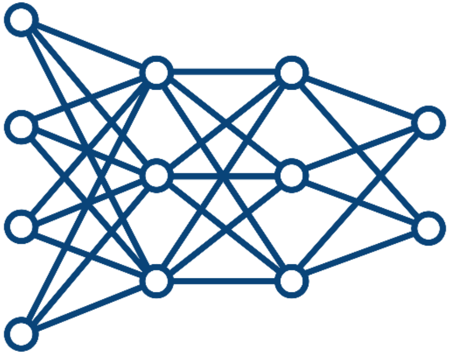
Overview



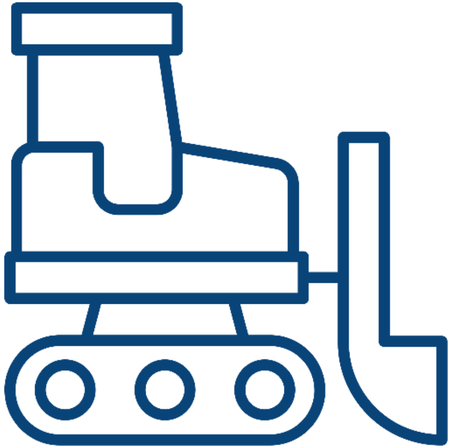
Overview

1. Convolutional Neural Networks
   a) CNN from scratch
   b) CNN with PyTorch

Convolutional Neural Networks



CNN from Scratch

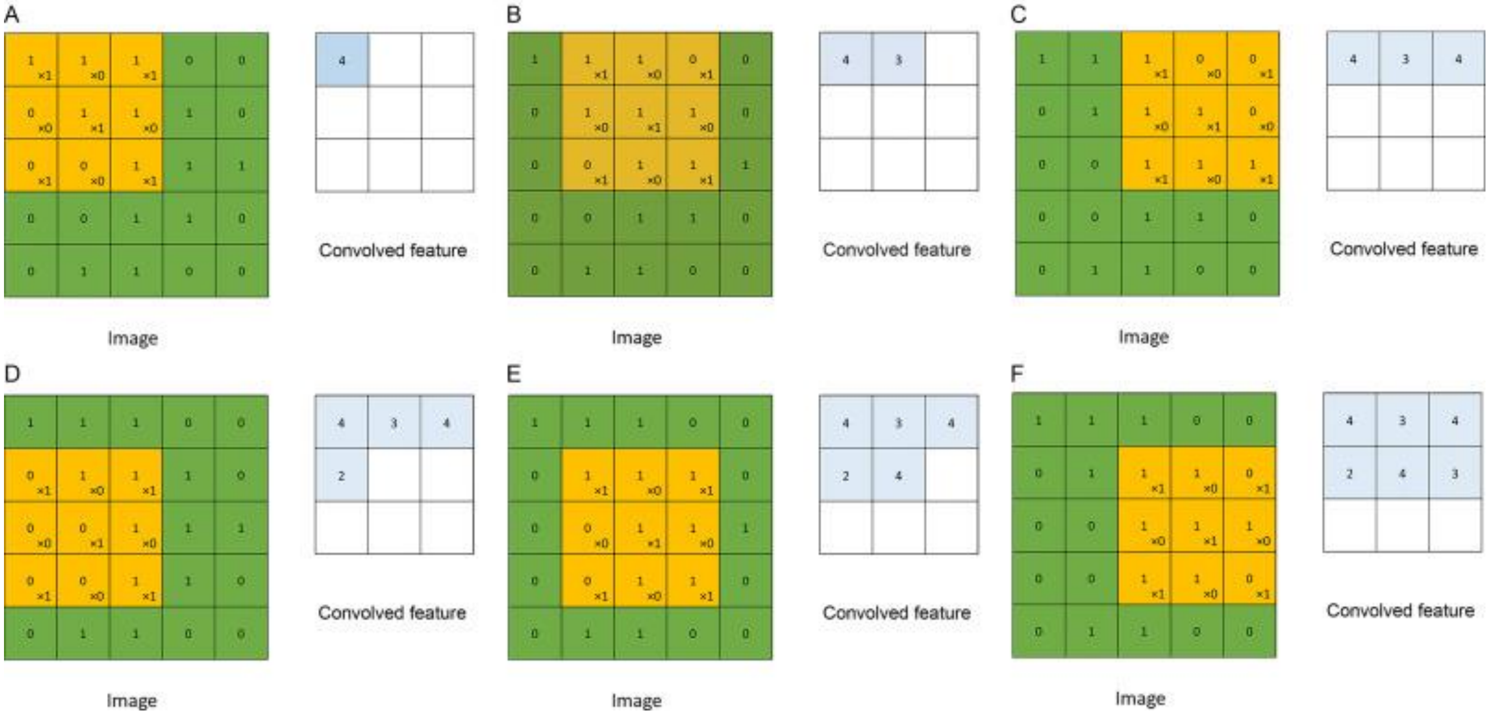


ToDo

- Implement modules/layers:
  - Convolution
  - Max Pooling
  - ReLU
  - Linear

- Implement optimizer
  - SGD with momentum

Convolution (or cross-correlation)



https://www.sciencedirect.com/topics/mathematics/convolutional-layer

Vectorization

- It’s okay to use loops for this assignment

- Vectorization is not necessary for this assignment but in practice, it is very important to speed up your code

- Note Convolutional layers are just linear transforms of kernels (weights) with different “views” of the image (i.e. toeplitz matrix)

- Use this notion to vectorize.

Vectorization – Tricks (1/2)

Goal:

Create views of an image the same size as the filters we’re applying:

```
(c, h, w) → (h_new, w_new, c, k, k)
```

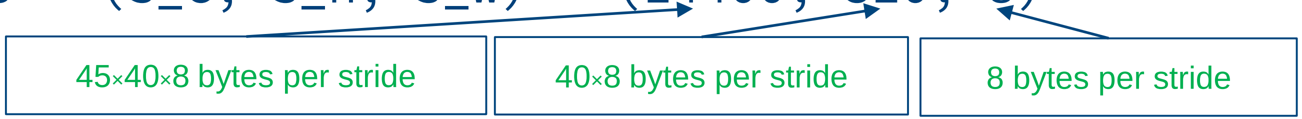
Given an image A as a NumPy array:

```
A.shape = (c, h, w) = (3, 45, 40)
```

Assuming A is of type float64, its strides from NumPy are:

```
A.strides = (s_c, s_h, s_w) = (14400, 320, 8)
```

“Strides represent how many bytes of offset to get to the next value in that dimension.”



45×40×8 bytes per stride

40×8 bytes per stride

8 bytes per stride

Vectorization – Tricks (2/2)

In preparation for a convolution layer, we want to create “views” of the image with the same size as the filter. Assuming filter size `k=3` and stride `stride=2`, we have:

```
    h_new = (45 - 3) // 2 + 1 = 22
    w_new = (40 - 3) // 2 + 1 = 19

np.lib.stride_tricks.as_strided(
    A,
    shape=(22, 19, 3, k, k),
    strides=(s_h*2, s_w*2, s_c, s_h, s_w),
    writeable=False)
```

Vectorization – Multiplying Tensors

As an example, given matrices:

A of shape `(n, c, h, w)` → containing n images

B of shape `(c, h, w, k)` → containing filters the same size as the image

How to apply the filters to all the images at once?

Method 1

```
np.tensordot(A, B, axes=3)
```

Method 2

```
np.einsum(‘nchw,chwk->nk’, A, B)
```

Vectorization – Broadcasting

Given two matrices:

`A` is of size `(a, b, c)` and `B` is of size `(b,)`

adding them together along a specific dimension can be done via:

`A + B[:, np.newaxis]` or `A + B[:, None]`

This tells NumPy to broadcast across the 1st and 3rd dimensions before performing addition.

Vectorization – Unravel Index

How to retrieve the location of a point given the argmax?

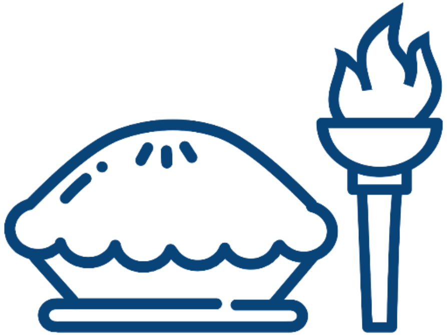
```
A = np.array([[ 3,  5],
              [17,  2],
              [16,  3]])

i = A.argmax() = 2
```

This can be done via:

```
np.unravel_index(i, A.shape) = (1, 0)
```

CNN with PyTorch



ToDo

- Complete the training loop of PyTorch
  - Notice the difference between training and validation

- Implement two specified models
  - Two fully connected layers with a sigmoid activation function in between
  - Vanilla CNN

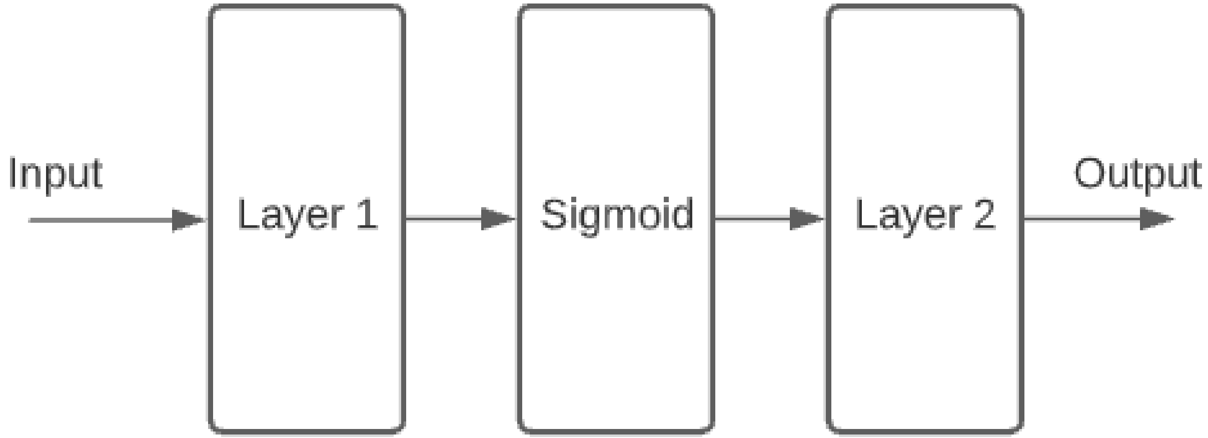
PyTorch – Complete the Training Loop

- Implement the training and validation step utilizing PyTorch

- Key concept is that in validation you won't be updating the gradients

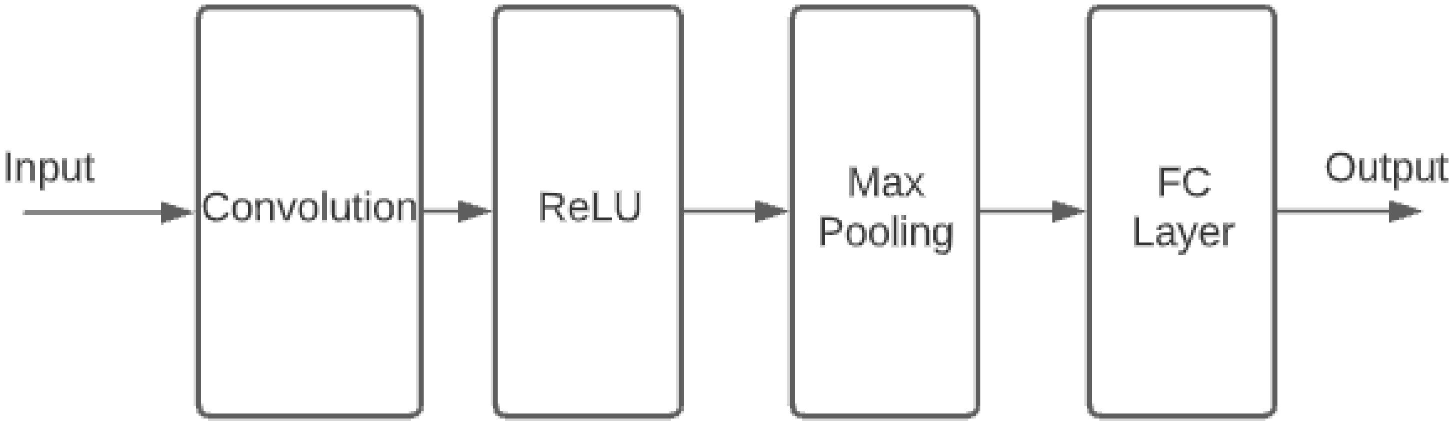
PyTorch – Two Layer Model

Two fully connected layers with a sigmoid activation function in between



PyTorch – CNN

Implement a basic CNN utilizing PyTorch


Input
Convolution
ReLU
Max Pooling
FC Layer
Output