**Week 1 – Notes**

**Convolutional Neural Networks**

**Computer Vision**

There are multiple compute vision problems like image classification, object detection and neural style transfer

CNNs appeared because you cannot use classical fully connected NN to learn from images because the input size and the number of weights would be of the order of millions or even billions

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**Edge Detection Example**

CNNs work based on finding features like edges (vertical, horizontal, and so on)

To detect them we are using filters / kernels that are applied on images through the process of convolution which means that you multiply each pixel with the corresponding filter value and in the end you just add the values

A screenshot of a whiteboard

Description automatically generated with low confidence

Higher values denote shades of white

A screenshot of a math game

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We can see that a vertical edge detector finds regions where there’s a transition from higher to lower values

**More Edge Detection**

If the transition is inverse, from lower values to higher ones, then, in our case, the result of the convolution would be a matrix composed on 0 and -30

In the same fashion we can detect horizontal edges

There are many types of filters (the first one is called Prewitt), for example the Sobel variant is more robust because it weighs more the central value of each side

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Essentially, we would want to let the CNN learn the values of these filter so that it can extract the best features for the data set at hand and in addition to find edges of all kinds of inclinations

To do this, we treat each value of a filter as a weight that is learned through backprop

**Padding**

After applying the convolution, we end up with a matrix of the size n – f + 1 x n – f + 1, where n represents the size of the input image and f the size of the filter

Thus, there are some flaws:by applying many convolutions, we end up with a smaller and smaller output and we do not take into consideration values that are on the edge of the image

To solve these problems, we can use a padding with zero values around the image, then the output after the convolution will have a size of n + 2p – f + 1 x n + 2p – f + 1

There are 2 types of convolutions:

Valid – they have not padding

Same – pad so that the output size is the same as the input size (p = (f – 1) / 2)

The filter size is usually odd (by convention) because in this way we have a central value when we apply it and because we can pad symmetrically on the left and right of the image

Common filters are 1x1, 3x3, 5x5 and 7x7

**Strided Convolutions**

You may want to use a strided convolution, so to move the kernel over the input by jumping a number of values (columns or rows)

If we use a stride of 2, we move the kernel by 2 positions, also a stride of 1 is the basic movement of the kernel

The dimension of the output can be computed by using the following formula:

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Description automatically generated (nxn image, fxf filter, padding p, stride s)

[image processing - 2D convolution: Flipping the kernel? - Computer Science Stack Exchange](https://cs.stackexchange.com/questions/11591/2d-convolution-flipping-the-kernel)

Technically, we aren’t using convolutions, we are applying an operation called cross-correlation

The convolution flips the kernel on both axis before applying it and this is the correct waw (it was coined in signal processing)

The convolution is associative, while the correlation is not: (A\*B)\*C = A\*(B\*C)

Let’s say that you have an image with a single 1 in the center and 0 otherwise + a kernel with values from 1 to 9 => by applying the convolution, you get the same kernel, but by applying cross-correlation you obtain the flipped kernel

**Convolutions Over Volume**

In DL, the convolutions are applied over volumes

For example, we use input images that have 3 channels, so the kernel also has 3 channels. However, the output has only one channel

A calculator and a calculator

Description automatically generated with low confidence

The convolutions are applied in such a way that in one kernel with 3 channels, we can detect on type of edge in each color channel

In DL, we usually apply several filter sin one layer, so we extract many features out of the input

For each filter we need to have as many channels as the input

**One Layer of a Convolutional Network**

We can trace a parallel between CNNs and fully connected NNs

a[l-1] are the inputs, w[l] the filters, b1 and b2 represent real values which are broadcasted to the matrices and we apply an activation function to obtain the a[l] output

a[l] is just a stacking of the results of applying several filters on the input

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Description automatically generated

The number of params of a layer of a CNN is stable regardless of the input image size

For a layer l of a CNN, we have the following dimensions:

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