2. Convolutional Neural Networks

Bookmark this page

Exercises due Nov 5, 2020 05:29 IST *Completed*

Introduction to Convolution Neural Networks

Start of transcript. Skip to the end.

Welcome back.

This is [INAUDIBLE] machine learning week number eight.

Today, we're going to be talking about image classification

and, in particular, a specialized architecture

for image classification known as convolutional neural

Video

Download video file

Transcripts

Download SubRip (.srt) file

Download Text (.txt) file

Motivation for CNN

2/2 points (graded)

Let's suppose that we wish to classify images of 1000×1000 dimensions.

We wish to pass the above input through a feed-forward neural network with a single hidden layer made up of 1000×1000 hidden units each of which is fully connected to the full image.

If the number of connections that exist between the first hidden layer and the input image is given by x, then enter below the value of $log_{10}\,(x)$, i.e. the logarithm of x to the base 10:

12 ✓ **Answer:** 12

Instead of a fully-connected layer, now suppose that we use a convolutional layer with 1 filter of shape 11×11 instead. Enter below the number of parameters in the first layer (ignoring the bias terms):

121 ✓ **Answer:** 121

Solution:

Each of the hidden unit is connected to all the pixels from the input image.
So, there are a total of $1000 * 1000 = 10^6$ connections between each of the hidden layers and the input.
Since there are $1000 * 1000 = 10^6$ hidden units in the first hidden layer, the total number of connections x amounts to $x = 10^6 * 10^6 = 10^{12}$
The first convolutional layer with a 11×11 filter will have $11 * 11 = 121$ parameters that operate on the entire image.

Submit You have used 2 of 3 attempts

Answers are displayed within the problem

Second Motivation for CNN

1/1 point (graded)

Suppose a feed-forward, non-convolutional neural network is learning how to classify images. Then, it can classify images even if the relevant object is in a different part of the image.

○ true

● false

✓

Solution:

The lecture explains this with a mushroom example. If the mushroom is in a different place, the weight matrix parameters at that location need to learn to recognize the mushroom anew. With convolutional layers, we have translational invariance as the same filter is passed over the entire image. Therefore, it will detect the mushroom regardless of location

Submit You have used 1 of 2 attempts

Answers are displayed within the problem

Convolution: Continuous Case

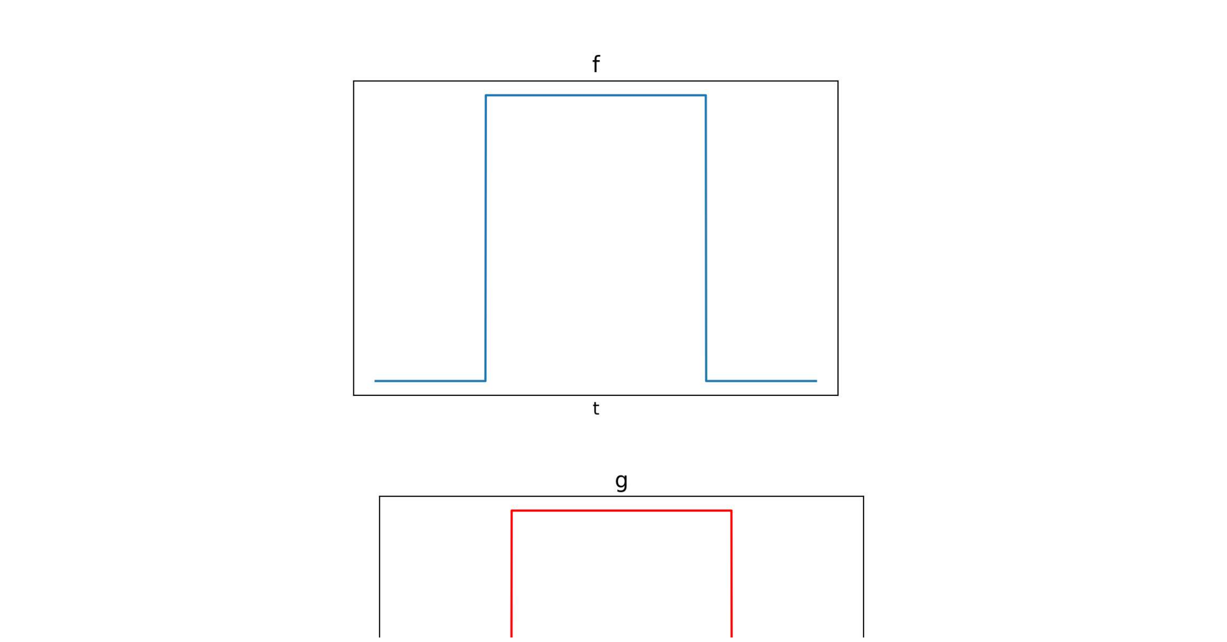
2/2 points (graded)

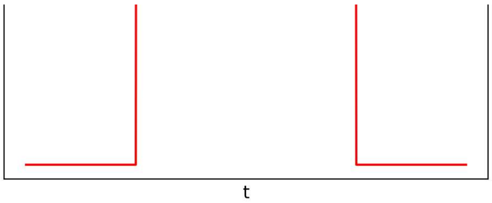
In the lecture we saw the example of using the convolution operation to create a feature map. Here we formally define the convolution as an operation between 2 functions f and g:

$$(f * g)(t) \equiv \int_{-\infty}^{+\infty} f(\tau)\, g(t-\tau)\, d\tau$$

In this integral, τ is the dummy variable for integration and t is the parameter. Intuitively, convolution 'blends' the two function f and g by expressing the amount of overlap of one function as it is shifted over another function.

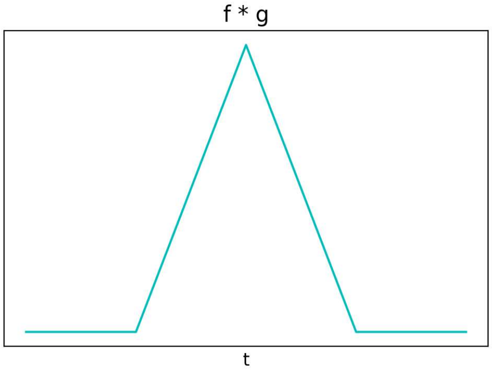
Now, suppose we are given two rectangular function f and g as shown in the figures below.



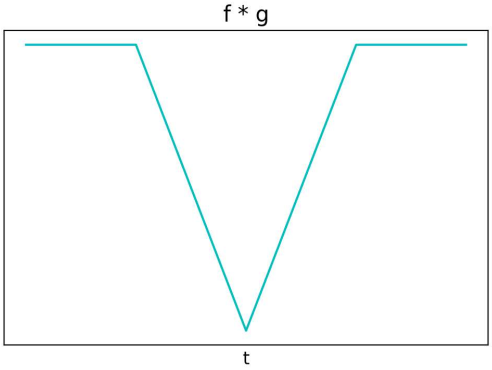


What is the shape of of $f * g$?

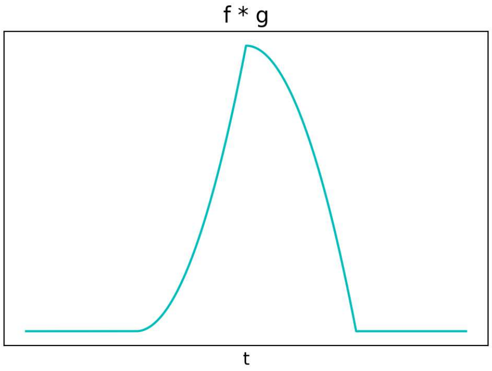
●



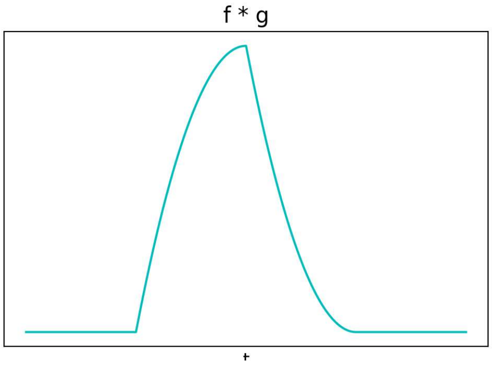
○



○



○



✓

What is the area under the convolution: $\int_{-\infty}^{+\infty}(f*g)\,dt$

○ The area under f

○ The area under g

● The product of the areas under f and g

○ The sum of the areas under f and g

✓

Solution:

We can flip g and shift it over f. $f*g$ stays at 0 when there's no overlap. It increse linearly and reach the peak when f and g fully overlap with each other.
The area under the convolution:

$$\begin{aligned}\int_{-\infty}^{+\infty}(f*g)\,dt &= \int_{-\infty}^{+\infty}[\int_{-\infty}^{+\infty}f(\tau)\,g(t-\tau)\,d\tau]\,dt\\ &= \int_{-\infty}^{+\infty}f(\tau)\,[\int_{-\infty}^{+\infty}g(t-\tau)\,dt]\,d\tau\\ &= [\int_{-\infty}^{+\infty}f(\tau)\,d\tau]\,[\int_{-\infty}^{+\infty}g(t)\,dt]\end{aligned}$$

This is the product of the areas under f and g.

Submit You have used 2 of 3 attempts

Answers are displayed within the problem

Convolution: 1D Discrete Case

2.0/2 points (graded)
Similarly, for discrete functions, we can define the convolution as:

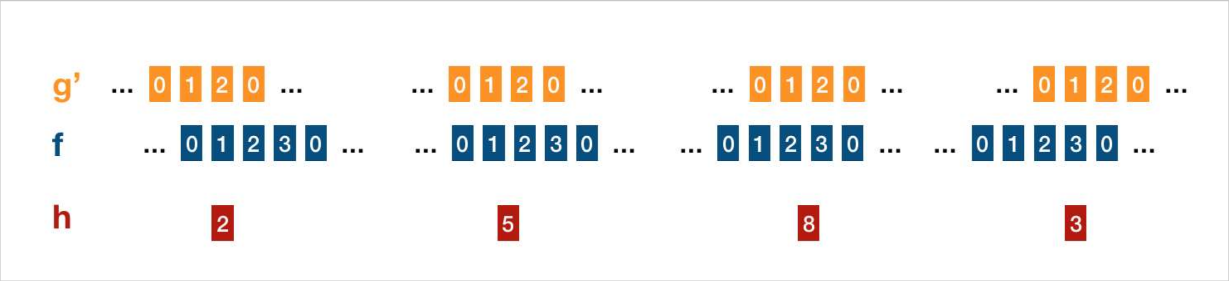
$$(f*g)[n] \equiv \sum_{m=-\infty}^{m=+\infty} f[m]\,g[n-m]$$

Here, we give an example of convolution on 1D discrete signal.
Let $f[n]=[1,2,3]$, $g[n]=[2,1]$ and suppose n starts from 0. We are computing $h[n]=f[n]*g[n]$.
As f and g are finite signals, we just put 0 to where f and g are not defined. This is usually called zero padding.
Now, let's compute $h[n]$ step by step:

$$\begin{aligned}h[0] &= f[0]\cdot g[0-0]+f[1]\cdot g[0-1]+\cdots=f[0]\cdot g[0]=2\\ h[1] &= f[0]\cdot g[1-0]+f[1]\cdot g[1-1]+f[2]\cdot g[1-2]+\cdots=f[0]\cdot g[1]+f[1]\cdot g[0]=5\\ h[2] &= f[0]\cdot g[2-0]+f[1]\cdot g[2-1]+f[2]\cdot g[2-2]+f[3]\cdot g[2-3]+\cdots=f[1]\cdot g[1]+f[2]\cdot g[0]=8\\ h[3] &= f[0]\cdot g[3-0]+f[1]\cdot g[3-1]+f[2]\cdot g[3-2]+f[3]\cdot g[3-3]+f[4]\cdot g[3-4]+\cdots=f[2]\cdot g[1]\end{aligned}$$

The other parts of h are all 0.

Intuitively, we can get this result by first flipping g[n] and shift it over f[n] and compute the inner product at each step, as shown in the figures below:



In practice, it is common to call the flipped g' as filter or kernel, for the input signal or image f.

As we forced to pad zeros to where the input are not defined, the result on the edge of the input may not be accurate. To avoid this, we can just keep the convolution result where g' has operated exclusively on where the input f is actually defined. That is $h\left[n\right] = \left[5, 8\right]$.

Now suppose the input $f = \left[1, 3, -1, 1, -3\right]$, and the filter $g' = \left[1, 0, -1\right]$, what is the convolutional output of $f * g$ without zero padding on f? Enter your answer as a list below (e.g. [0,0,0])

[2,2,2]

✓ **Answer:** [2,2,2]

What is the convolutional output of $f * g$ if we pad a 0 on both edges of f so that the output dimension is the same as the input? Enter your answer as a list below (e.g. [0,0,0,0,0])

[-3,2,2,2,1]

✓ **Answer:** [-3,2,2,2,1]

Solution:

Without zero padding, we have

$$\begin{aligned} f * g\left(0\right) &= 1 \times 1 + 3 \times 0 + \left(-1\right) \times \left(-1\right) = 2 \\ f * g\left(1\right) &= 3 \times 1 + \left(-1\right) \times 0 + 1 \times \left(-1\right) = 2 \\ f * g\left(2\right) &= \left(-1\right) \times 1 + 1 \times 0 + \left(-3\right) \times \left(-1\right) = 2 \end{aligned}$$

With zero padding, we add 0 to f such that $f = \left[0, 1, 3, -1, 1, -3, 0\right]$,

$$\begin{aligned} f * g\left(0\right) &= 0 \times 1 + 1 \times 0 + 3 \times \left(-1\right) = -3 \\ f * g\left(1\right) &= 1 \times 1 + 3 \times 0 + \left(-1\right) \times \left(-1\right) = 2 \\ f * g\left(2\right) &= 3 \times 1 + \left(-1\right) \times 0 + 1 \times \left(-1\right) = 2 \\ f * g\left(3\right) &= \left(-1\right) \times 1 + 1 \times 0 + \left(-3\right) \times \left(-1\right) = 2 \\ f * g\left(4\right) &= 1 \times 1 + \left(-3\right) \times 0 + 0 \times \left(-1\right) = 1 \end{aligned}$$

Submit

You have used 1 of 5 attempts

Answers are displayed within the problem

Convolution: 2D Discrete Case

1/1 point (graded)

Now, let's apply the same idea on images, which are 2D discrete signals. Suppose we had an image f and a filter g' as shown below. Calculate the sum of the elements in the output matrix after passing the image through the convolutional filter, without zero padding.

$$f = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 1 & 1 \end{bmatrix}$$

$$f = \begin{bmatrix} 2 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

$$g' = \begin{bmatrix} 1 & 0.5 \\ 0.5 & 1 \end{bmatrix}$$

15

✓ **Answer:** 15

Solution:

We align the filter with the top left corner of the image, and take the element wise multiplication of the filter and the 2 by 2 square in the top left corner. We then shift the filter along the top row, doing the same thing. We then apply the same procedure to the next row. If we went another row down, the bottom row of the filter would not have any numbers to be multiplied with. Thus, we stop.

The result of the convolution is

$$C = \begin{bmatrix} 4 & 4 \\ 4 & 3 \end{bmatrix}$$

. The sum is therefore 15

Submit You have used 1 of 3 attempts

Answers are displayed within the problem

Pooling Practice

1/1 point (graded)

A pooling layer's purpose is to pick up on a feature regardless of where it appears in the image.

● true

○ false

✓

Solution:

A pooling layer finds the maximum value over a given area. The max value can be seen as a "signal" representing whether or not the feature exists. For example, a high max value could indicate that the feature did appear in the image.

Submit You have used 1 of 2 attempts

Answers are displayed within the problem

Discussion

Hide Discussion

Topic: Unit 3 Neural networks (2.5 weeks):Lecture 12. Convolutional Neural Networks / 2. Convolutional Neural Networks

Add a Post

Show all posts ⌄ by recent activity ⌄

💬	A *great* explanation about Convolution (and a free ebook) The best explanation of Convolution I ever saw was in an old book from Steven Smith (available for free at the author's website: [htt... Pinned	1 new
💬	Convolution- wrong definition?? For a convolution as I've studied in discrete signal processing, the size of resulting convolution would be M+N-1 where M is the size ...	2
?	Where does the weights used to make feature maps come from So, from what I was able to grasp they come from training with relation to the smaller patches. But when and how this is made? Bec...	2
?	Help to way my answer in 1D isn't valid Hi. I have written my answer as [1,2,3] and [1,2,3,1,2,3] but it comes back with the answer: "Expected answer to be a vector, but inpu...	2
💬	where are you scooopydoo): where are you scooopydoo):	3
💬	[Staff] Grader does not mark the answer of the 1st question correctly if given in a ln(...) format If someone wanted to include the answer in ln() format, the grader currently does not mark it correctly. Maybe confirm that ln() sho...	1
💬	A good video for convolution of discrete distribution in class 6.431x This is a video that introduces convolution formula of discrete distribution by Prof. John Tsitsiklis in class 6.431x https://youtu.be/zb...	4
💬	Accepted Matrix Syntax Convolution: 1D Discrete Case I had enter formate1: [1,2,3] format2: ([1,2,3]) format3: (1,2,3) in all formats Invalid Input: Could not parse which one is correct	7
?	Convolution: 1D Discrete Case	3
?	staff. subtitles are not synchronised subtitles are not synchronised for the video	1
💬	Convolution: 1D Discrete Case: Answer checker is wrong I think Answer checker is not working properly. Correct Answers are : [1,3,-2] [0 ,1 ,3 ,-2,-2]	3
?	Convolution - Continuous Case I dont have any clue on how can i solve that! Anyone can help me?	3
💬	Deep Learning MIT course	4

‹ Previous

Next ›

edX

About
Affiliates
edX for Business
Open edX
Careers
News

Legal

Terms of Service & Honor Code
Privacy Policy
Accessibility Policy
Trademark Policy
Sitemap

Connect

Blog
Contact Us
Help Center
Media Kit
Donate

GET IT ON Google play

Download on the App Store