



Fundamentals of Deep Learning

Part 3: Convolutional Neural Networks



Agenda

- Part 1: An Introduction to Deep Learning

- Part 2: How a Neural Network Trains

- Part 3: Convolutional Neural Networks
- Part 4: Data Augmentation and Deployment

- Part 5: Pre-Trained Models

- Part 6: Advanced Architectures

Recap of the exercise

Trained a dense neural network model

Training accuracy was high

Validation accuracy was low

Evidence of overfitting

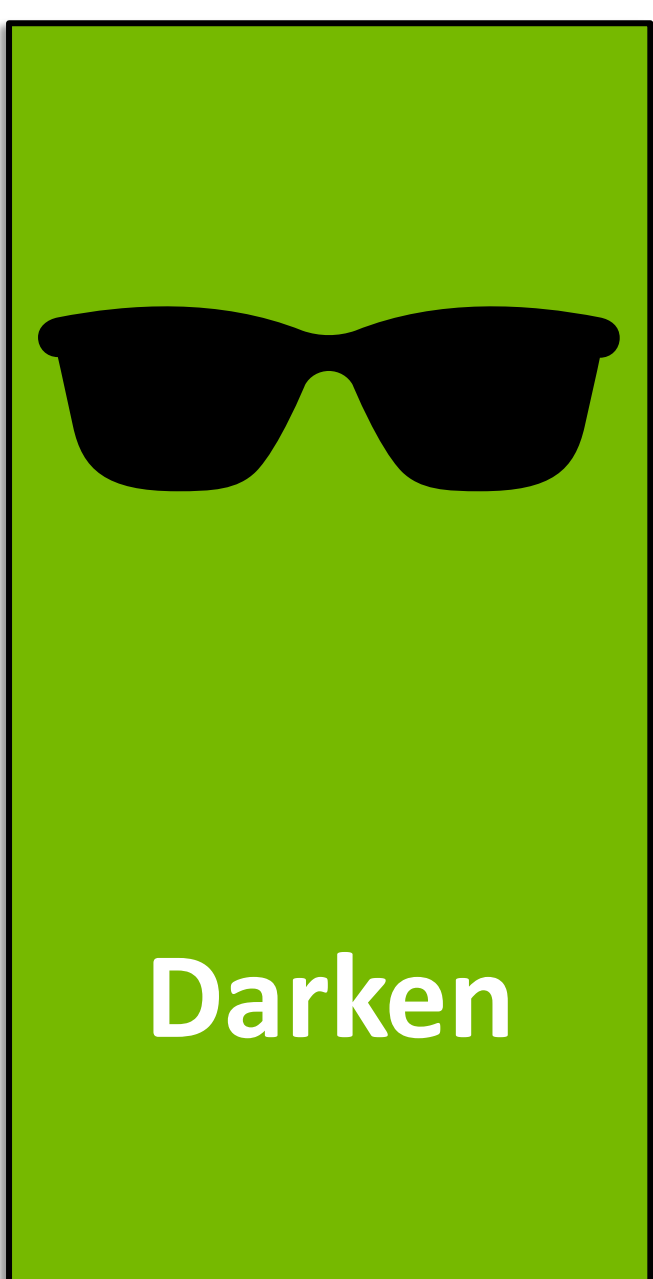
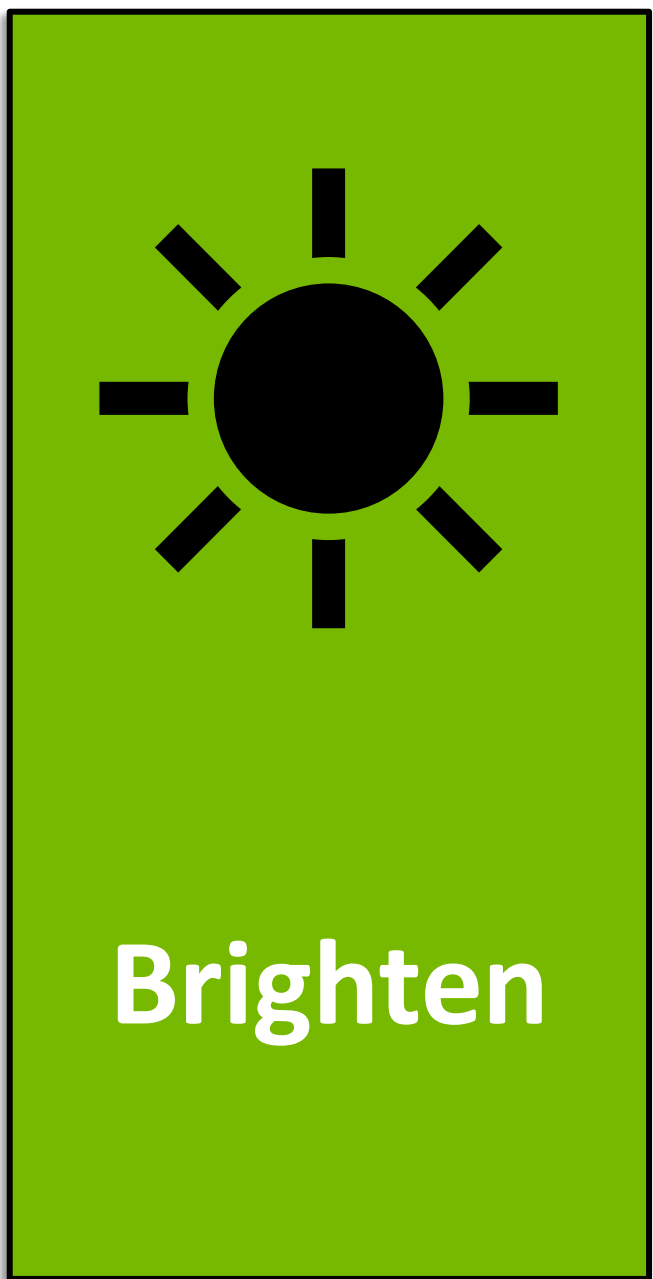
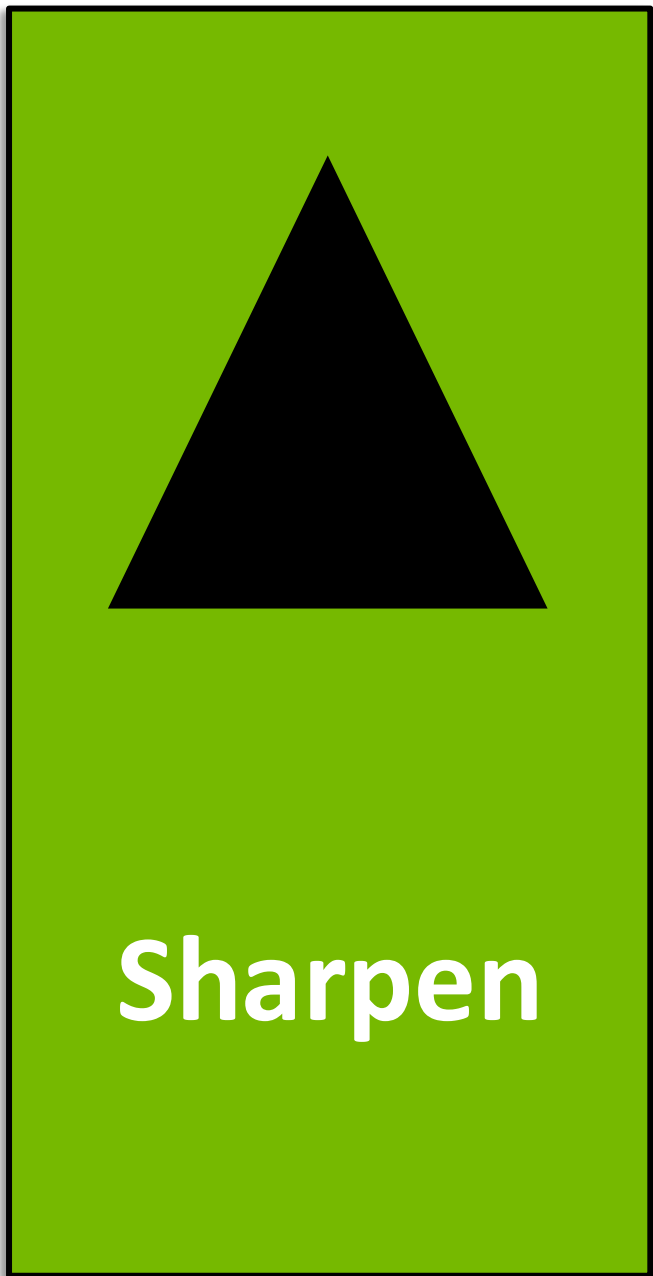
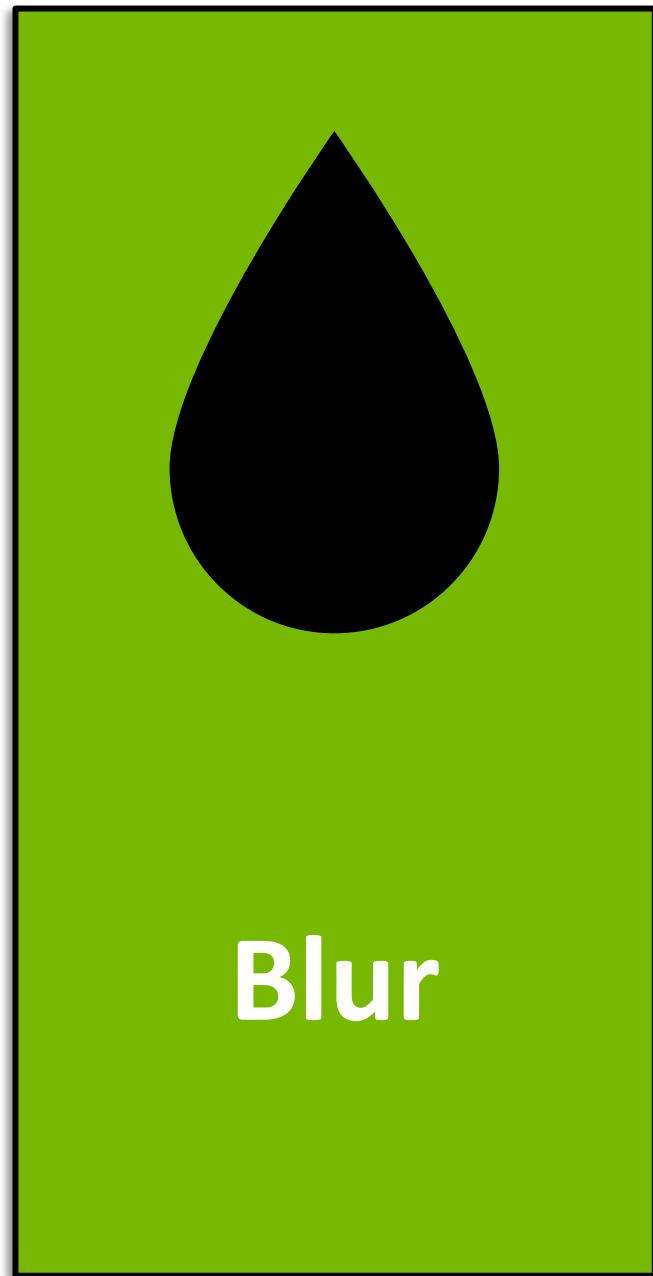


Kernels and Convolution

Kernels and Convolution



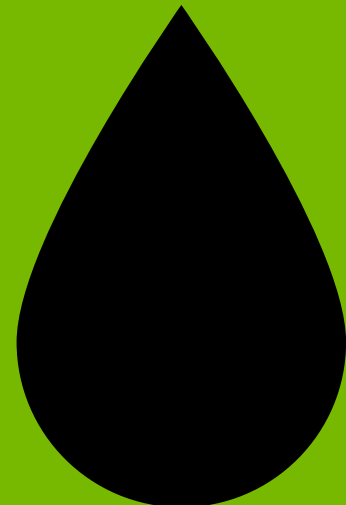
Original Image



Kernels and Convolution

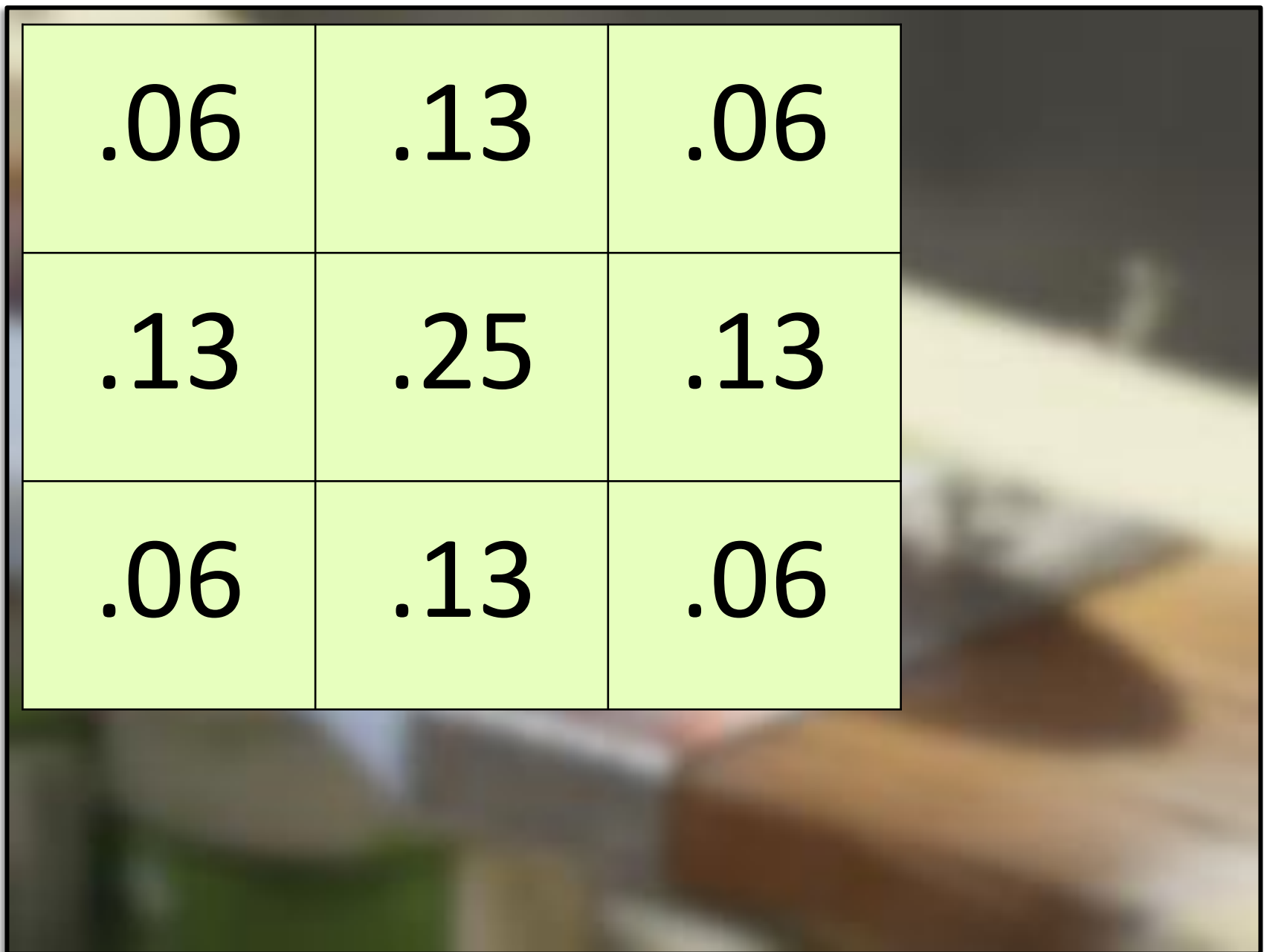



Original Image



Blur

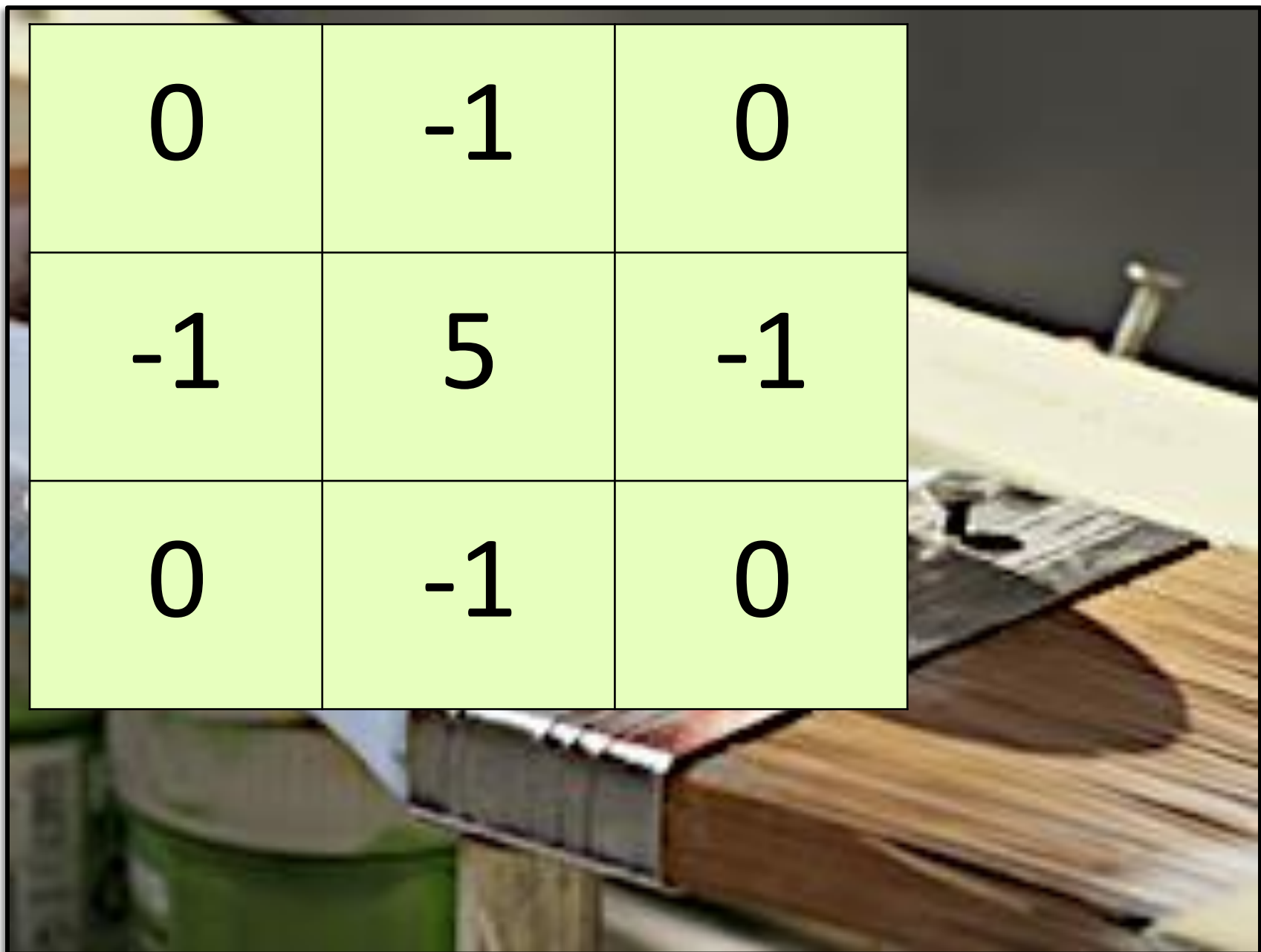
| | | |
|-----|-----|-----|
| .06 | .13 | .06 |
| .13 | .25 | .13 |
| .06 | .13 | .06 |






Sharpen

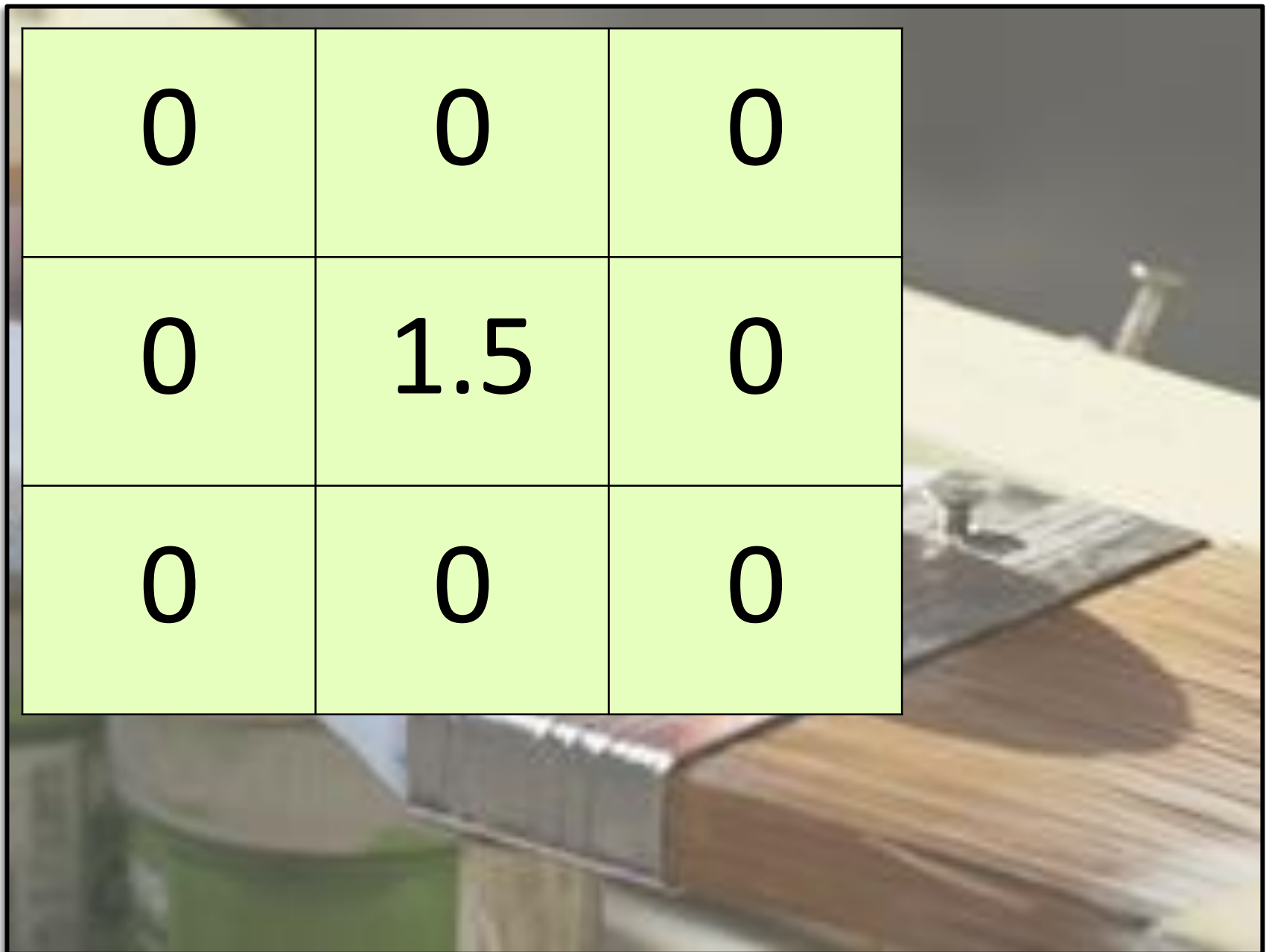
| | | |
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| -1 | 5 | -1 |
| 0 | -1 | 0 |






Brighten

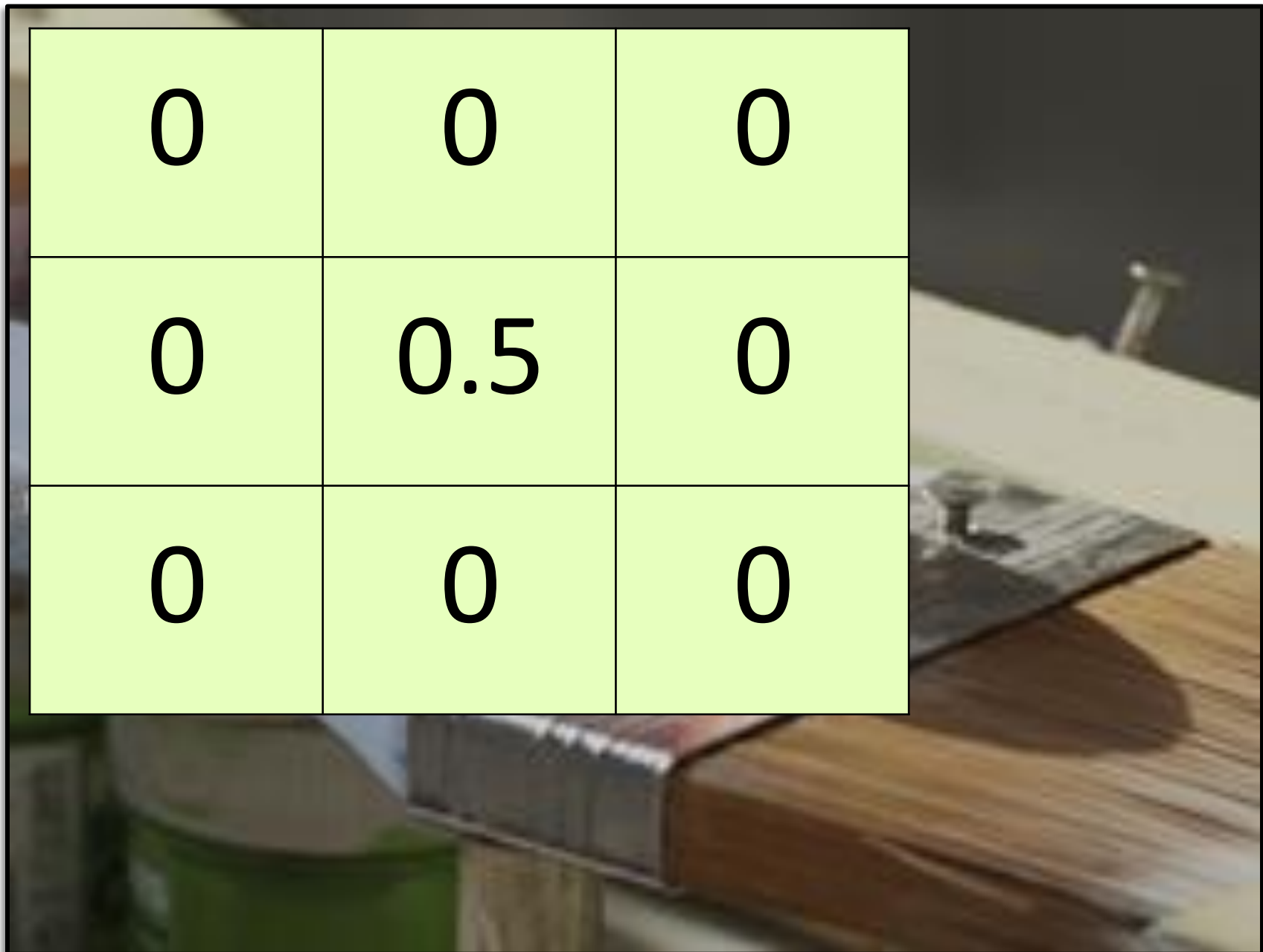
| | | |
|---|-----|---|
| 0 | 0 | 0 |
| 0 | 1.5 | 0 |
| 0 | 0 | 0 |





Darken

| | | |
|---|-----|---|
| 0 | 0 | 0 |
| 0 | 0.5 | 0 |
| 0 | 0 | 0 |



Kernels and Convolution

Blur Kernel

| | | |
|-----|-----|-----|
| .06 | .13 | .06 |
| .13 | .25 | .13 |
| .06 | .13 | .06 |

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Original Image

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

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Convolved Image

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Kernels and Convolution

Blur Kernel

| | | |
|-----|-----|-----|
| .06 | .13 | .06 |
| .13 | .25 | .13 |
| .06 | .13 | .06 |

*

Original Image

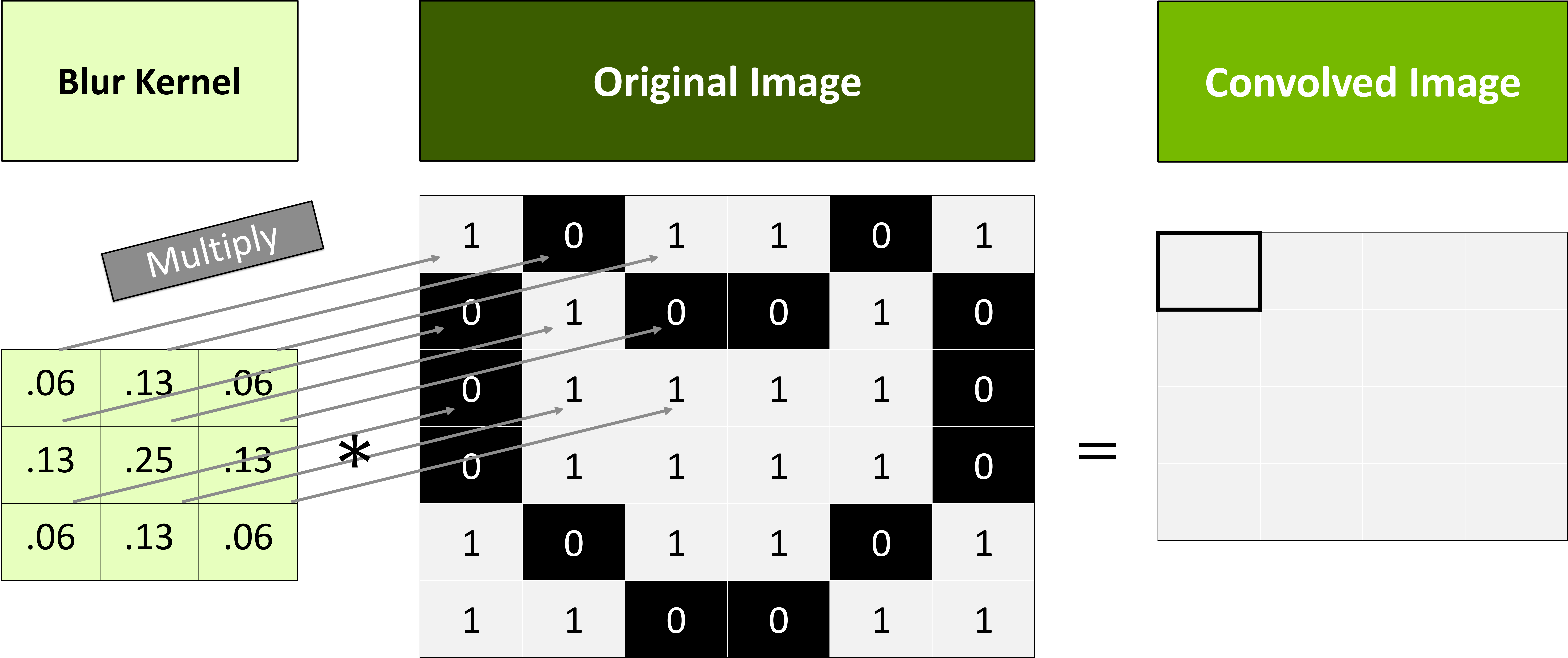
| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

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Convolved Image

| | | | |
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| | | | |

Kernels and Convolution



Kernels and Convolution

Blur Kernel

Original Image

Convolved Image

| | | |
|-----|-----|-----|
| .06 | .13 | .06 |
| .13 | .25 | .13 |
| .06 | .13 | .06 |

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| | | | | | |
|-----|-----|-----|-------|---|---|
| .06 | 0 | .06 | 1 | 0 | 1 |
| 0 | .25 | 0 | Total | | 0 |
| 0 | .13 | .06 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

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| | | | |
|-----|--|--|--|
| .56 | | | |
| | | | |
| | | | |
| | | | |

Kernels and Convolution

Blur Kernel

| | | |
|-----|-----|-----|
| .06 | .13 | .06 |
| .13 | .25 | .13 |
| .06 | .13 | .06 |

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Original Image

| | | | | | |
|---|-----|-----|-----|---|---|
| 1 | 0 | .13 | .06 | 0 | 1 |
| 0 | .13 | 0 | 0 | 1 | 0 |
| 0 | .06 | .13 | .06 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

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Convolved Image

| | | | |
|-----|-----|--|--|
| .56 | .57 | | |
| | | | |
| | | | |
| | | | |

Kernels and Convolution

Blur Kernel

| | | |
|-----|-----|-----|
| .06 | .13 | .06 |
| .13 | .25 | .13 |
| .06 | .13 | .06 |

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Original Image

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

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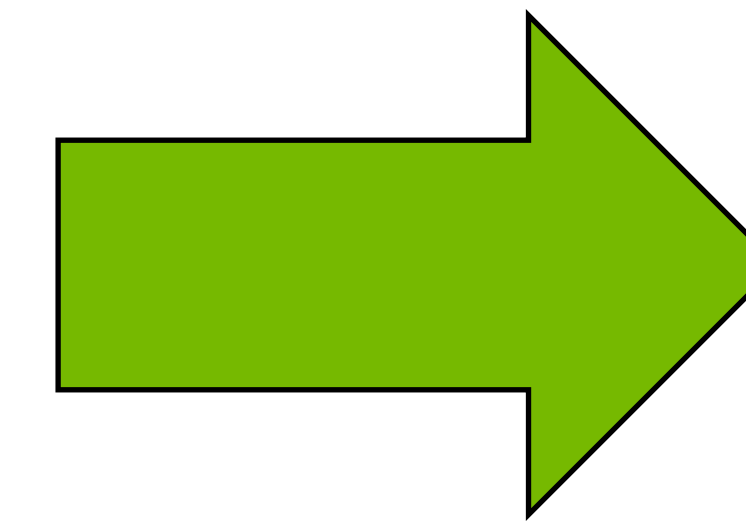
Convolved Image

| | | | |
|-----|-----|-----|-----|
| .56 | .57 | .57 | .56 |
| .7 | .82 | .82 | .7 |
| .69 | .95 | .95 | .69 |
| .64 | .69 | .69 | .64 |

Stride

Stride 1

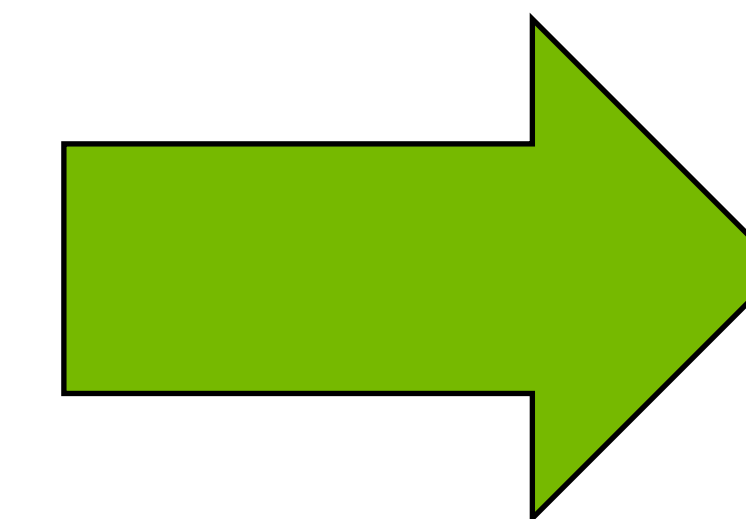
| | | | | | |
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| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |



| | | | |
|-----|-----|-----|-----|
| .56 | .57 | .57 | .56 |
|-----|-----|-----|-----|

Stride 2

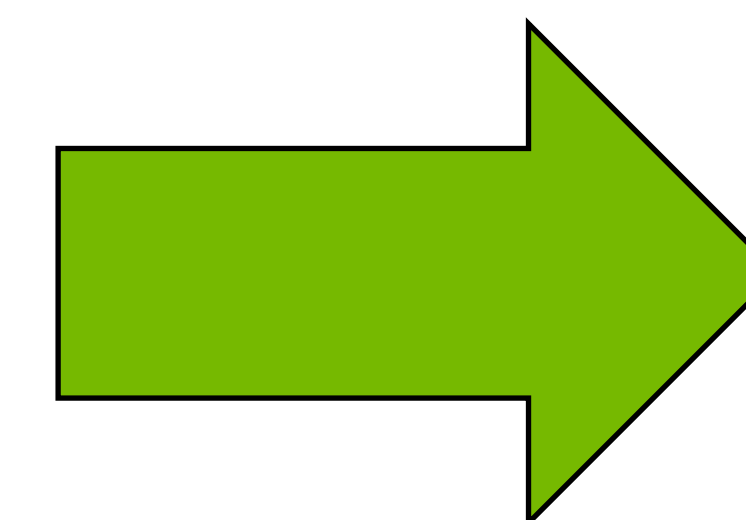
| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |



| | |
|-----|-----|
| .56 | .57 |
|-----|-----|

Stride 3

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |



| | |
|-----|-----|
| .56 | .56 |
|-----|-----|

Padding

Original Image

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

Zero Padding

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |


Padding

Original Image

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 |

Mirror Padding

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |



Kernels and Neural Networks

Kernels and Neural Networks

Kernel

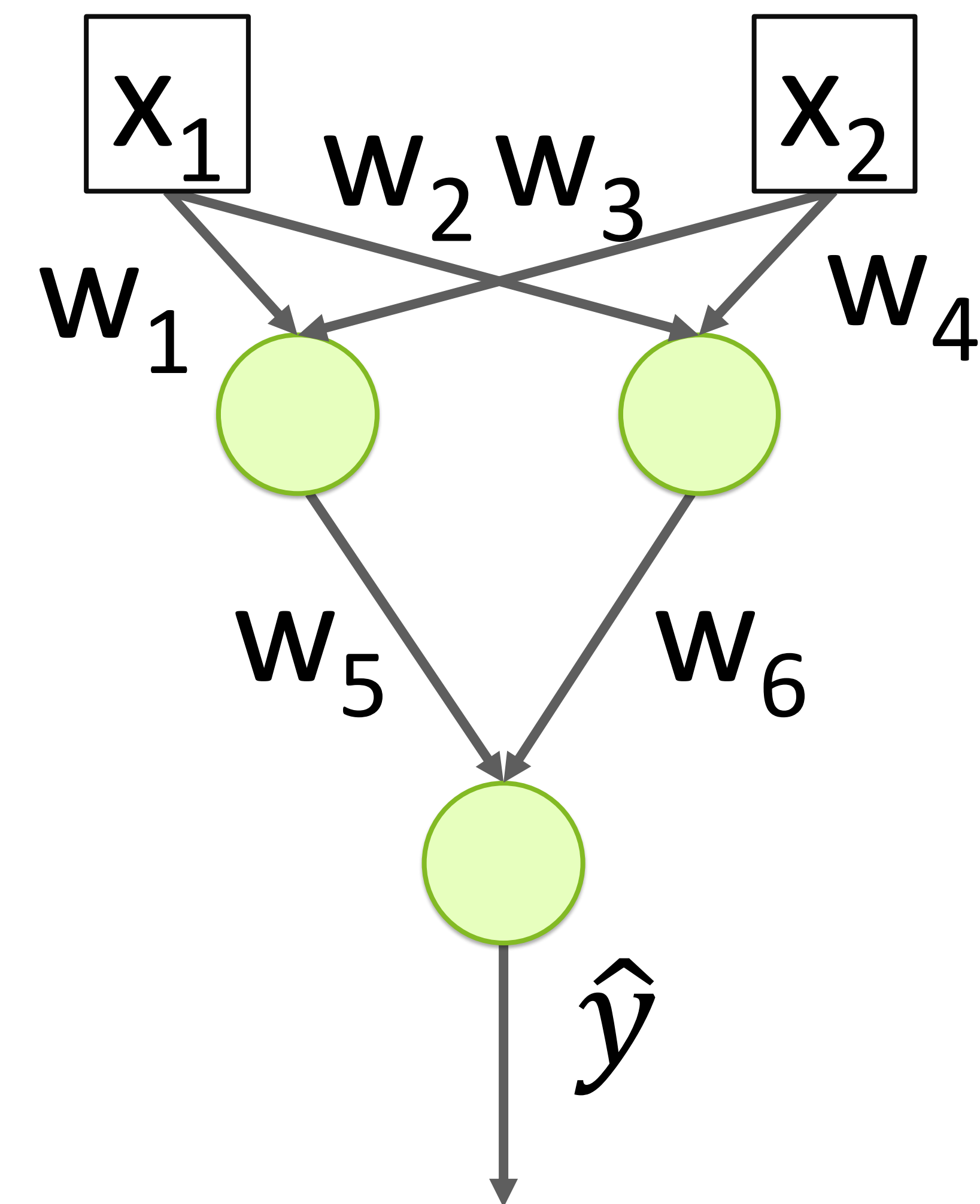
| | | |
|-------|-------|-------|
| W_1 | W_2 | W_3 |
| W_4 | W_5 | W_6 |
| W_7 | W_8 | W_9 |

Kernels and Neural Networks

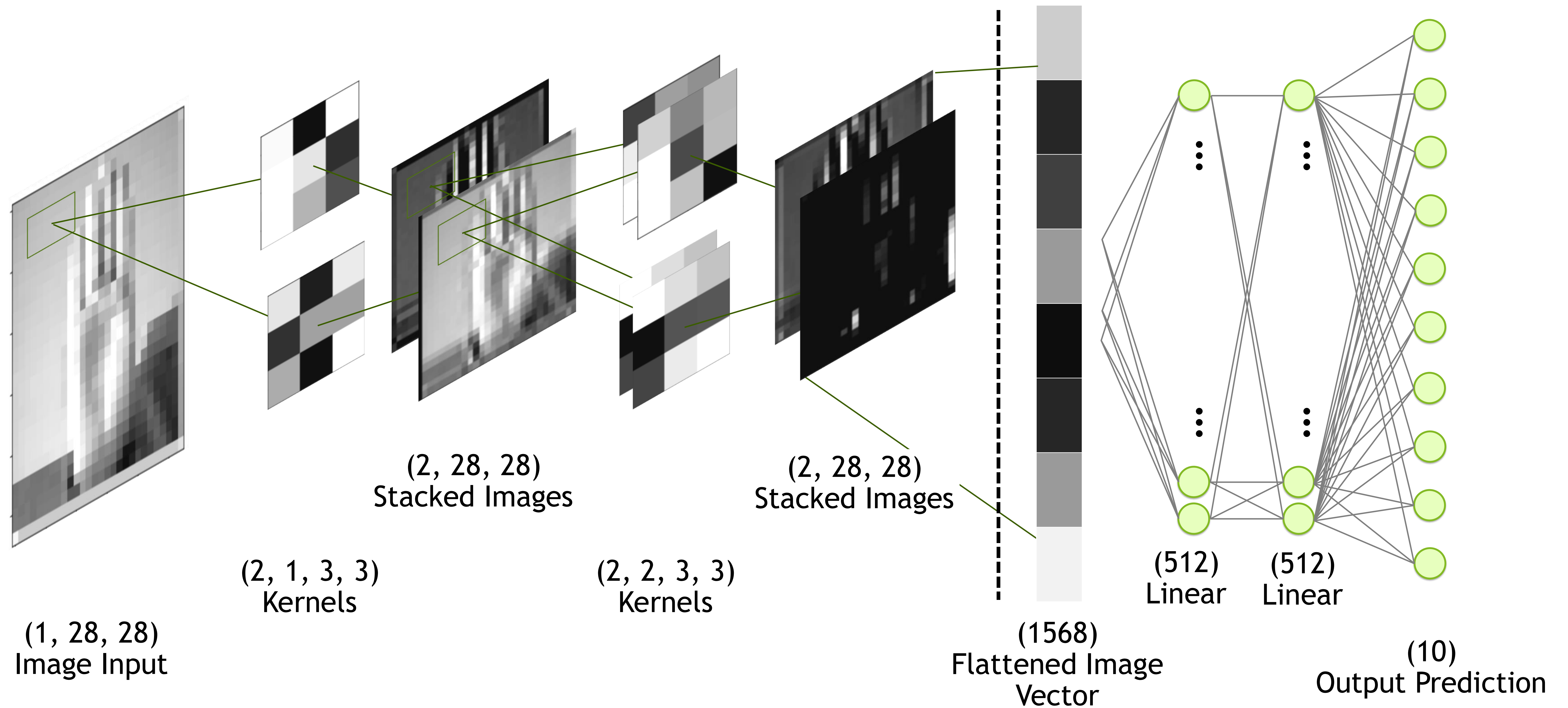
Kernel

| | | |
|-------|-------|-------|
| w_1 | w_2 | w_3 |
| w_4 | w_5 | w_6 |
| w_7 | w_8 | w_9 |

Neuron

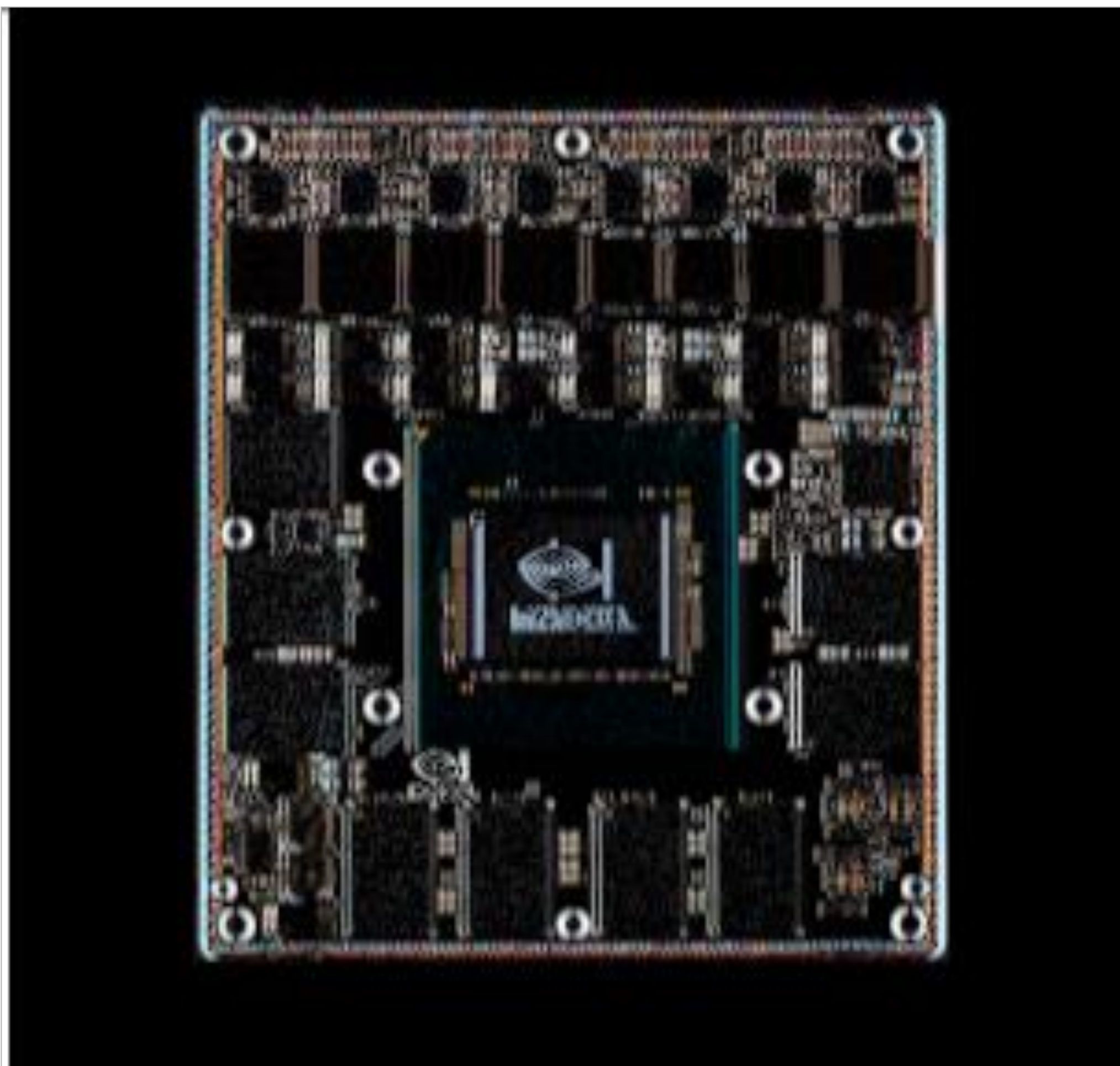


Kernels and Neural Networks



Finding Edges

Vertical Edges



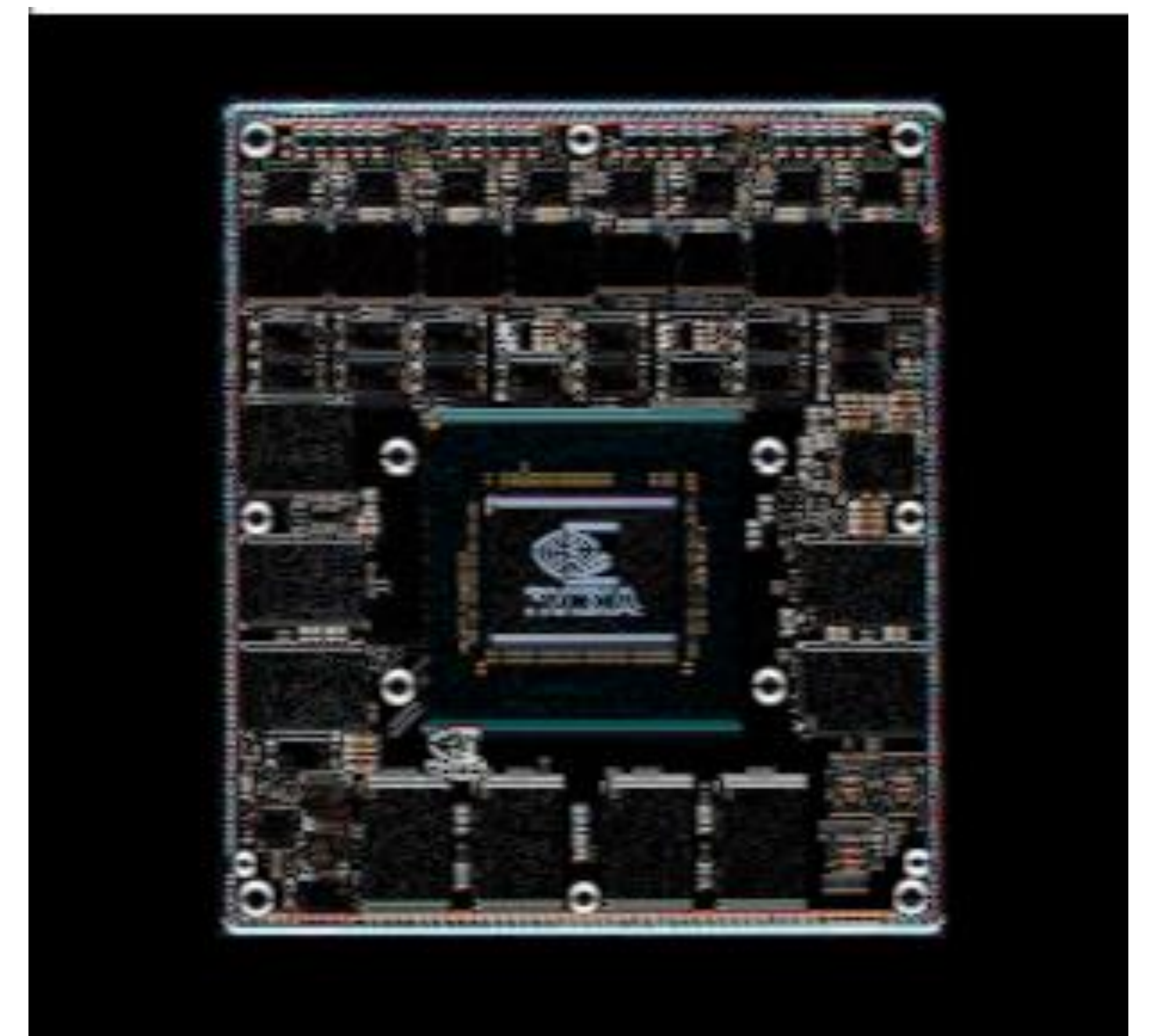
| | | |
|---|---|----|
| 1 | 0 | -1 |
| 2 | 0 | -2 |
| 1 | 0 | -1 |

Original Image



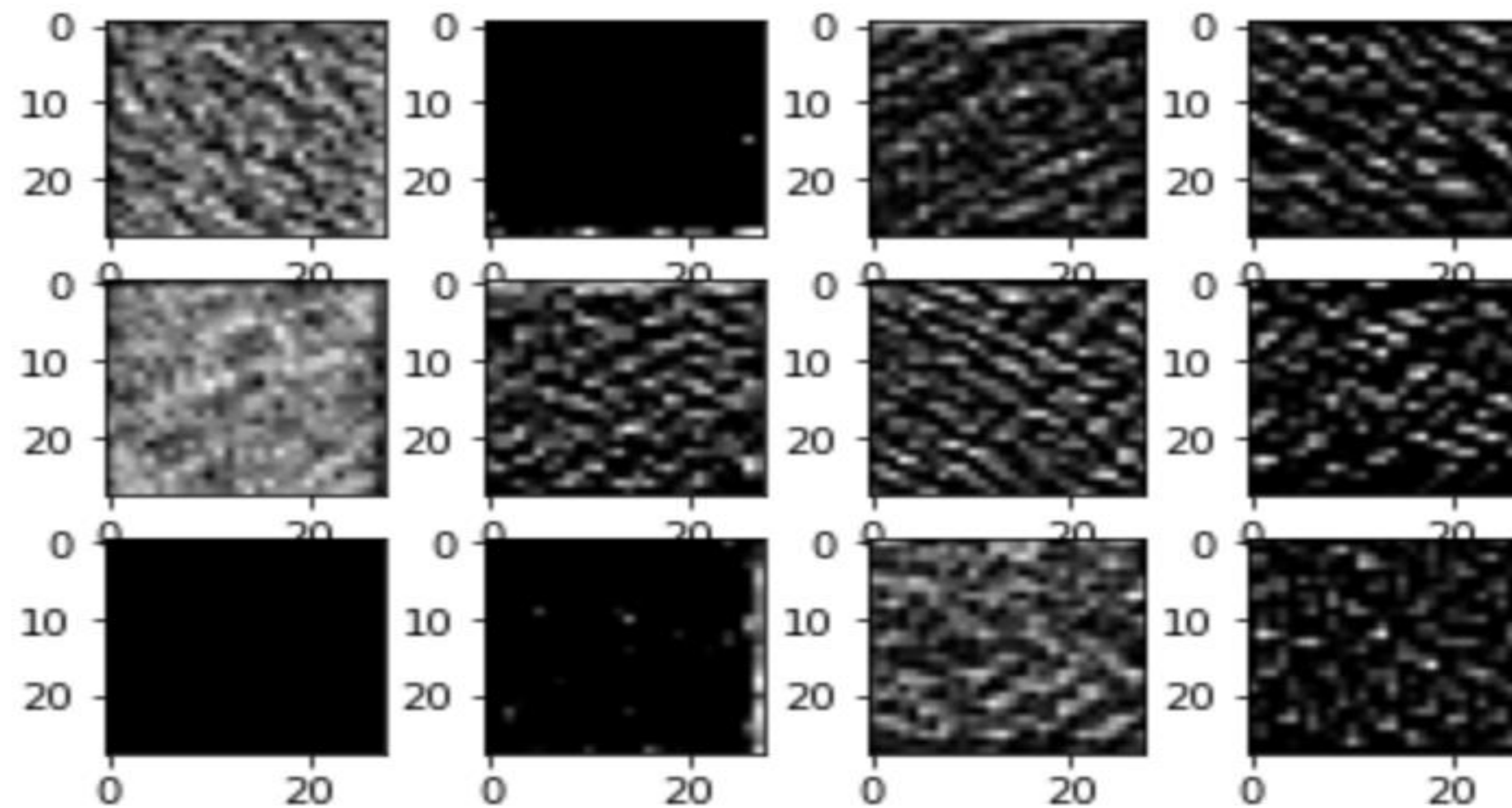
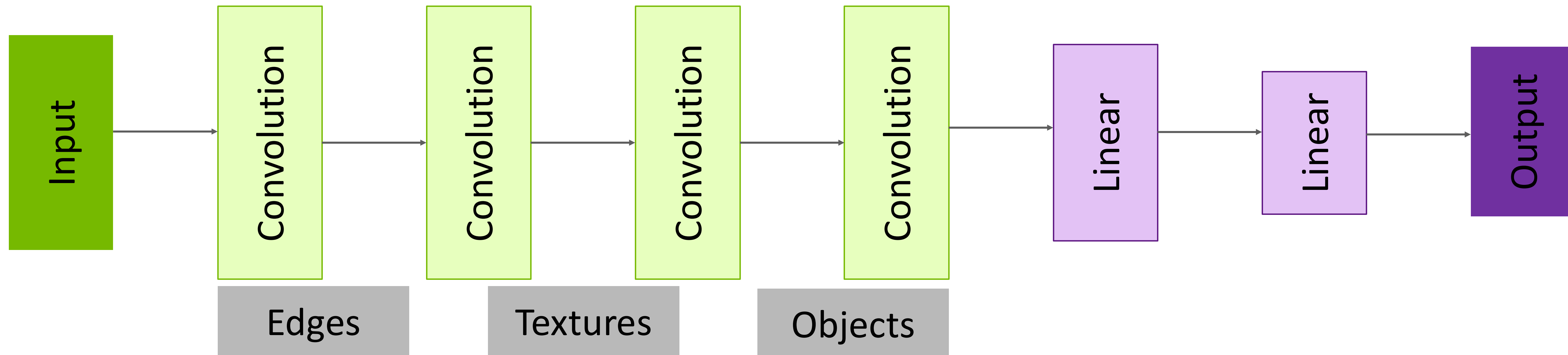
| | | |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 0 | 0 | 0 |

Horizontal Edges



| | | |
|----|----|----|
| 1 | 2 | 1 |
| 0 | 0 | 0 |
| -1 | -2 | -1 |

Neural Network Perception



Neural Network Perception

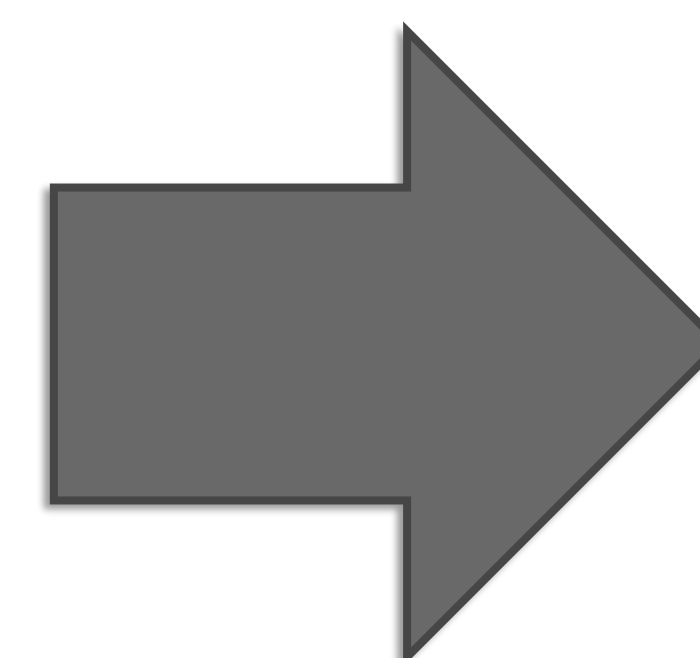




Other Layers in the Model

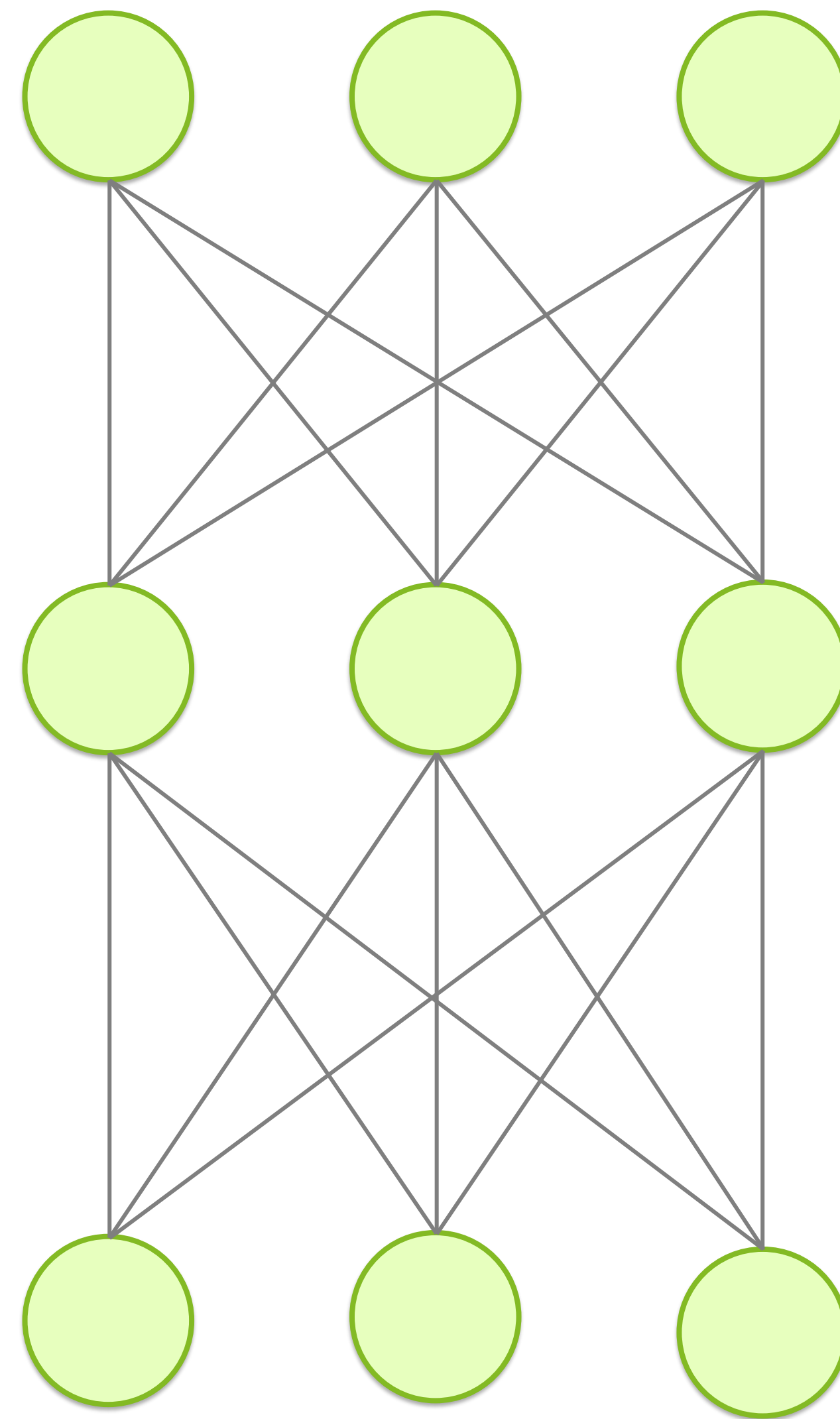
Max Pooling

| | | | |
|-----|-----|-----|----|
| 110 | 256 | 153 | 67 |
| 12 | 89 | 88 | 43 |
| 10 | 15 | 50 | 55 |
| 23 | 9 | 49 | 23 |

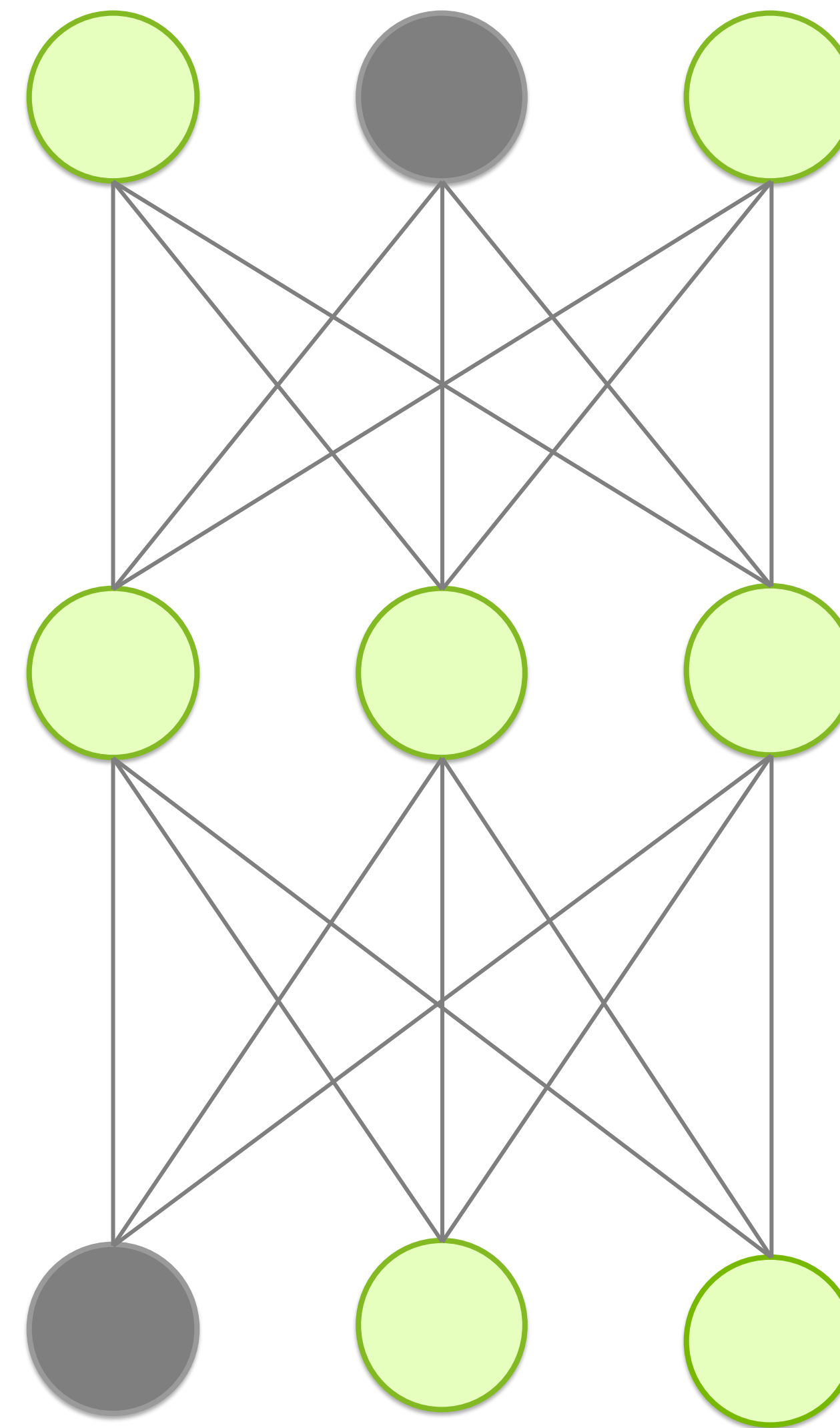


| | |
|-----|-----|
| 256 | 153 |
| 23 | 55 |

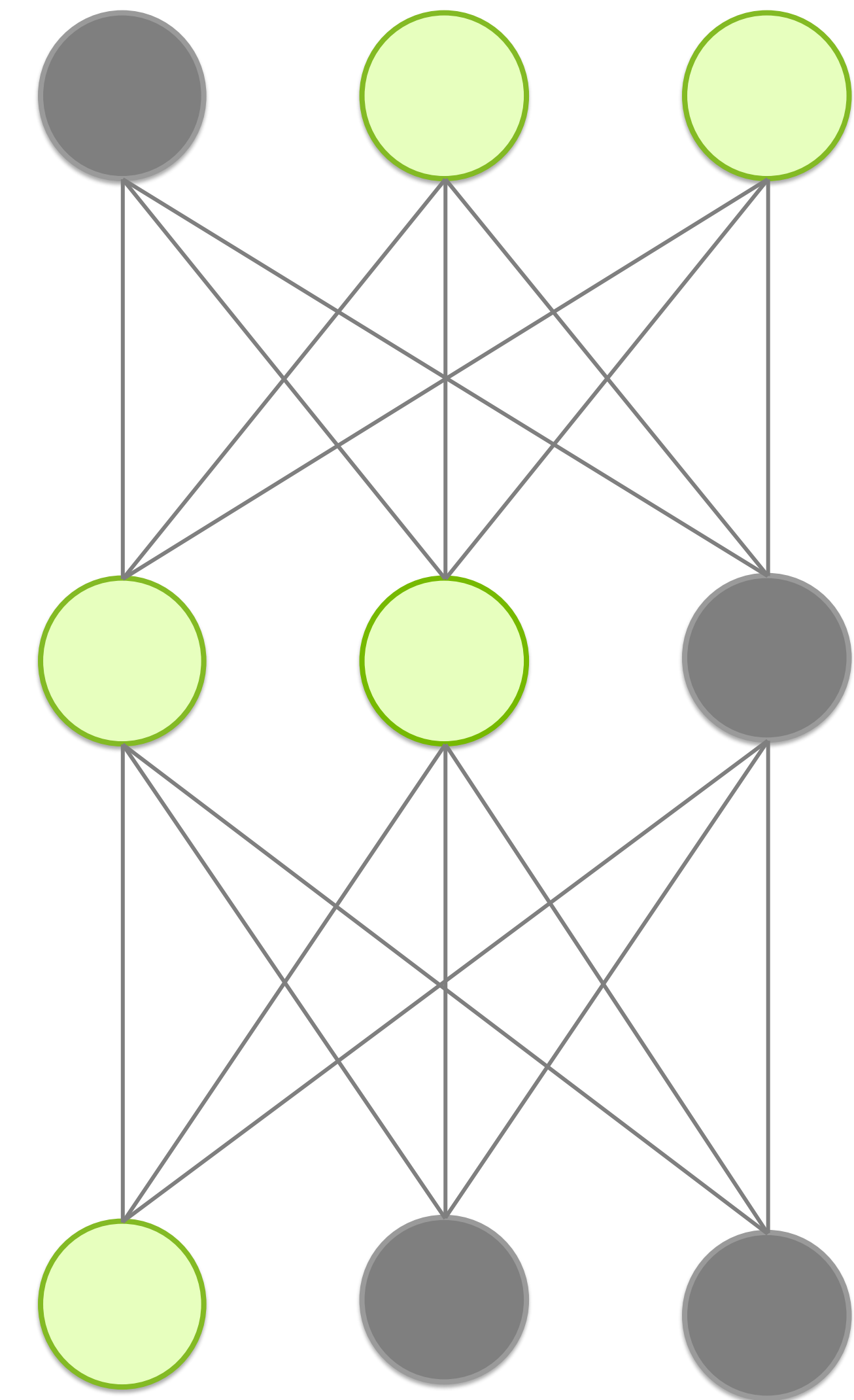
Dropout



rate = 0

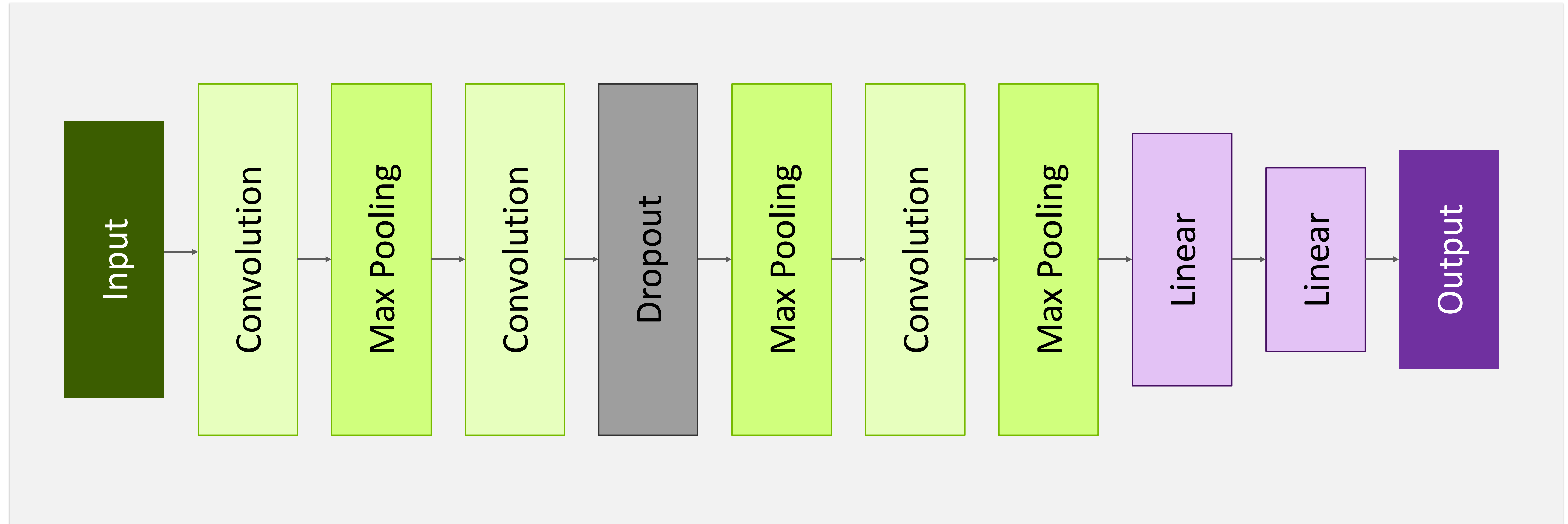


rate = .2



rate = .4

Whole Architecture





Let's go!

