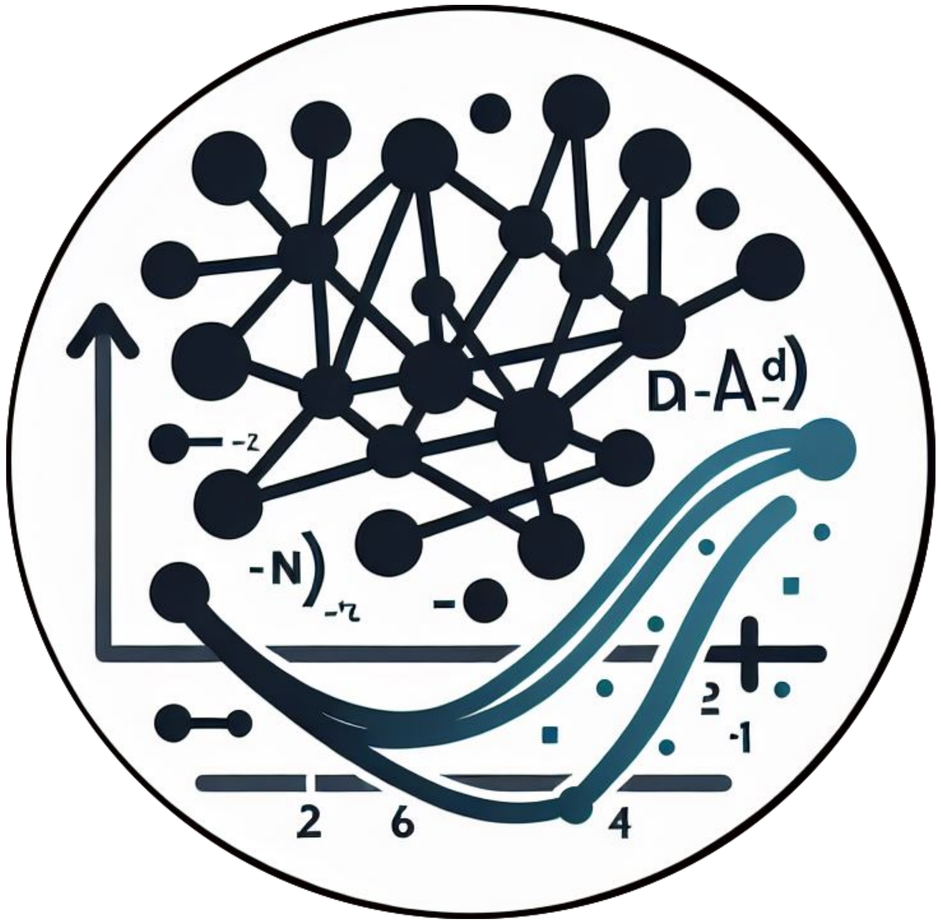
# Convolutional Neural Nets



Deep Learning for Engineers
Andrew Ning
aning@byu.edu

# What do we use Neural ODEs for?

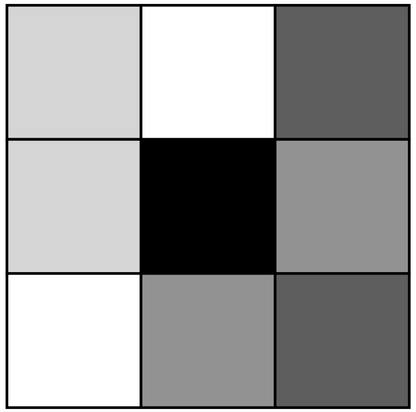
Predict forward in time (e.g., weather problem)

Predict different initial conditions

Increase or reduce dimensionality to make problem better behaved numerically, or linear, etc.

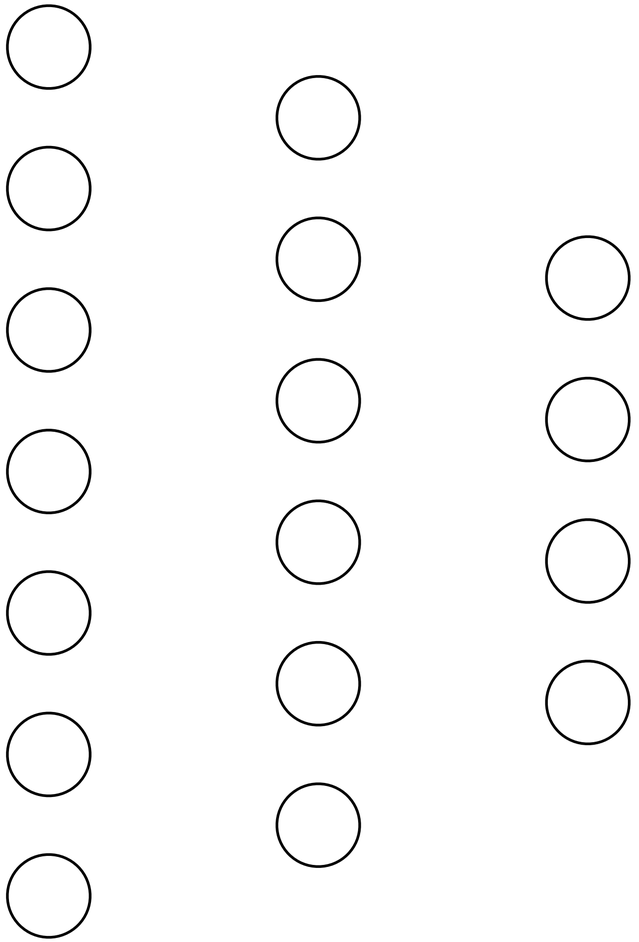
Symbolic regression

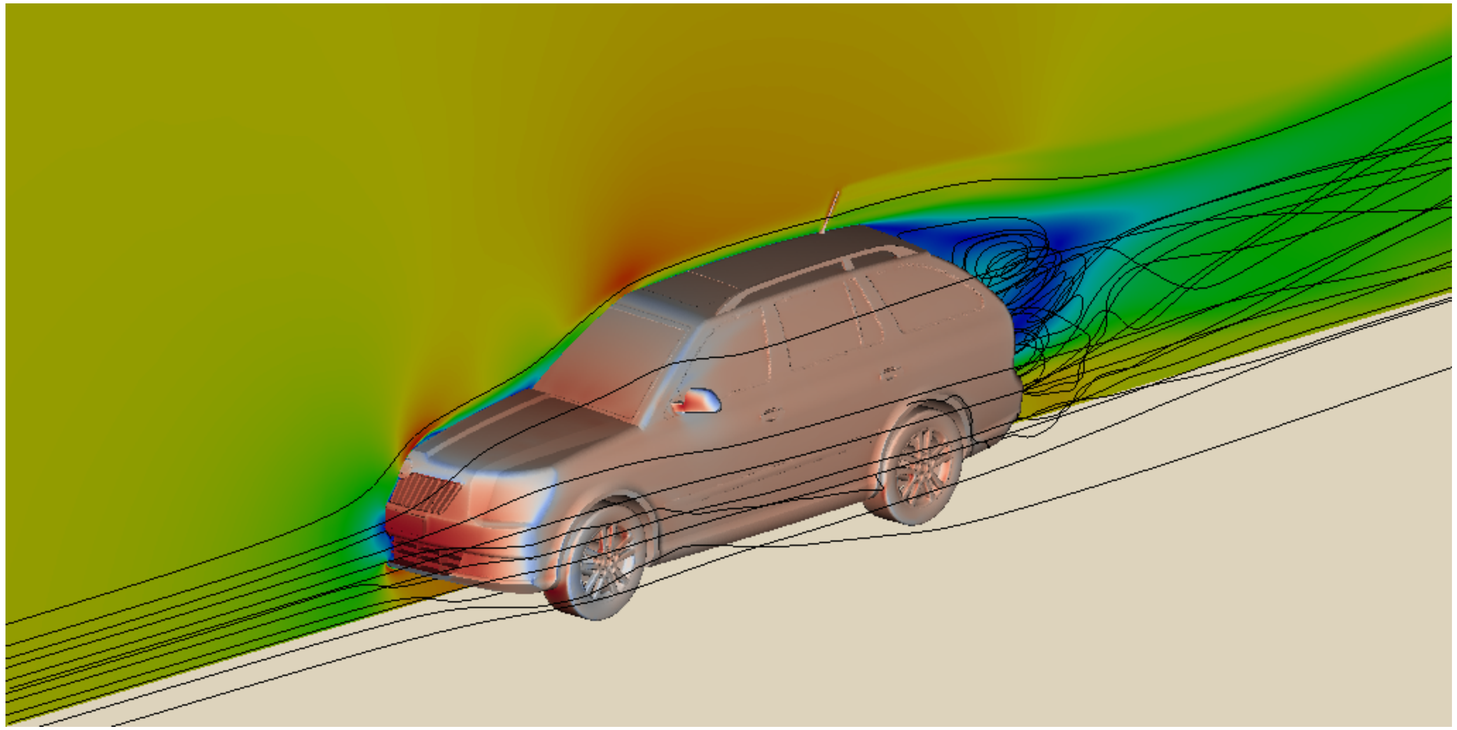
Speed

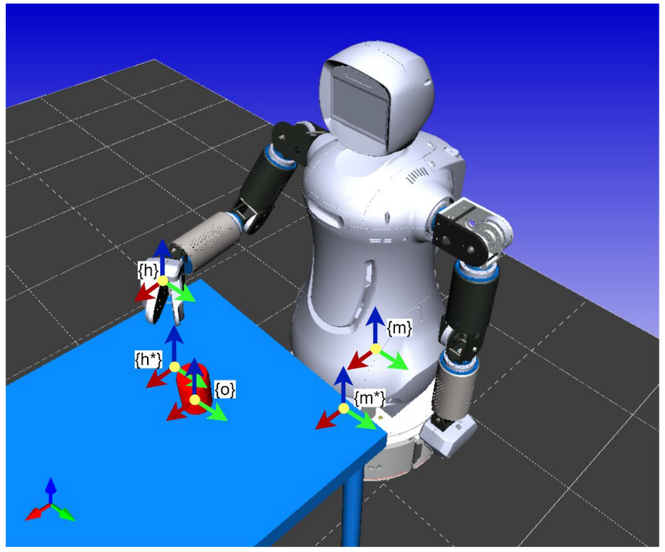


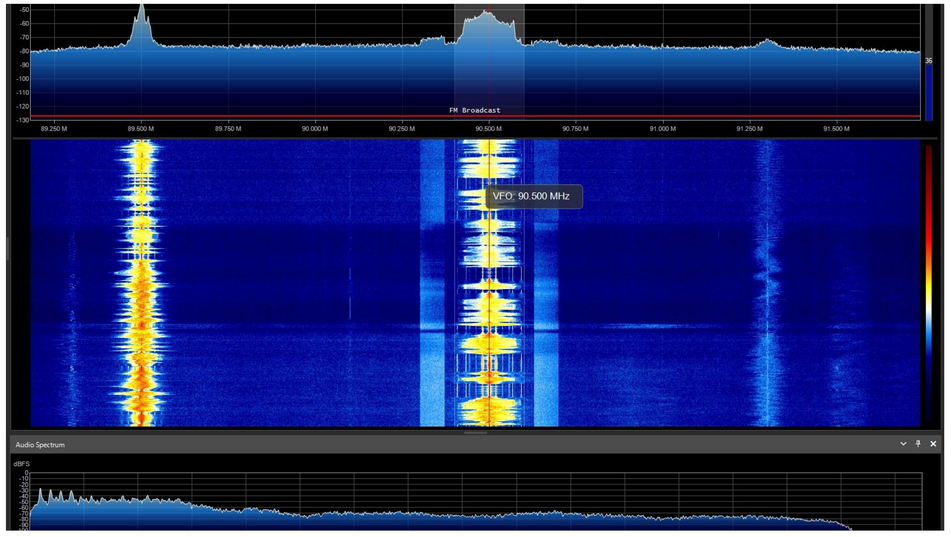
| | | |
|---|---|---|
| .75 | 1 | .25 |
| .75 | 0 | .5 |
| 1 | .5 | .25 |

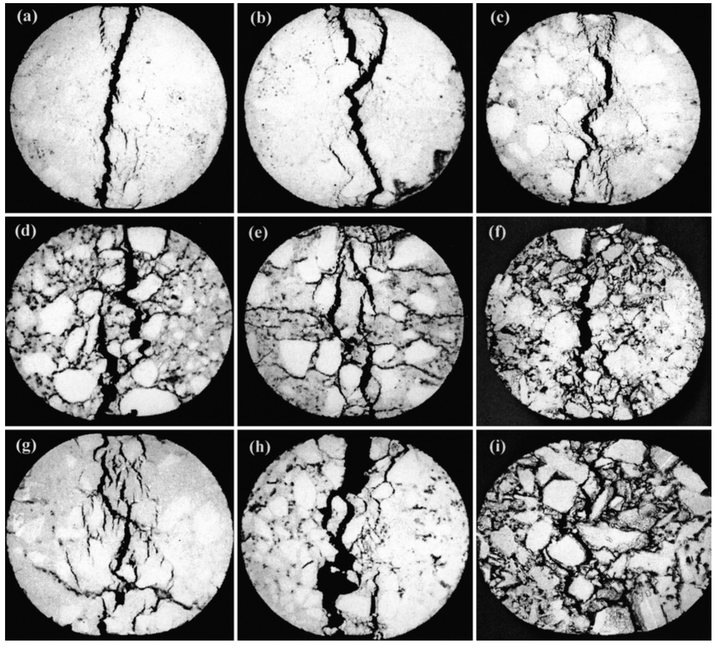
| |
|---|
| .75 |
| 1 |
| .25 |
| .75 |
| 0 |
| .5 |
| 1 |
| .5 |
| .25 |



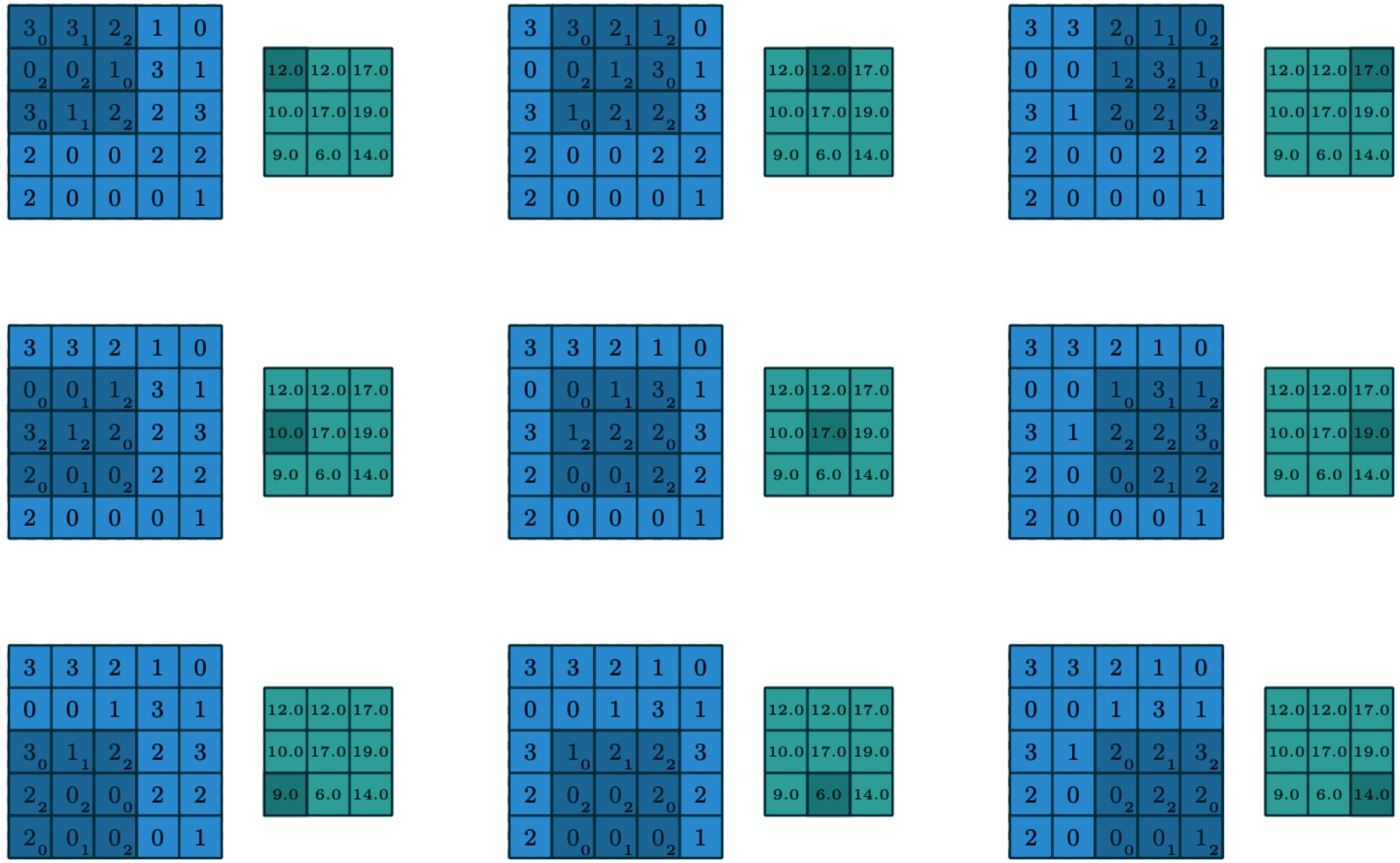



{h}
{h*}
{o}
{m}
{m*}


FM Broadcast
VFO: 90.500 MHz
Audio Spectrum


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)

# Kernel

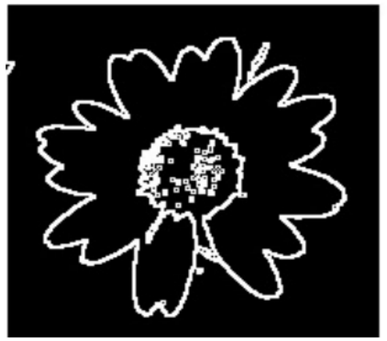



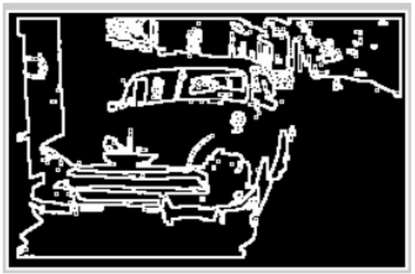
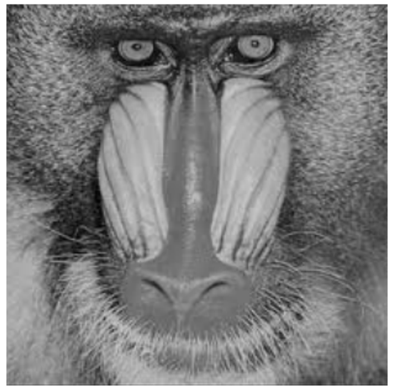

A guide to convolution arithmetic for deep learning, Dumoulin and Visinn

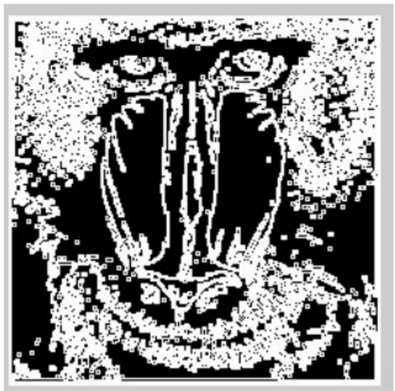
# Edge Detection

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







kernel

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

input

| | | | | |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 2 | 1 | 3 | 0 | 3 |
| 1 | 1 | 0 | 3 | 2 |
| 2 | 0 | 1 | 0 | 1 |

output

kernel

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

input

| | | | | |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 2 | 1 | 3 | 0 | 3 |
| 1 | 1 | 0 | 3 | 2 |
| 2 | 0 | 1 | 0 | 1 |

output

| | | | |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

kernel

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

input

| | | | | |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 2 | 1 | 3 | 0 | 3 |
| 1 | 1 | 0 | 3 | 2 |
| 2 | 0 | 1 | 0 | 1 |

output

| | | | |
|---|---|---|---|
| 3 | | | |
| | | | |
| | | | |
| | | | |

kernel

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

input

| | | | | |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 2 | 1 | 3 | 0 | 3 |
| 1 | 1 | 0 | 3 | 2 |
| 2 | 0 | 1 | 0 | 1 |

output

| | | | |
|---|---|---|---|
| 3 | 4 | | |
| | | | |
| | | | |
| | | | |

kernel

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

input

| | | | | |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 2 | 1 | 3 | 0 | 3 |
| 1 | 1 | 0 | 3 | 2 |
| 2 | 0 | 1 | 0 | 1 |

output

| | | | |
|---|---|---|---|
| 3 | 4 | 9 | |
| | | | |
| | | | |
| | | | |

kernel

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

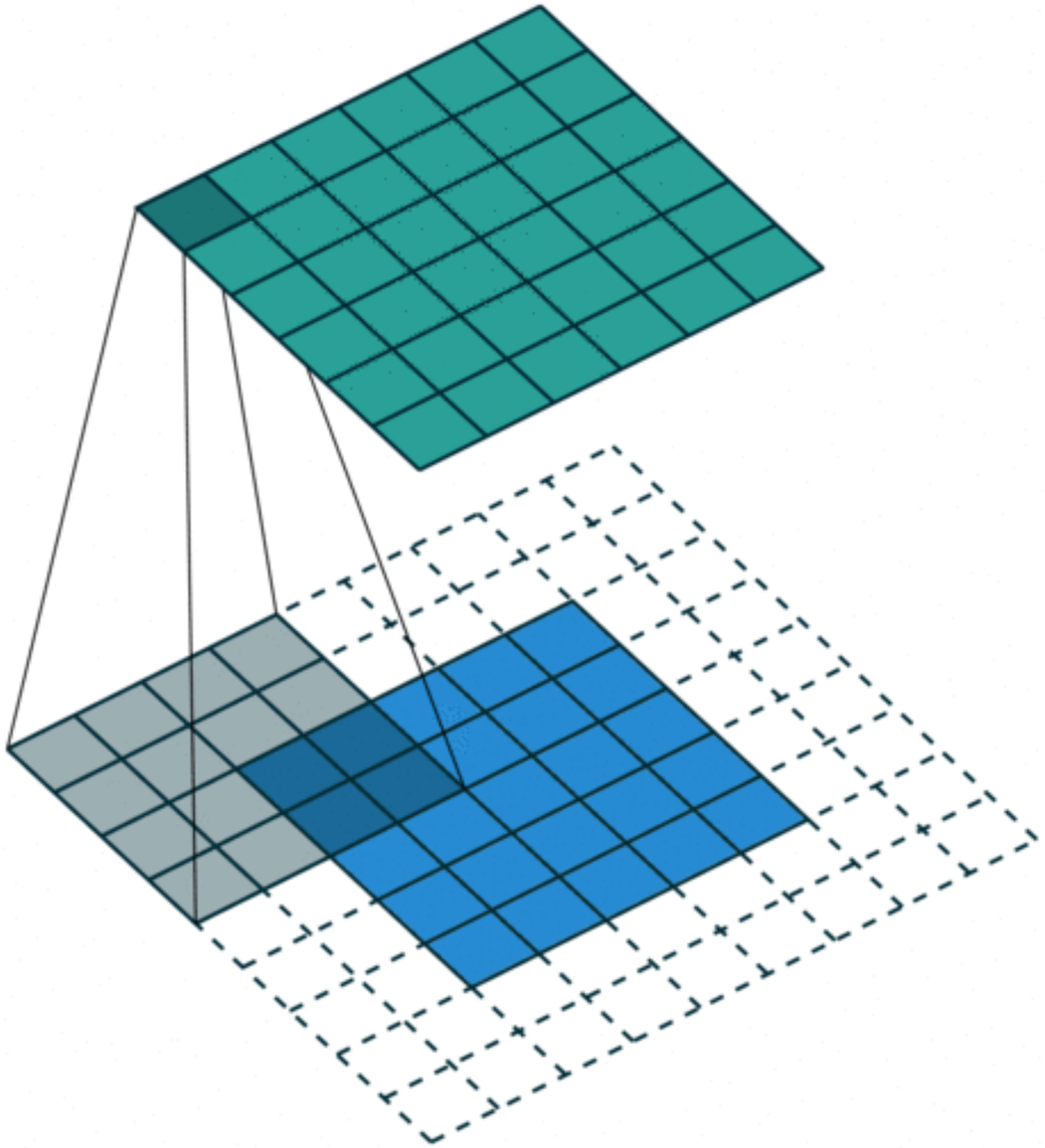
input

| | | | | |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 0 |
| 0 | 0 | 1 | 3 | 1 |
| 2 | 1 | 3 | 0 | 3 |
| 1 | 1 | 0 | 3 | 2 |
| 2 | 0 | 1 | 0 | 1 |

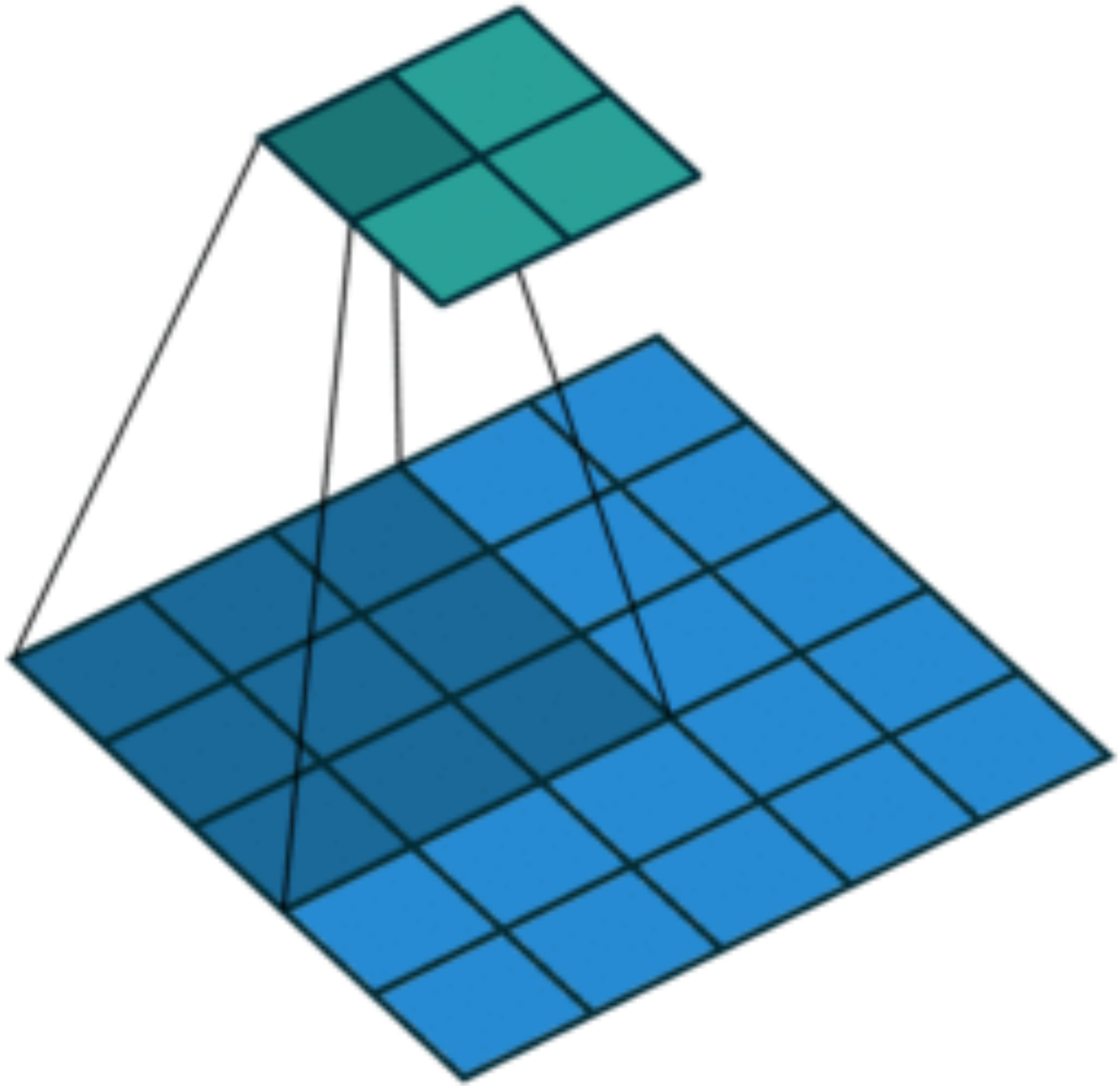
output

| | | | |
|---|---|---|---|
| 3 | 4 | 9 | 8 |
| | | | |
| | | | |
| | | | |

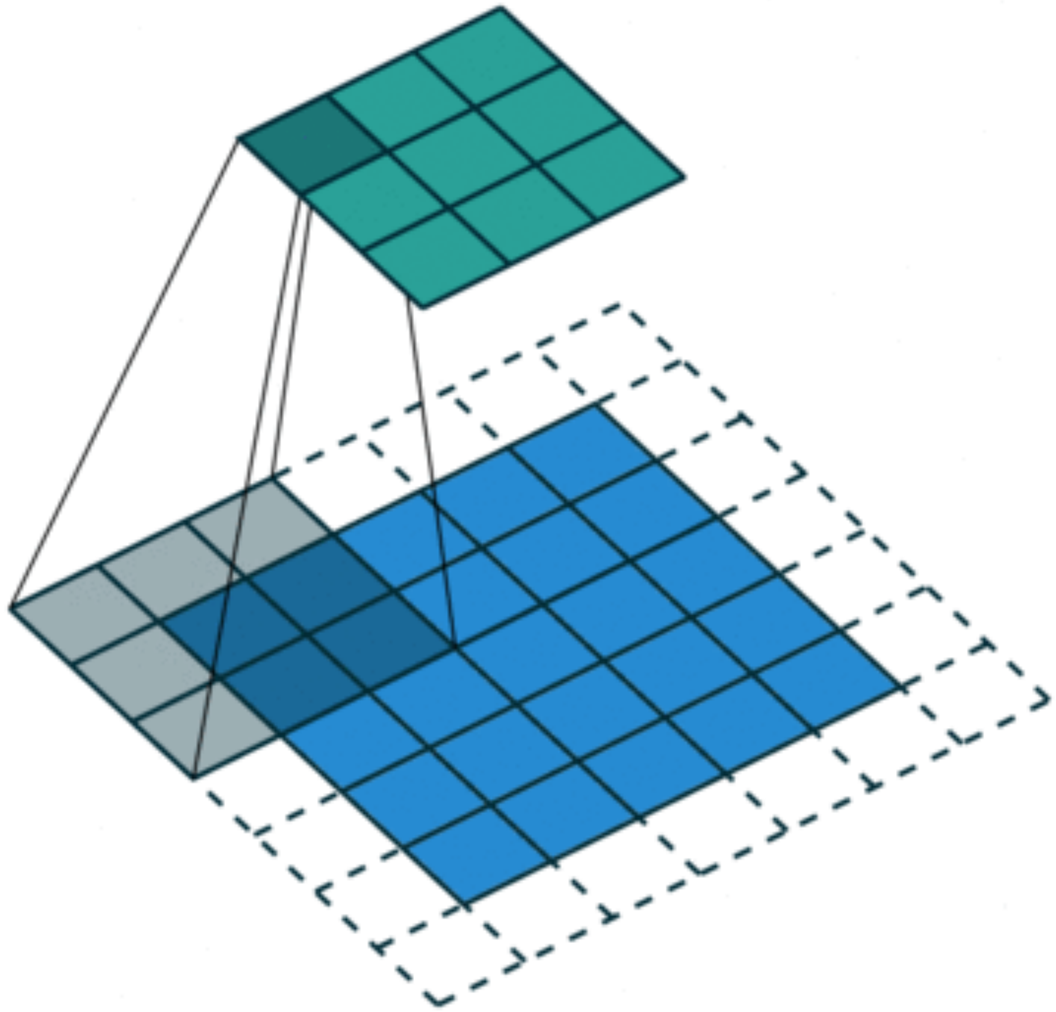
# Padding



# Strides



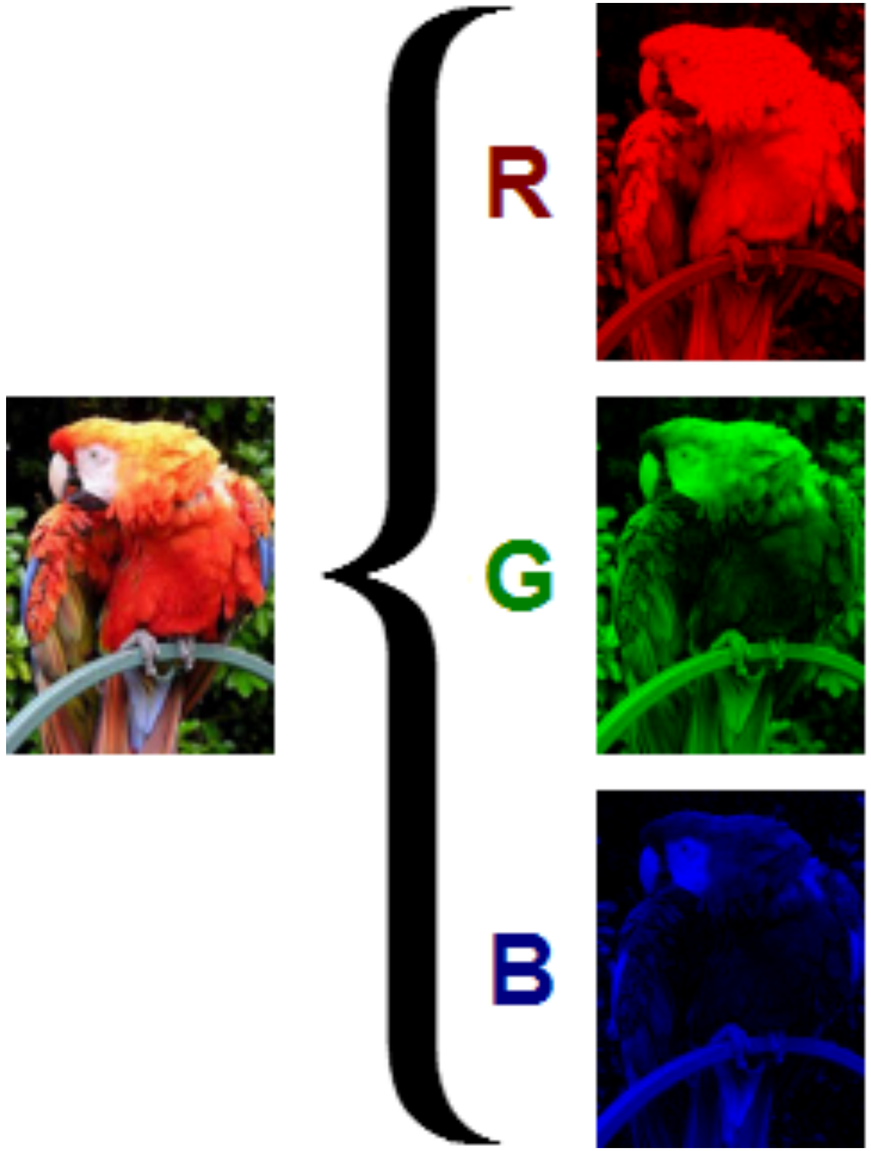
# Padding and Strides

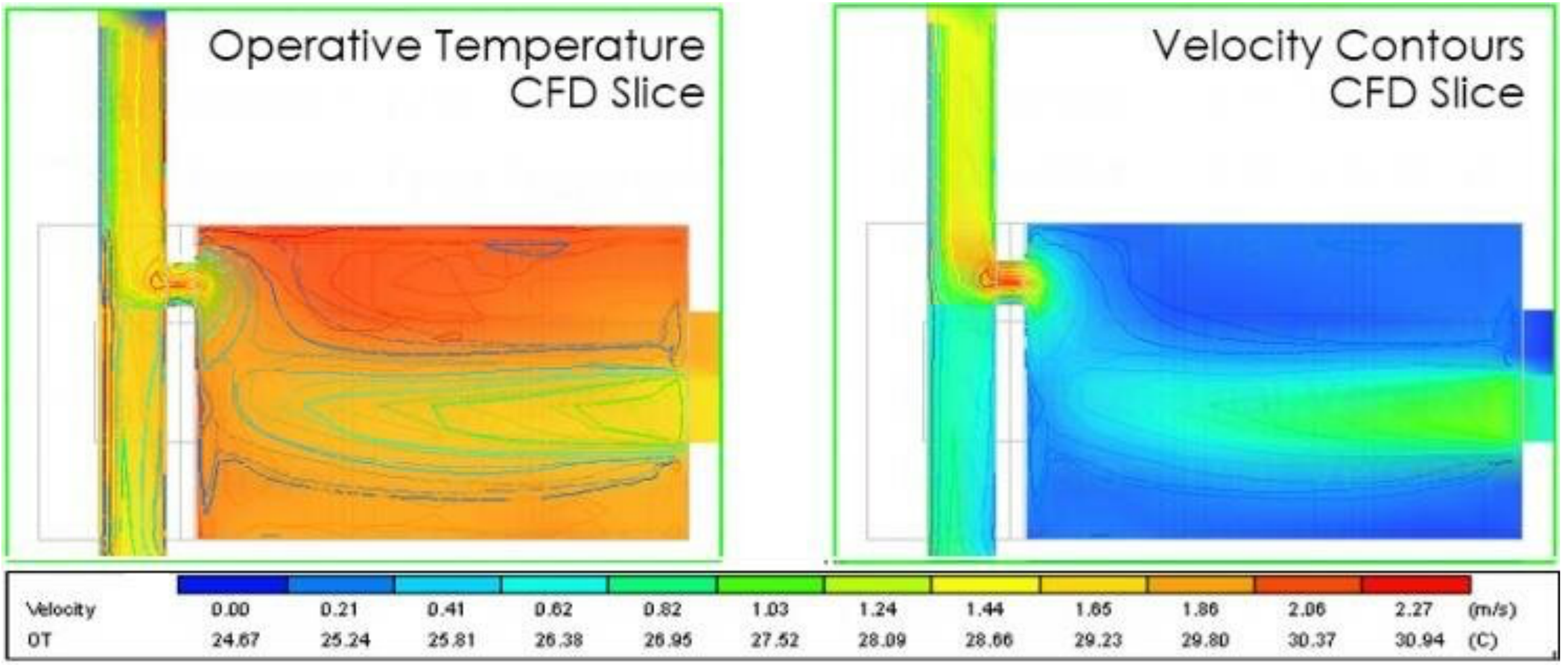


# new size

$$H_{out} = \frac{H_{in} - K + (2 \times \text{padding})}{\text{stride}} + 1$$

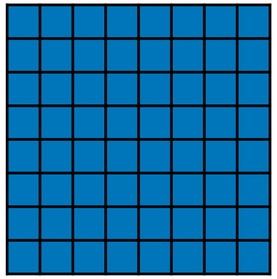
# Channels



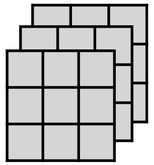



Solar Chimney for Enhanced Natural Ventilation Based on CFD-Simulation for a Housing Prototype in Alexandria, Egypt. Gehad Mekkawi and Rana Elgendy

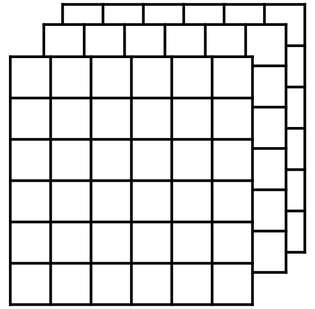
# Multiple Outputs



8 x 8 x 1

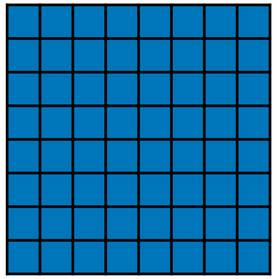


3 x 3 x 1 x 3



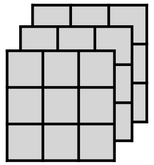
6 x 6 x 3

# Multiple Outputs



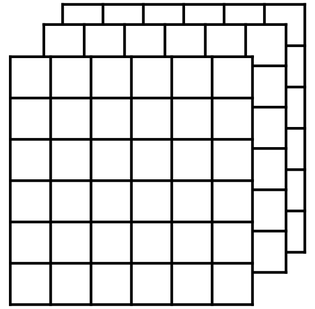
8 x 8 x 1

in channels



3 x 3 x 1 x 3

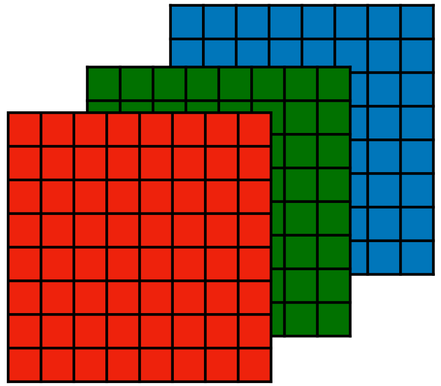
kernel size



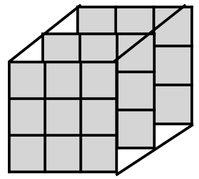
6 x 6 x 3

out channels

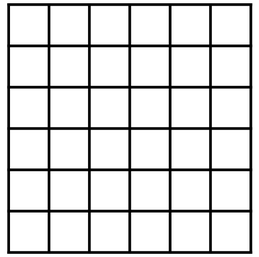
# Multiple Inputs



8 x 8 x 3

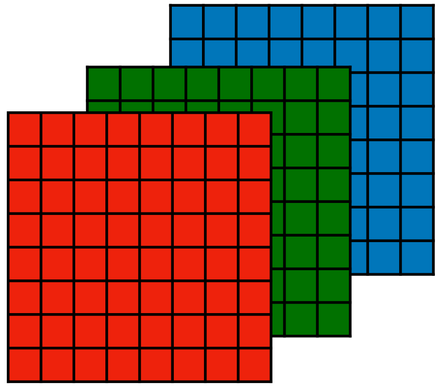


3 x 3 x 3 x 1



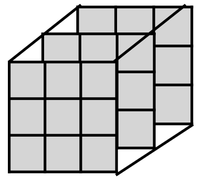
6 x 6 x 1

# Multiple Inputs



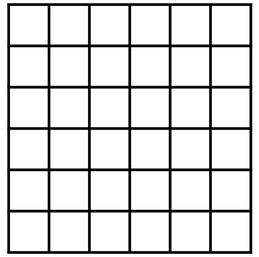
8 x 8 x 3

in channels



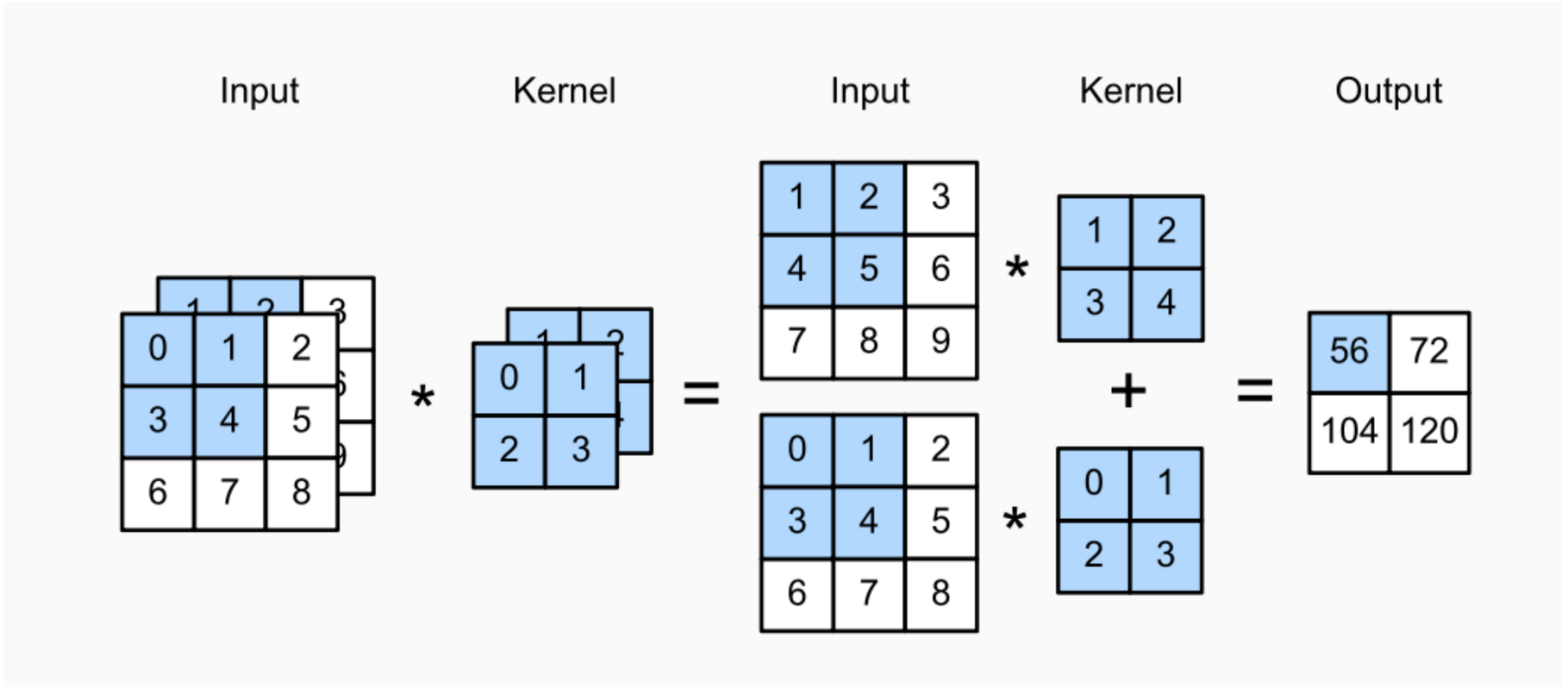
3 x 3 x 3 x 1

kernel size



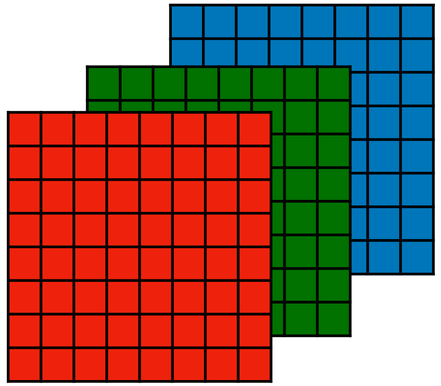
6 x 6 x 1

out channels

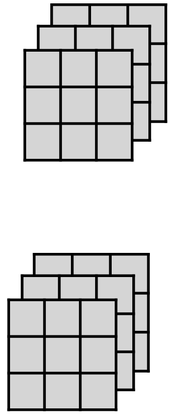

Input
Kernel
Input
Kernel
Output
0 1 2
3 4 5
6 7 8
0 1
2 3
1 2 3
4 5 6
7 8 9
1 2
3 4
0 1 2
3 4 5
6 7 8
0 1
2 3
56 72
104 120

http://d2l.ai

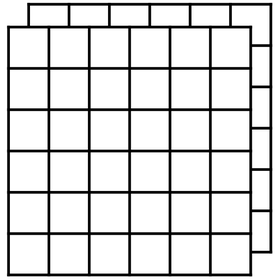
# Multiple Inputs and Multiple Outputs



8 x 8 x 3

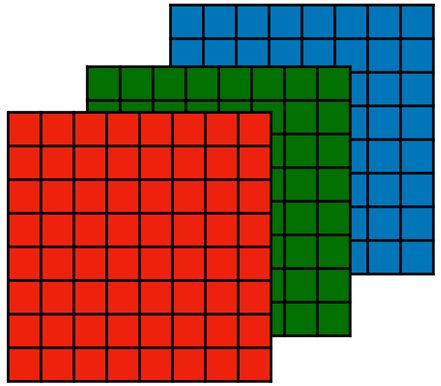


3 x 3 x 3 x 2



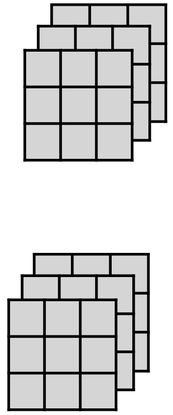
6 x 6 x 2

# Multiple Inputs and Multiple Outputs



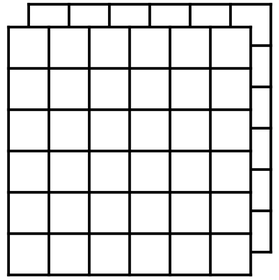
8 x 8 x 3

in channels



3 x 3 x 3 x 2

kernel size



6 x 6 x 2

out channels

# Conv2d

torch.nn.Conv2d(in_channels, out_channels, kernel_size, stride=1, padding=0)

# Pooling

| | | | |
|---|---|---|---|
| 3 | 2 | 2 | 1 |
| 0 | 3 | 1 | 0 |
| 0 | 1 | 1 | 2 |
| 1 | 1 | 0 | 2 |

max pool

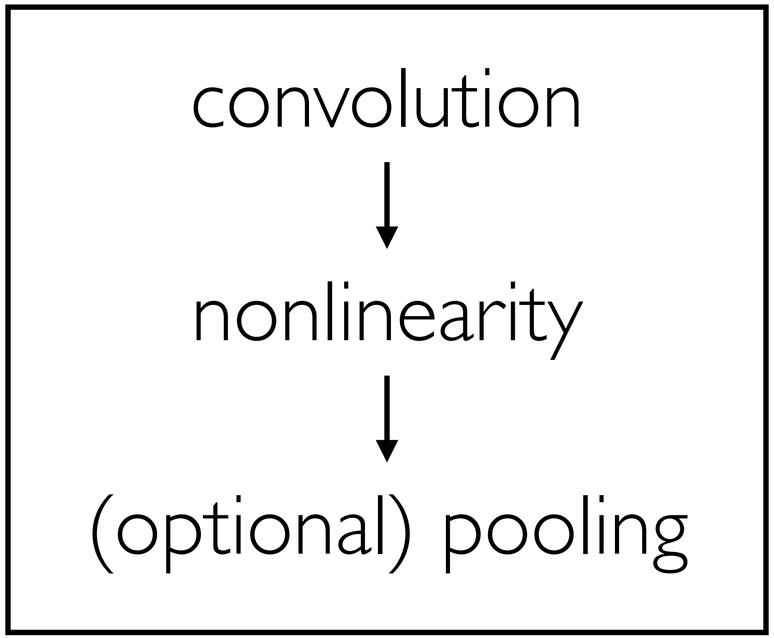
2x2 filter

stride = 2

| | |
|---|---|
| 3 | 2 |
| 1 | 2 |

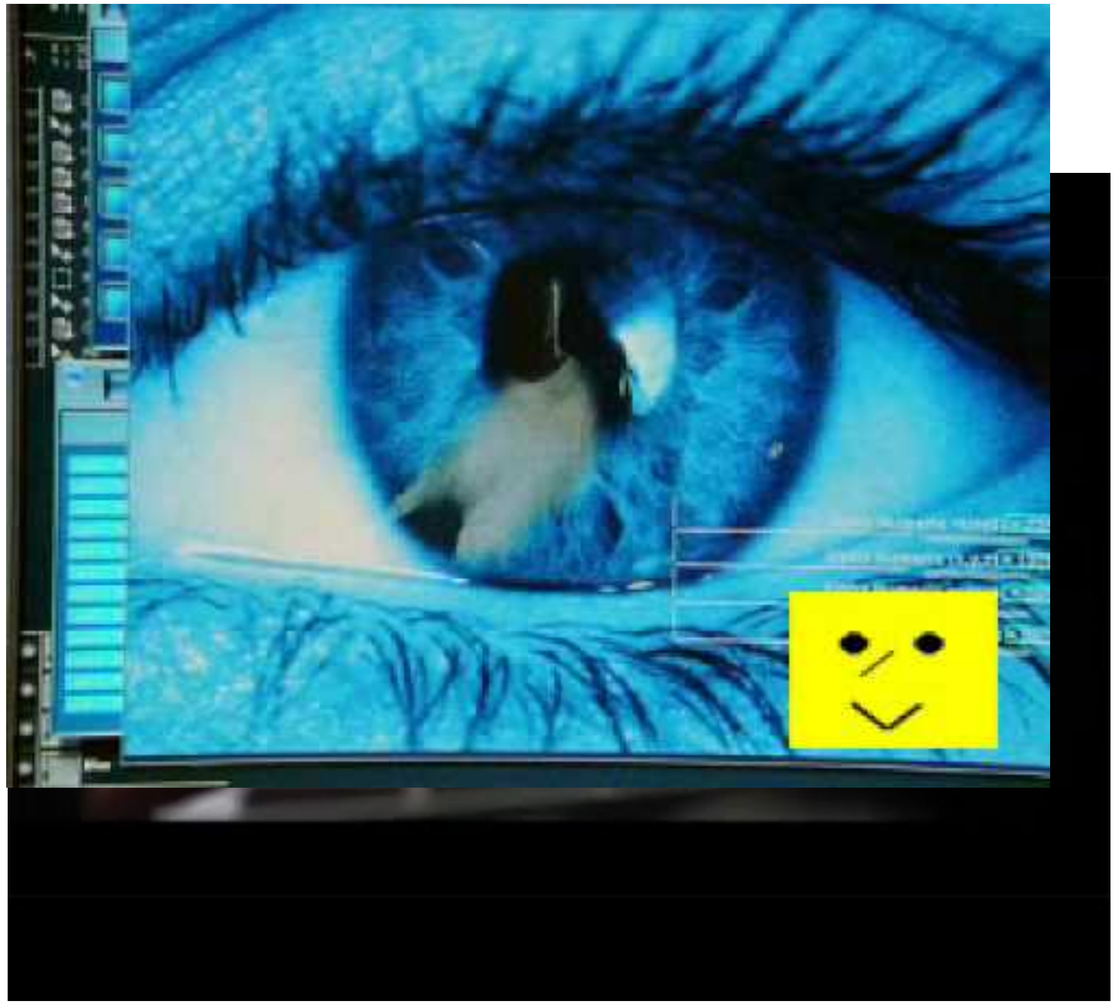
torch.nn.MaxPool2d

torch.nn.AvgPool2d




(potentially a linear layer(s) after all the convolution layers)

# Super Resolution




original

?upscale=true

Physics of Fluids ARTICLE scitation.org/journal/phf

# Super-resolution and denoising of fluid flow using physics-informed convolutional neural networks without high-resolution labels

Cite as: Phys. Fluids **33**, 073603 (2021); doi: 10.1063/5.0054312
Submitted: 16 April 2021 · Accepted: 1 June 2021 ·
Published Online: 7 July 2021

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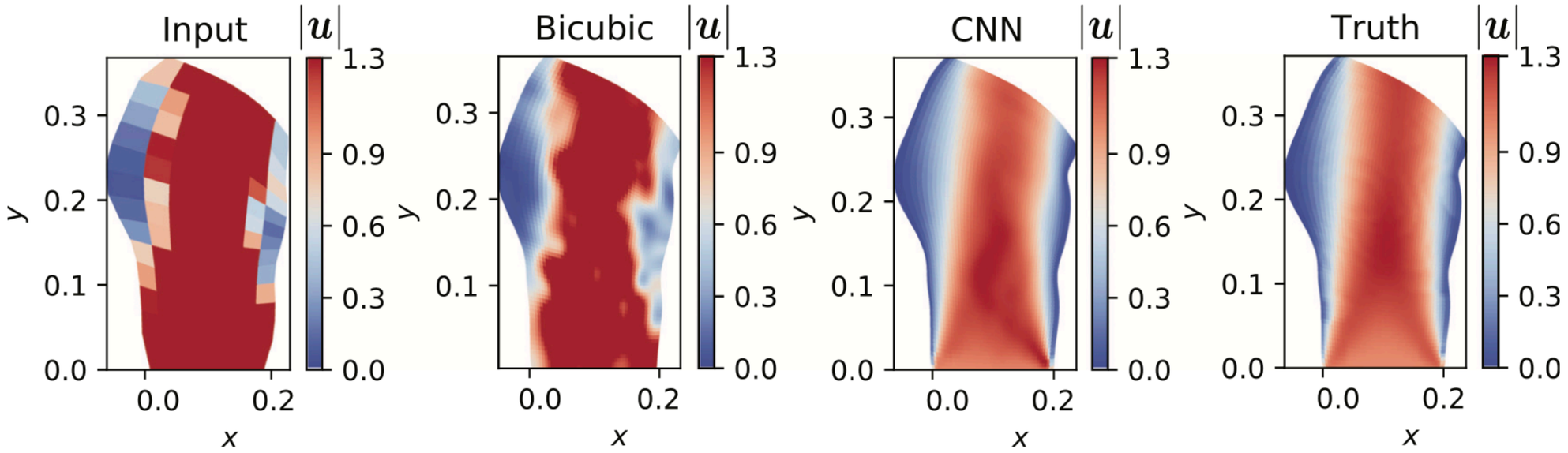
**AFFILIATIONS**

Department of Aerospace and Mechanical Engineering, University of Notre Dame, Notre Dame, Indiana 46556, USA


Input
Bicubic
CNN
Truth
$|u|$
1.3
0.9
0.6
0.3
0.0
0.0
0.1
0.2
0.3
$y$
$x$