Lecture 11:

Convolution and Image Classification & Segmentation

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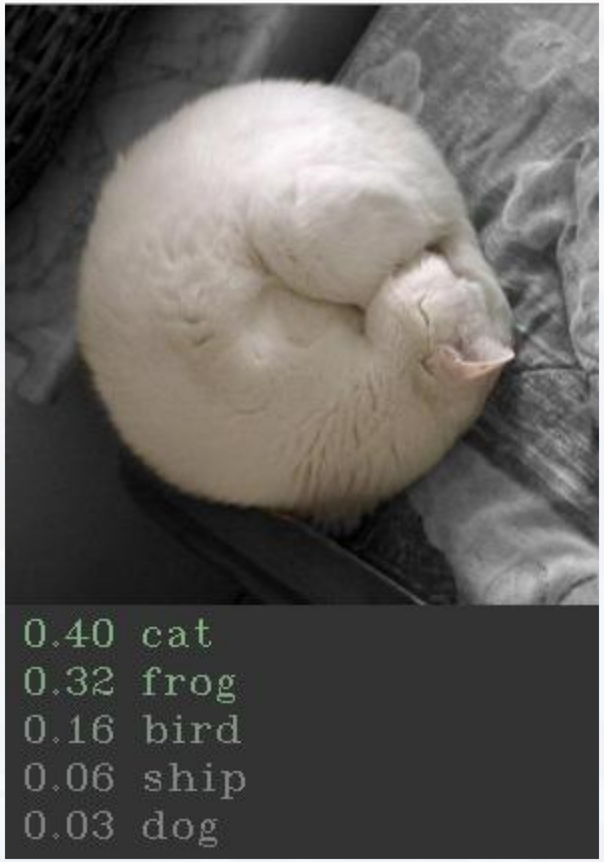
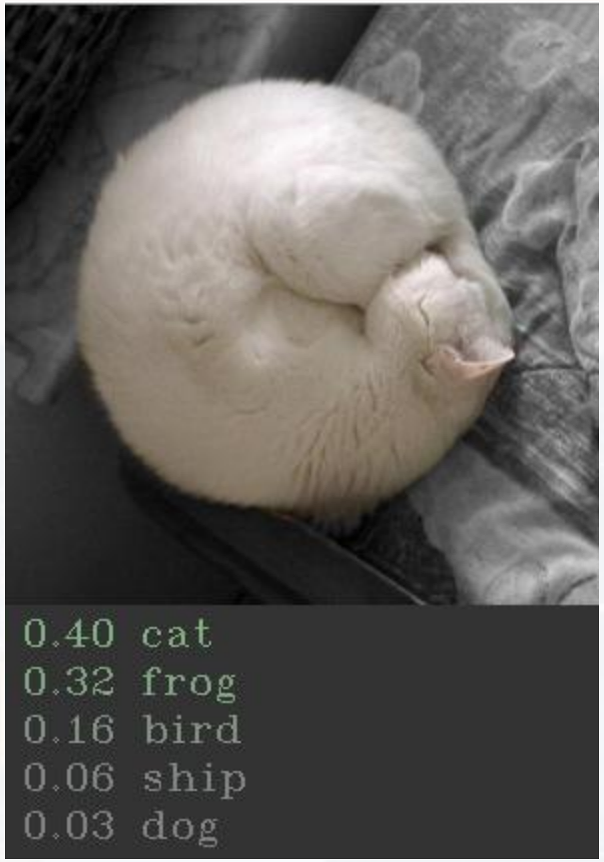
Bayesian Data Analysis and Machine Learning for Physical Sciences

Course Map

Part II





Outline

The Problem

Convolution

CNN Architectures

Data Preparation & Training

Example

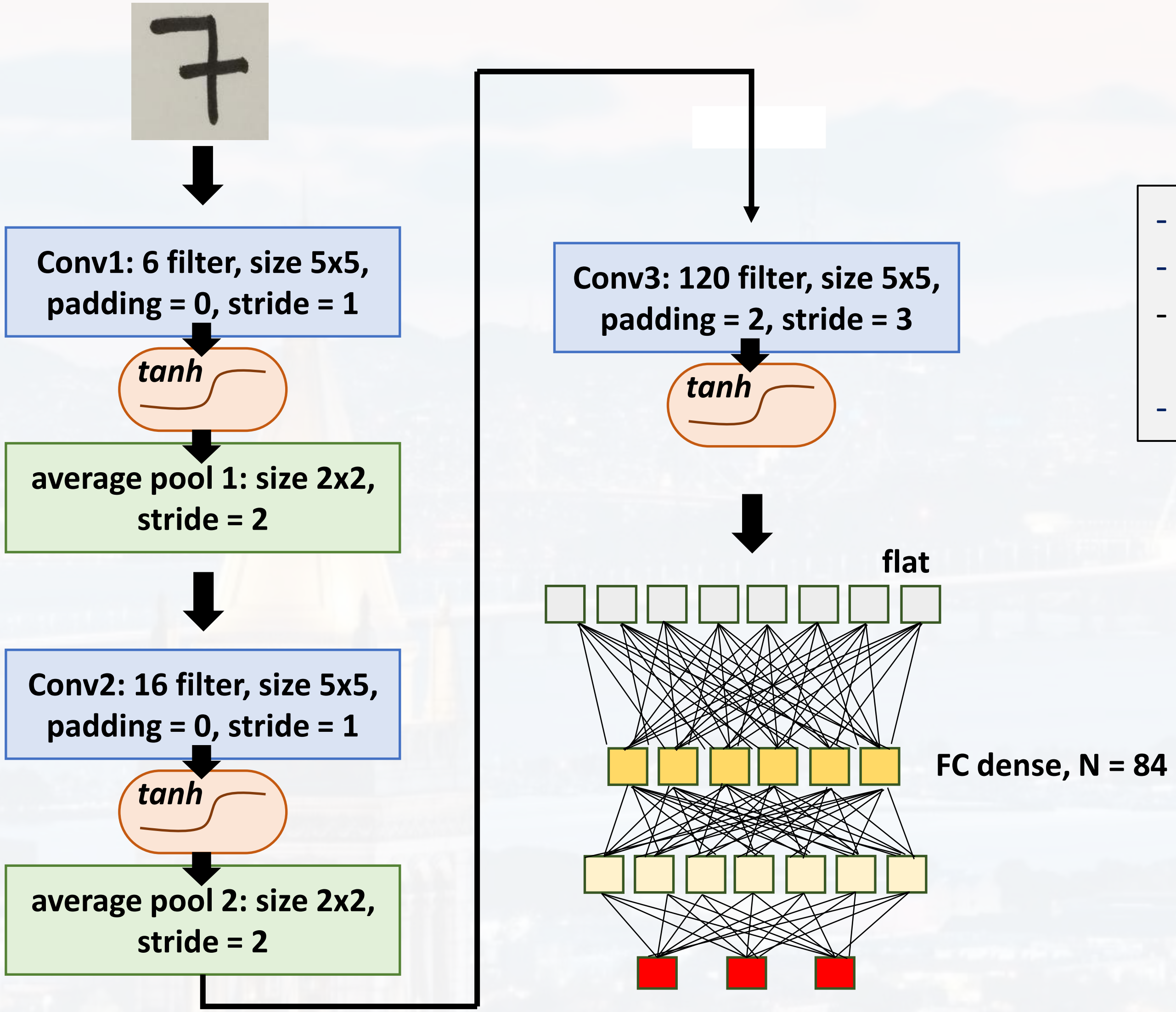
- LeNet numpy only
- LeNet TensorFlow
- sequences as images
- segmentation

LeNet:

- Yann LeCun, Leon Bottou, Yoshua Bengio and Patrick Haffner, 1998
- one of the 1st CNN that was able to categorize images
- MNIST data set

- only **seven layers** in total
- modern CNNs (google, ResNet etc have **100 or more** layers)

LeNet: **- Yann LeCun, Leon Bottou, Yoshua Bengio and Patrick Haffner, 1998**



- ***tanh*** as activation function
- **three different** filter
- from Conv1 → Conv2 not all the **channels are combined**
- **average** pool

We know already how the forward part works:

```
for c in range(numChans):# loop over channels
      for y in range(yOutput):# loop over y axis of output
          for x in range(xOutput):# loop over x axis of output

              # finding corners of the current "slice"
              y_start = y*stride
              y_end   = y*stride + yK
              x_start = x*stride
              x_end   = x*stride + xK

              #selecting the current part of the image
              current_slice = imagePadded[x_start:x_end,\
                                           y_start:y_end, c]

              #the actual convolution part
              s             = np.multiply(current_slice, K)
              output[x,y,c] = np.sum(s)
```

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

see MyCNN.py

- MyCNN.py
  - Read_Scale_Imds
  - ConvLayer
    - __init__
    - forward
    - backward
  - Average_Pool
  - Min_Pool
  - Max_Pool
  - Sigmoid
  - Tanh
  - Activation_ReLU
  - Flat
  - Layer_Dense
  - Activation_Softmax
  - Loss
  - Loss_CategoricalCrossEntropy
  - CalcSoftmaxLossGrad
  - Optimizer_SGD

we know these parts already

```
import matplotlib.pyplot as plt
from MyCNN import *

read_and_scale = Read_Scale_Imds(5, [250,250])
[I, _]         = read_and_scale.Read_Scale()

Conv1 = ConvLayer(3,3,5)
Conv2 = ConvLayer(5,5,4)
Conv3 = ConvLayer(2,2,4)

Conv1.forward(I,0,1)
Conv2.forward(Conv1.output,2,4)
Conv3.forward(Conv2.output,0,2)

plt.imshow(Conv1.output[:,:,0,4], cmap = 'gray')
plt.show()
plt.imshow(Conv2.output[:,:,0,4], cmap = 'gray')
plt.show()
plt.imshow(Conv3.output[:,:,0,4], cmap = 'gray')
plt.show()
```

initializing convolution layer (kernel size x kernel size, number of kernels)

passing image through convolution layer (padding, stride lenght)

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from MyCNN import *

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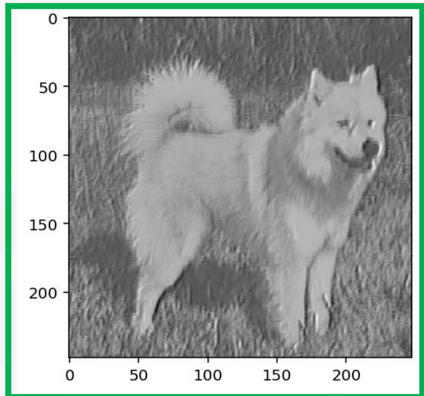
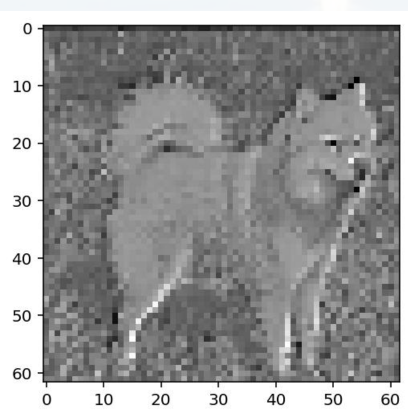
Conv3 = ConvLayer(2,2,4)

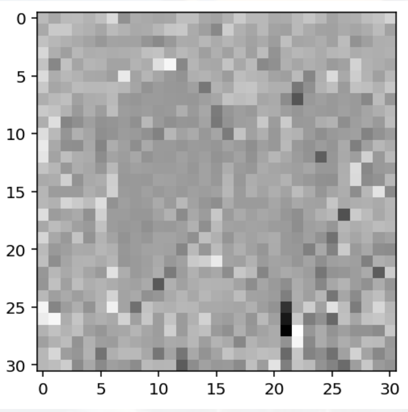
Conv1.forward(I,0,1)
Conv2.forward(Conv1.output,2,4)
Conv3.forward(Conv2.output,0,2)
```




```
plt.imshow(Conv1.output[:,:,0,4], cmap = 'gray')
plt.show()
```




```
plt.imshow(Conv2.output[:,:,0,4], cmap = 'gray')
plt.show()
```




```
plt.imshow(Conv3.output[:,:,0,4], cmap = 'gray')
plt.show()
```

Convolution, Image Classification & Segmentation

see `MyCNN.py`

- MyCNN.py
  - Read_Scale_Imds
  - ConvLayer
    - __init__
    - forward
    - backward
  - Average_Pool
  - Min_Pool
  - Max_Pool
  - Sigmoid
  - Tanh
  - Activation_ReLU
  - Flat
  - Layer_Dense
  - Activation_Softmax
  - Loss
  - Loss_CategoricalCrossEntropy
  - CalcSoftmaxLossGrad
  - Optimizer_SGD

LeNet numpy only
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```
y_start = y*stride
y_end   = y_start + yK
x_start = x*stride
x_end   = x_start + xK

sx = slice(x_start, x_end)
sy = slice(y_start, y_end)

current_slice      = currentIm_pad[sx,sy,c]
slice_max          = float(current_slice.max())
output[x, y, c, i] = slice_max
```

here: max pool

LeNet numpy only
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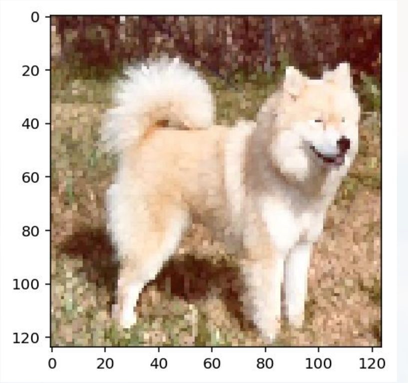
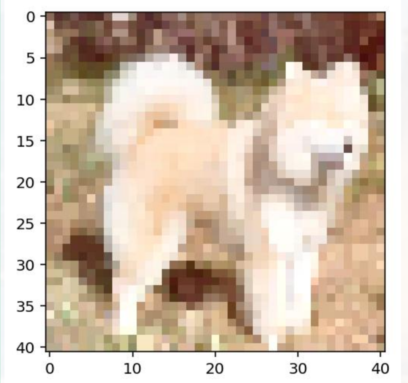
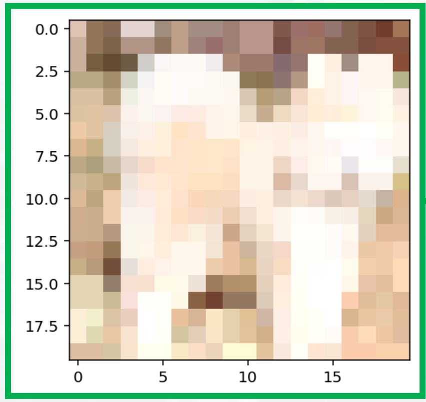







```
MP1   = Max_Pool()
MP2   = Max_Pool()
MP3   = Max_Pool()
```

initializing ax pool layer

```
MP1.forward(I,2,3)
MP2.forward(MP1.output,3,3)
MP3.forward(MP2.output,2,3)
```

passing image through max pool layer (stride length, kernel size)

```
plt.imshow(MP1.output[:,:,:,4].astype(int))
plt.show()
```

```
plt.imshow(MP2.output[:,:,:,4].astype(int))
plt.show()
```

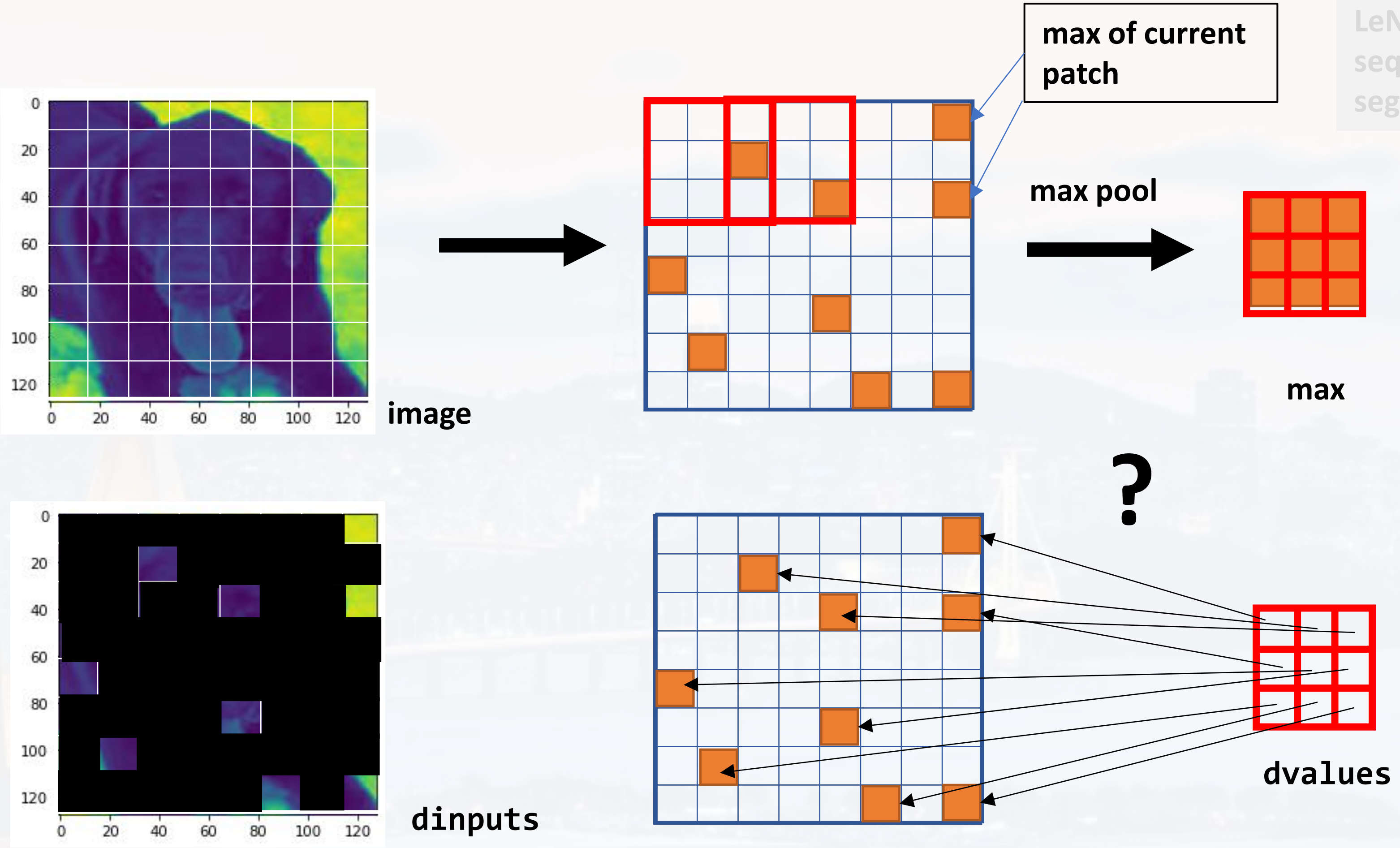
```
plt.imshow(MP3.output[:,:,:,4].astype(int))
plt.show()
```

Convolution, Image Classification & Segmentation

for **backpropagation**, we need to **up-sample** the images!

forward:

backward:



We need **to track, where the max came from** for each patch: creating a **mask** in the forward part
For those pixel: `dinputs = dvalues`

Convolution, Image Classification & Segmentation

for **backpropagation**, we need to **up-sample** the images!

Input I stride = 3; xK = yK = 5

	0	1	2	3	4	5	6
0	0	0	0	0	0	0	0
1	0	538	538	538	538	541	541
2	0	538	538	538	538	541	541
3	0	535	535	538	538	541	541
4	0	535	535	538	538	541	541
5	0	535	535	538	538	538	538
6	0	535	535	538	538	538	538
7	0	535	535	538	538	541	541
8	0	535	535	538	538	541	541
9	0	535	535	538	538	538	544

max pool

output

	0	1	2	3	4	5	6
0	538	544	545	551	543	357	364
1	538	544	547	550	544	369	361
2	538	544	548	554	554	369	361
3	544	547	548	554	554	361	358
4	544	544	499	364	362	368	375
5	424	363	355	355	350	363	375
6	352	354	358	358	356	356	357
7	352	353	354	359	368	368	350
8	353	353	362	362	360	359	356
9	357	356	367	367	366	365	356

mask

and so on…

	0	1	2	3	4	5	6
0	0	0	0	0	0	0	0
1	0	538	538	538	538	0	0
2	0	538	538	538	538	0	0
3	0	0	0	538	538	0	0
4	0	0	0	538	538	0	0
5	0	0	0	538	538	0	0
6	0	0	0	538	538	0	0
7	0	0	0	538	538	0	0
8	0	0	0	538	538	0	0
9	0	0	0	538	538	0	544

Convolution, Image Classification & Segmentation

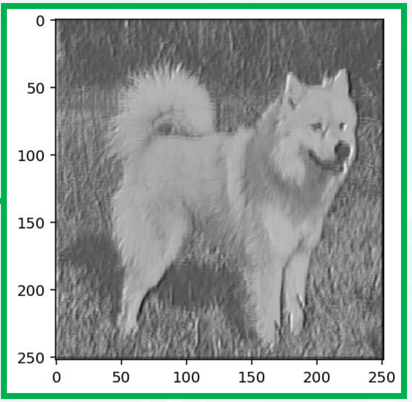
for **backpropagation**, we need to **up-sample** the images!

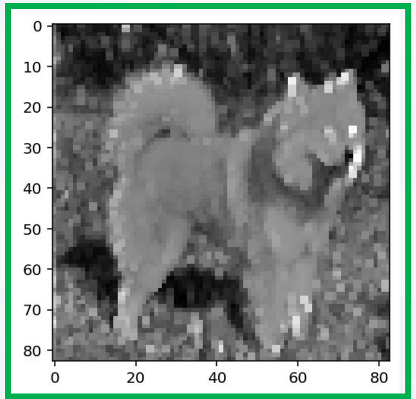
dinputs and mask have to look the same (but different values)!

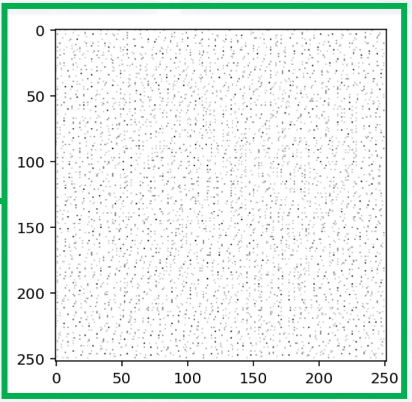
```
Conv1.forward(I,2,1)
MP1.forward(Conv1.output,3,5)
MP1.backward(MP1.output)

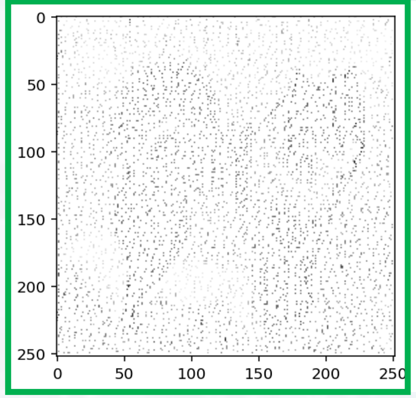
plt.imshow(Conv1.output[:,:,0,4], cmap = 'gray')
plt.show()
plt.imshow(MP1.output[:,:,0,4], cmap = 'gray')
plt.show()
plt.imshow(MP1.dinputs[:,:,0,4], cmap = 'gray_r')
plt.show()
plt.imshow(MP1.mask[:,:,0,4], cmap = 'gray_r')
plt.show()

Diff = MP1.mask[:,:,0,4]/np.max(MP1.mask[:,:,0,4])-\
       MP1.dinputs[:,:,0,4]/np.max(MP1.dinputs[:,:,0,4])
```









Convolution, Image Classification & Segmentation

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

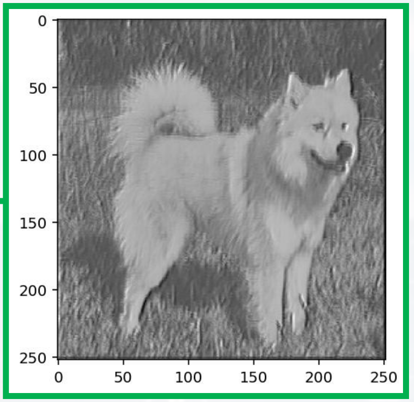
for **backpropagation**, we need to **up-sample** the images!

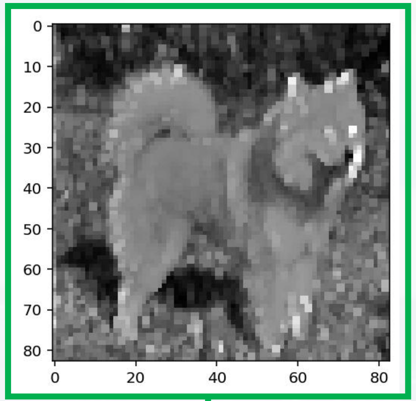
dinputs and mask have to look the same (but different values)!

```
Conv1.forward(I,2,1)
MP1.forward(Conv1.output,3,5)
MP1.backward(MP1.output)

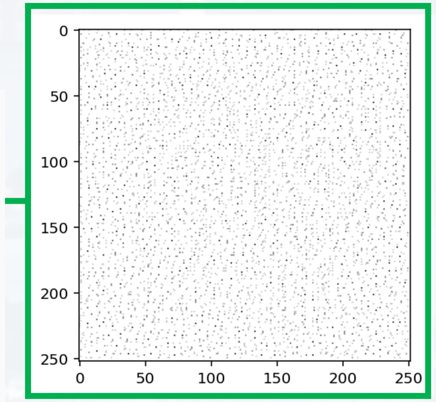
plt.imshow(Conv1.output[:,:,0,4], cmap = 'gray')
plt.show()
plt.imshow(MP1.output[:,:,0,4], cmap = 'gray')
plt.show()
plt.imshow(MP1.dinputs[:,:,0,4], cmap = 'gray_r')
plt.show()
plt.imshow(MP1.mask[:,:,0,4], cmap = 'gray_r')
plt.show()

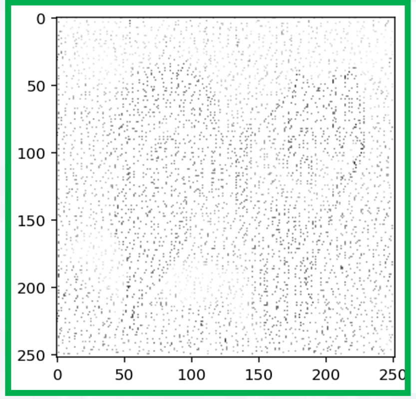
Diff = MP1.mask[:,:,0,4]/
       MP1.dinputs[:,:,0,
```






```
In [20]: Diff
Out[20]:
array([[ 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., -0.],
       [ 0.,  0.,  0., ...,  0., -0., -0.]])
```





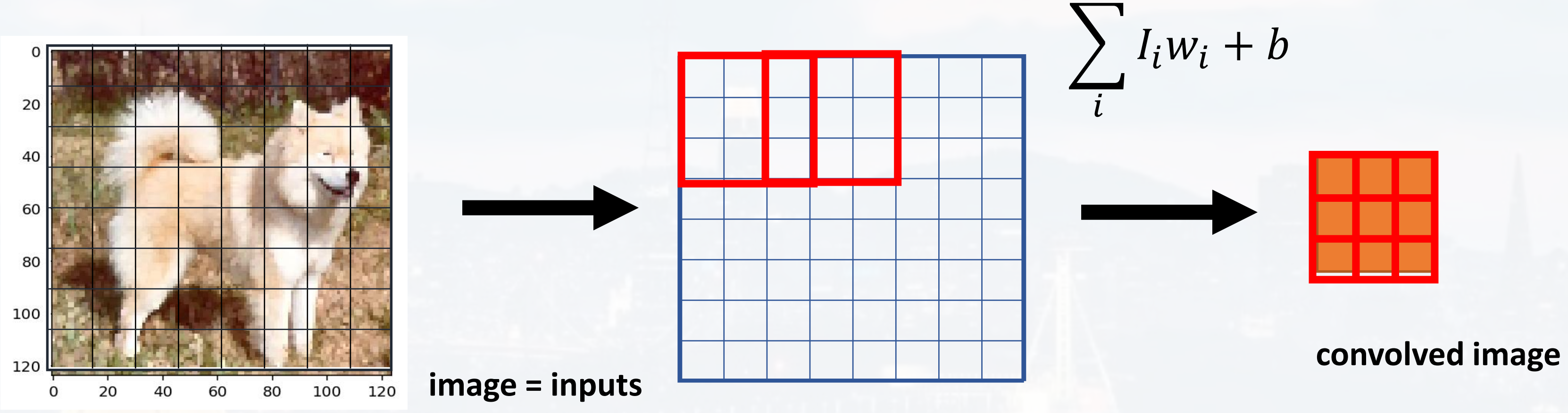
Convolution, Image Classification & Segmentation

for **backpropagation**, we need to **up-sample** the images!

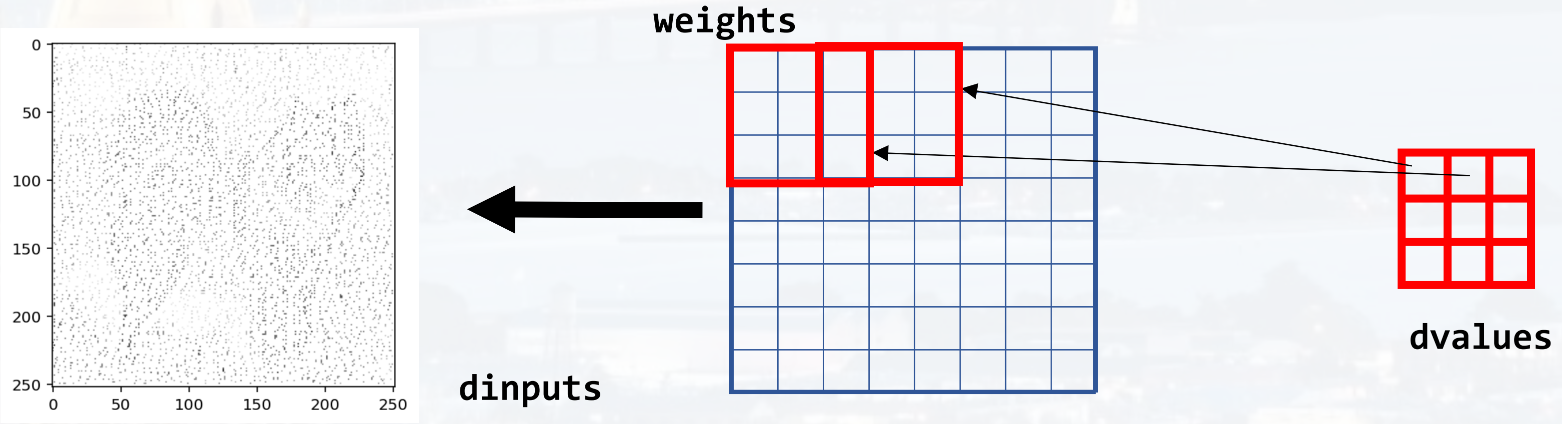
same for convolution layer now:

`backward` `dinputs = dvalues * weights` (we don't need for first conv layer!)

forward:



backward:



Convolution, Image Classification & Segmentation

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same for convolution layer now:

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forward:

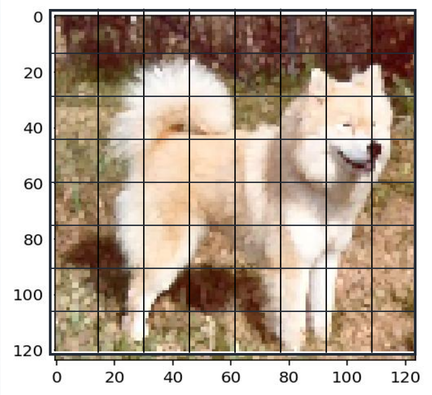
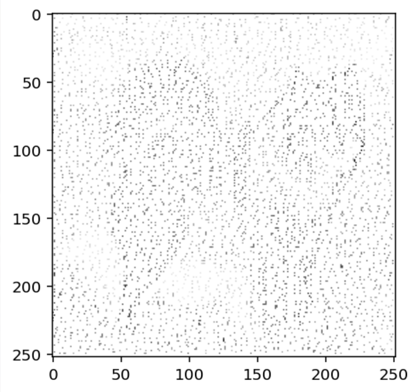


image = inpu

backward:




```
for i in range(numImds):# loop over number of images
    currentIm_pad = imagePadded[:,:,:,i]# Select ith padded image
    for k in range(NK):# loop over kernels (= #filters)
      for c in range(numChan):# loop over channels of incomming data

          if filt[c,k] ==1:

            for y in range(yd):# loop over axis of output
                for x in range(xd):# loop over axis of output


                    # finding corners of the current "slice" (≈4 lines)
                    y_start = y*stride
                    y_end   = y_start + yK
                    x_start = x*stride
                    x_end   = x_start + xK

                    sx      = slice(x_start,x_end)
                    sy      = slice(y_start,y_end)

                    current_slice = currentIm_pad[sx,sy,c]

                    dweights[:,:,k]    += current_slice * dvalues[x,y,k,i]
dinputs[sx,sy,c,i] += weights[:,:,k]* dvalues[x,y,k,i]

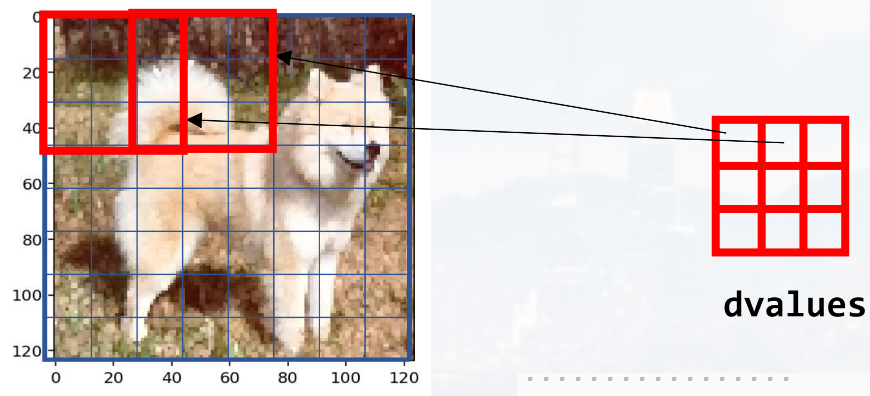
      dbiases[0,k] += np.sum(np.sum(dvalues[:,:,k,i],axis=0),axis=0)
```

for **backpropagation**, we need to **up-sample** the images!

same for convolution layer now:

backward `dweights = dvalues * inputs`

backward:



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sequences as images
segmentation

```
                    # finding corners of the current "slice" (≈4 lines)
                    y_start = y*stride
                    y_end   = y_start + yK
                    x_start = x*stride
                    x_end   = x_start + xK

                    sx      = slice(x_start,x_end)
                    sy      = slice(y_start,y_end)

                    current_slice = currentIm_pad[sx,sy,c]
dweights[:,:,k]    += current_slice * dvalues[x,y,k,i]
                    dinputs[sx,sy,c,i] += weights[:,:,k]* dvalues[x,y,k,i]


      dbiases[0,k] += np.sum(np.sum(dvalues[:,:,k,i],axis=0),axis=0)
```

Convolution, Image Classification & Segmentation

for **backpropagation**, we need to **up-sample** the images!

same for convolution layer now:

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backward `dbiases = dvalues`

backward:

```
                    # finding corners of the current "slice" (≈4 lines)
                    y_start = y*stride
                    y_end   = y_start + yK
                    x_start = x*stride
                    x_end   = x_start + xK

                    sx      = slice(x_start,x_end)
                    sy      = slice(y_start,y_end)

                    current_slice = currentIm_pad[sx,sy,c]

                    dweights[:,:,k]     += current_slice * dvalues[x,y,k,i]
                    dinputs[sx,sy,c,i] += weights[:,:,k]* dvalues[x,y,k,i]

      dbiases[0,k] += np.sum(np.sum(dvalues[:,:,k,i],axis=0),axis=0)
```

$$\boxed{\texttt{dbiases[0,k] += np.sum(np.sum(dvalues[:,:,k,i],axis=0),axis=0)}}$$

Convolution, Image Classification & Segmentation

Examples

LeNet numpy only
LeNet TensorFlow
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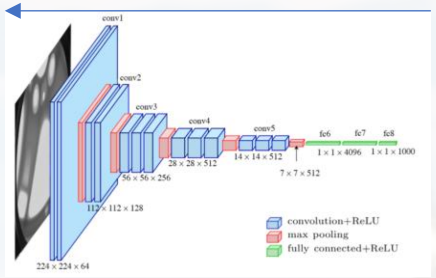
CNNs have an "hourglass" structure

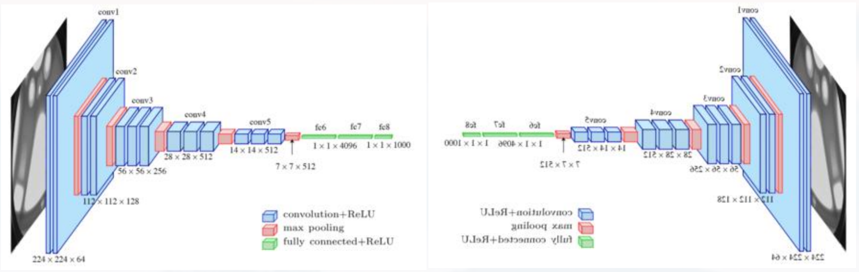
classification:

backward (up-sampling)



forward (down-sampling)

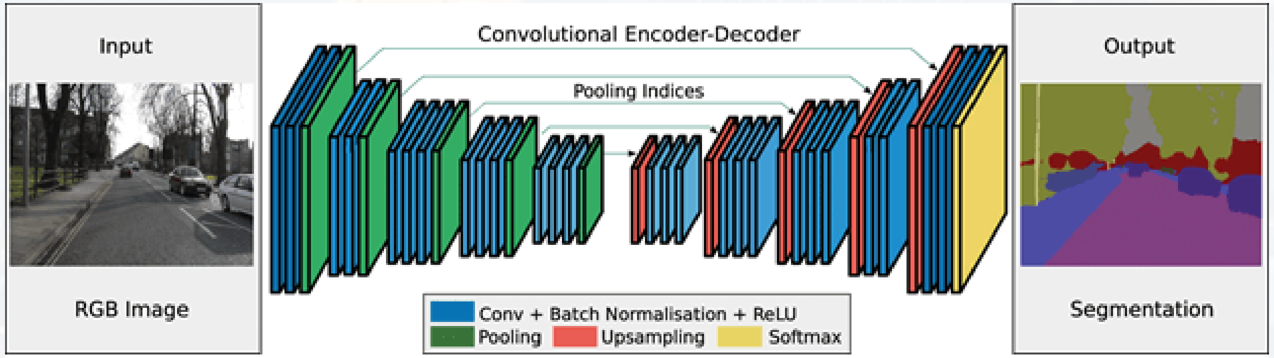
backward (up-sampling)



forward (down-sampling)

segmentation:

backward (up-sampling) *backward (down-sampling)*



forward (down-sampling) *forward (up-sampling)*

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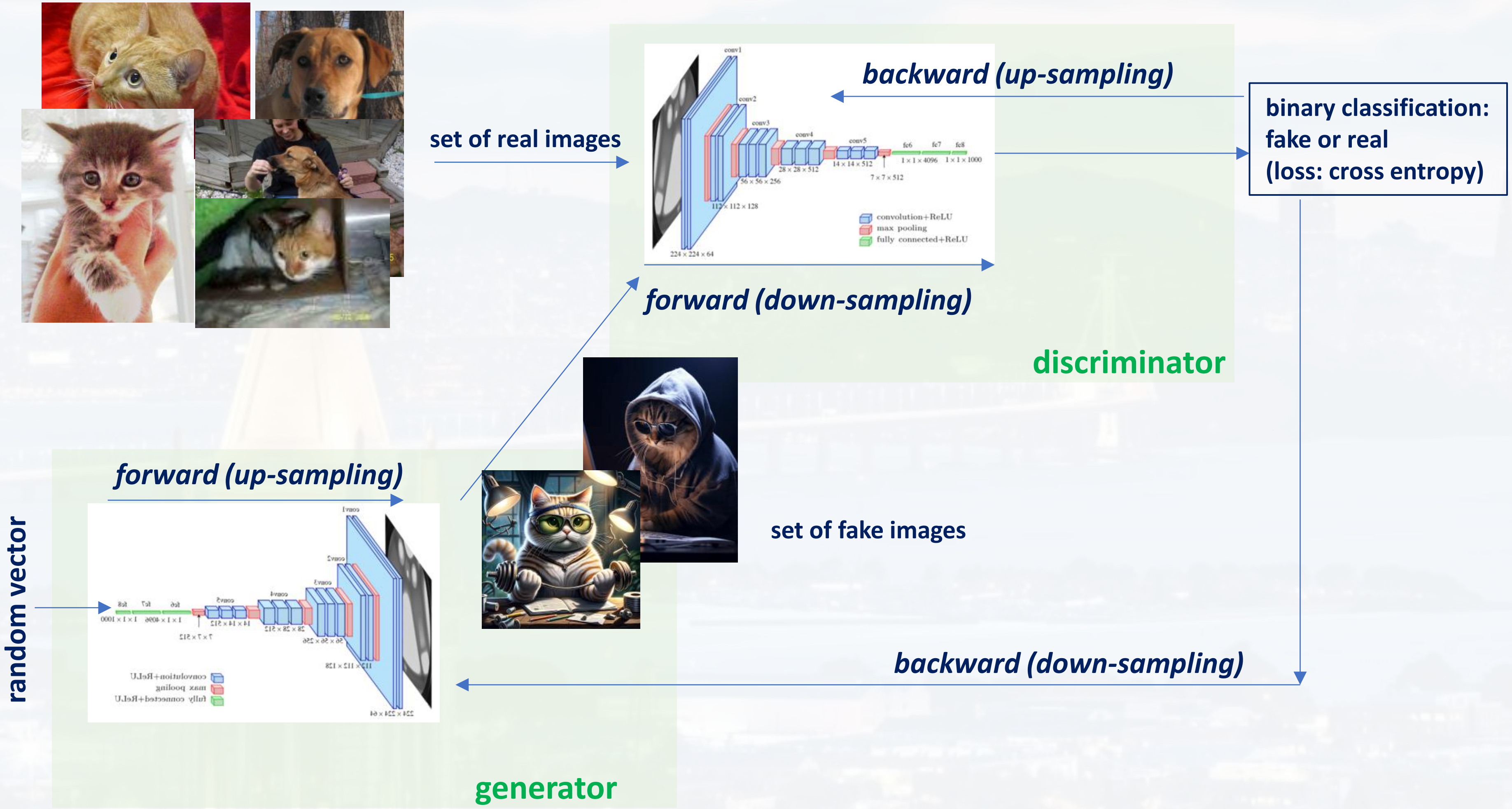
CNNs have an “hourglass” structure

Generative **A**dversarial **N**etwork (GAN):



Convolution, Image Classification & Segmentation

We are done now and can explore our self-made LeNet

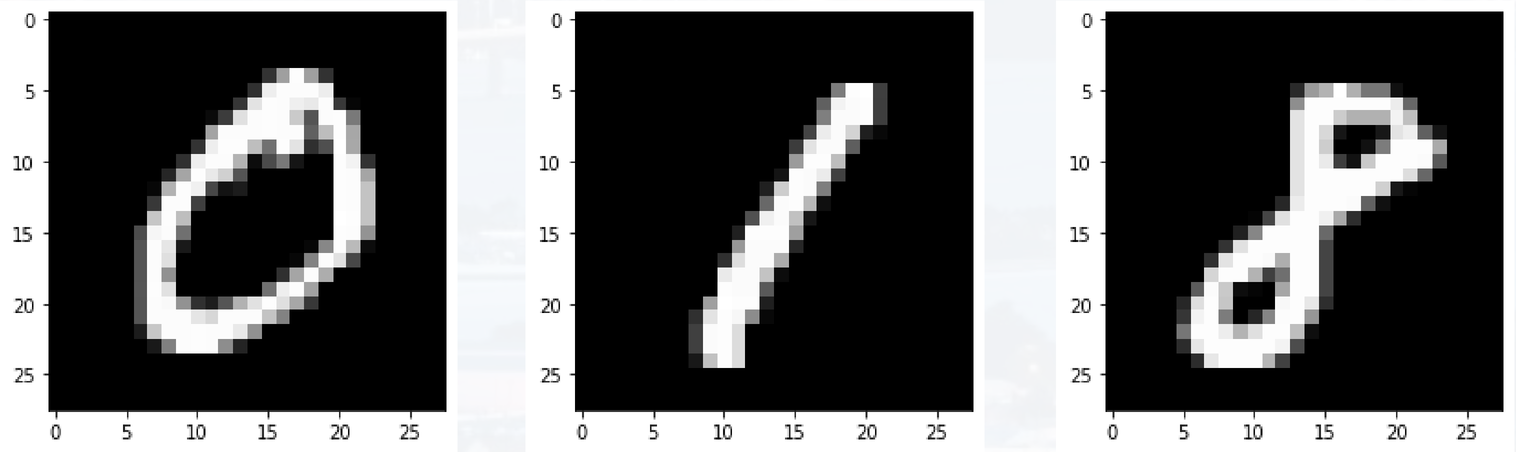
- MyCNN.py
  - Read_Scale_Imds
  - ConvLayer
    - __init__
    - forward
    - backward
  - Average_Pool
  - Min_Pool
  - Max_Pool
  - Sigmoid
  - Tanh
  - Activation_ReLU
  - Flat
  - Layer_Dense
  - Activation_Softmax
  - Loss
  - Loss_CategoricalCrossEntropy
  - CalcSoftmaxLossGrad
  - Optimizer_SGD

```
#pip install keras
#pip install tensorflow

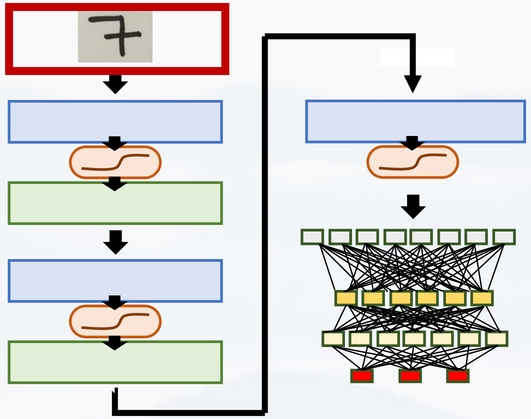
from keras.datasets import mnist

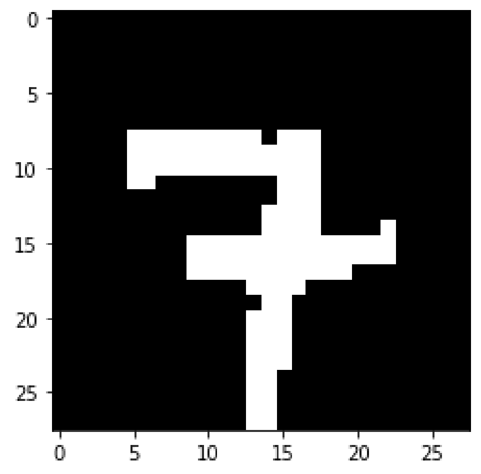
(train_x, train_y), (test_x, test_y) = mnist.load_data()
```

```
plt.imshow(train_x[1,:,:], cmap = 'gray')
```



exploring self-made LeNet:





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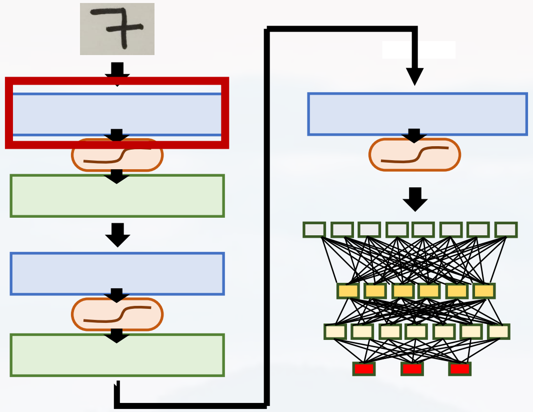
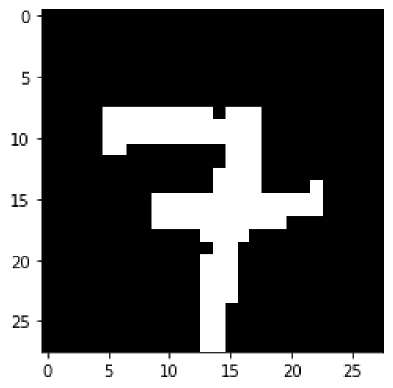
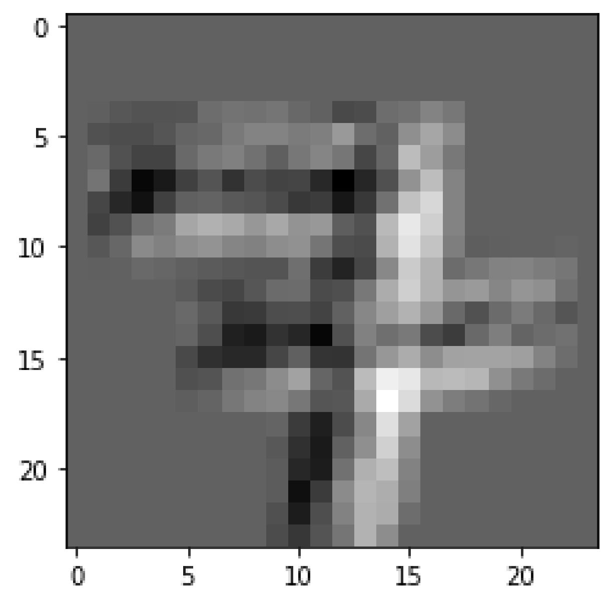
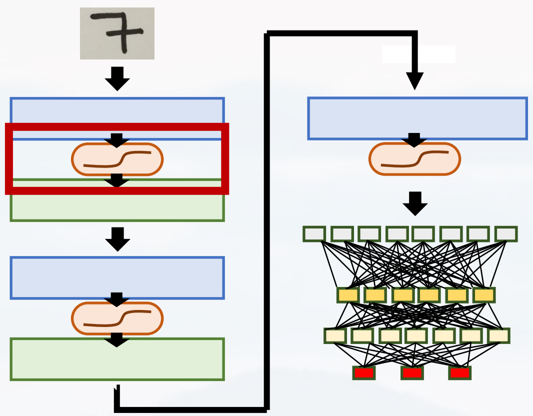
exploring self-made LeNet:

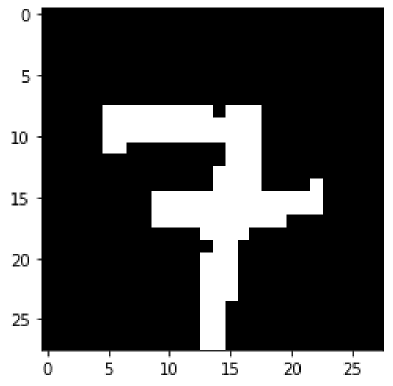


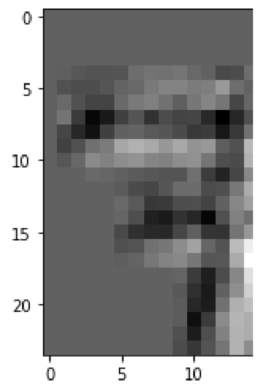


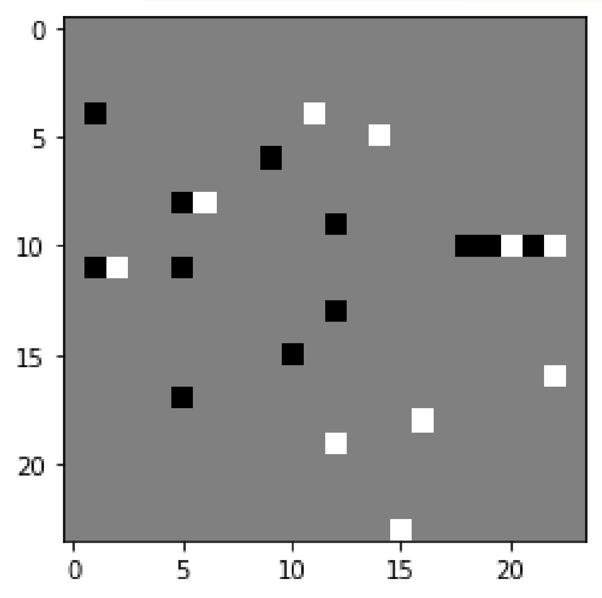


exploring self-made LeNet:









LeNet numpy only
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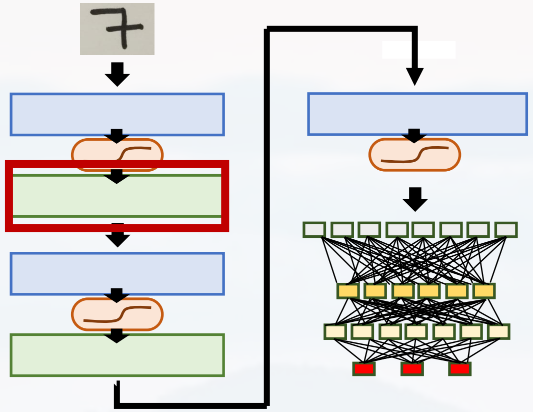
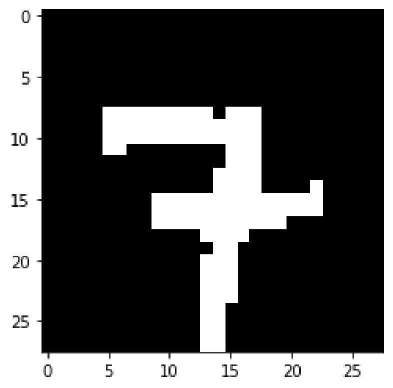
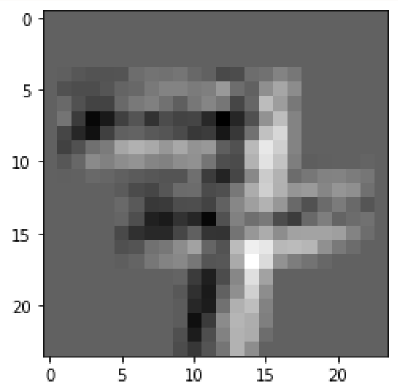
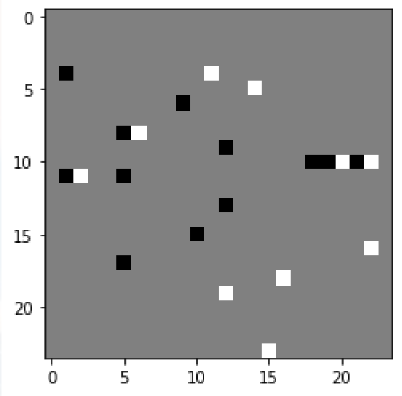
exploring self-made LeNet:









LeNet numpy only
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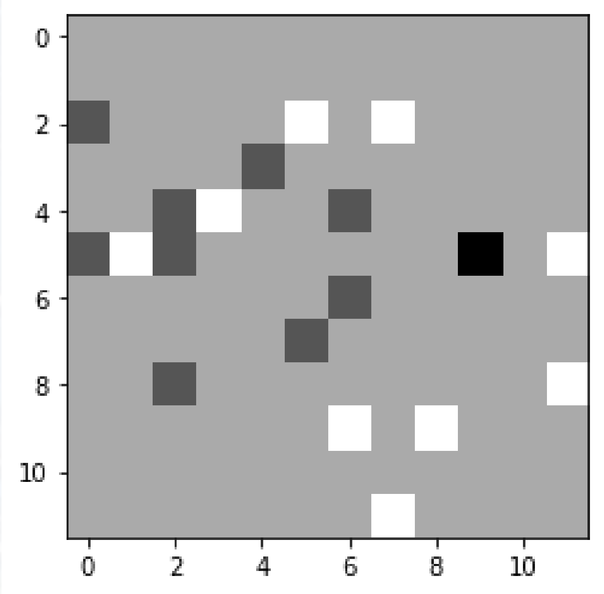
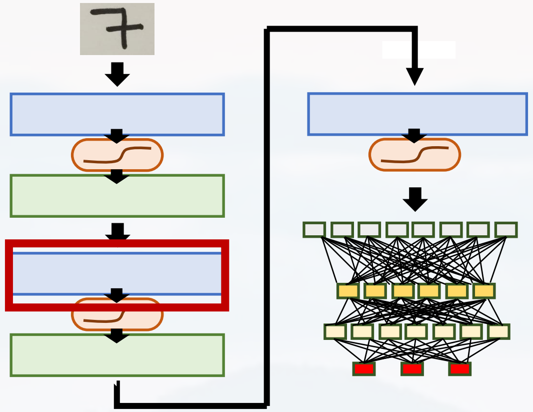
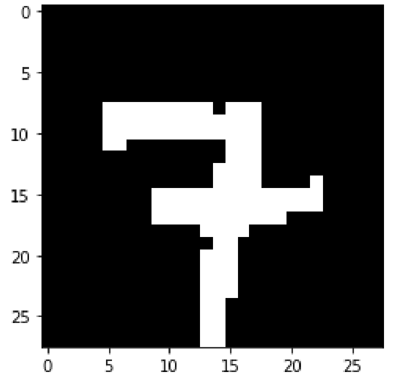
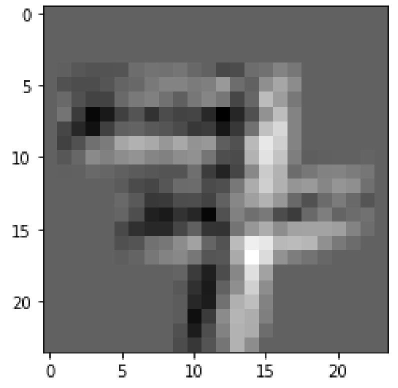


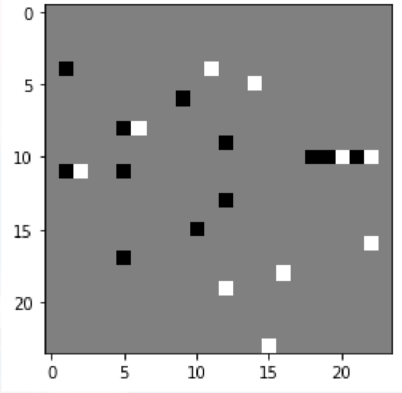
Convolution, Image Classification & Segmentation

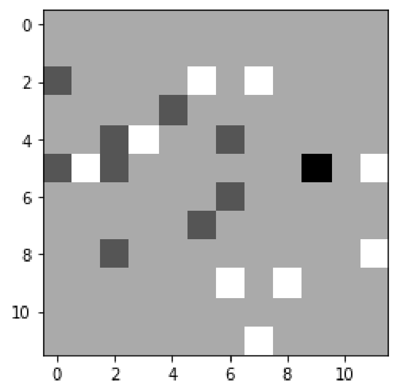
exploring self-made LeNet:

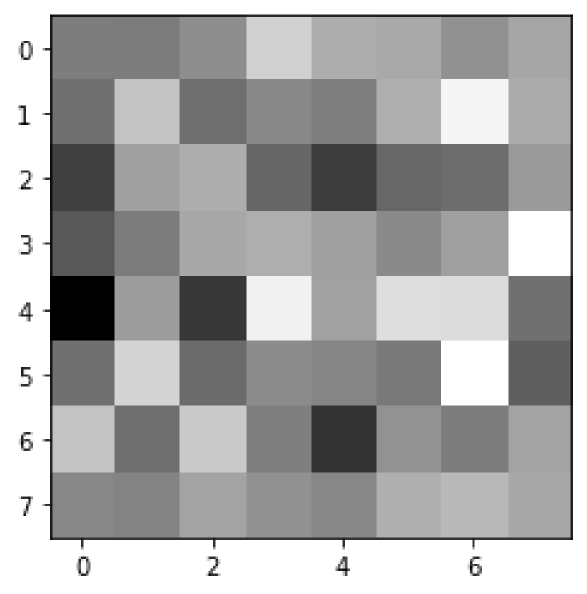












exploring self-made LeNet:

LeNet numpy only
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sequences as images
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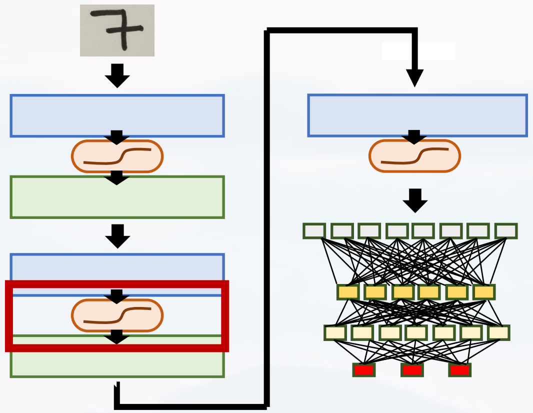
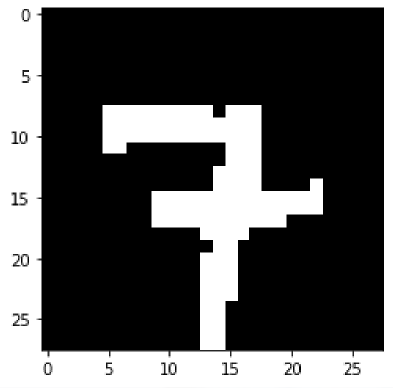
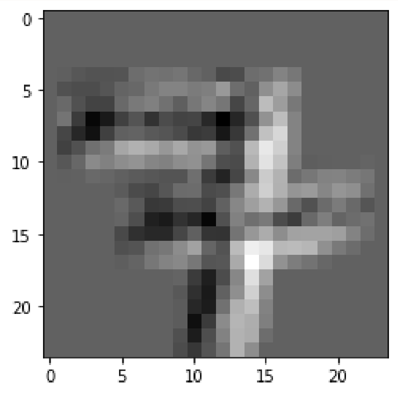
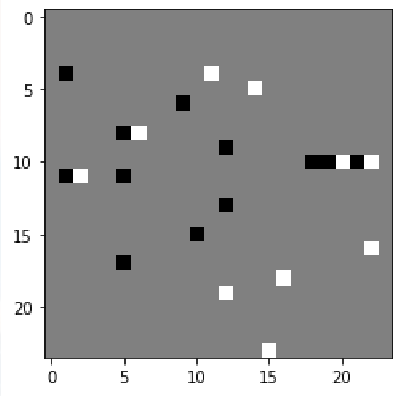
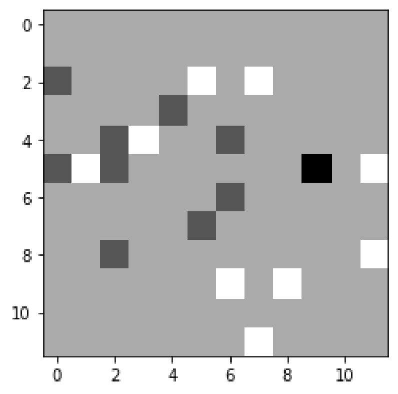
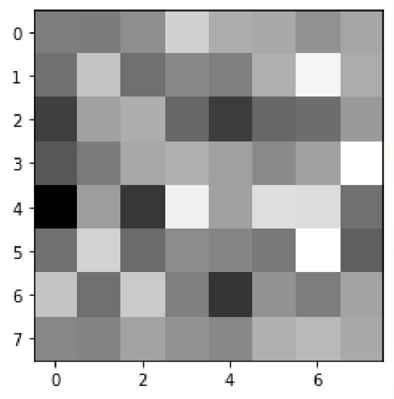


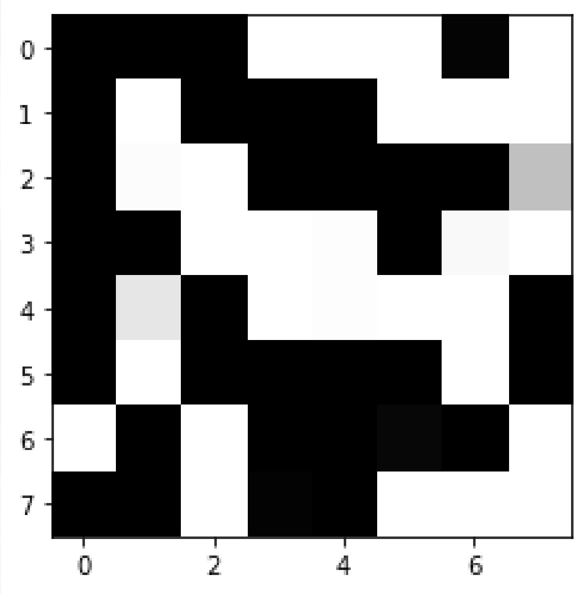






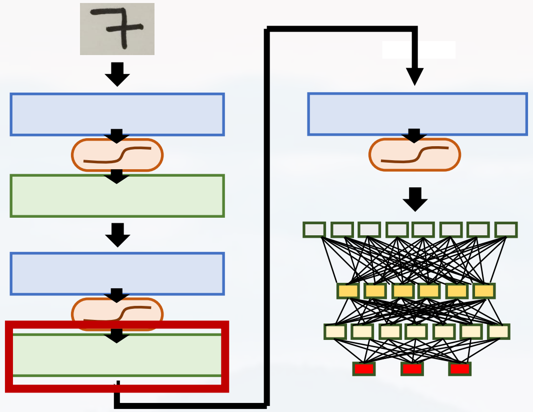


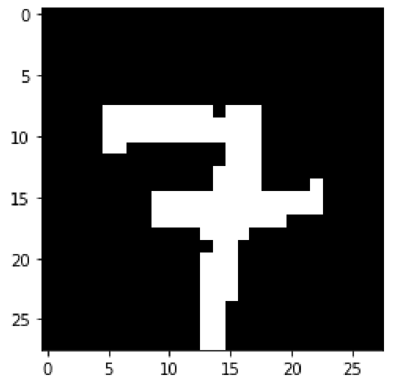


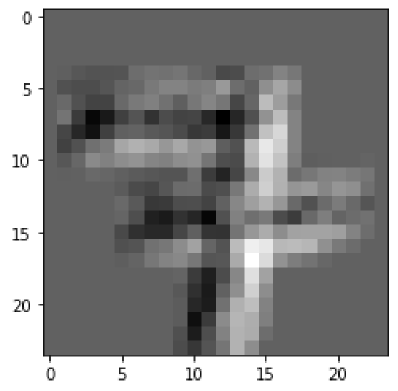


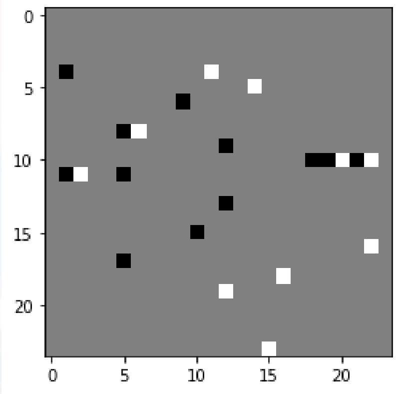
Convolution, Image Classification & Segmentation

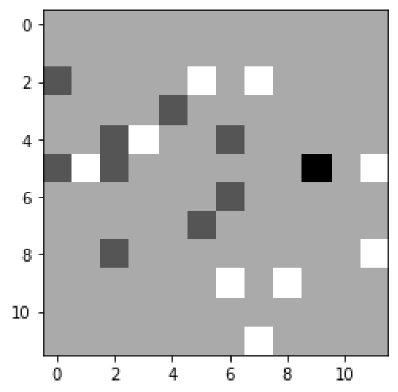
exploring self-made LeNet:

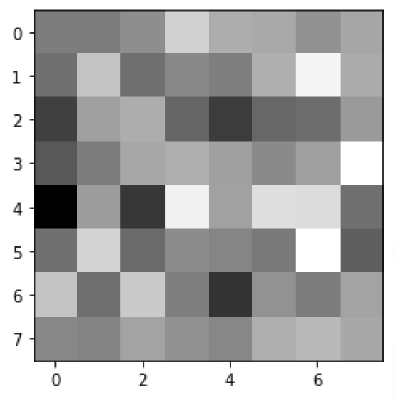


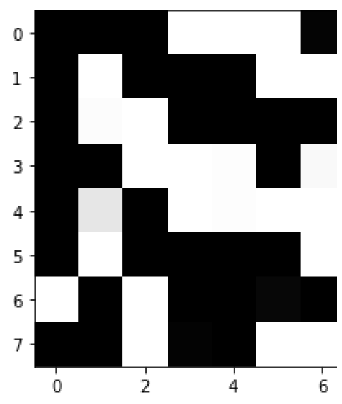


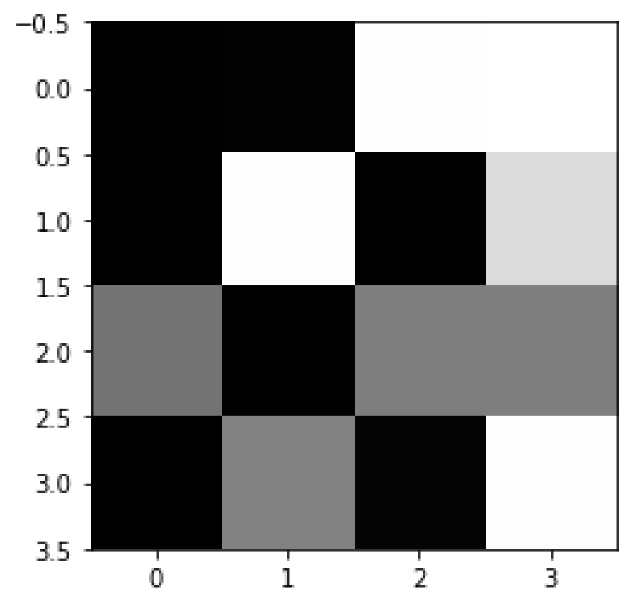




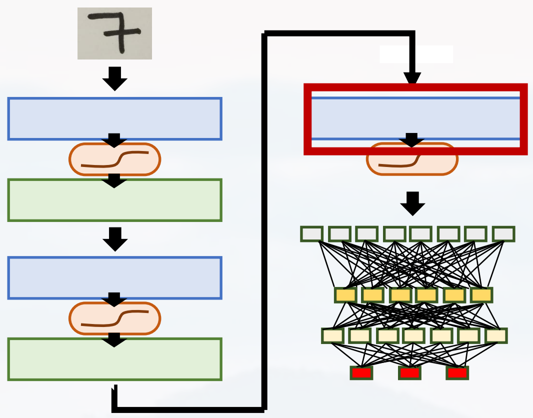


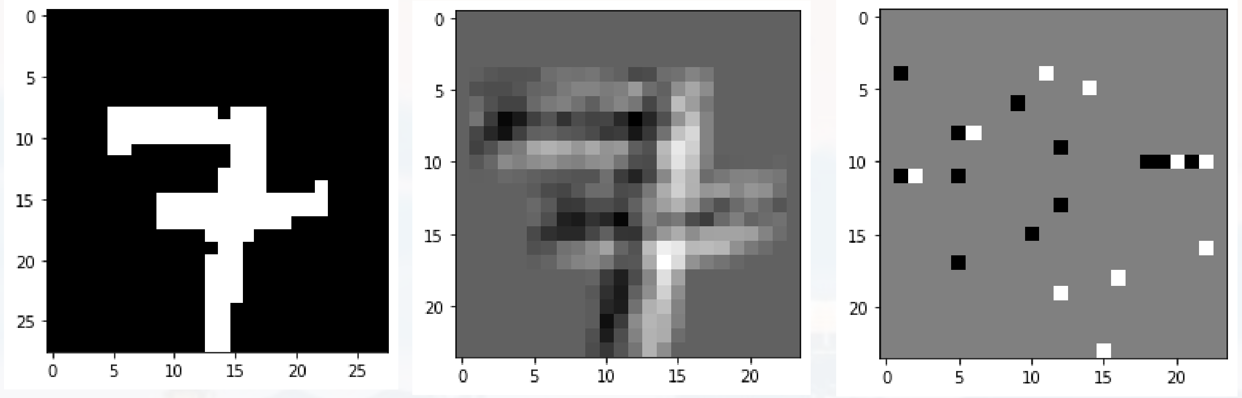


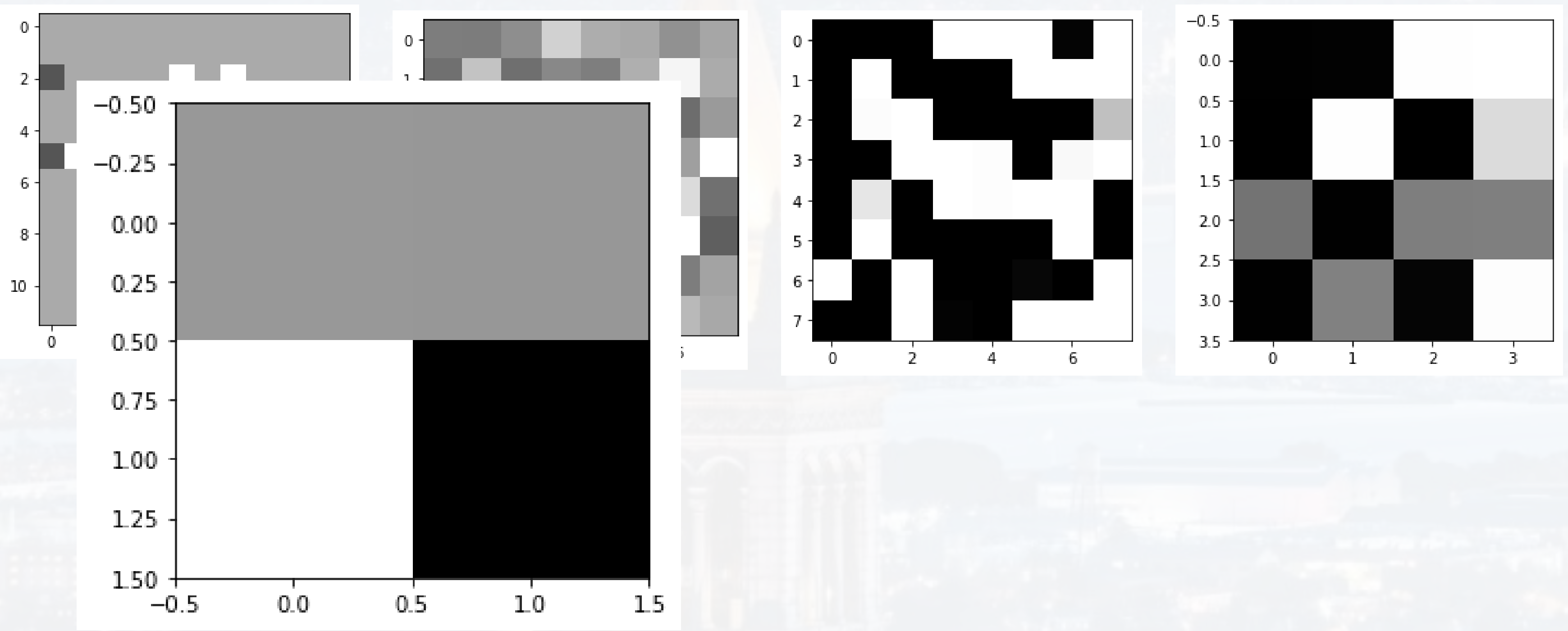




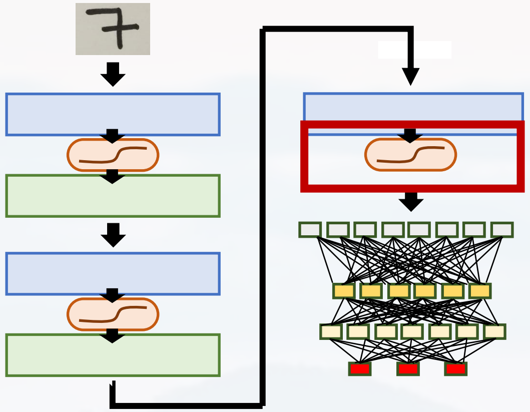
exploring self-made LeNet:

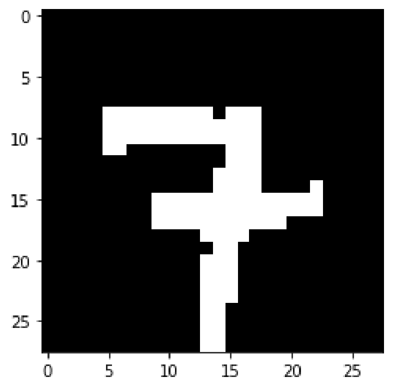


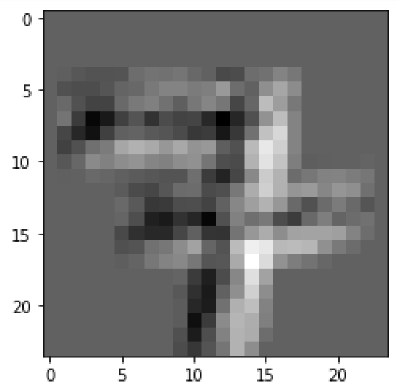


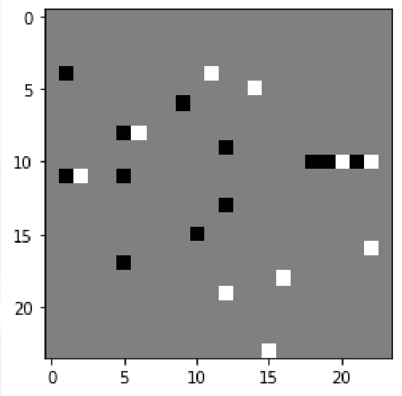


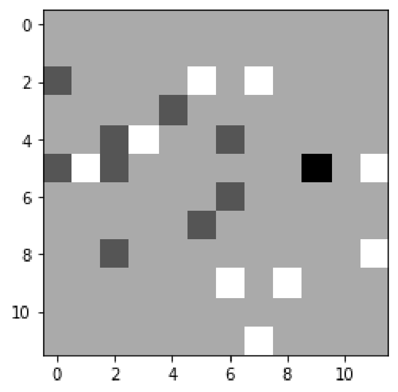
exploring self-made LeNet:

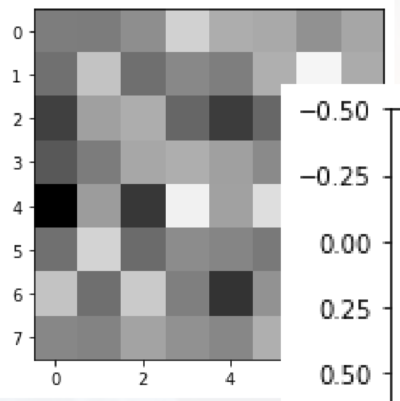


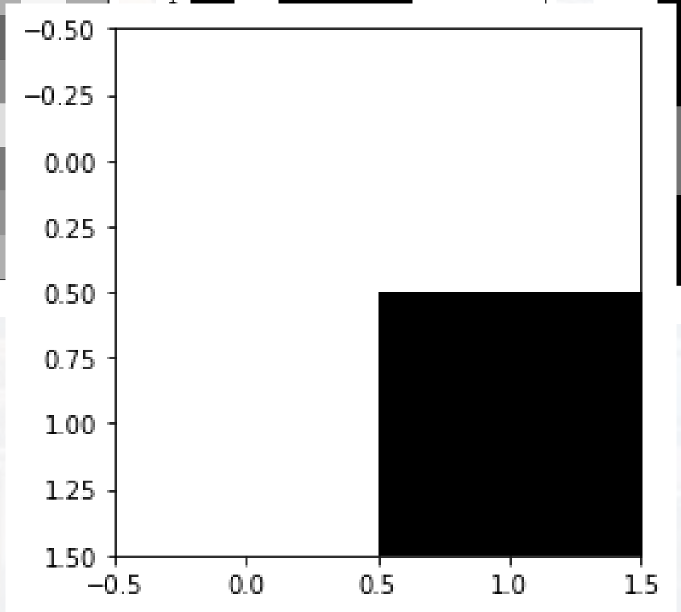


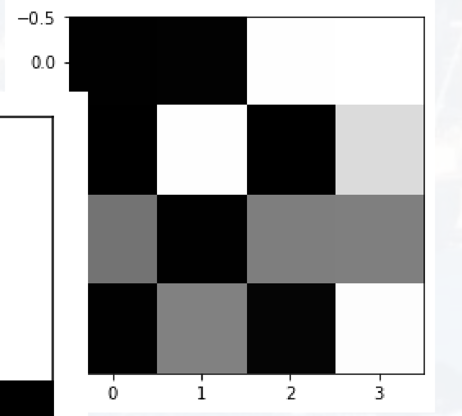


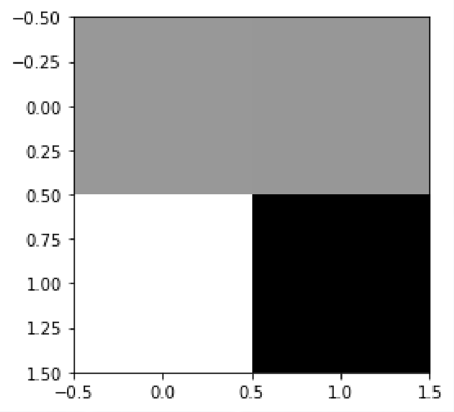






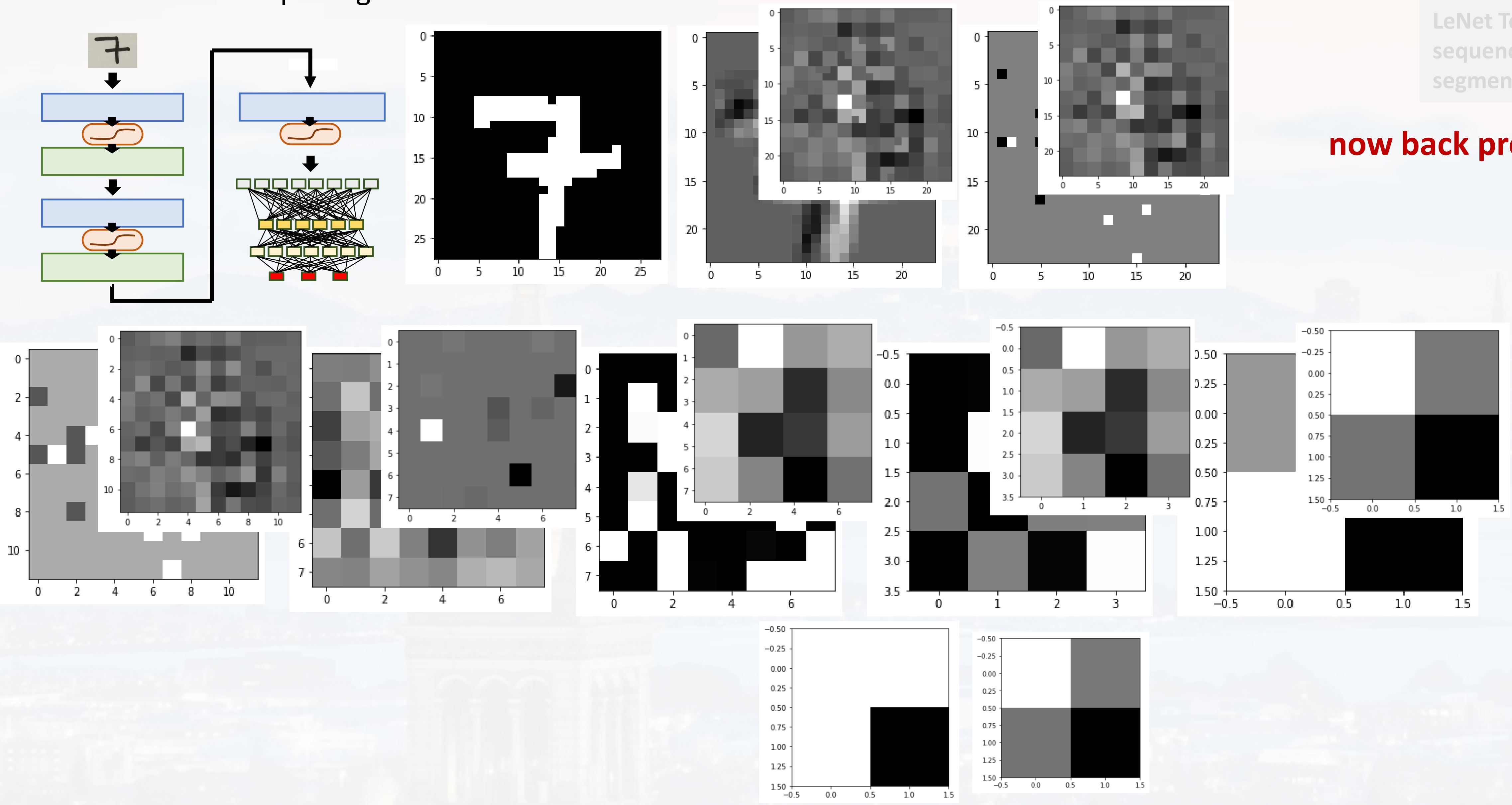






LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

exploring self-made LeNet:



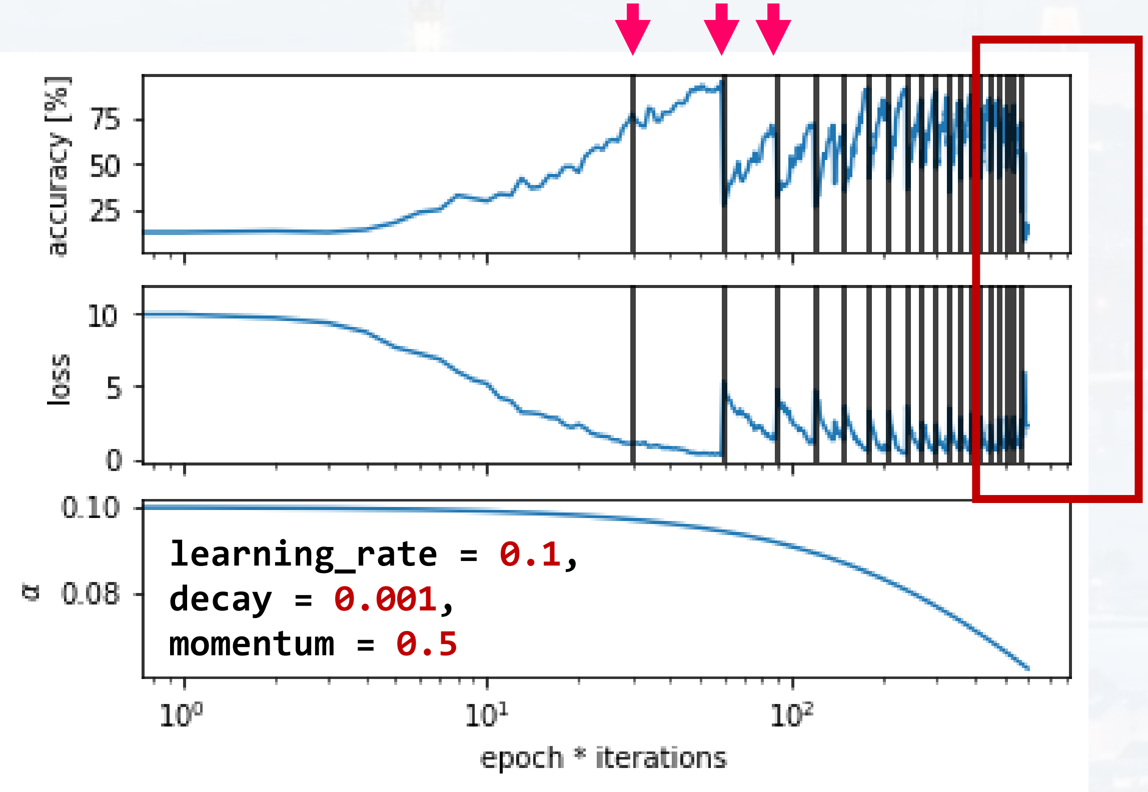
LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

now back propagation!

running self-made LeNet:

```
LeNet = MyLeNet()
LeNet.RunTraining()
```


loads new batch



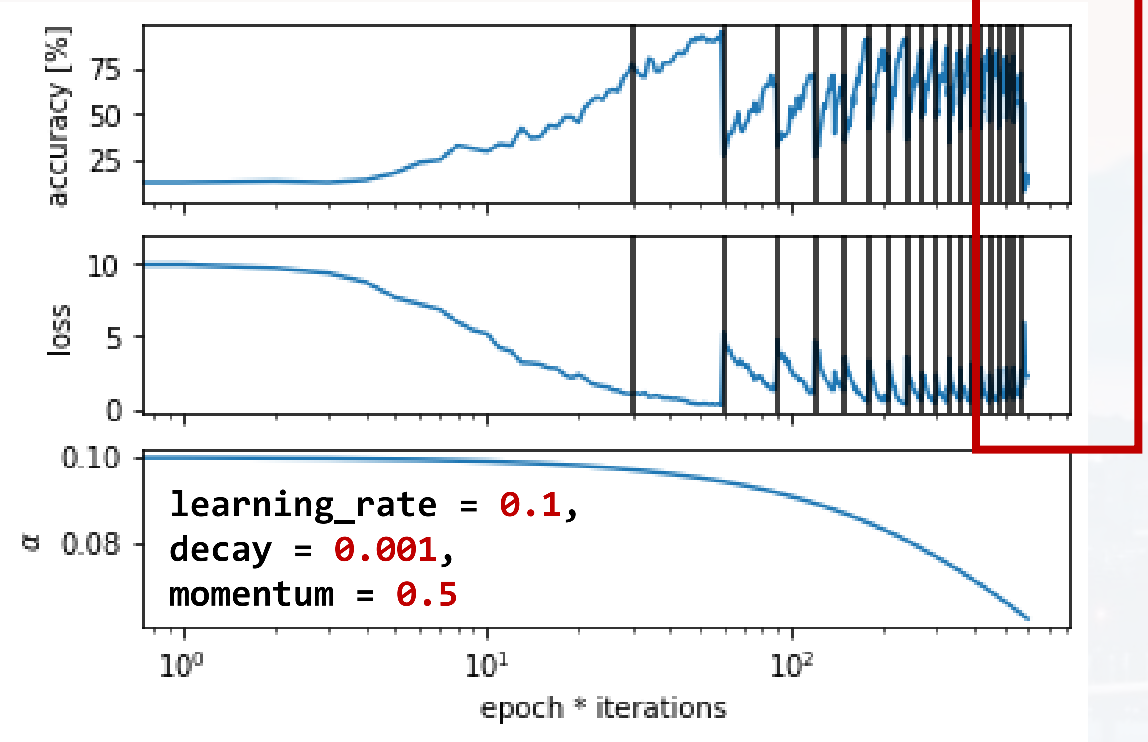
after several iterations:

→ accuracy drops and loss gets up again

→ gets stuck

Why???

running self-made LeNet:



after several iterations:

→ accuracy drops and loss gets up again

→ gets stuck

Why???

LeNet numpy only

LeNet TensorFlow

sequences as images

segmentation

	0	1	2	3
0	-15923.3	-16647.4	-16277.1	-16993.1
1	9795.1	8468.91	9110.83	8205.6
2	37956.4	36572.6	37324.2	37008.4
3	39686.6	39131	39087.4	39614.6
4	25465.3	26270.1	25232.4	25836.7

```
W = np.load('weightsC1.npy')
W[:,:,0]
```

<u>Weights are exploding!</u>

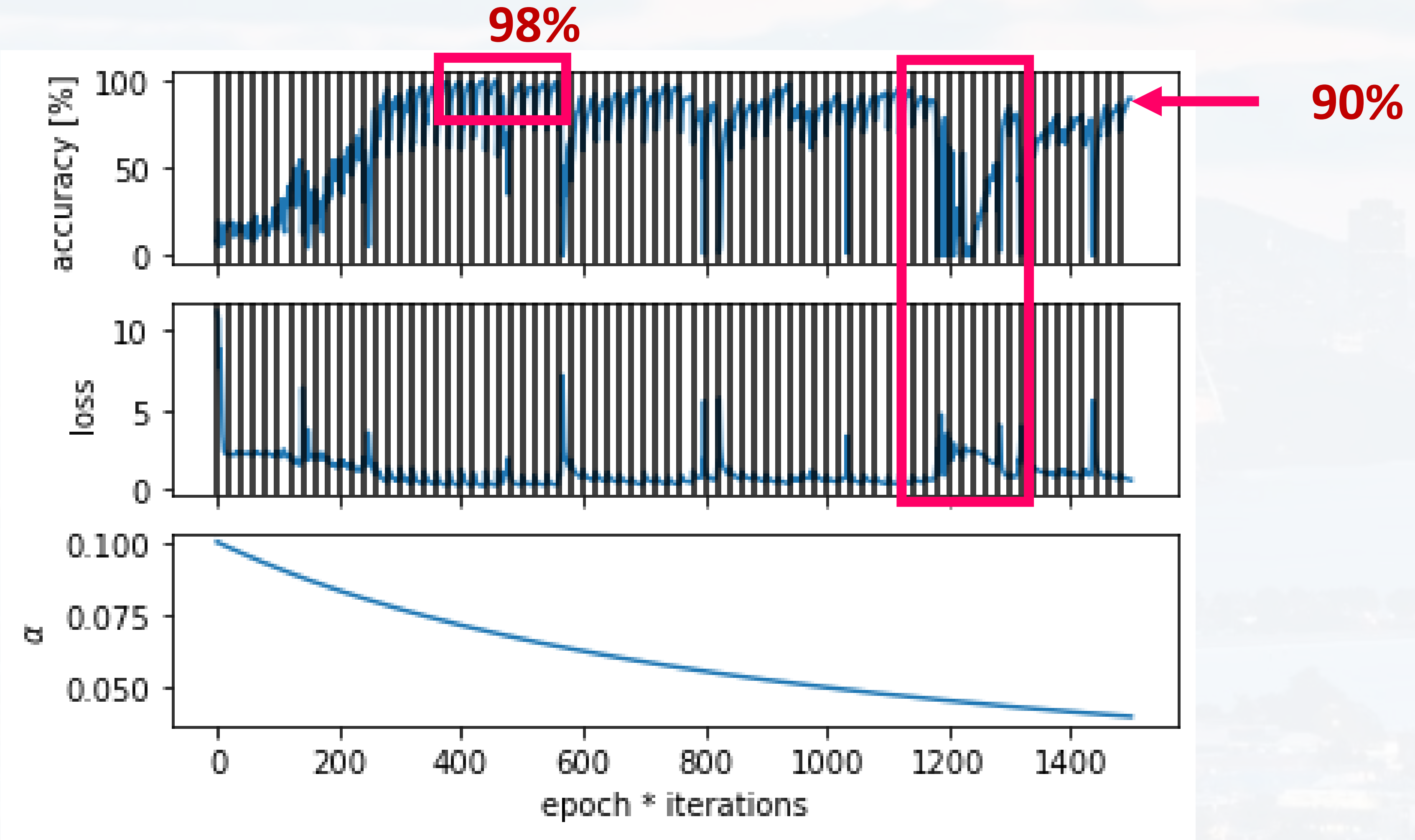
→ penalizing large weights

→ L2 regularization

running self-made LeNet:

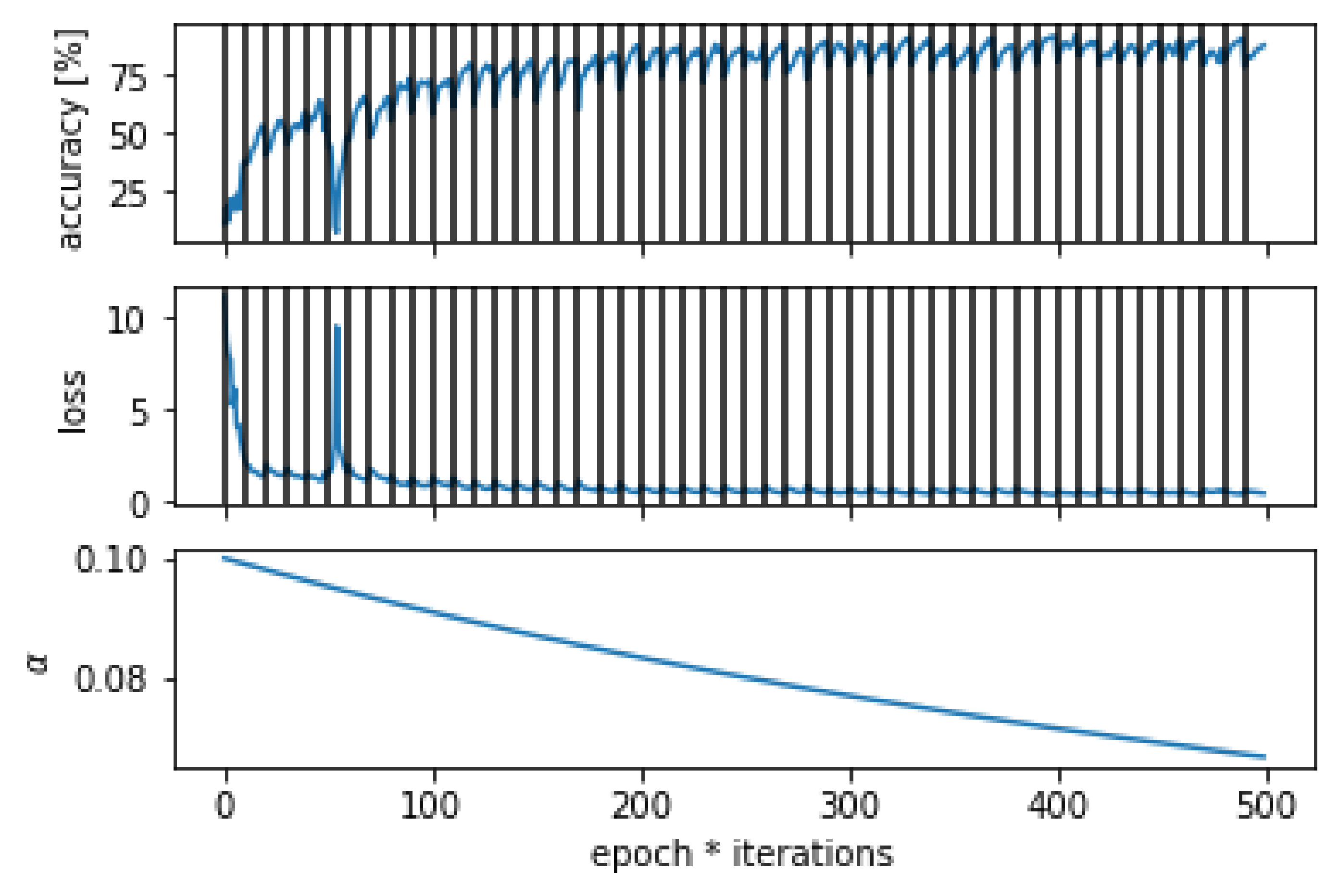
run the function `MyLeNet` again, but this time with `L2`

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation



running self-made LeNet:

```
minibatch_size = 512, iterations = 10, epochs = 50
```



LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

evaluating self-made LeNet:

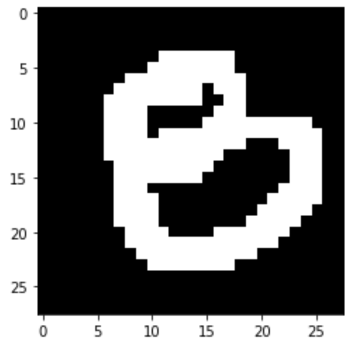
```
EvaluateMyLeNet(N = 50)
```

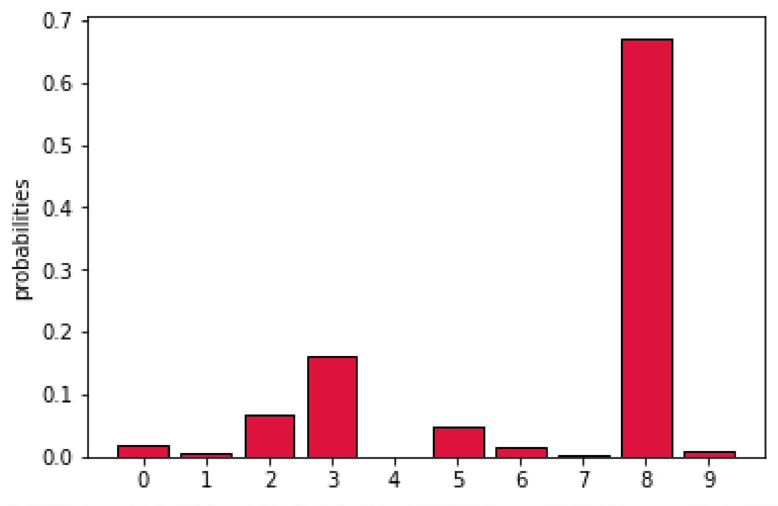
predicted

	0
0	1
1	4
2	8
3	7
4	5
5	8
6	0
7	6
8	2

actual

	0
0	3
1	5
2	8
3	7
4	5
5	3
6	0
7	6
8	2





Convolution, Image Classification & Segmentation

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

evaluating self-made LeNet:

```
EvaluateMyLeNet(N = 50)
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predicted

	0
0	1
1	4
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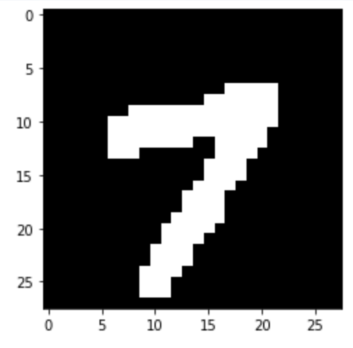
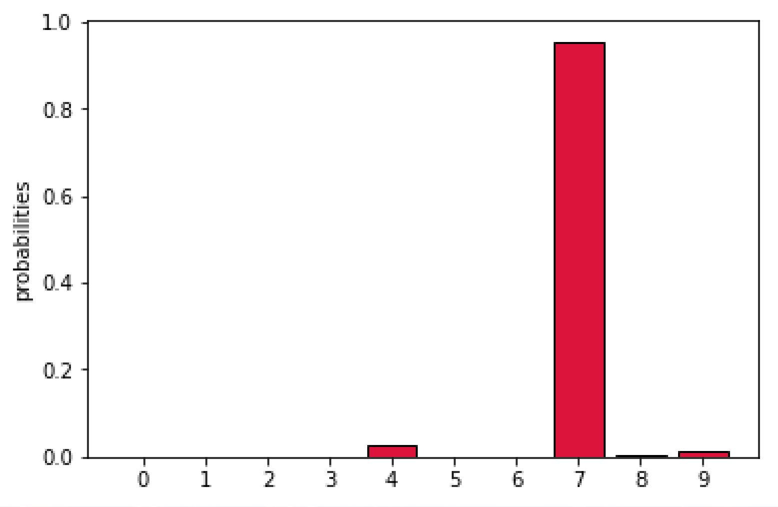
6	0
7	6
8	2

actual

	0
0	3
1	5
2	8
3	7
4	5
5	3
6	0
7	6
8	2





Convolution, Image Classification & Segmentation

see `LeNetTF.py` and `LeNetTF.ipynb`

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.losses import categorical_crossentropy
from tensorflow.keras.layers import Dense, Flatten, Conv2D, AveragePooling2D
```

```
class MyLeNet(Sequential):

    def __init__(self, input_shape, num_classes):
        super().__init__()

#building LeNet ##########################################################################################
        #Note padding: string, either "valid" or "same" (case-insensitive). "valid" means no padding. "same"
        #more info: https://keras.io/api/layers/convolution_layers/convolution2d/

        self.add(Conv2D(6,   kernel_size = (5, 5),    strides = (1, 1), activation = 'tanh', input_shape = input_shape, padding = 'same'))
        self.add(AveragePooling2D(pool_size = (2, 2), strides = (2, 2),                                      padding = 'valid'))
        self.add(Conv2D(16,  kernel_size = (5, 5),    strides = (1, 1), activation = 'tanh',                 padding = 'valid'))
        self.add(AveragePooling2D(pool_size = (2, 2), strides = (2, 2),                                      padding = 'valid'))
        self.add(Conv2D(120, kernel_size = (5, 5),    strides = (3, 3), activation = 'tanh',                 padding = 'valid'))
        self.add(Flatten())
        self.add(Dense(84,                                              activation = 'tanh'))
        self.add(Dense(num_classes,                                     activation = 'softmax'))
        #########################################################################################################

#building the optimizer ##################################################################################

        lr_schedule = tf.keras.optimizers.schedules.ExponentialDecay(initial_learning_rate = 1e-2, decay_steps = 10000, decay_rate = 0.98)
        opt         = tf.keras.optimizers.SGD(learning_rate = lr_schedule, momentum = 0.9)

        self.compile(optimizer = opt, loss = categorical_crossentropy, metrics = ['accuracy'])
```

Convolution, Image Classification & Segmentation

see `LeNetTF.py` and `LeNetTF.ipynb`


```
Model: "my_le_net_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)           (None, 28, 28, 6)         156

 average_pooling2d_2 (Avera  (None, 14, 14, 6)         0
 gePooling2D)

 conv2d_4 (Conv2D)           (None, 10, 10, 16)        2416

 average_pooling2d_3 (Avera  (None, 5, 5, 16)          0
 gePooling2D)

 conv2d_5 (Conv2D)           (None, 1, 1, 120)         48120

 flatten_1 (Flatten)         (None, 120)               0

 dense_2 (Dense)             (None, 84)                10164

 dense_3 (Dense)             (None, 10)                850

=================================================================
Total params: 61706 (241.04 KB)
Trainable params: 61706 (241.04 KB)
Non-trainable params: 0 (0.00 Byte)
```

input = (N images, 28 x 28 pixel, 3 colors)
output = (N images, 28 x 28 pixel, 6 Conv filter)

6 Conv filter * shape (5, 5) = 150
plus 1 bias for each filter → total 156

Each image is represented by a vector of length 120

output layer: one neuron for each class

Convolution, Image Classification & Segmentation

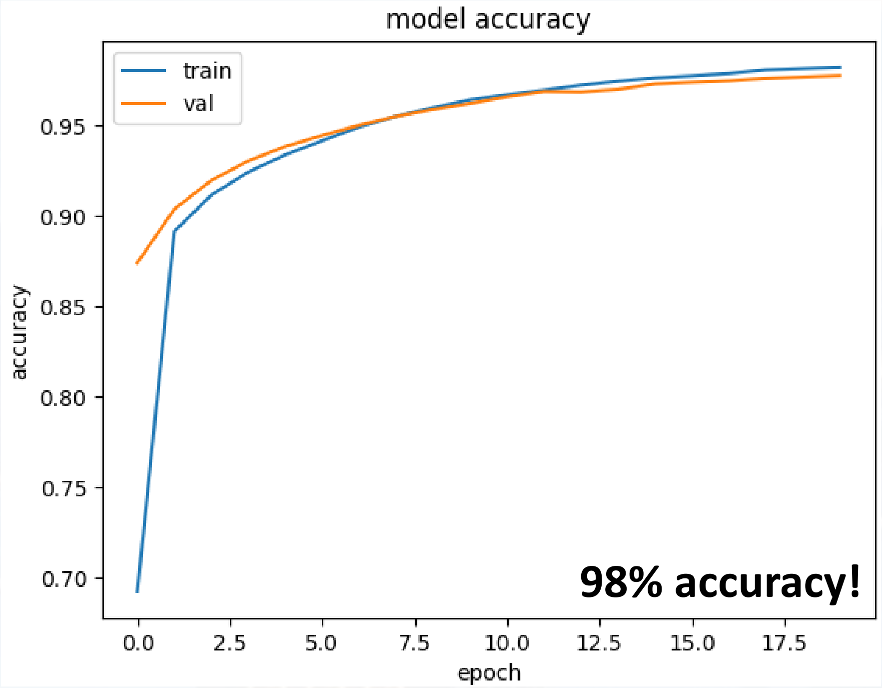
see `LeNetTF.py` and `LeNetTF.ipynb`

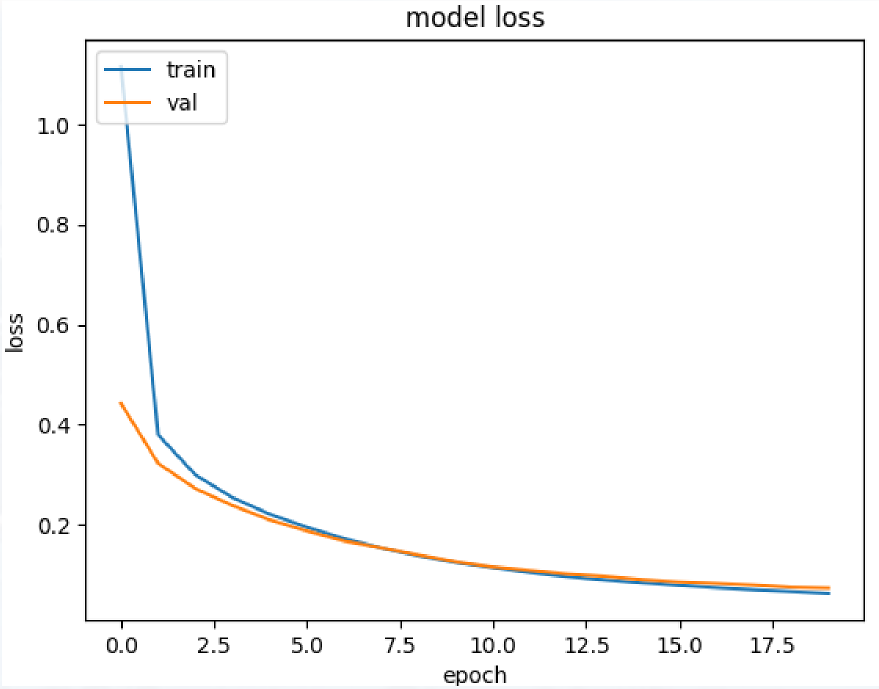
```
running model...
Epoch 1/20
94/94 [==============================] - 9s 92ms/step - loss: 1.1172 - accuracy: 0.7160 - val_loss: 0.4217 - val_accuracy: 0.8838
Epoch 2/20
94/94 [==============================] - 8s 88ms/step - loss: 0.3577 - accuracy: 0.8990 - val_loss: 0.3096 - val_accuracy: 0.9109
Epoch 3/20
94/94 [==============================] - 7s 73ms/step - loss: 0.2876 - accuracy: 0.9163 - val_loss: 0.2606 - val_accuracy: 0.9231
Epoch 4/20
94/94 [==============================] - 8s 90ms/step - loss: 0.2444 - accuracy: 0.9287 - val_loss: 0.2238 - val_accuracy: 0.9333
Epoch 5/20
94/94 [==============================] - 7s 69ms/step - loss: 0.2113 - accuracy: 0.9376 - val_loss: 0.1944 - val_accuracy: 0.9423
```

<u>epoch:</u> passing the entire dataset through the network

60, 000 images / batch size = **512** = 117 iterations per epoch
= **117 * 80**% for training = **94 iterations per epoch**

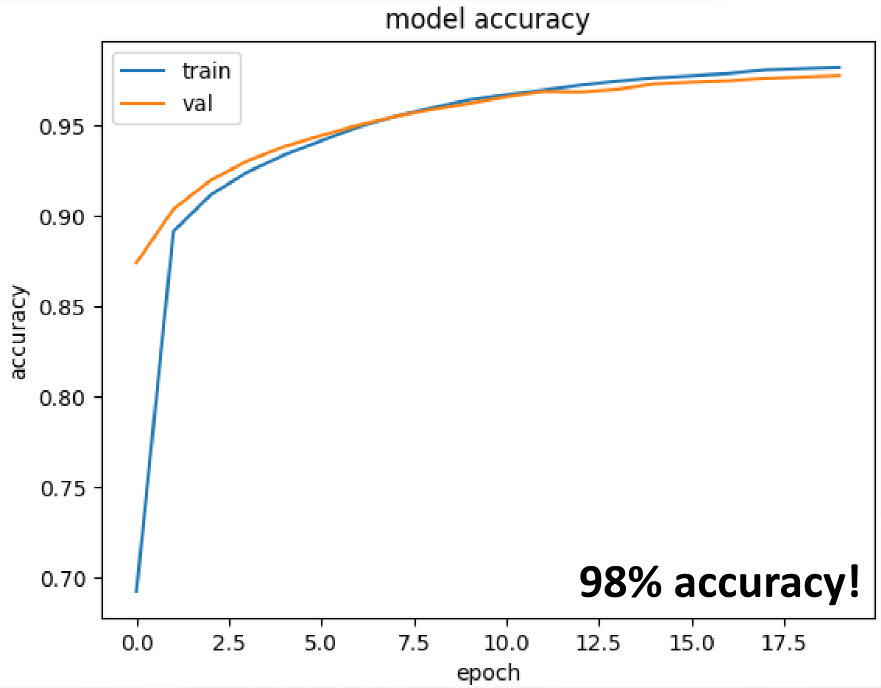
see `LeNetTF.py` and `LeNetTF.ipynb`

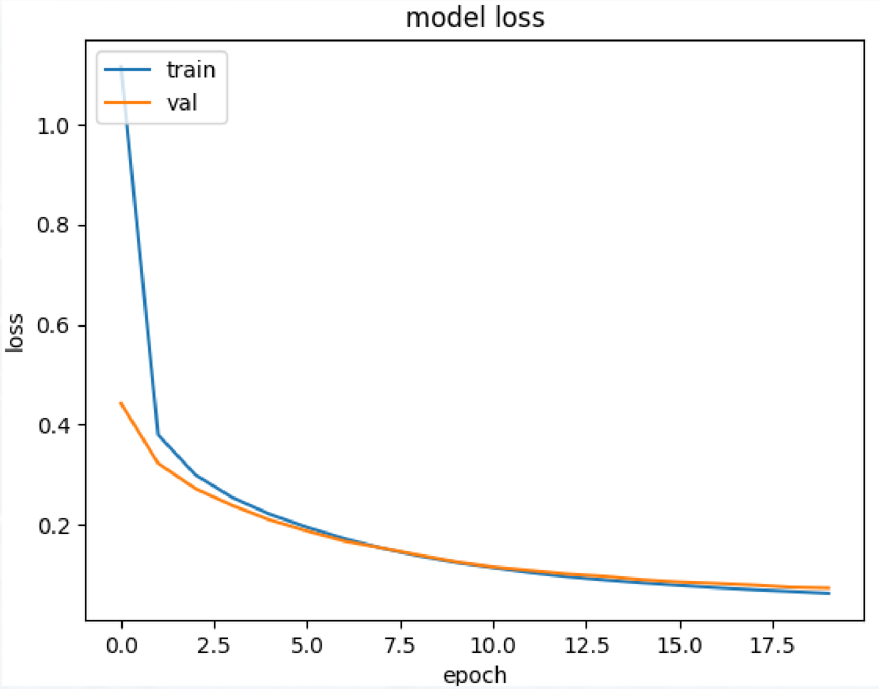




Convolution, Image Classification & Segmentation

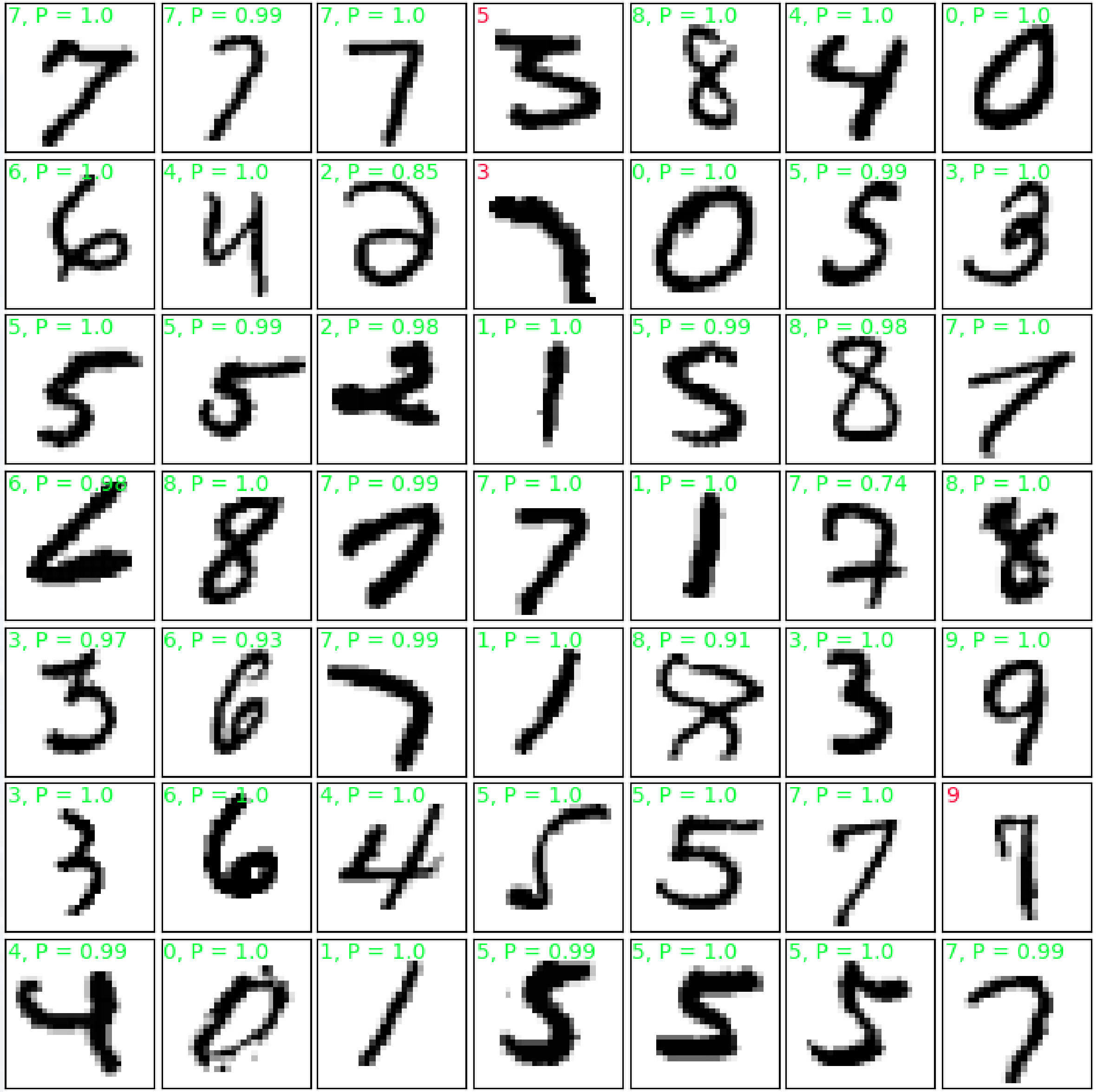
see `LeNetTF.py` and `LeNetTF.ipynb`





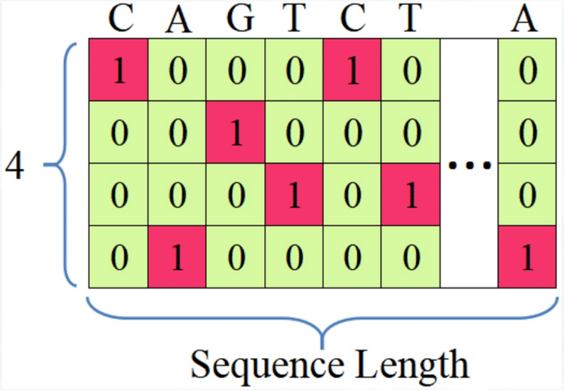
training loss should ≈ validation loss
if validation loss >> training loss → overfitting
- too many parameter
- too few images in batch
- too specific/unique batch)

see `LeNetTF.py` and `LeNetTF. ipynb`

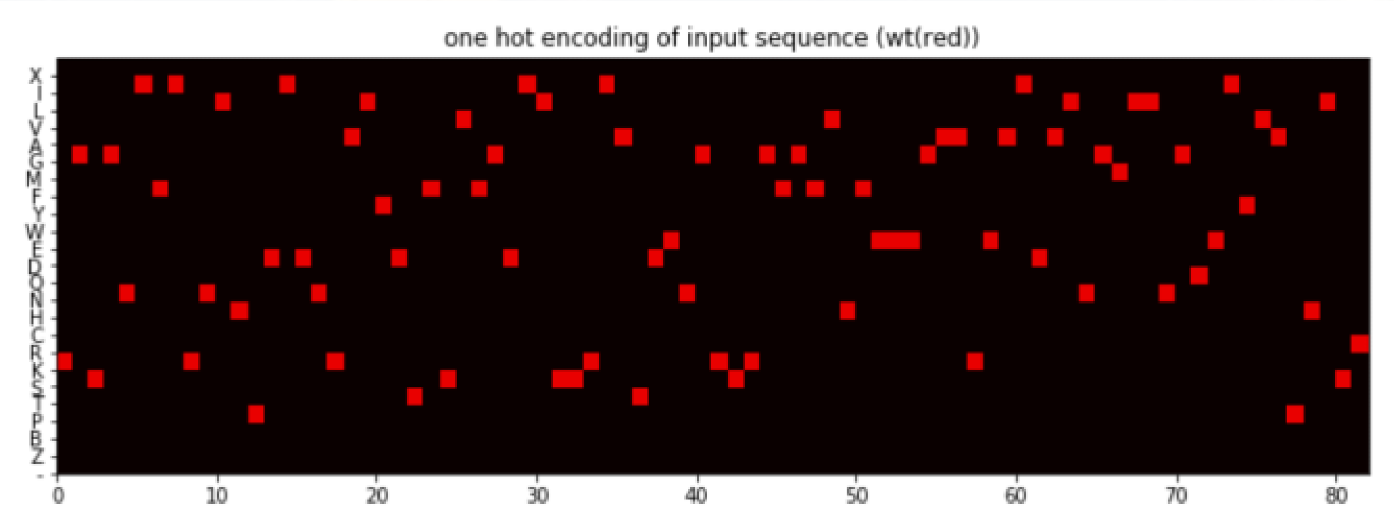


DNA/RNA/AA sequences
natural languages (encoding, see NLP lecture)

motif finding / sequence analysis



one – hot encoded NT or AA sequences can be interpreted as b/w images!



Convolution, Image Classification & Segmentation

- barcodes are short DNA sequence for identifying species

- we want to see, if we can us a CNN for classification

- loading a so called ***fasta*** file

```
>BEISA025-19|Culex|COI-5P
AACATTATATTTCATTTTTGGTGCTTGAGCAGGAATAATTGGAACTTCTTTAAGTCTTCTTATTCG
AGCTGAATTAAGTCAACCAGGAGTTTTTATTGGGAATGATCAAATTTATAATGTAATTGTTACAGC
TCATGCTTTTATTATAATTTTTTTATAGTAATACCTATTATAATTGGAGGATTTGGAAATTGATT
AGTTCCTTTAATACTAGGAGCTCCTGATATAGCTTTTCCTCGAATAAATAATATAAGATTTTGAAT
ACTTCCCCCCTCATTAACACTTCTACTTTCTAGTAGTATAGTAGAAAATGGAGCTGGTACAGGTTG
AACAGTATATCCTCCTCTTTCTTCTGGAACAGCTCATGCTGGAGCTTCTGTTGATTTAGCTATTTT
TTCTTTACATTTAGCCGGAATTTCTTCAATTTTAGGAGCTGTAAATTTTATTACTACTGTAATTAA
TATGCGATCTTCTGGTATTACCCTTGATCGAATACCTTTATTTGTTTGATCAGTTGTAATTACTGC
TATTCTTTTATTATTATCTCTTCCTGTTTTAGCTGGAGCTATTACTATATTATTAACAGATCGTAA
TTTAAATACTTCTTTTTTCGATCCTATTGGAGGAGGAGATCCTATTTTATATCAACATTTATTT
>BEISA121-19|Anopheles|COI-5P
AACATTATATTTTATTTTCGGTGCTTGAGCAGGAATAGTAGGAACTTCTTTAAGTATTCTTATTCG
```

true label

sequence as image

Convolution, Image Classification & Segmentation

the data set:

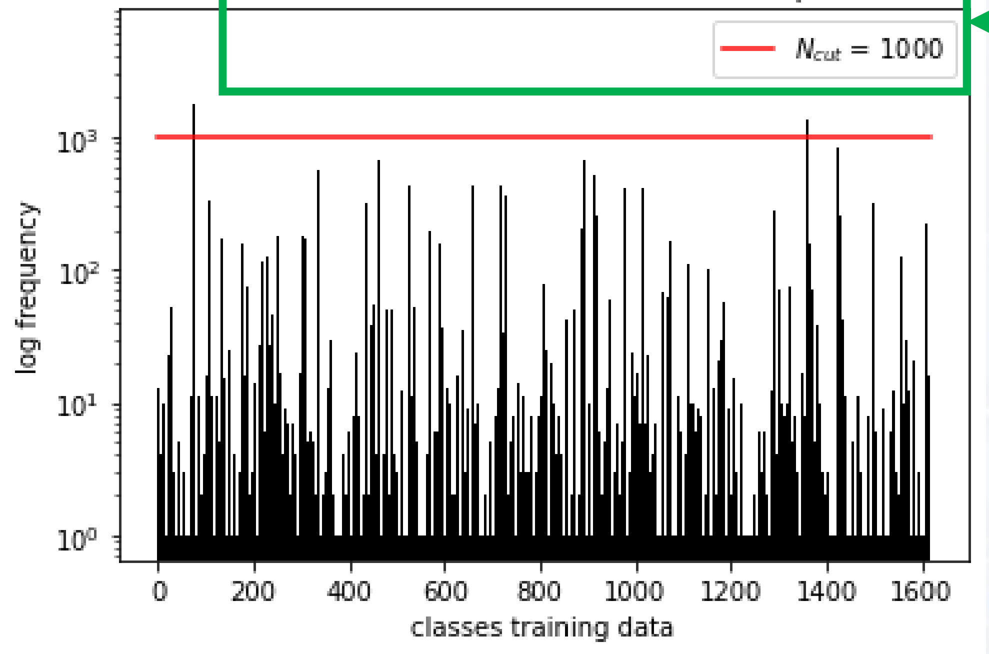
- 86k samples
- 1.6k classes
- classes are not evenly distributed

→ picking only those with >1k samples (12 classes)

run the package `AnalyzBarcode2.py`

```
A = Analyzer()
```

12 classes with more than 1000 samples



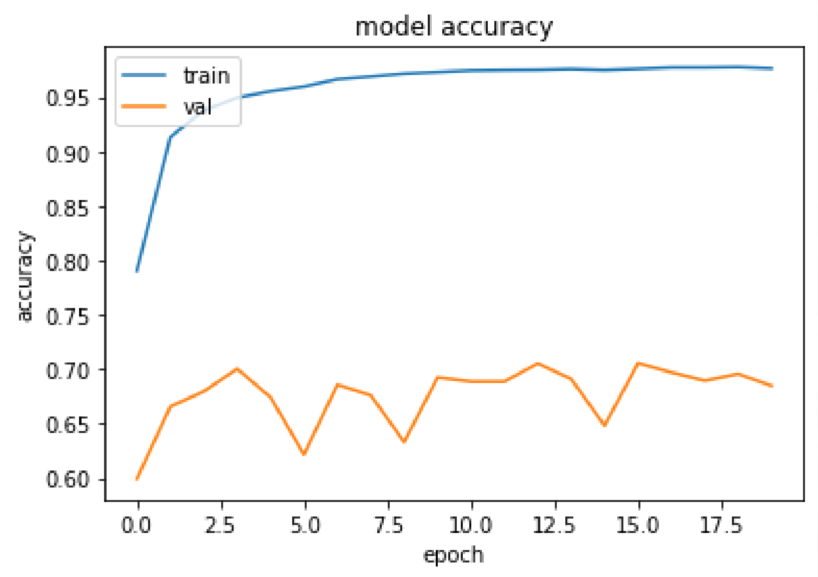
`__init__`
reads the data, one-hot encodes the nucleotides and passes only those samples where `Nsample > Ncut`

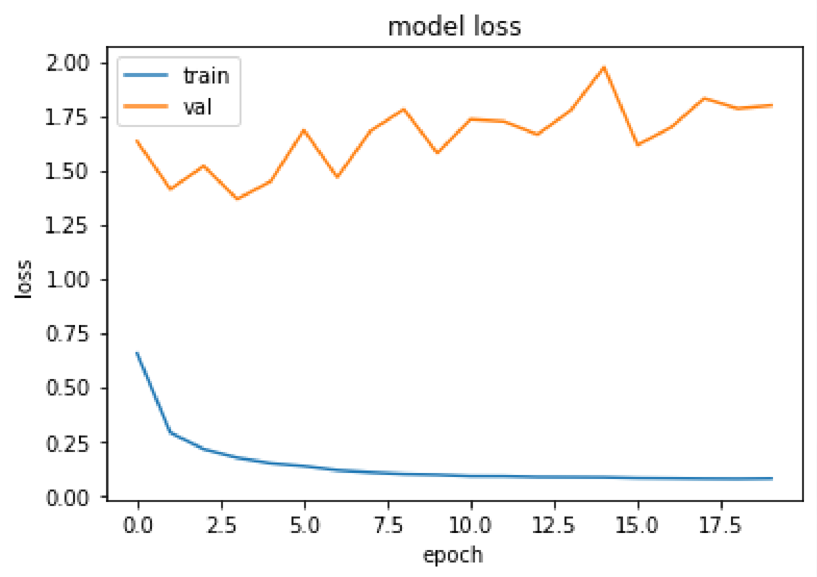
Convolution, Image Classification & Segmentation

A.RunCNN()

```
Layer (type)                Output Shape              Param #
=================================================================
conv2d_6 (Conv2D)           (None, 1256, 1, 24)       408

flatten_6 (Flatten)         (None, 30144)             0

dense_12 (Dense)            (None, 84)                2532180

dense_13 (Dense)            (None, 12)                1020

=================================================================
Total params: 2533608 (9.66 MB)
Trainable params: 2533608 (9.66 MB)
Non-trainable params: 0 (0.00 Byte)
```

runs very simple CNN

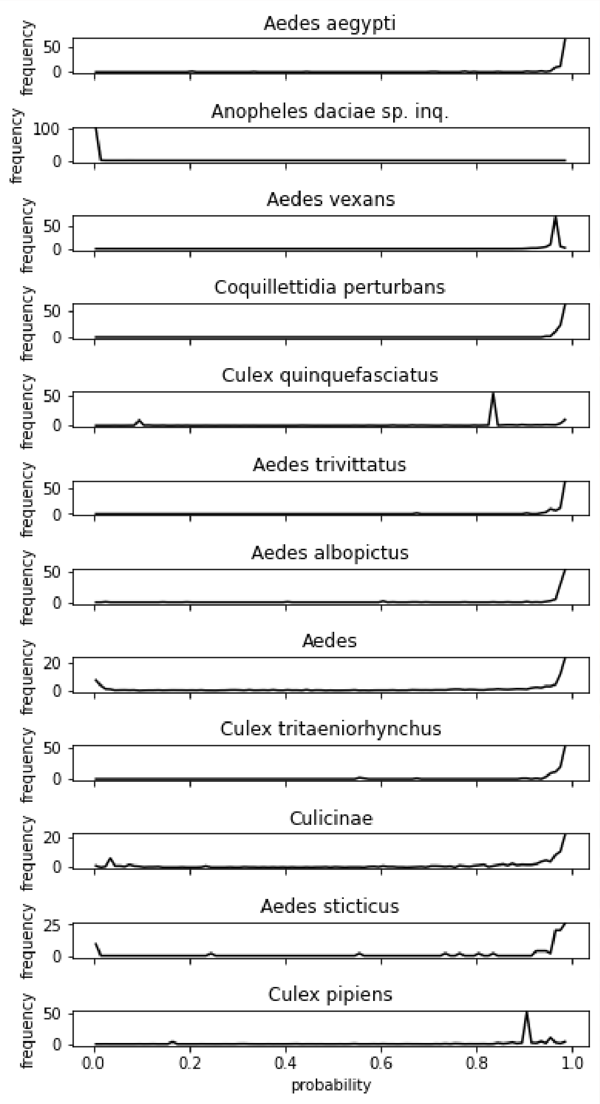


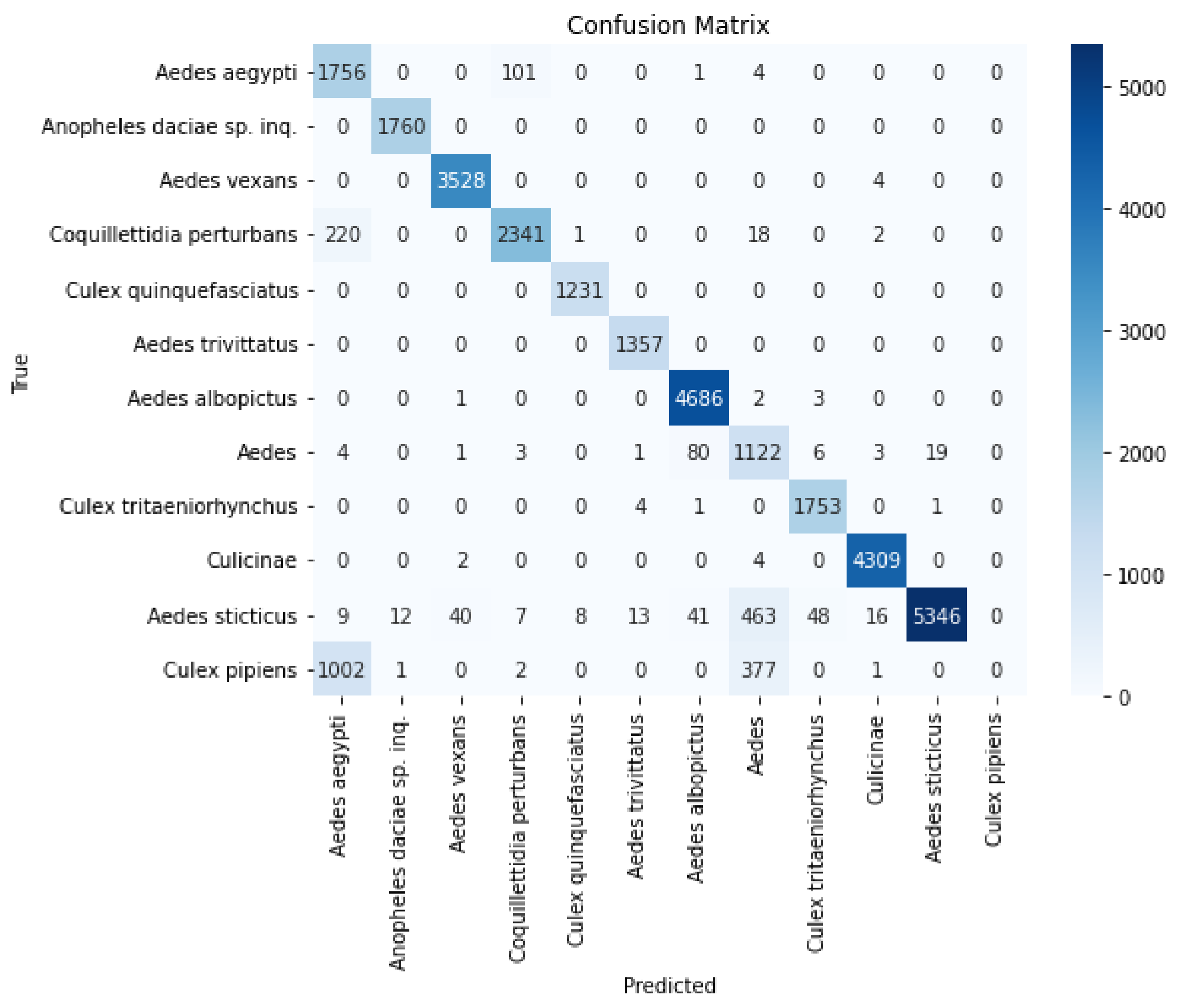


results are not great, but it demonstrates the principle

`A.EvalModel()`

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation



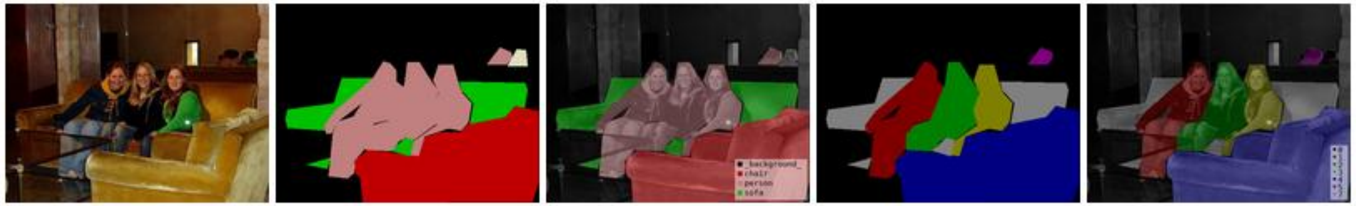


training images have to be labeled!

"labelme"

Description

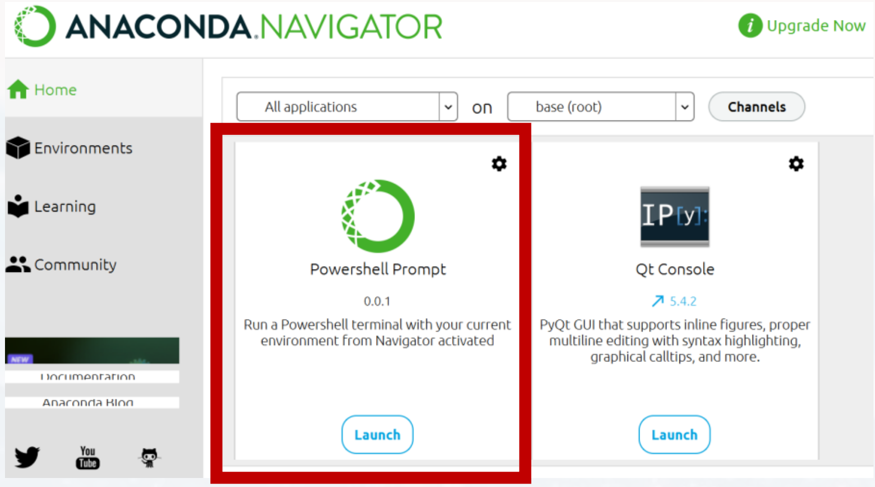
Labelme is a graphical image annotation tool inspired by http://labelme.csail.mit.edu.
It is written in Python and uses Qt for its graphical interface.



VOC dataset example of instance segmentation.

Other examples (semantic segmentation, bbox detection, and classification).

Various primitives (polygon, rectangle, circle, line, and point).



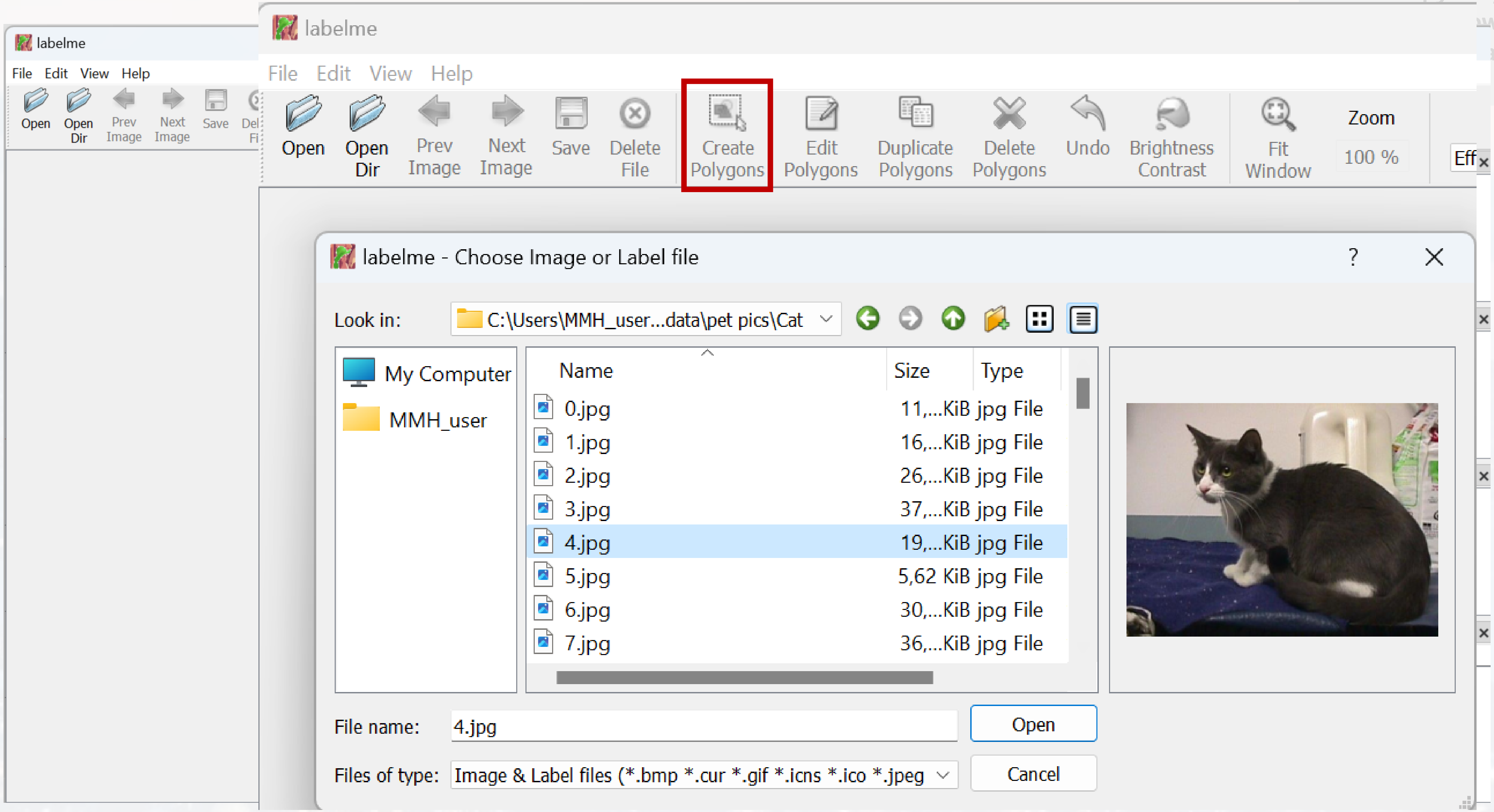

```
conda install labelme
```

C:\WINDOWS\System32\Win

```
(base) PS C:\Users\MMH_user> conda create --name=labelme python=3
```

```
(base) PS C:\Users\MMH_user> conda activate labelme
```

```
(labelme) PS C:\Users\MMH_user> labelme
```


labelme
File Edit View Help
Open
Open Dir
Prev Image
Next Image
Save
Delete File
Create Polygons
Edit Polygons
Duplicate Polygons
Delete Polygons
Undo
Brightness Contrast
Fit Window
Zoom
100 %
labelme - Choose Image or Label file
Look in:
C:\Users\MMH_user...data\pet pics\Cat
My Computer
MMH_user
Name
Size
Type
0.jpg 11,...KiB jpg File
1.jpg 16,...KiB jpg File
2.jpg 26,...KiB jpg File
3.jpg 37,...KiB jpg File
4.jpg 19,...KiB jpg File
5.jpg 5,62 KiB jpg File
6.jpg 30,...KiB jpg File
7.jpg 36,...KiB jpg File
File name:
4.jpg
Open
Files of type:
Image & Label files (*.bmp *.cur *.gif *.icns *.ico *.jpeg
Cancel

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

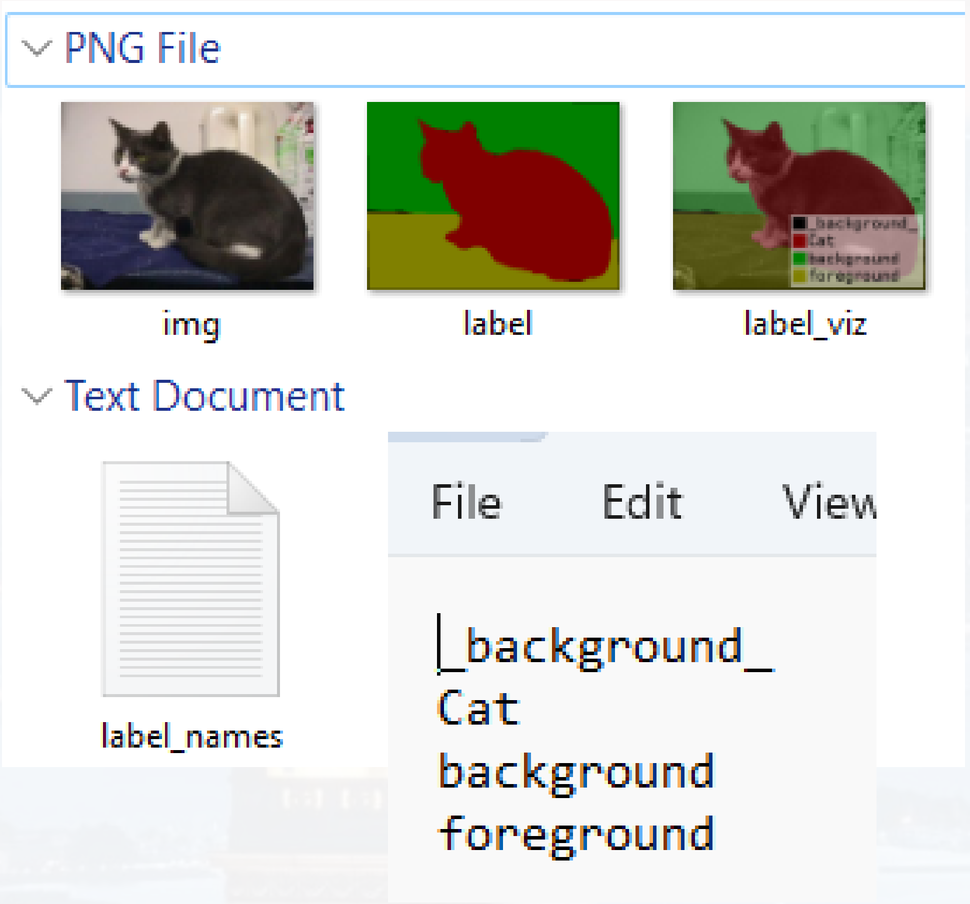
training images have to be labeled!

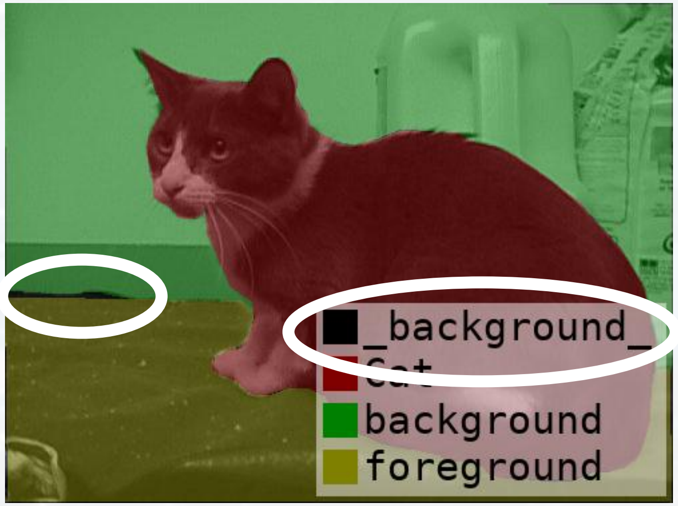
image is saved as `.json`

run within the labelme prompt:

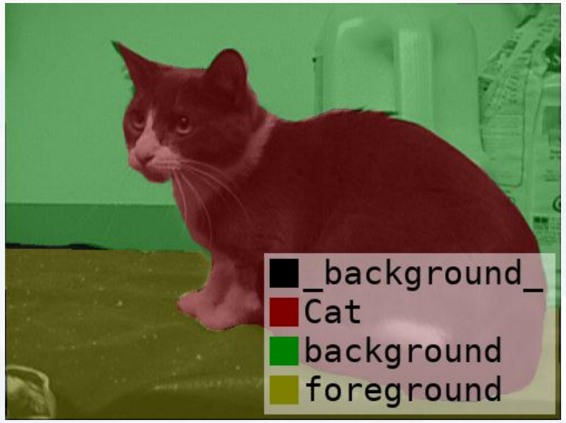
```
labelme_export_json .\Cat4label.json -o Cat4label_json
```

training images have to be labeled!



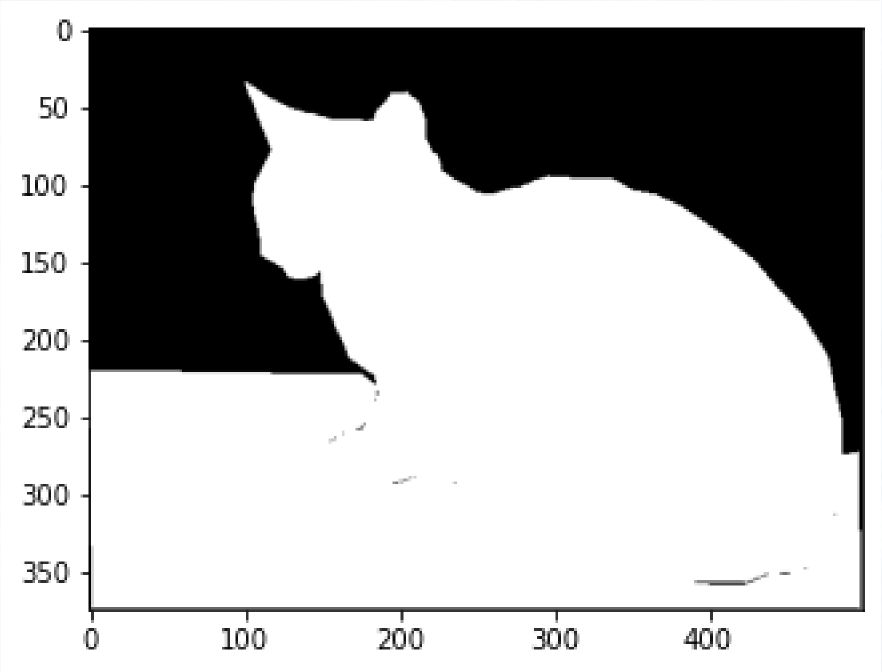


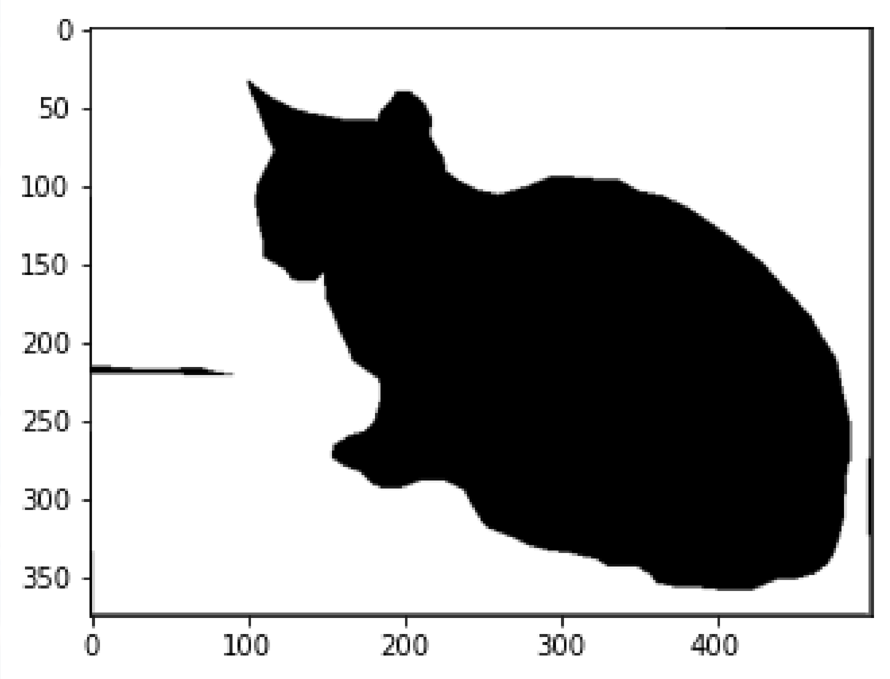
training images have to be labeled!




```
I = plt.imread('Cat/Cat4label_json/label.png')
I.shape
(375, 500, 4)
```

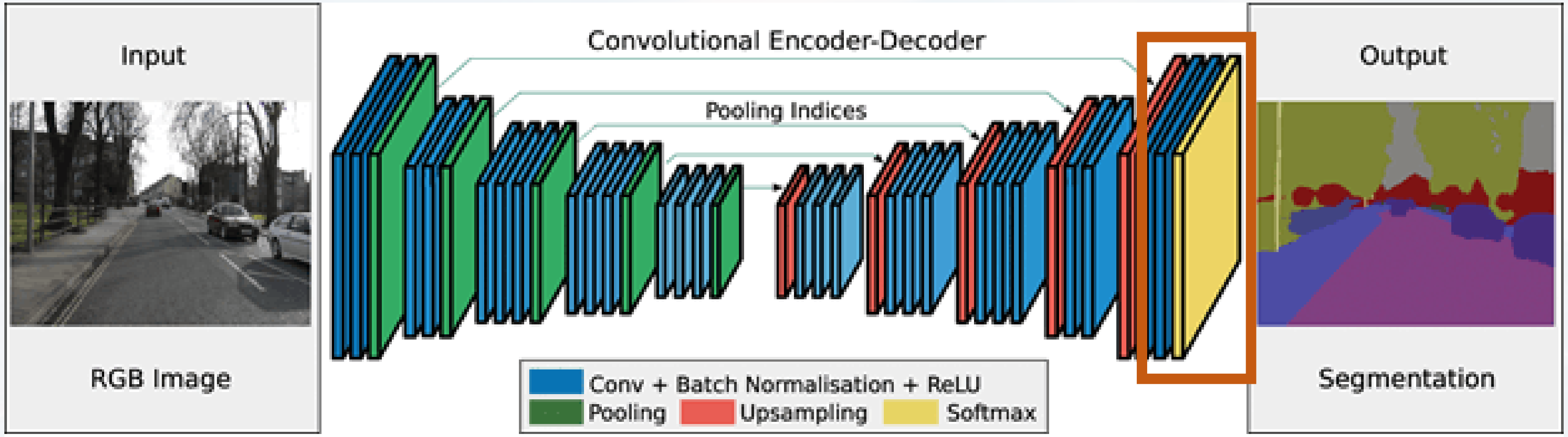
each label = channel

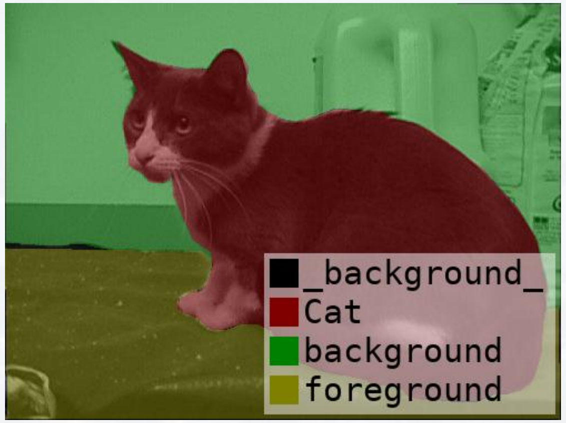




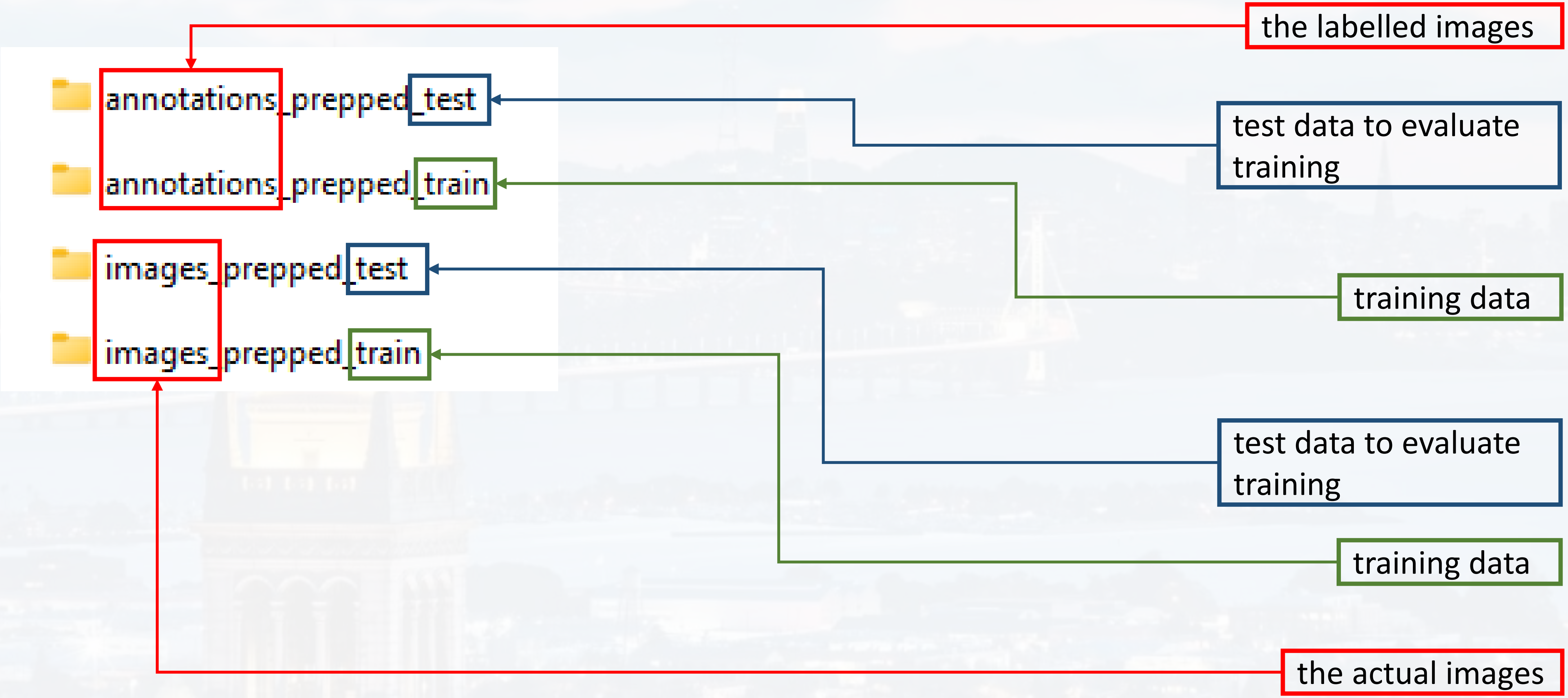
Convolution, Image Classification & Segmentation

training images have to be labeled!





training images have to be labeled!

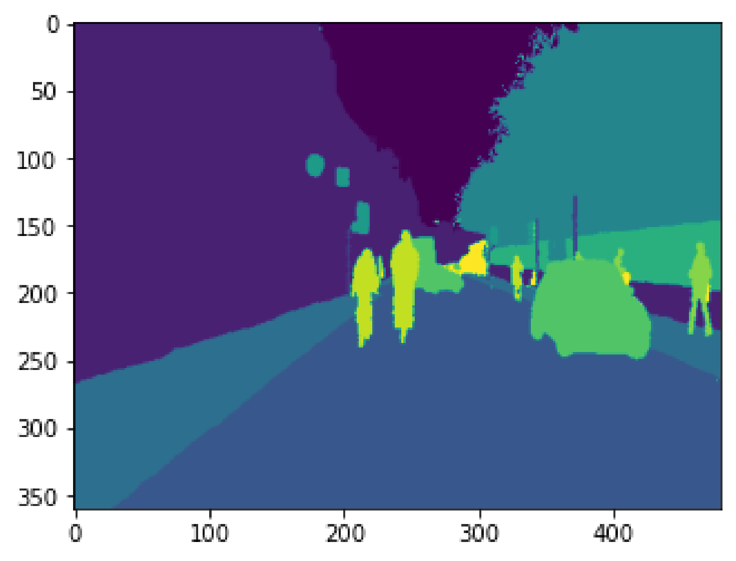


Convolution, Image Classification & Segmentation

training images have to be labeled!

[nice dataset]

images_prepped_test



annotations_prepped_test

```
I = plt.imread('segmentation/pics/annotations_prepped_test/0016E5_07959.png')
```

```
I.shape
(360, 480)
```

Convolution, Image Classification & Segmentation

example: TF Unet architecture

check out: `SegmentMyImages.py`
`AugmentMyImages.py`

Convolution, Image Classification & Segmentation

example: TF Unet architecture

```
from keras_segmentation.models.unet import *
```

Type	Names
VGG	'vgg16' 'vgg19'
ResNet	'resnet18' 'resnet34' 'resnet50' 'resnet101' 'resnet152'
SE-ResNet	'seresnet18' 'seresnet34' 'seresnet50' 'seresnet101' 'seresnet152'
ResNeXt	'resnext50' 'resnext101'
SE-ResNeXt	'seresnext50' 'seresnext101'
SENet154	'senet154'
DenseNet	'densenet121' 'densenet169' 'densenet201'
Inception	'inceptionv3' 'inceptionresnetv2'
MobileNet	'mobilenet' 'mobilenetv2'
EfficientNet	'efficientnetb0' 'efficientnetb1' 'efficientnetb2' 'efficientnetb3' 'efficientnetb4' 'efficientnetb5' efficientnetb6' efficientnetb7'

```
model = unet(n_classes = n_classes,\
                          input_height = 416, input_width = 608)

model.train(
        train_images      = my_path + r"images_prepped_train//",
        train_annotations = my_path + r"annotations_prepped_train//",
        checkpoints_path  = my_path + r"checkpoints//",
        do_augment              = True,
        gen_use_multiprocessing = True,
        auto_resume_checkpoint  = True,
        epochs  = 5)
```

calling the specific net-work

saves current weights

Keras provides an augmentation routine

example: TF Unet architecture

```
model = vgg_unet(n_classes = n_classes,\
                           input_height = 416, input_width = 608)

model.train(
       train_images       = my_path + r"images_prepped_train//",
       train_annotations = my_path + r"annotations_prepped_train//",
       checkpoints_path  = my_path + r"checkpoints//",
       do_augment             = True,
       gen_use_multiprocessing = True,
       auto_resume_checkpoint  = True,
       epochs = 5)
```

Keras provides an augmentation routine

Note: I always run my **own augmentation** routine, see e.g. `AugmentMyImages.py`

run:

```
S = SegmentMyImages()

S.Training()
```

Convolution, Image Classification & Segmentation

example: TF Unet architecture

```
S = SegmentMyImages()

S.Training()
```

```
Dataset verified!
Epoch 1/5
512/512 [==============================] - ETA: 0s - loss: 4.1406 - accuracy: 0.0353    saved  ../data/segmentation
pics/checkpoints//.0
512/512 [==============================] - 3888s 8s/step - loss: 4.1406 - accuracy: 0.0353
Epoch 2/5
512/512 [==============================] - ETA: 0s - loss: 3.7805 - accuracy: 0.1636    saved  ../data/segmentation
pics/checkpoints//.1
512/512 [==============================] - 4133s 8s/step - loss: 3.7805 - accuracy: 0.1636
Epoch 3/5
512/512 [==============================] - ETA: 0s - loss: 3.4534 - accuracy: 0.3338    saved  ../data/segmentation
pics/checkpoints//.2
512/512 [==============================] - 4072s 8s/step - loss: 3.4534 - accuracy: 0.3338
Epoch 4/5
512/512 [==============================] - ETA: 0s - loss: 3.1926 - accuracy: 0.3980    saved  ../data/segmentation
pics/checkpoints//.3
512/512 [==============================] - 3363s 7s/step - loss: 3.1926 - accuracy: 0.3980
Epoch 5/5
512/512 [==============================] - ETA: 0s - loss: 3.0071 - accuracy: 0.4318   saved  ../data/segmentation
pics/checkpoints//.4
512/512 [==============================] - 3616s 7s/step - loss: 3.0071 - accuracy: 0.4318
```

example: TF Unet architecture

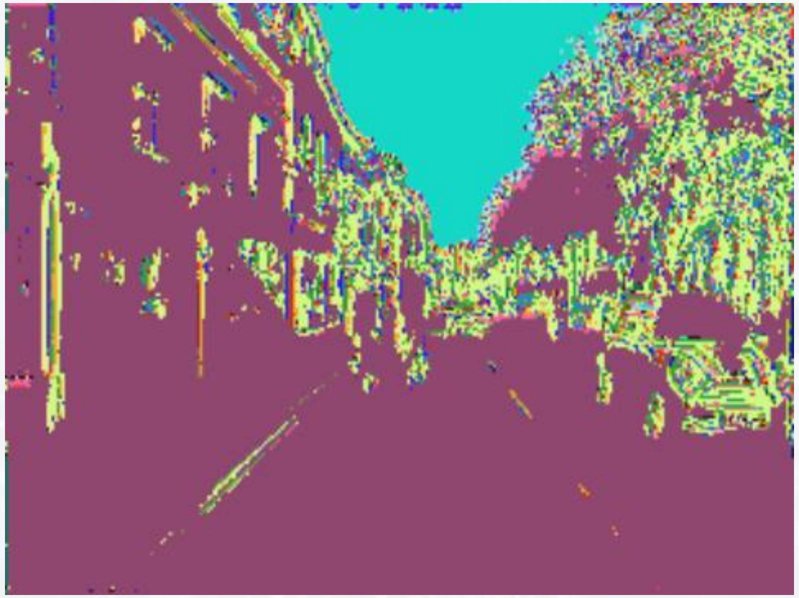
```
MyModel = S.TrainedModel
```

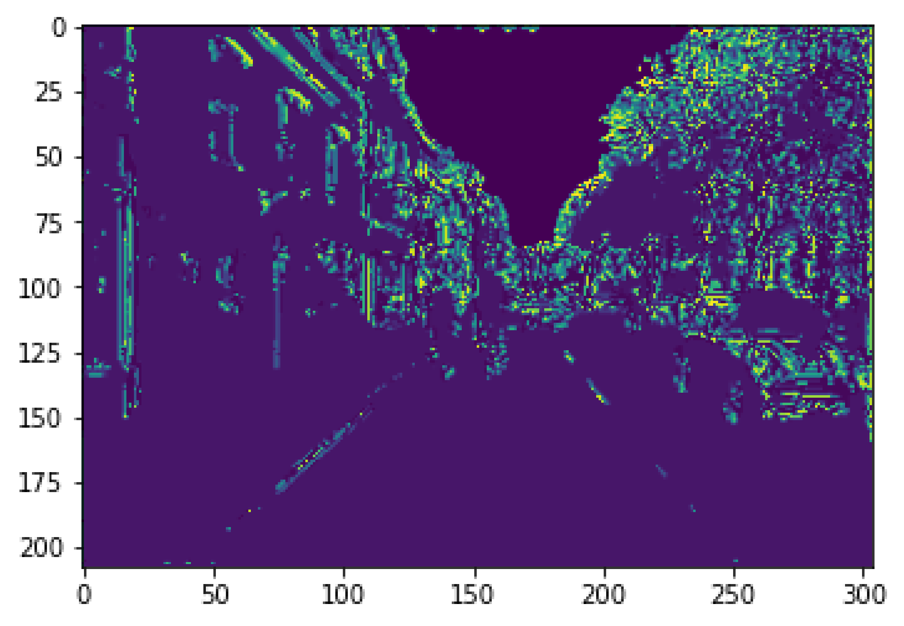
```
MyModel.summary()
```
→ returns the structure of the CNN

applying the trained CNN to an image:

```
out = S.ApplyTrainedNetwork()
```

```
plt.imshow(out)
```





LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

example: TF Unet architecture

recovering model from checkpoints:

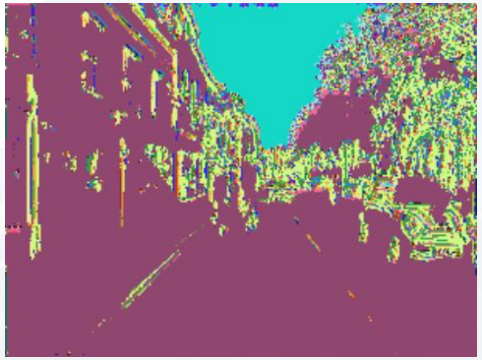
```
MyModel = S.TrainedModel
out     = S.ApplyTrainedNetwork()

S.RecoverFromCheckpoint()
```

applying the trained CNN to an image:

untrained model (just CNN itself)

```
#loading untrained CNN
model = self.model

if not image_name:
    image_name = '0016E5_07965.png'

#calling input from checkpoints
latest = tf.train.latest_checkpoint(self.checkpoint_path)
model.load_weights(latest)
```

transfer the saved weights to untrained network → now it starts from latest training state

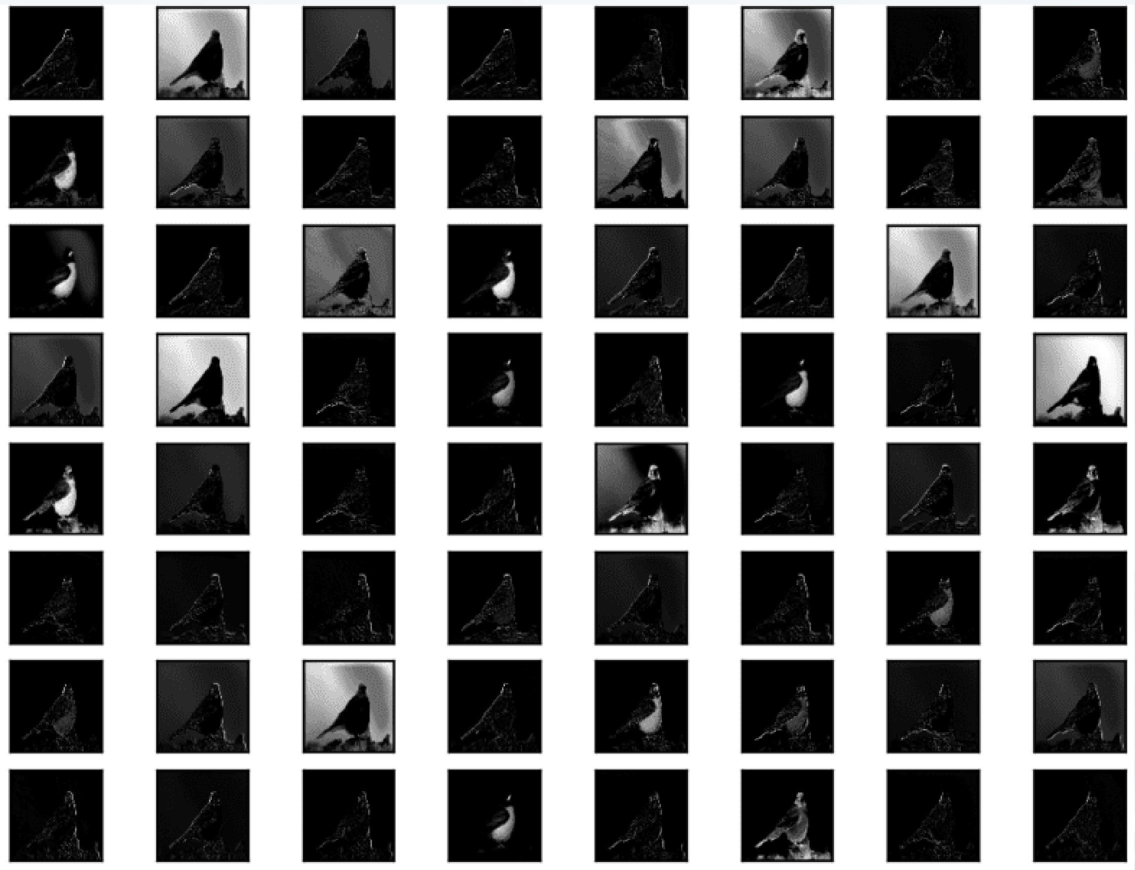


example: TF Unet architecture

visualizing weights:

→ see `model.layers`

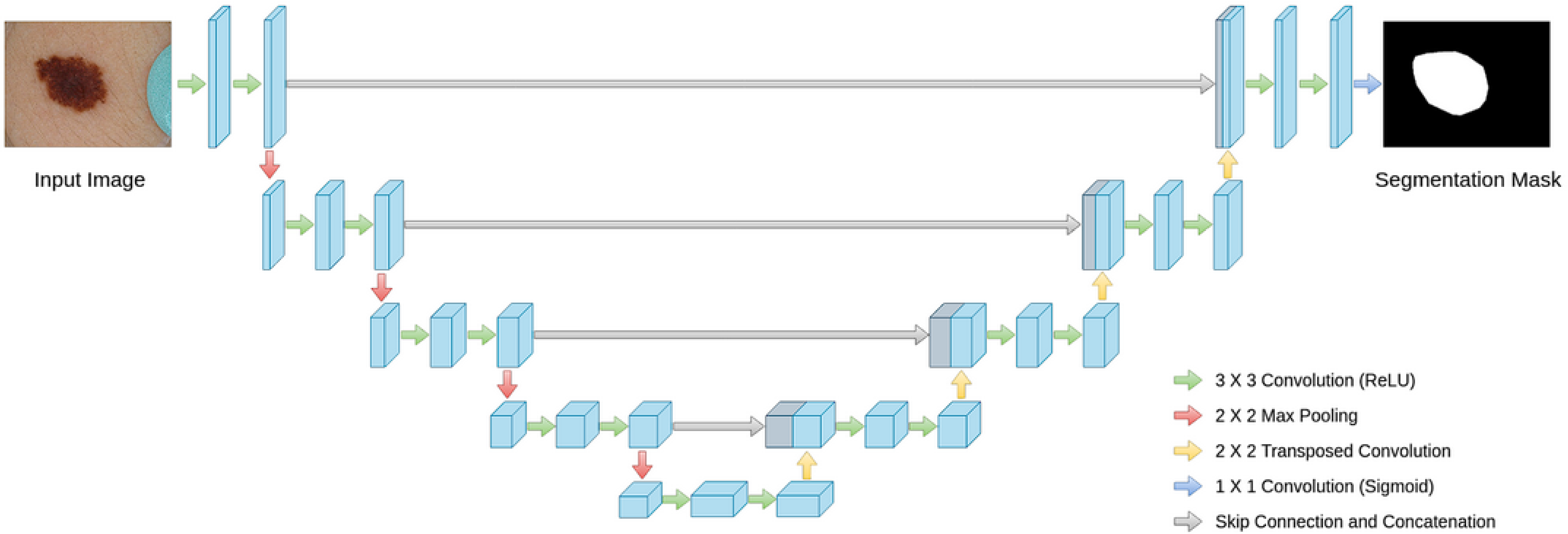
nice example



example: **custom** Unet architecture

see `Unet architecture.ipynb`

https://www.kaggle.com/code/abdallahwagih/brain-tumor-segmentation-unet-dice-coef-89-6/notebook

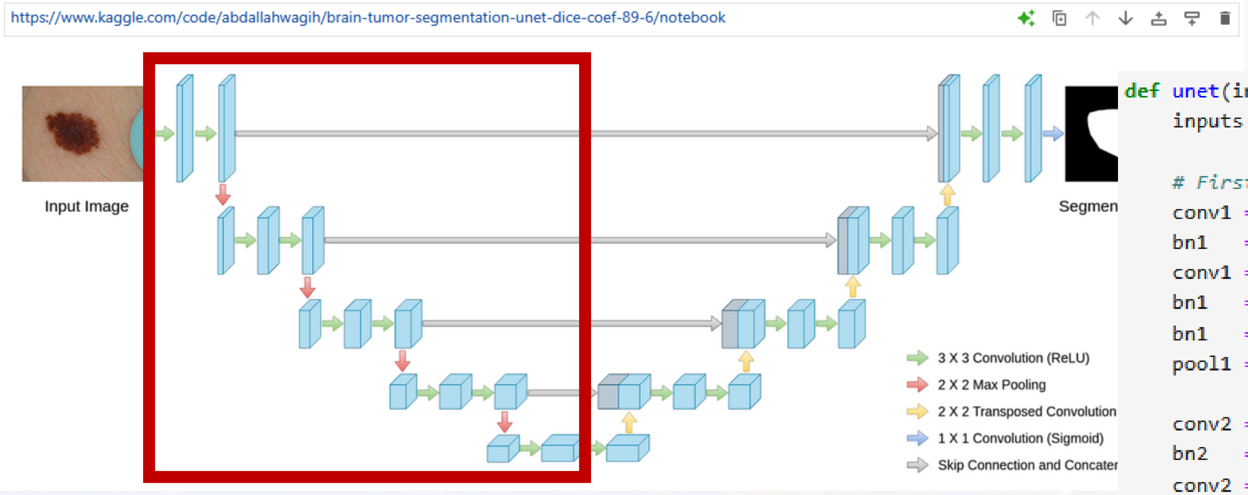


Convolution, Image Classification & Segmentation

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

example: **custom** Unet architecture

see `Unet architecture.ipynb`



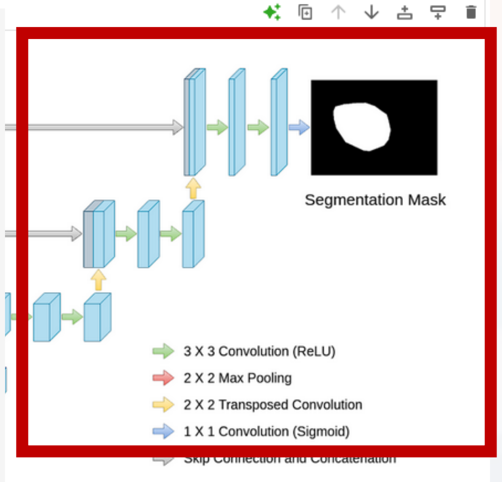

```python
def unet(input_size = (256, 256, 3)):
    inputs = Input(input_size)

    # First DownConvolution / Encoder Leg will begin, so start with Conv2D
    conv1 = Conv2D(filters = 64, kernel_size = (3, 3), padding = "same")(inputs)
    bn1   = Activation("relu")(conv1)
    conv1 = Conv2D(filters = 64, kernel_size = (3, 3), padding = "same")(bn1)
    bn1   = BatchNormalization(axis = 3)(conv1)
    bn1   = Activation("relu")(bn1)
    pool1 = MaxPooling2D(pool_size = (2, 2))(bn1)

    conv2 = Conv2D(filters = 128, kernel_size = (3, 3), padding = "same")(pool1)
    bn2   = Activation("relu")(conv2)
    conv2 = Conv2D(filters = 128, kernel_size = (3, 3), padding = "same")(bn2)
    bn2   = BatchNormalization(axis = 3)(conv2)
    bn2   = Activation("relu")(bn2)
    pool2 = MaxPooling2D(pool_size = (2, 2))(bn2)

    conv3 = Conv2D(filters = 256, kernel_size = (3, 3), padding = "same")(pool2)
    bn3   = Activation("relu")(conv3)
    conv3 = Conv2D(filters = 256, kernel_size = (3, 3), padding = "same")(bn3)
    bn3   = BatchNormalization(axis = 3)(conv3)
    bn3   = Activation("relu")(bn3)
    pool3 = MaxPooling2D(pool_size = (2, 2))(bn3)

    conv4 = Conv2D(filters = 512, kernel_size = (3, 3), padding = "same")(pool3)
    bn4   = Activation("relu")(conv4)
    conv4 = Conv2D(filters = 512, kernel_size = (3, 3), padding = "same")(bn4)
    bn4   = BatchNormalization(axis = 3)(conv4)
    bn4   = Activation("relu")(bn4)
    pool4 = MaxPooling2D(pool_size = (2, 2))(bn4)

    conv5 = Conv2D(filters = 1024, kernel_size = (3, 3), padding = "same")(pool4)
    bn5   = Activation("relu")(conv5)
    conv5 = Conv2D(filters = 1024, kernel_size = (3, 3), padding = "same")(bn5)
    bn5   = BatchNormalization(axis = 3)(conv5)
    bn5   = Activation("relu")(bn5)
```

example: **custom** Unet architecture

see Unet architecture.ipynb

LeNet numpy only
LeNet TensorFlow

```
up6   = concatenate([Conv2DTranspose(512, kernel_size = (2, 2), strides = (2, 2), padding = "same")(bn5), conv4], axis = 3)
conv6 = Conv2D(filters = 512, kernel_size = (3, 3), padding = "same")(up6)
bn6   = Activation("relu")(conv6)
conv6 = Conv2D(filters = 512, kernel_size = (3, 3), padding = "same")(bn6)
bn6   = BatchNormalization(axis = 3)(conv6)
bn6   = Activation("relu")(bn6)

up7   = concatenate([Conv2DTranspose(256, kernel_size = (2, 2), strides = (2, 2), padding = "same")(bn6), conv3], axis = 3)
conv7 = Conv2D(filters = 256, kernel_size = (3, 3), padding = "same")(up7)
bn7   = Activation("relu")(conv7)
conv7 = Conv2D(filters = 256, kernel_size = (3, 3), padding = "same")(bn7)
bn7   = BatchNormalization(axis = 3)(conv7)
bn7   = Activation("relu")(bn7)

up8   = concatenate([Conv2DTranspose(128, kernel_size = (2, 2), strides = (2, 2), padding = "same")(bn7), conv2], axis = 3)
conv8 = Conv2D(filters = 128, kernel_size = (3, 3), padding = "same")(up8)
bn8   = Activation("relu")(conv8)
conv8 = Conv2D(filters = 128, kernel_size = (3, 3), padding = "same")(bn8)
bn8   = BatchNormalization(axis = 3)(conv8)
bn8   = Activation("relu")(bn8)

up9   = concatenate([Conv2DTranspose(64, kernel_size = (2, 2), strides = (2, 2), padding = "same")(bn8), conv1], axis = 3)
conv9 = Conv2D(filters = 64, kernel_size = (3, 3), padding = "same")(up9)
bn9   = Activation("relu")(conv9)
conv9 = Conv2D(filters = 64, kernel_size = (3, 3), padding = "same")(bn9)
bn9   = BatchNormalization(axis = 3)(conv9)
bn9   = Activation("relu")(bn9)

conv10 = Conv2D(filters = 1, kernel_size = (1, 1), activation = "sigmoid")(bn9)

return Model(inputs = [inputs], outputs = [conv10])
```



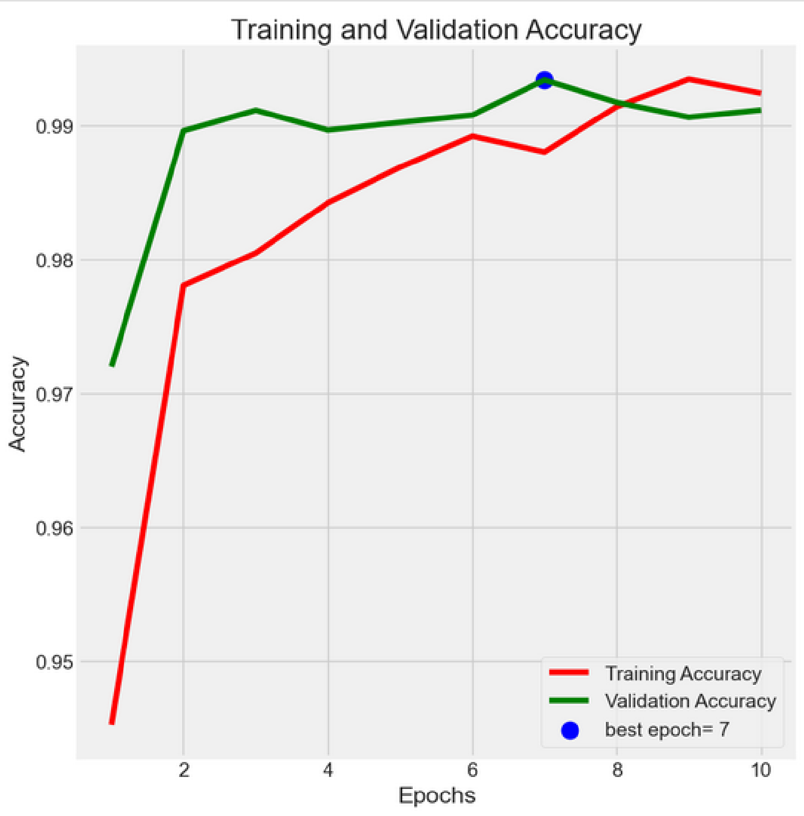
Convolution, Image Classification & Segmentation

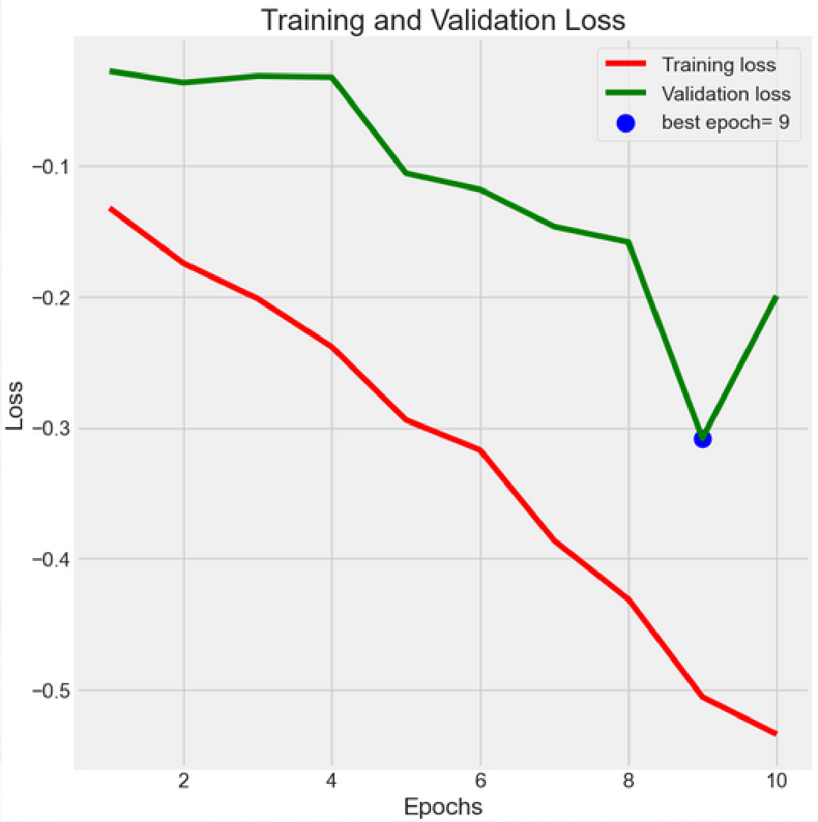
example: **custom** Unet architecture

see `Unet architecture.ipynb`

LeNet numpy only
LeNet TensorFlow
sequences as images
segmentation

```
--------------------------------------------
Total params: 31043521 (118.42 MB)
Trainable params: 31037633 (118.40 MB)
Non-trainable params: 5888 (23.00 KB)
```





Convolution, Image Classification & Segmentation

example: **custom** Unet architecture

see Unet `architecture.ipynb`


```
----------------------------------------
Total params: 31043521 (118.42 MB)
Trainable params: 31037633 (118.40 MB)
Non-trainable params: 5888 (23.00 KB)
```

3,000 training images, 400 validation images, 10 epochs, 10hrs (Lenovo T14)

Thank you very much for your attention!