Convolutional Neural Network

ALS User Meeting

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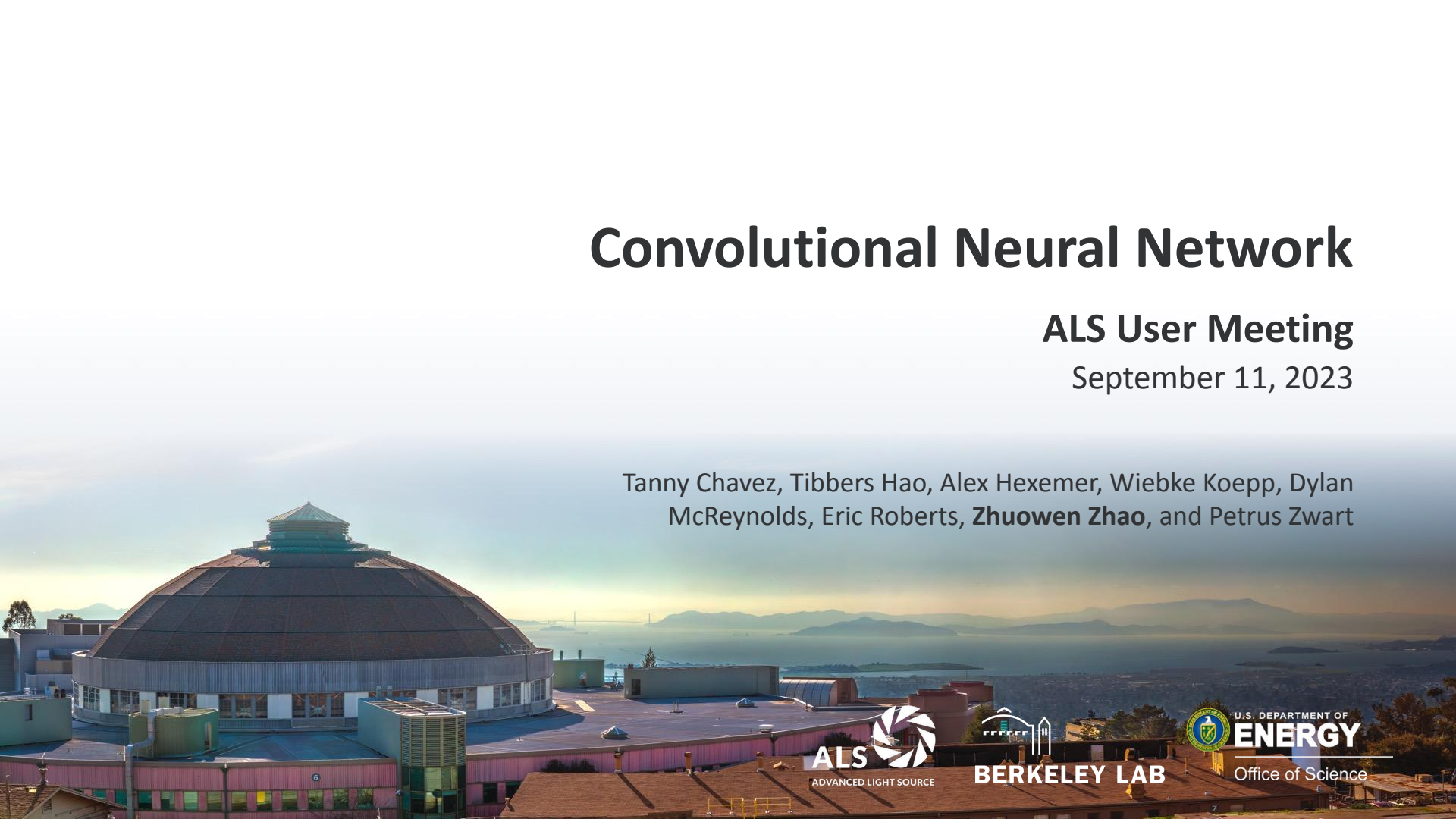
Tanny Chavez, Tibbers Hao, Alex Hexemer, Wiebke Koepp, Dylan McReynolds, Eric Roberts, **Zhuowen Zhao**, and Petrus Zwart



What are convolutional neural networks?

Convolutional neural networks are distinguished from other neural networks by their superior performance with image inputs. They have 3 main types of layers: the convolutional layer, pooling layer, and fully-connected (FC) layer.

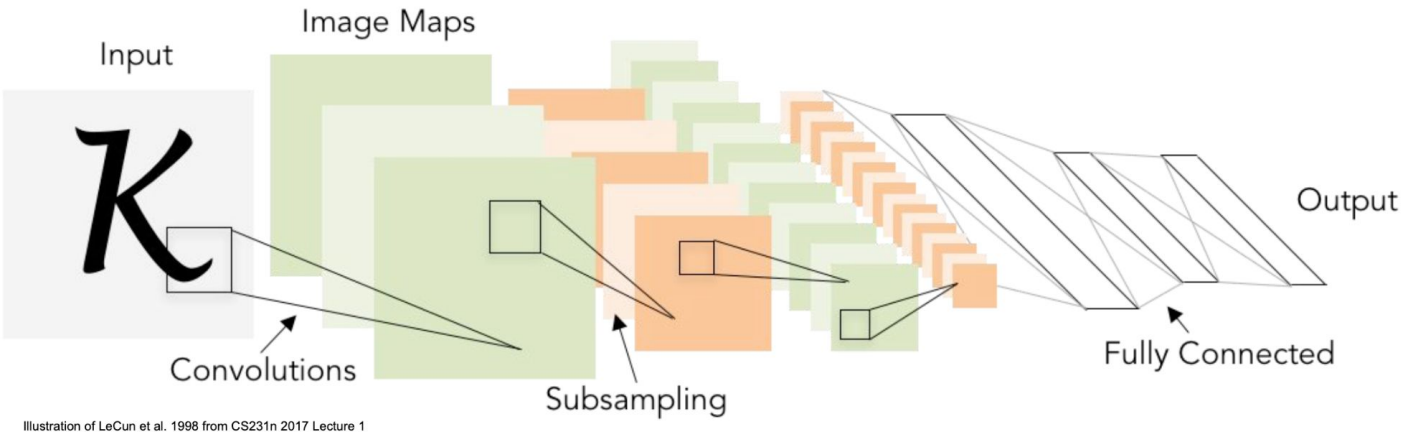
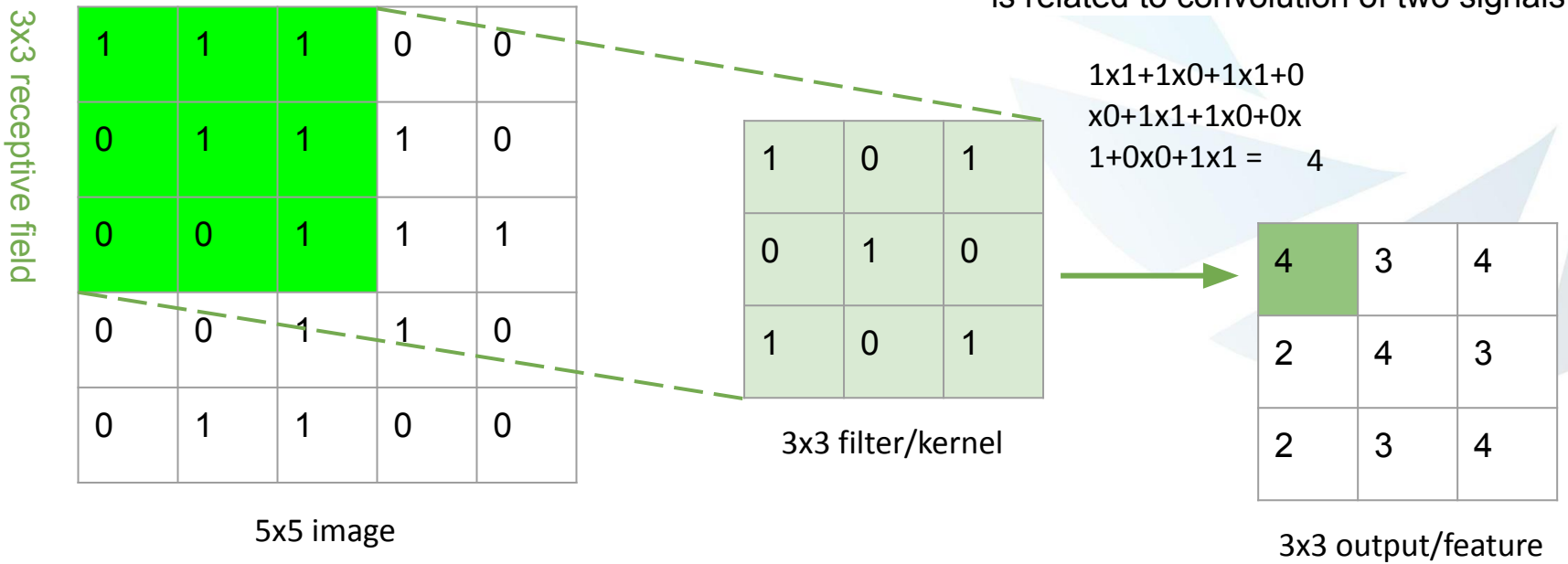


Illustration of LeCun et al. 1998 from CS231n 2017 Lecture 1

Convolutional layer

The convolutional layer **convolve** the filter with the image i.e. “slide over the image spatially, computing dot products”.

We call the layer convolutional because it is related to convolution of two signals



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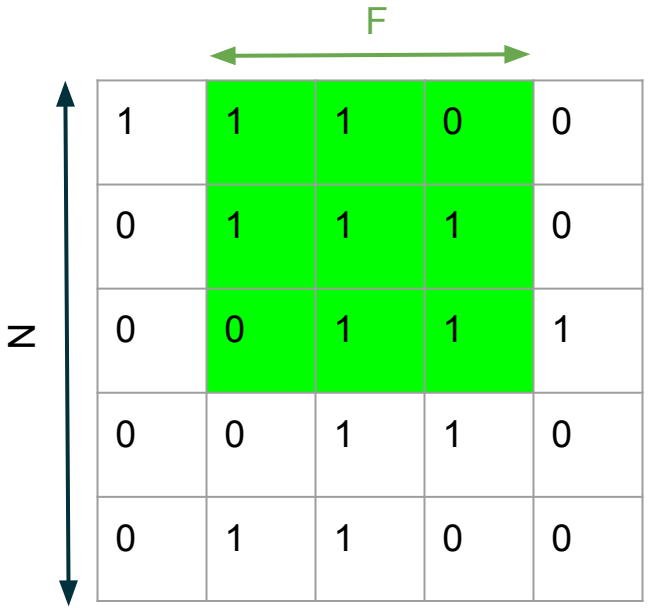

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

stride (step size) = 1

output size = (N-F)/stride + 1

4	3	4
2	4	3
2	3	4

3x3 output/feature

Convolutional layer

The convolutional layer **convolve** the filter with the image i.e. “slide over the image spatially, computing dot products”.

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

4	3	4
2	4	3
2	3	4

3x3 output/feature

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1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

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2	4	3
2	3	4

3x3 output/feature

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1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

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2	4	3
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1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

4	3	4
2	4	3
2	3	4

3x3 output/feature

Convolutional layer

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1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

4	3	4
2	4	3
2	3	4

3x3 output/feature

Convolutional layer

The convolutional layer **convolve** the filter with the image i.e. “slide over the image spatially, computing dot products”.

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

4	3	4
2	4	3
2	3	4

3x3 output/feature

Convolutional layer

The convolutional layer **convolve** the filter with the image i.e. “slide over the image spatially, computing dot products”.

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

5x5 image

1	0	1
0	1	0
1	0	1

3x3 filter/kernel

4	3	4
2	4	3
2	3	4

3x3 output/feature

Padding

When kernel size and stride cannot fit the image dimension, add 0s outside the boundaries.

padding = 1

0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0
0	0	1	1	0	1	0	1	0
0	0	0	1	1	0	0	0	0
0	1	1	0	0	0	0	1	0
0	0	0	1	1	0	0	0	0
0	0	0	0	0	1	1	1	0
0	0	0	0	1	1	0	1	0
0	0	0	0	0	0	0	0	0

7x7 image

output size = (N-F)/stride + 1

1	0	1
0	1	0
1	0	1

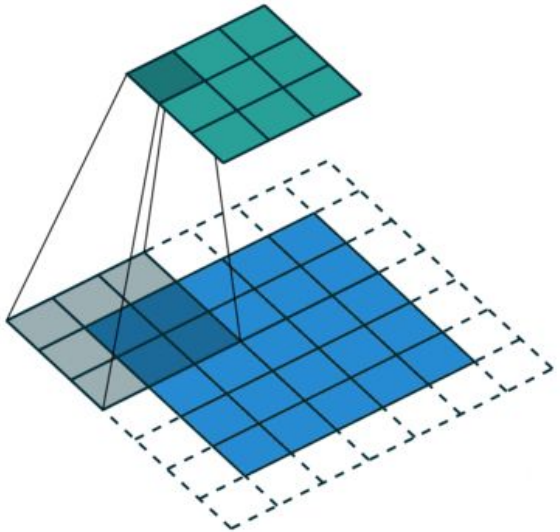
3x3 filter/kernel

2	2	0
1	2	1
0	2	2

3x3 output/feature

PyTorch implementation

torch.nn.Conv2d(in_channels=1, out_channels=1, kernel_size=(3,3), stride=(2,2), padding=1)

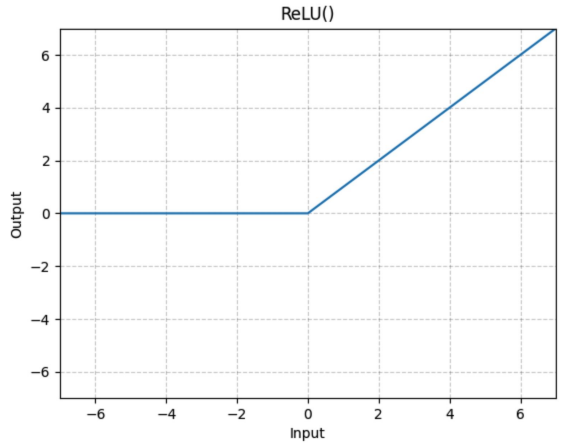


Note: default format for image data in PyTorch: NCHW

Activation function: ReLU

Adding nonlinearity to the neural network

Pytorch implementation: **torch.nn.ReLU()**



$$\mathrm{ReLU}(x) = (x)^+ = \max(0, x)$$

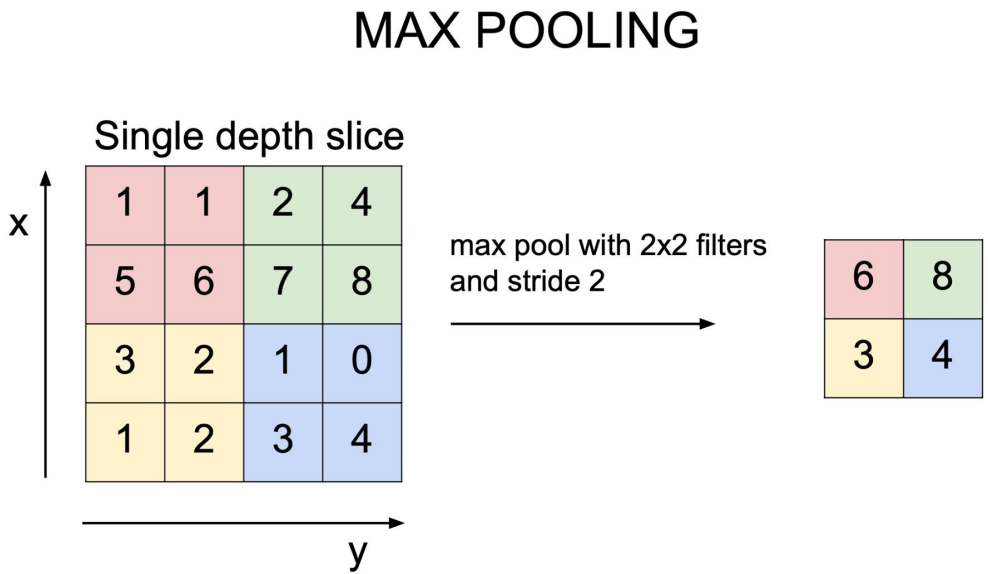
Pooling layer

The pooling layer makes the representations smaller and more manageable..

PyTorch implementation: **torch.nn.MaxPool2d(kernel_size=2)**

Other pooling layer APIs: https://pytorch.org/docs/stable/nn.html#pooling-layers

- max pooling
- min pooling
- average pooling



Fully connected layer

In the fully-connected layer, each node in the output layer connects directly to a node in the previous layer.

Pytorch implementation: **torch.nn.Linear(input_size, output_size)**