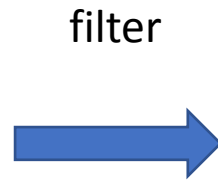


Filters

Feature Extraction using Filter

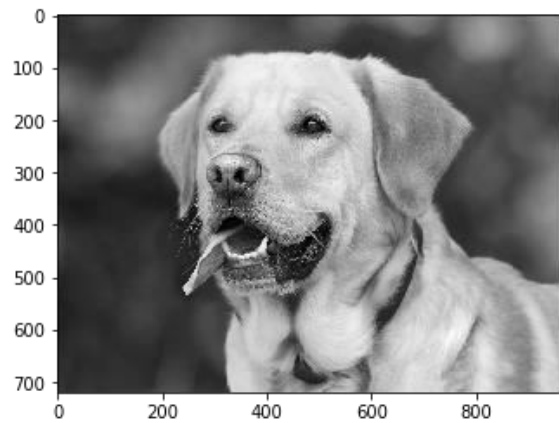


Original Gray Scale Image



Vertical lines detected in
Image

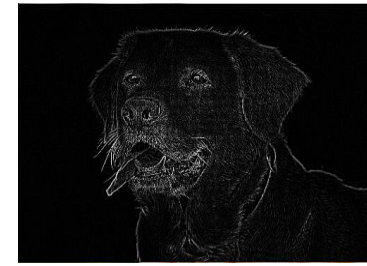
Different kinds of Features Extracted



filters



Blur



Outline



Horizontal lines



Contrast

What are Filters?



Original Image



-1	0	1
-1	0	1
-1	0	1

Filter – Right Sobel



Extracted Feature – Vertical lines

Some Common Filters

-1	0	1
-1	0	1
-1	0	1

Right Sobel Filter

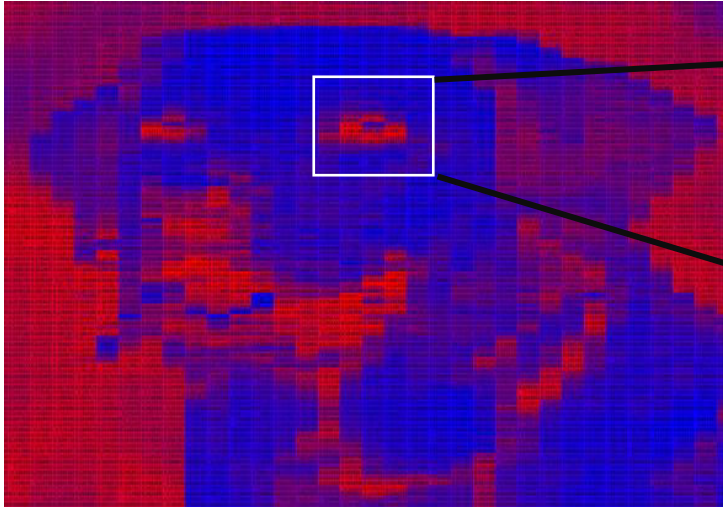
1	1	1
0	0	0
-1	-1	-1

Top Sobel Filter

0.0625	0.125	0.0625
0.125	0.25	0.125
0.0625	0.125	0.0625

Blur Filter

Filter Multiplication - Intuition



0.8339626471	0.7752729686	0.8496176471	0.8463136471	0.8645830784
0.811281898	0.6884468941	0.7211700706	0.8495867843	0.8279193529
0.7525818549	0.653362251	0.7388461569	0.8090005804	0.8228711765
0.6453872549	0.5273884235	0.4800212078	0.6906715804	0.8567361765
0.6236279216	0.3365561961	0.1517752941	0.6811608627	0.8337013725
0.5486478431	0.1678780275	0.741726898	0.3716159882	0.8031474314
0.5487873529	0.0487339882	0.3671621216	0.0938979098	0.7350317647
0.3125158667	0.1347844627	0.1789385098	0.0424032078	0.7038336471
0.4360508941	0.3002052	0.1831386392	0.3817118196	0.5960921373
0.5992862745	0.5671545098	0.5137871176	0.6495110588	0.769567549
0.6764950196	0.6749075686	0.8024092941	0.8398778745	0.7011775098
0.7198897725	0.8392635961	0.7926207843	0.8406682353	0.7113323137
0.7363734392	0.8453247451	0.8283599961	0.773751949	0.6828554314
0.7478241961	0.7984980549	0.8325079216	0.7087661412	0.6787604706

$$= (36 \times -1) + (31 \times 0) + (28 \times 1) + (38 \times -1) + (34 \times 0) + (29 \times 1) + (39 \times -1) + (35 \times 0) + (32 \times 1)$$

-1	0	1
-1	0	1
-1	0	1

Filter

36	31	28	24	23	27	23	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

Image

-24					

Feature Map

$4 \times 0) + (23 \times 1) + (29 \times -1) + (26 \times 0)$
 $+ (32 \times -1) + (28 \times 0) + (27 \times 1)$

The diagram illustrates the calculation of the dot product for the first row of the result matrix. It shows a 3x3 matrix of weights (red and blue), a 3x3 matrix of input values (red and blue), and a 3x3 matrix of output values (red and blue). Green lines connect the weights to the input values and the output values.

28	24	23	27	33	39
29	26	25	30	37	41
32	28	27	33	40	43

-1	0	1
-1	0	1
-1	0	1

-24	-22

$4 \times 0) + (23 \times 1) + (29 \times -1) + (26 \times 0)$
 $+ (32 \times -1) + (28 \times 0) + (27 \times 1)$

The diagram illustrates the calculation of the dot product for the first row of the result matrix. It shows a 3x3 matrix of weights (red and blue), a 3x3 matrix of input values (red and blue), and a 3x3 matrix of output values (red and blue). Green lines connect the weights to the input values and the output values.

28	24	23	27	33	39
29	26	25	30	37	41
32	28	27	33	40	43

-1	0	1
-1	0	1
-1	0	1

-24	-22

$4 \times 0) + (23 \times 1) + (29 \times -1) + (26 \times 0)$
 $+ (32 \times -1) + (28 \times 0) + (27 \times 1)$

The diagram illustrates the calculation of the dot product for the first row of the result matrix. It shows the first row of the first matrix (28, 24, 23, 27, 33, 30) and the first row of the second matrix (-1, 0, 1, -1, 0, 1). The elements are multiplied pairwise, and the results are summed to produce the first element of the result matrix, -24.

28	24	23	27	33	30
29	26	25	30	37	41
32	28	27	33	40	43

-1	0	1	-1	0	1
-1	0	1	-1	0	1
-1	0	1	-1	0	1

-24	-22

$$= (24 \times -1) + (23 \times 0) + (27 \times 1) + (26 \times -1) + (25 \times 0) \\ + (30 \times 1) + (28 \times -1) + (27 \times 0) + (33 \times 1)$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

[illegible]

$$= (27 \times -1) + (33 \times 0) + (39 \times 1) + (30 \times -1) + (37 \times 0) \\ + (41 \times 1) + (33 \times -1) + (40 \times 0) + (43 \times 1)$$

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-1	0	1
-1	0	1
-1	0	1

[illegible]

Row Stride = 1

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

[illegible]

$1) + (29 \times 0) + (26 \times 1) + (35 \times -1) + (32 \times 0)$
 $8 \times 1) + (36 \times -1) + (34 \times 0) + (30 \times 1)$

-1	0	1
-1	0	1
-1	0	1

$1) + (29 \times 0) + (26 \times 1) + (35 \times -1) + (32 \times 0)$
 $8 \times 1) + (36 \times -1) + (34 \times 0) + (30 \times 1)$

-1	0	1
-1	0	1
-1	0	1

$1) + (29 \times 0) + (26 \times 1) + (35 \times -1) + (32 \times 0)$
 $8 \times 1) + (36 \times -1) + (34 \times 0) + (30 \times 1)$

-1	0	1
-1	0	1
-1	0	1

-1	0	1
-1	0	1
-1	0	1

[illegible]

-1	0	1
-1	0	1
-1	0	1

[illegible]

-1	0	1
-1	0	1
-1	0	1

[illegible]

$$= (30 \times -1) + (37 \times 0) + (41 \times 1) + (33 \times -1) + (40 \times 0) \\ + (43 \times 1) + (56 \times -1) + (43 \times 0) + (46 \times 1)$$

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-1	0	1
-1	0	1
-1	0	1

[illegible]

$$\begin{aligned}
 &= (38 \times -1) + (39 \times 0) + (37 \times 1) + (34 \times -1) + (37 \times 0) \\
 &\quad + (36 \times 1) + (31 \times -1) + (35 \times 0) + (35 \times 1)
 \end{aligned}$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5					

$$\begin{aligned}
 &= (39 \times -1) + (37 \times 0) + (40 \times 1) + (37 \times -1) + (36 \times 0) \\
 &\quad + (39 \times 1) + (35 \times -1) + (35 \times 0) + (39 \times 1)
 \end{aligned}$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5	8				

$$\begin{aligned}
 &= (37 \times -1) + (40 \times 0) + (44 \times 1) + (36 \times -1) + (39 \times 0) \\
 &\quad + (43 \times 1) + (35 \times -1) + (39 \times 0) + (44 \times 1)
 \end{aligned}$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5	8	23			

$$\begin{aligned}
 &= (40 \times -1) + (44 \times 0) + (49 \times 1) + (39 \times -1) + (43 \times 0) \\
 &\quad + (48 \times 1) + (39 \times -1) + (44 \times 0) + (49 \times 1)
 \end{aligned}$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5	8	23	28		

$$\begin{aligned}
 &= (44 \times -1) + (49 \times 0) + (55 \times 1) + (43 \times -1) + (48 \times 0) \\
 &\quad + (54 \times 1) + (44 \times -1) + (49 \times 0) + (53 \times 1)
 \end{aligned}$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5	8	23	28	30	

$$\begin{aligned}
 &= (49 \times -1) + (55 \times 0) + (58 \times 1) + (48 \times -1) + (54 \times 0) \\
 &\quad + (56 \times 1) + (49 \times -1) + (53 \times 0) + (55 \times 1)
 \end{aligned}$$

-1	0	1
-1	0	1
-1	0	1

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5	8	23	28	30	23

Shapes with Single Filter

-1	0	1
-1	0	1
-1	0	1

3 X 3

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

13 X 8

-24	-22	-15	12	35	33
-23	-23	-13	14	39	32
-22	-23	-11	18	41	31
-22	-23	-6	22	41	29
-20	-19	0	25	40	26
-18	-15	4	27	37	23
-15	-10	9	28	36	23
-13	-7	13	29	34	23
-8	-3	18	29	33	25
-2	2	20	28	32	25
5	8	23	28	30	23

11 X 6

Calculating shape of Output(Feature Map)

$$OutputHeight = \frac{InputHeight - FilterHeight}{RowStride} + 1$$

$$OutputWidth = \frac{InputWidth - FilterWidth}{ColumnStride} + 1$$

Shapes with 3 Filters and 2-D Image

-1	0	1		
-1	-1	-1	-1	
-1	0	0	-1	0
	1	-1	0	-1
		0	-1	0

36	31	28	24	23	27	33	39
38	34	29	26	25	30	37	41
39	35	32	28	27	33	40	43
42	38	34	30	30	36	43	46
43	40	36	32	34	40	48	50
44	41	37	35	37	43	51	52
45	42	39	37	41	46	53	54
45	42	40	39	42	48	54	55
43	42	39	40	43	49	55	57
41	41	38	39	44	49	55	58
38	39	37	40	44	49	55	58
34	37	36	39	43	48	54	56
31	35	35	39	44	49	53	55

13 X 8

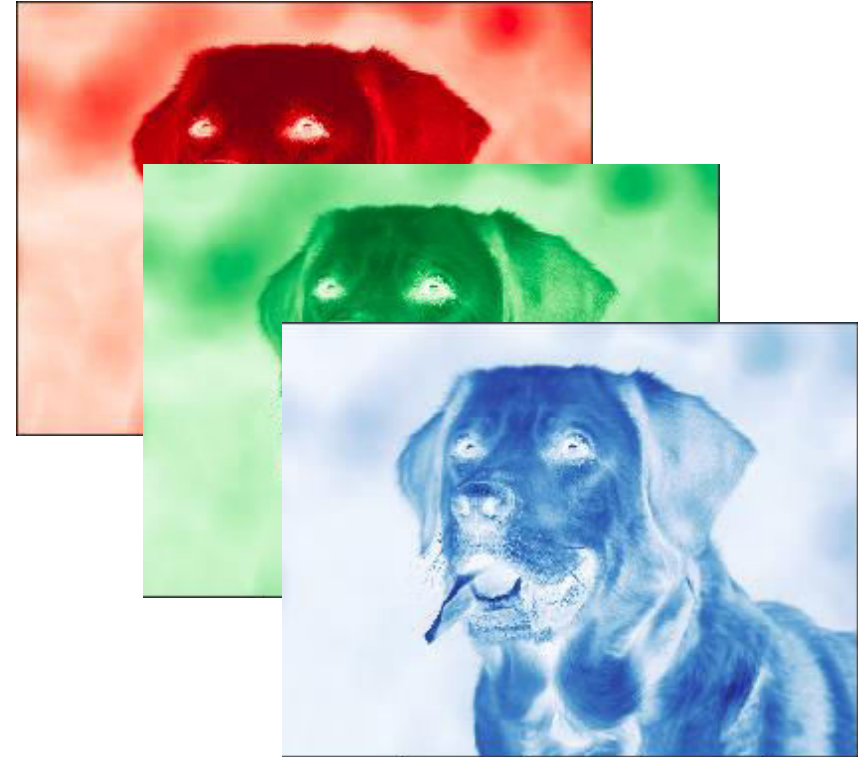
3 X 3

- 3

-24	-22	-15	12	35	33		
-23	11	12	12	14	17	17	
-22	13	-134	-119	-106	-105	-121	-144
-22	14	-142	-127	-114	-116	-132	-156
-20	9	-151	-136	-124	-126	-146	-170
-18	6	-159	-144	-134	-139	-161	-183
-15	4	-164	-151	-144	-153	-174	-196
-13	-2	-168	-156	-153	-163	-186	-205
-8	-7	-168	-159	-159	-171	-192	-211
-2	-10	-165	-159	-160	-175	-196	-215
5	-13	-159	-156	-161	-176	-197	-217
	-13	-152	-153	-160	-176	-197	-215
		-144	-148	-158	-176	-194	-212

11 X 6 X 3

Shapes with 1 Filter and 3-D Image



720 X 960 X 3

R G B

Shapes with 1 Filter and 3-D Image



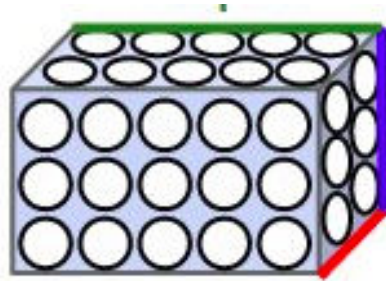
720 X 960 X 3

R G B

-1	0	1
-1	0	1
-1	0	1

3 X 3

Shapes with 1 Filter and 3-D Image

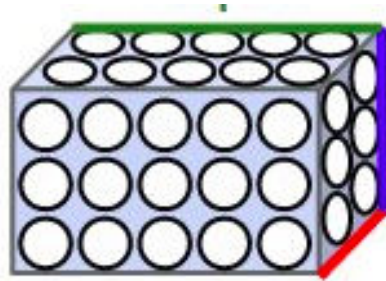


720 X 960 X 3

3 X 3 X 3

Same

Shapes with 1 Filter and 3-D Image

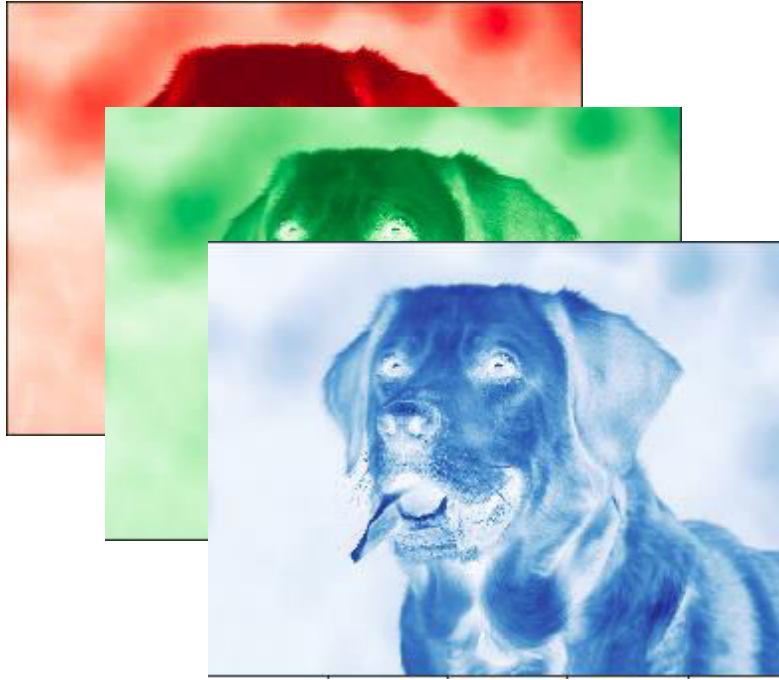


720 X 960 X 5

3 X 3 X 5

Same

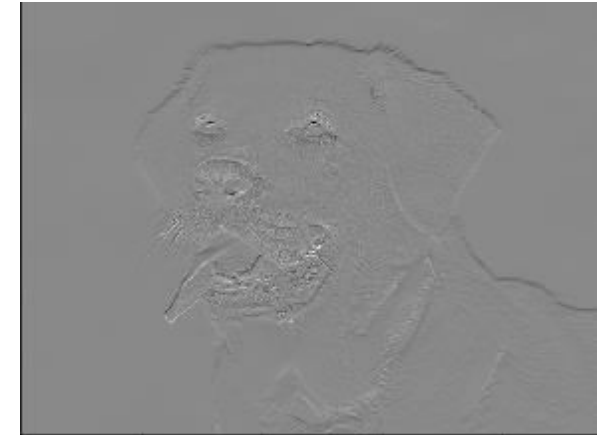
Shapes with 1 Filter and 3-D Image



720 X 960 X 3

-1	0	1		
-1	-1	0	1	
-1	-1	-1	0	1
	-1	-1	0	1
		-1	0	1

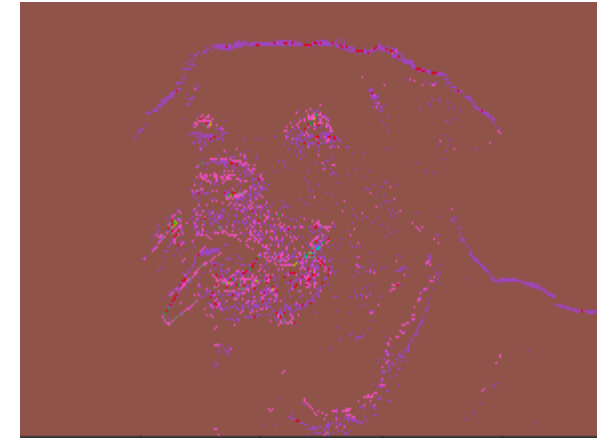
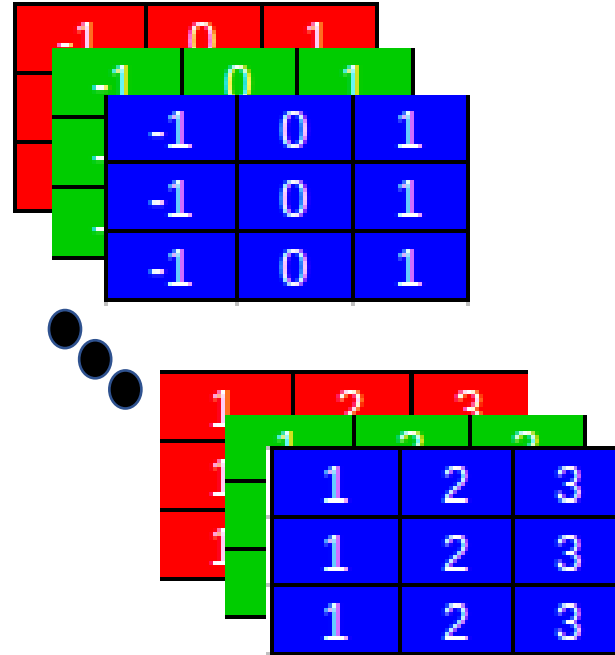
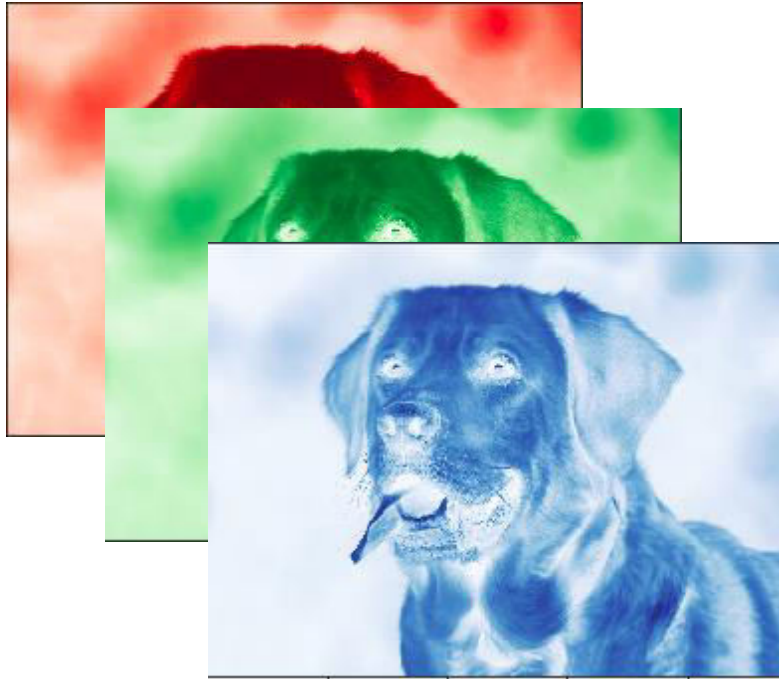
3 X 3 X 3



718 X 958

Same

Shapes with N Filters and 3-D Image



720 X 960 X 3

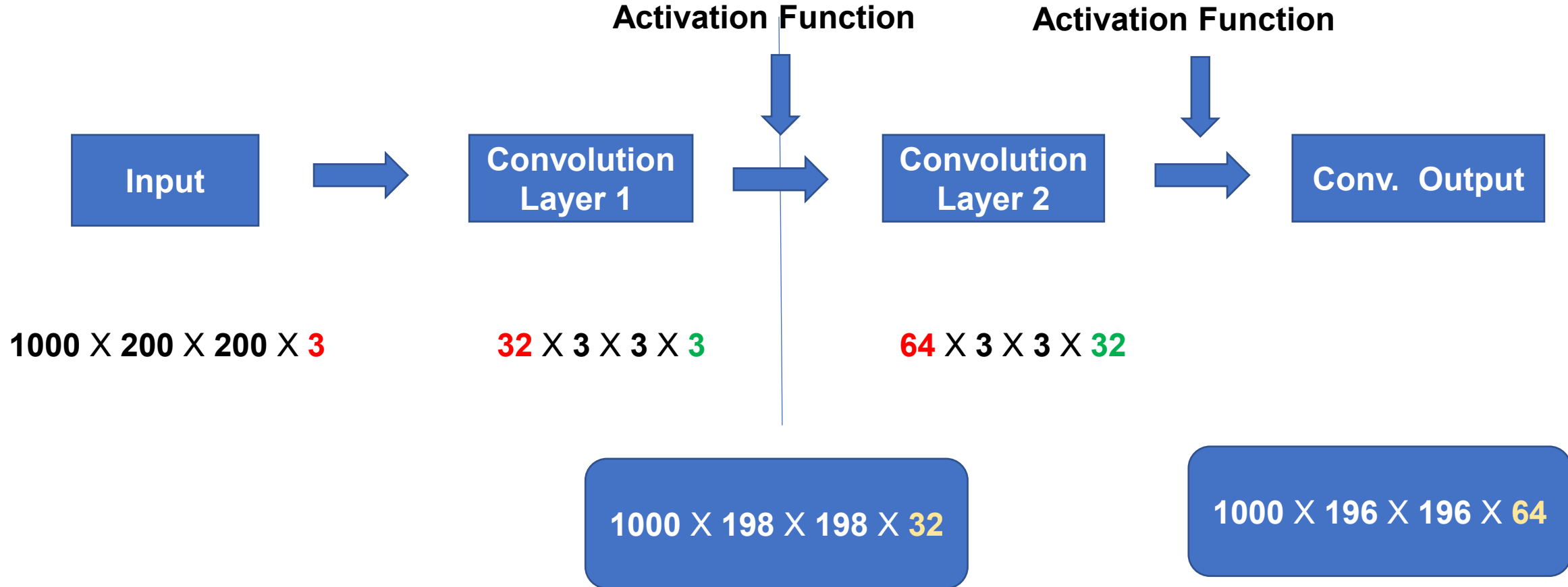
N

3 X 3 X 3

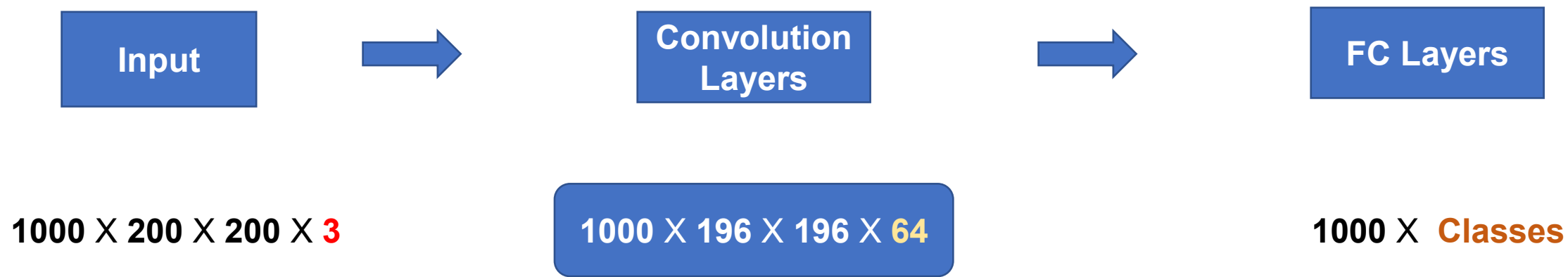
718 X 958 X N

Same

Output of Successive Convolutions

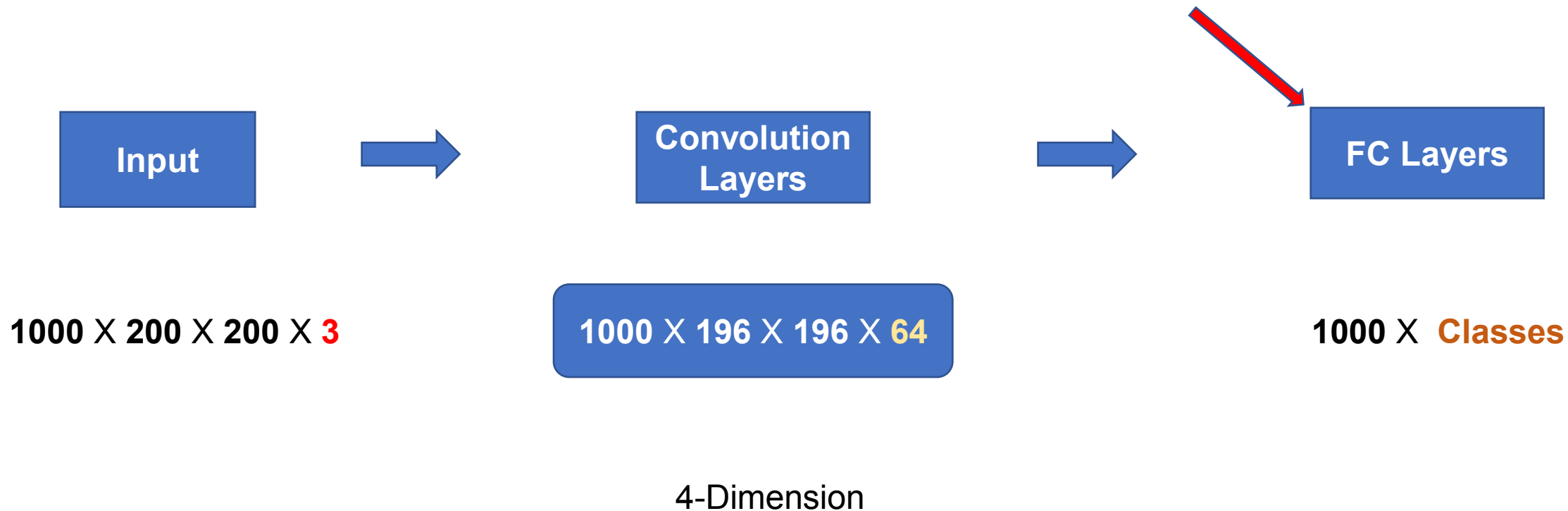


Forward Propagation with Convoluted layers

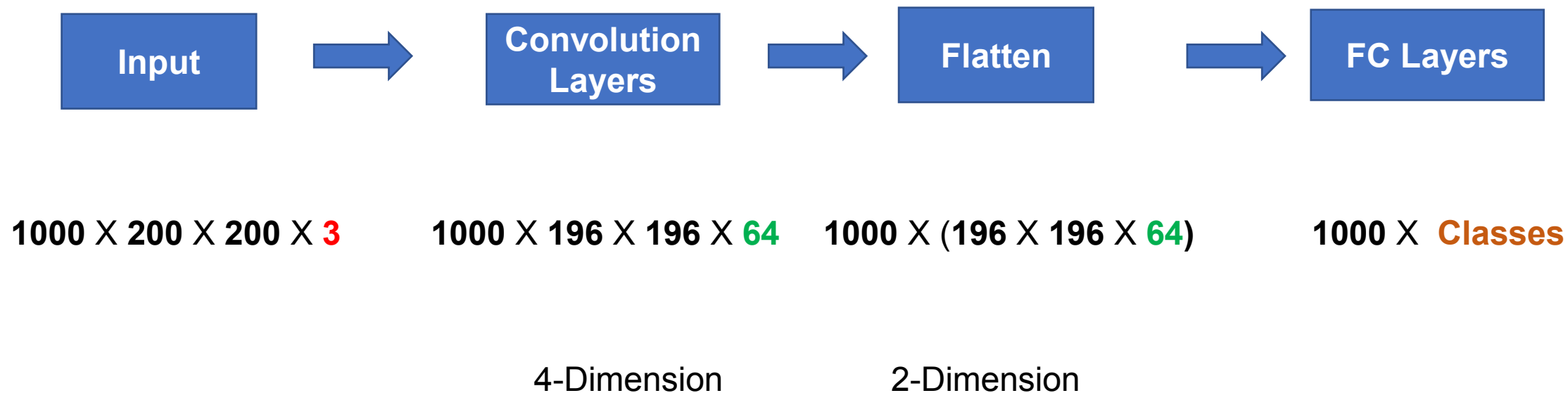


Forward Propagation with Convolved layers

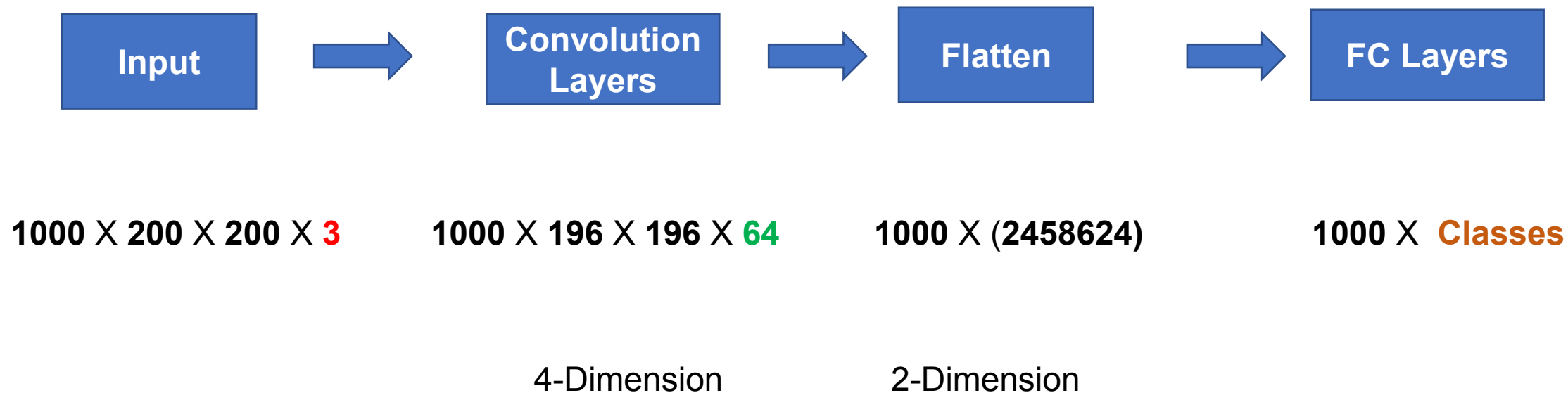
Input to FC can only be 2-Dimensional



Forward Propagation with Convolution layers



Forward Propagation with Convolution layers



Thank You