### Image Processing and Neural Network Computation

The input is an RGB image of size  $6\times 6\times 3$  (height × width × channels).

# \*Input Image Channels

R Channel:

 $\begin{bmatrix} 112 & 125 & 25 & 80 & 220 & 110 \\ 150 & 95 & 15 & 100 & 115 & 152 \\ 200 & 100 & 48 & 90 & 70 & 175 \\ 187 & 56 & 43 & 86 & 180 & 200 \\ 190 & 87 & 70 & 37 & 24 & 35 \\ 80 & 75 & 65 & 45 & 32 & 200 \\ \end{bmatrix}$ 

G Channel:

 $\begin{bmatrix} 150 & 125 & 38 & 80 & 20 & 10 \\ 130 & 95 & 25 & 100 & 115 & 152 \\ 80 & 100 & 148 & 90 & 70 & 175 \\ 170 & 160 & 43 & 160 & 170 & 180 \\ 100 & 150 & 70 & 37 & 124 & 135 \\ 85 & 75 & 65 & 45 & 232 & 120 \\ \end{bmatrix}$ 

B Channel:

 $\begin{bmatrix} 200 & 125 & 25 & 80 & 220 & 150 \\ 50 & 95 & 15 & 150 & 115 & 152 \\ 90 & 110 & 48 & 190 & 70 & 175 \\ 180 & 135 & 43 & 106 & 180 & 110 \\ 55 & 98 & 70 & 37 & 24 & 35 \\ 78 & 150 & 65 & 45 & 32 & 80 \end{bmatrix}$ 

## Layer 1: Convolution

• Filter size:  $4 \times 4$ 

Stride: 2Padding: 1

### Output Size Calculation

$$O_h = \lfloor rac{I_h + 2P - F_h}{S} 
floor + 1 = \lfloor rac{6 + 2 \cdot 1 - 4}{2} 
floor + 1 = 3$$

$$O_w = \lfloor rac{I_w + 2P - F_w}{S} 
floor + 1 = \lfloor rac{6 + 2 \cdot 1 - 4}{2} 
floor + 1 = 3$$

#### Convolution Calculation

### Channel R:

#### Padded Input:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 112 & 125 & 25 & 80 & 220 & 110 & 0 \\ 0 & 150 & 95 & 15 & 100 & 115 & 152 & 0 \\ 0 & 200 & 100 & 48 & 90 & 70 & 175 & 0 \\ 0 & 187 & 56 & 43 & 86 & 180 & 200 & 0 \\ 0 & 190 & 87 & 70 & 37 & 24 & 35 & 0 \\ 0 & 80 & 75 & 65 & 45 & 32 & 20 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \end{bmatrix}$$

#### Convolution Kernel:

$$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & -1 \end{bmatrix}$$

#### Step-by-step Computation:

$$(0 \cdot 1) + (0 \cdot 1) + (0 \cdot 1) + (0 \cdot 0) + (0 \cdot 0) + (112 \cdot 1) + (125 \cdot 1) + (25 \cdot 1) + (25 \cdot 1) + (0 \cdot -1) + (15 \cdot 0) + (95 \cdot 1) + (15 \cdot 0) + (0 \cdot -1) + (200 \cdot 0) + (100 \cdot 1) + (48 \cdot -1) = 409$$

$$(0 \cdot 1) + (0 \cdot 1) + (0 \cdot 1) + (0 \cdot 0) + (125 \cdot 0) + (25 \cdot 1) + (80 \cdot 1) + (220 \cdot 1) + (95 \cdot -1) + (15 \cdot 0) + (100 \cdot 1) + (115 \cdot 0) + (100 \cdot -1) + (48 \cdot 0) + (90 \cdot 1) + (70 \cdot -1) = 250$$

$$(0 \cdot 1) + (0 \cdot 1) + (0 \cdot 1) + (0 \cdot 0) + (80 \cdot 0) + (220 \cdot 1) + (110 \cdot 1) + (0 \cdot 1) + (100 \cdot -1) + (115 \cdot 0) + (152 \cdot 1) + (0 \cdot 0) + (90 \cdot -1) + (70 \cdot 0) + (175 \cdot 1) + (0 \cdot -1) = 467$$

$$(0 \cdot 1) + (150 \cdot 1) + (95 \cdot 1) + (15 \cdot 0) + (0 \cdot 0) + (200 \cdot 1) + (100 \cdot 1) + (48 \cdot 1) + (0 \cdot -1) + (187 \cdot 0) + (56 \cdot 1) + (43 \cdot 0) + (0 \cdot -1) + (190 \cdot 0) + (87 \cdot 1) + (70 \cdot -1) = 666$$

$$(95 \cdot 1) + (15 \cdot 1) + (100 \cdot 1) + (115 \cdot 0) + (100 \cdot 0) + (48 \cdot 1) + (90 \cdot 1) + (70 \cdot 1) + (56 \cdot -1) + (43 \cdot 0) + (86 \cdot 1) + (180 \cdot 0) + (87 \cdot -1) + (70 \cdot 0) + (37 \cdot 1) + (24 \cdot -1) = 374$$

$$(100 \cdot 1) + (115 \cdot 1) + (152 \cdot 1) + (0 \cdot 0) + (90 \cdot 0) + (70 \cdot 1) + (175 \cdot 1) + (0 \cdot 1) + (86 \cdot -1) + (180 \cdot 0) + (200 \cdot 1) + (0 \cdot 0) + (37 \cdot -1) + (24 \cdot 0) + (35 \cdot 1) + (0 \cdot -1) = 724$$

$$(0 \cdot 1) + (187 \cdot 1) + (56 \cdot 1) + (43 \cdot 0) + (0 \cdot 0) + (190 \cdot 1) + (87 \cdot 1) + (70 \cdot 1) + (0 \cdot -1) + (80 \cdot 0) + (75 \cdot 1) + (65 \cdot 0) + (0 \cdot -1) + (0 \cdot 0) + (0 \cdot 1) + (0 \cdot -1) = 665$$

$$(56 \cdot 1) + (43 \cdot 1) + (86 \cdot 1) + (180 \cdot 0) + (87 \cdot 0) + (70 \cdot 1) + (37 \cdot 1) + (24 \cdot 1) + (75 \cdot -1) + (65 \cdot 0) + (45 \cdot 1) + (32 \cdot 0) + (0 \cdot -1) + (0 \cdot 0) + (0 \cdot 1) + (0 \cdot -1) = 286$$

$$(86 \cdot 1) + (180 \cdot 1) + (200 \cdot 1) + (0 \cdot 0) + (37 \cdot 0) + (24 \cdot 1) + (35 \cdot 1) + (0 \cdot 1) + (45 \cdot -1) + (32 \cdot 0) + (20 \cdot 1) + (0 \cdot 0) + (0 \cdot -1) + (0 \cdot 0) + (0 \cdot 1) + (0 \cdot -1) = 500$$

## Output After Convolution and ReLU:

$$\begin{bmatrix} 409 & 250 & 467 \\ 666 & 374 & 724 \\ 665 & 286 & 500 \end{bmatrix}$$

### Channel G:

#### Padded Input:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 150 & 125 & 38 & 80 & 20 & 10 & 0 \\ 0 & 130 & 95 & 25 & 100 & 115 & 152 & 0 \\ 0 & 80 & 100 & 148 & 90 & 70 & 175 & 0 \\ 0 & 170 & 160 & 43 & 160 & 170 & 180 & 0 \\ 0 & 100 & 150 & 70 & 37 & 124 & 135 & 0 \\ 0 & 85 & 75 & 65 & 45 & 232 & 120 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

#### Convolution Kernel:

$$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & -1 \end{bmatrix}$$

#### Output After Convolution and ReLU:

#### Padded Input:

[0	0	0	0	0	0	0	0]
0	200	125	25	80	220	150	0
0	50	95	15	150	115	152	0
0	90	110	48	190	70	175	0
0	180	135	43	106	180	110	0
0	55	98	70	37	24	35	0
0	78	150	65	45	32	80	0
0	0	0	0	0	0	0	0]

#### Convolution Kernel:

$$\begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & -1 \end{bmatrix}$$

# --> Output After Convolution and ReLU:

510	390	717
418	578	752
596	399	440

# Layer 2: Max Pooling

- Pool size:  $2 \times 2$
- Stride: 1

### Output Size Calculation

$$O_h = \lfloor rac{I_h - F_h}{S} 
floor + 1 = \lfloor rac{3-2}{1} 
floor + 1 = 2$$

$$O_w = \lfloor rac{I_w - F_w}{S} 
floor + 1 = \lfloor rac{3-2}{1} 
floor + 1 = 2$$

# Max Pooling Calculation

Channel R:

- [666 724]
- $\begin{bmatrix} 665 & 500 \end{bmatrix}$

Channel G:

- $\begin{bmatrix} 578 & 632 \\ 640 & 676 \end{bmatrix}$

Channel B:

- $\begin{bmatrix} 578 & 752 \\ 596 & 578 \end{bmatrix}$

# **Layer 3: Fully Connected**

• Input: Flattened output from Max Pooling ( $2 \times 2 \times 3 = 12$  values)

• Output: 4 neurons

#### Weight Matrix:

$$W = \begin{bmatrix} 0.1 & 0.2 & -0.1 & -0.2 & 0.3 & 0.1 & 0.0 & 0.2 & 0.3 & 0.1 & -0.1 & 0.2 \\ -0.1 & 0.1 & 0.1 & 0.3 & -0.2 & 0.2 & 0.1 & 0.3 & 0.1 & 0.0 & 0.2 & 0.1 \\ 0.2 & -0.1 & 0.3 & 0.1 & 0.1 & 0.0 & 0.2 & -0.2 & -0.1 & 0.3 & 0.1 & 0.2 \\ 0.0 & 0.3 & 0.1 & -0.1 & 0.2 & 0.1 & -0.1 & 0.1 & 0.2 & 0.0 & 0.3 & -0.2 \end{bmatrix}$$

Bias Vector:

$$b = [0.5 \quad -0.3 \quad 0.2 \quad 0.1]$$

Flattened Input:

$$x = [666 \quad 724 \quad 665 \quad 500 \quad 578 \quad 632 \quad 640 \quad 676 \quad 578 \quad 752 \quad 596 \quad 578]$$

Output Calculation:

$$y = W \cdot x + b$$

Thought for 1 secondYou're right, let me recalculate the final output correctly:

Output Calculation:

$$y = W \cdot x + b$$

#### --> Detailed Calculation:

```
y_1 = (0.1 \times 666) + (0.2 \times 724) + (-0.1 \times 665) + (-0.2 \times 500) + (0.3 \times 578) + (0.1 \times 632) + (0.0 \times 640) + (0.2 \times 676) + (0.3 \times 578) + (0.1 \times 752) + (-0.1 \times 596) + (0.2 \times 578) + 0.5
= 66.6 + 144.8 - 66.5 - 100 + 173.4 + 63.2 + 0 + 135.2 + 173.4 + 75.2 - 59.6 + 115.6 + 0.5
= 721.8
y_2 = (-0.1 \times 666) + (0.1 \times 724) + (0.1 \times 665) + (0.3 \times 500) + (-0.2 \times 578) + (0.2 \times 632) + (0.1 \times 640) + (0.3 \times 676) + (0.1 \times 578) + (0.0 \times 752) + (0.2 \times 596) + (0.1 \times 578) - 0.3
= -66.6 + 72.4 + 66.5 + 150 - 115.6 + 126.4 + 64 + 202.8 + 57.8 + 0 + 119.2 + 57.8 - 0.3
= 734.4
y_3 = (0.2 \times 666) + (-0.1 \times 724) + (0.3 \times 665) + (0.1 \times 500) + (0.1 \times 578) + (0.0 \times 632) + (0.2 \times 640) + (-0.2 \times 676) + (-0.1 \times 578) + (0.3 \times 752) + (0.1 \times 596) + (0.2 \times 578) + 0.2
= 133.2 - 72.4 + 199.5 + 50 + 57.8 + 0 + 128 - 135.2 - 57.8 + 225.6 + 59.6 + 115.6 + 0.2
= 704.1
y_4 = (0.0 \times 666) + (0.3 \times 724) + (0.1 \times 665) + (-0.1 \times 500) + (0.2 \times 578) + (0.1 \times 632) + (-0.1 \times 640) + (0.1 \times 676) + (0.2 \times 578) + (0.0 \times 752) + (0.3 \times 596) + (-0.2 \times 578) + 0.1
= 0 + 217.2 + 66.5 - 50 + 115.6 + 63.2 - 64 + 67.6 + 115.6 + 0 + 178.8 - 115.6 + 0.1
= 595.0
```

### ▼ Final Computed Output

 $y = \begin{bmatrix} 721.8 & 734.4 & 704.1 & 595.0 \end{bmatrix}$