CSC 578 Homework 6: Written CNN

Update 5/11/2022 for Spring 2022

- **Graded out of 4 points.**
- Create a single pdf file containing all of your answers. **The file must start with your name, the course number and the assignment name/number (i.e., "CSC 578 Homework #6")**. Files without this information will be returned ungraded.
- Do all questions
- **DO NOT include the question** in your submission. Just number your answers.
- You may find this video from Andrew Ng useful

The purpose of this HW is to help you understand the different parameters of CNNs and how they interact. There is no separate video explaining it, but it was introduced in class in Weeks 6 and 7.

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1. Convolutional layer volume

Assume that a convolution layer accepts as input a volume of size $W_1 \times H_1 \times D_1$ (for width, height and depth respectively) and has these additional parameters:

- K = number of filters,
- F = their spatial extent (width or height, assuming square filters),
- S = the stride length,
- P = the amount of zero padding.

This layer produces an output volume of size $W_2 \times H_2 \times D_2$. Give a formula for each of these three (W_2, H_2, and D_2), in terms of the parameters above. (That is, provide 3 separate formulas.)

Note: If you find an answer for this problem somewhere (as opposed to working it out on your own), include the answer, and indicate where it came from AND briefly explain why it makes sense. *Hint: If you're struggling, review the Additional Resources posted on my course homepage related to CNNs.*

2. Volume calculation example

For an input image of size 32 × 32, 100 filters are applied where each filter is of size 3 × 3 and with stride=1. Find:

A. the size of feature map (including depth) **and**
B. the total number of parameters.

Show your calculations. Note that the input image is in gray scale, therefore its depth is 1.

3. Convolution filter application

Consider the convolution filter below.

```
1.0  1.0  -1.0  -1.0
1.0  1.0  -1.0  -1.0
1.0  1.0  -1.0  -1.0
1.0  1.0  -1.0  -1.0
```

Apply the filter to the image (of a small square, made of 2.0's) below, with stride=1.

```
0.0  0.0  0.0  0.0  0.0  0.0
0.0  2.0  2.0  2.0  0.0  0.0
0.0  2.0  2.0  2.0  0.0  0.0
0.0  2.0  2.0  2.0  0.0  0.0
0.0  0.0  0.0  0.0  0.0  0.0
0.0  0.0  0.0  0.0  0.0  0.0
```

A. Draw the output feature map. Assume 'convolution' as it is used in deep learning, that is, the dot product (without 180 degree rotation — described in a mathematical context as cross-correlation). Assume the bias value is 0. Also use the **ReLU** activation function.

B. What kind of feature in the image would you say that this filter captures?

4. Padding

For an input image of size 7 × 7, applying a 3 × 3 filter with $stride = 2$ produces an output feature map of 3 × 3. If you want to create an output of the same size as the input using padding, what should the padding size be? Assume the depth is 1 for both input image and filter.

5. CNN Parameters

Given the following CNN model for an input image of 32 × 32 × 3 (i.e., a color image with RGB channels):

- [1st layer] Convolution – 32 5x5 filters, stride (1,1), activation ReLU
- [2nd layer] Max pooling – size 2x2, stride (2,2)
- [3rd layer] Convolution – 32 5x5 filters, stride (1,1), activation ReLU
- [4th layer] Max pooling – size 2x2, stride (2,2)
- [5th layer] Fully connected (Dense) – 512 nodes, activation ReLU
- [6th layer] Fully connected (Dense) – 10 nodes, activation Softmax

Explain how each of the number of parameters (`Param #`) is calculated in the following model summary:

```
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 32)        2432
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 10, 10, 32)        25632
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 32)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 800)               0
_________________________________________________________________
dense_1 (Dense)              (None, 512)               410112
_________________________________________________________________
dense_2 (Dense)              (None, 10)                5130

=================================================================

Total params: 443,306
Trainable params: 443,306
Non-trainable params: 0
```

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