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Kernel Based Image Processing

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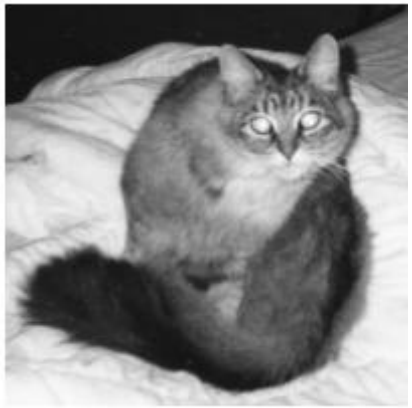
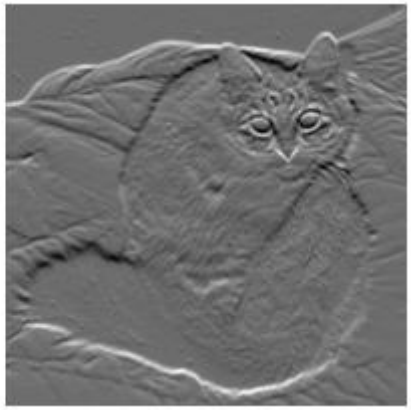
Overview of Presentation

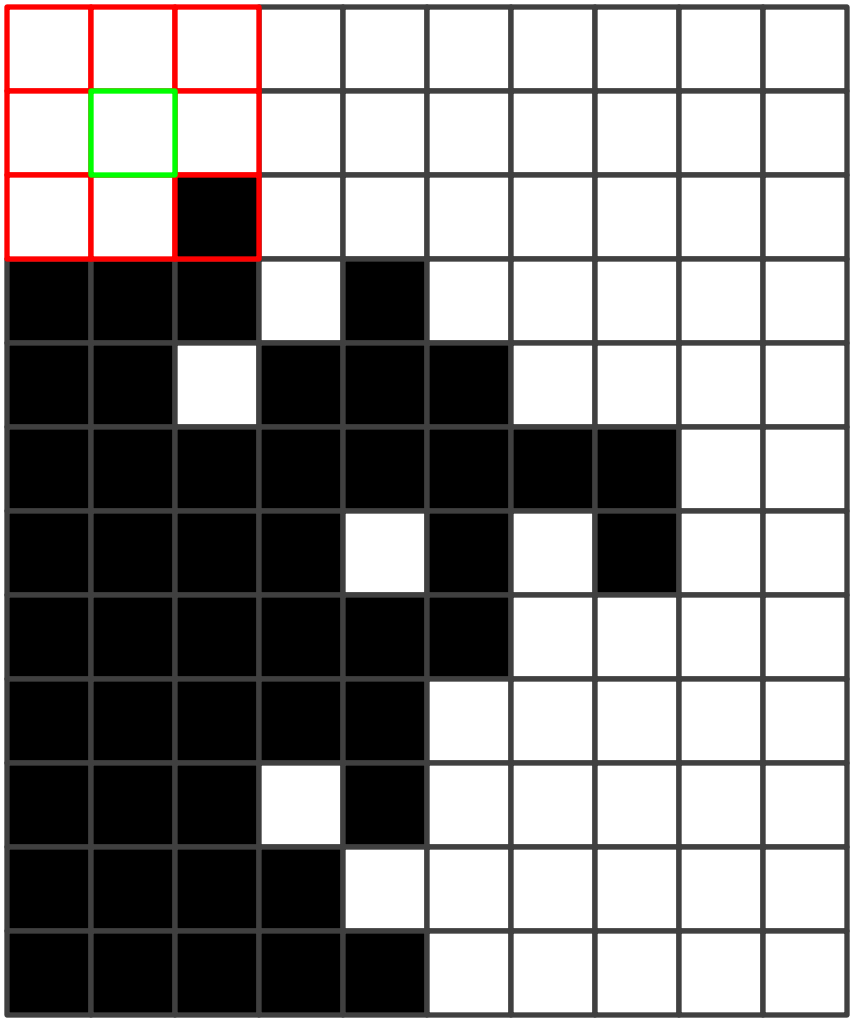
- What is a kernel and how does it work?
- A variety of different kernels
- Dilate and Erode Example
- Mean Filter Example





Wide Variety of Kernels

Original Image



We can evaluate the different properties that a pixel has by comparing it to the other pixels in its surrounding area

Examples include:

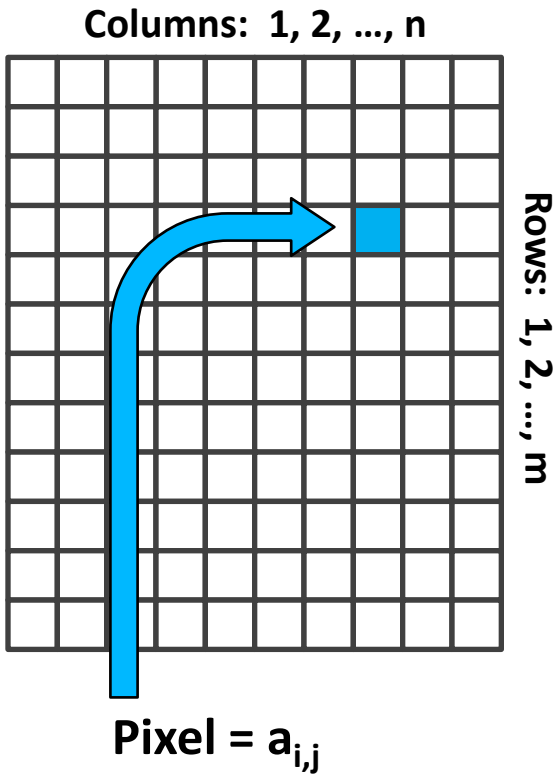
- Smoothing Filters
- Image Enhancement
- Noise Reduction
- Edge Detection

All linear image filtering will involve using a kernel

Many other non-linear processing is also kernel based

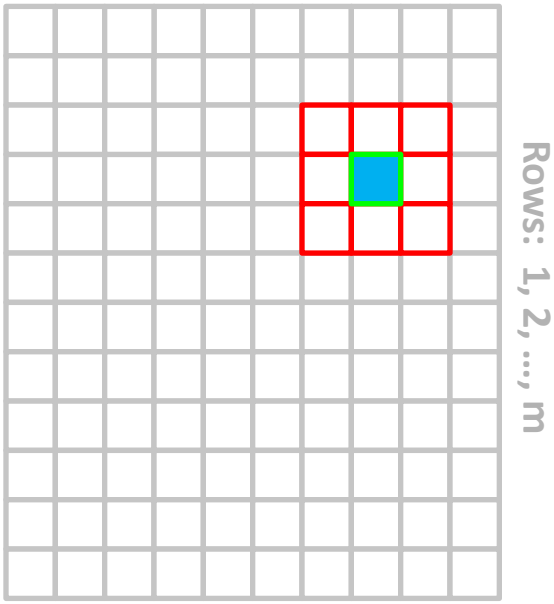
How does the process work?

A pixel can be thought of an element designated by its location in the image



How does the process work?

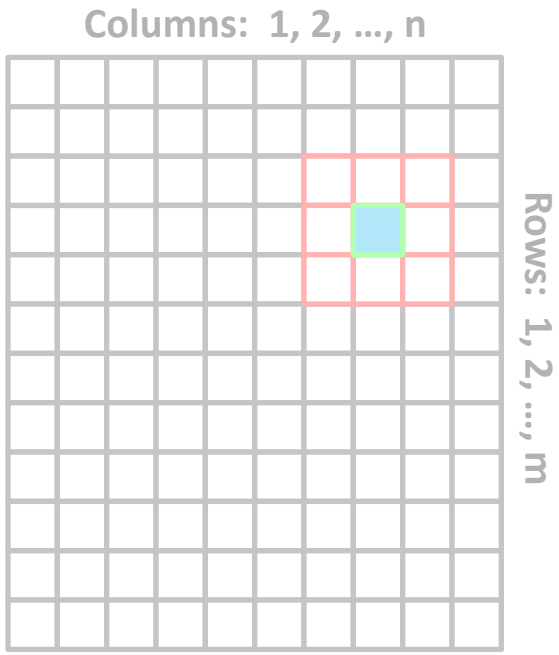
We are then going to perform an operation on that pixel using a kernel to reassign its value in our output image

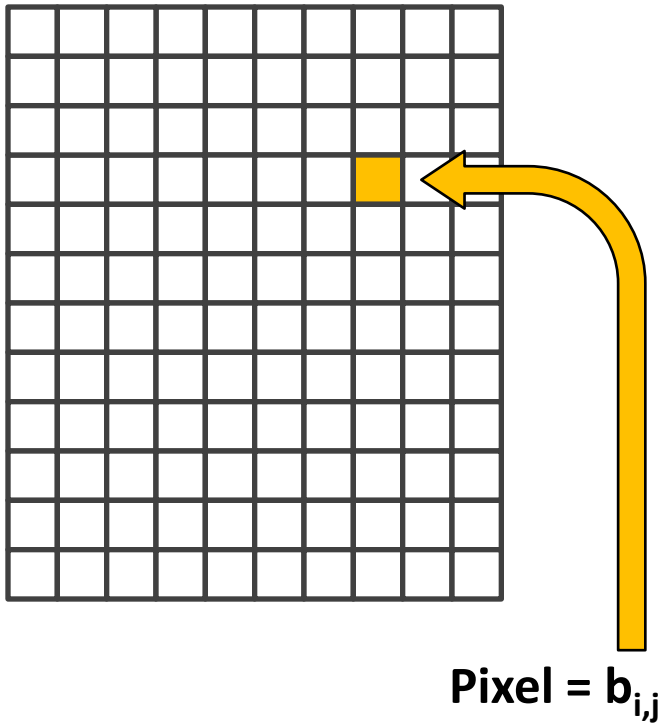


$a_{1,1}$	$a_{2,1}$	$a_{3,1}$
$a_{1,2}$	$a_{2,2}$	$a_{3,2}$
$a_{1,3}$	$a_{2,3}$	$a_{3,3}$

How does the process work?

We now assign the processed value to our new output image at location $b_{i,j}$





Dilate/Erode Kernels

Dilate Filter

$a_{1,1}$	$a_{2,1}$	$a_{3,1}$
$a_{1,2}$	$a_{2,2}$	$a_{3,2}$
$a_{1,3}$	$a_{2,3}$	$a_{3,3}$

$$b_{i,j} = MAX \begin{Bmatrix} a_{1,1}, \dots, a_{n,1} \\ \vdots \\ a_{1,m}, \dots, a_{n,m} \end{Bmatrix}$$

$a_{2,2}$ = MAX($a_{1,1}$, $a_{2,1}$, $a_{3,1}$, $a_{1,2}$, $a_{2,2}$, $a_{3,2}$, $a_{1,3}$, $a_{2,3}$, $a_{3,3}$)

Erode Filter

$a_{1,1}$	$a_{2,1}$	$a_{3,1}$
$a_{1,2}$	$a_{2,2}$	$a_{3,2}$
$a_{1,3}$	$a_{2,3}$	$a_{3,3}$

$$b_{i,j} = MIN \begin{Bmatrix} a_{1,1}, \dots, a_{n,1} \\ \vdots \\ a_{1,m}, \dots, a_{n,m} \end{Bmatrix}$$

$a_{2,2}$ = MIN($a_{1,1}$, $a_{2,1}$, $a_{3,1}$, $a_{1,2}$, $a_{2,2}$, $a_{3,2}$, $a_{1,3}$, $a_{2,3}$, $a_{3,3}$)

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Mean Filtering Kernel

Mean Filter

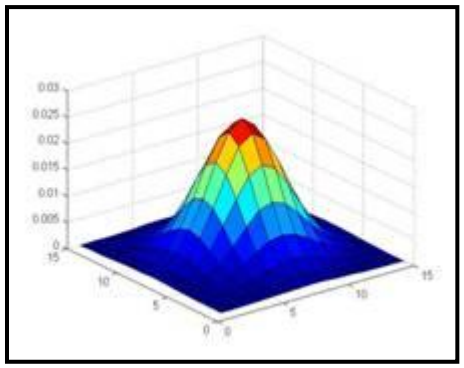
$a_{1,1}$	$a_{2,1}$	$a_{3,1}$
a_{12}	$a_{2,2}$	$a_{3,2}$
$a_{1,3}$	$a_{2,3}$	$a_{3,3}$

$$a_{i,j} = \frac{1}{nm} \sum_{i=1}^{n} \sum_{j=1}^{m} a_{i,j}$$

$$a_{2,2} = \frac{1}{9} \sum_{i=1}^{3} \sum_{j=1}^{3} a_{i,j} \; = \; a_{2,2} = \frac{1}{9} \left(a_{1,1} + a_{1,2} + a_{1,3} + a_{2,1} + a_{2,2} + a_{2,3} + a_{3,1} + a_{3,2} + a_{3,3} \right)$$

Wide Variety of Kernels

Gaussian Filter



$$a_{i,j} = \frac{1}{2\pi\sigma^2} e^{-\frac{i^2+j^2}{2\sigma^2}}$$

Horizontal Derivative Filter

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

Vertical Derivative Filter

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

Horizontal Derivative Filter

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

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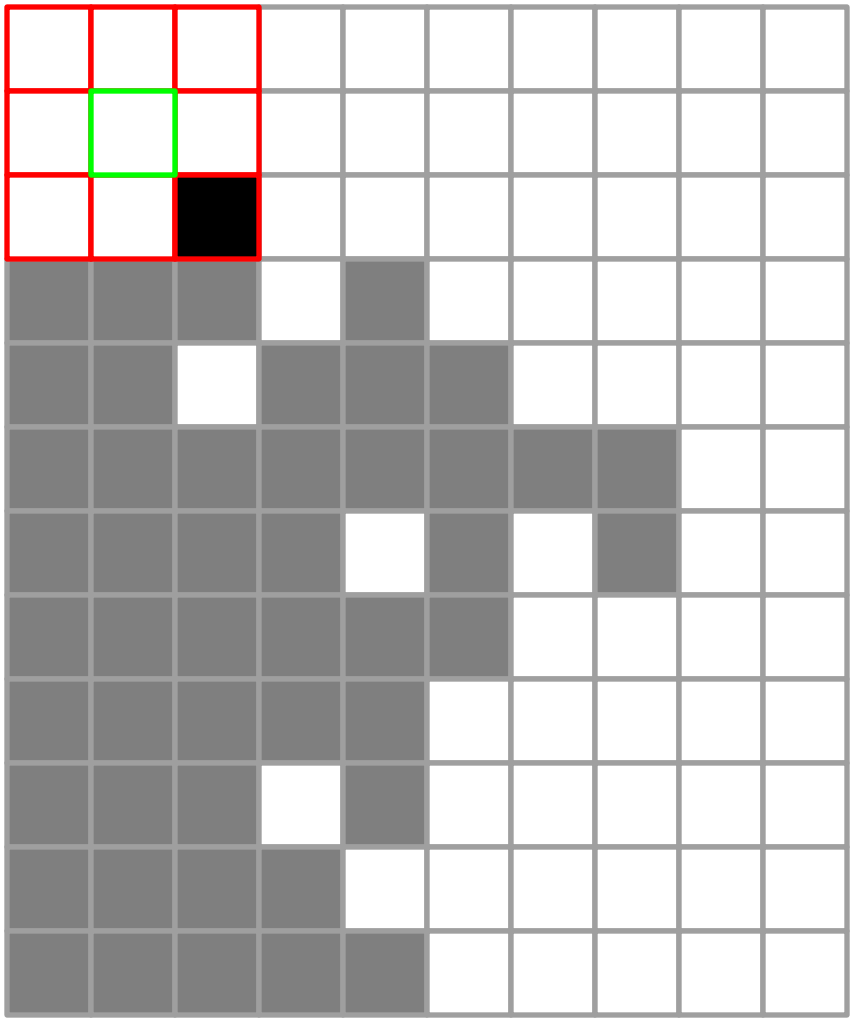
Dilate Function

Original Image



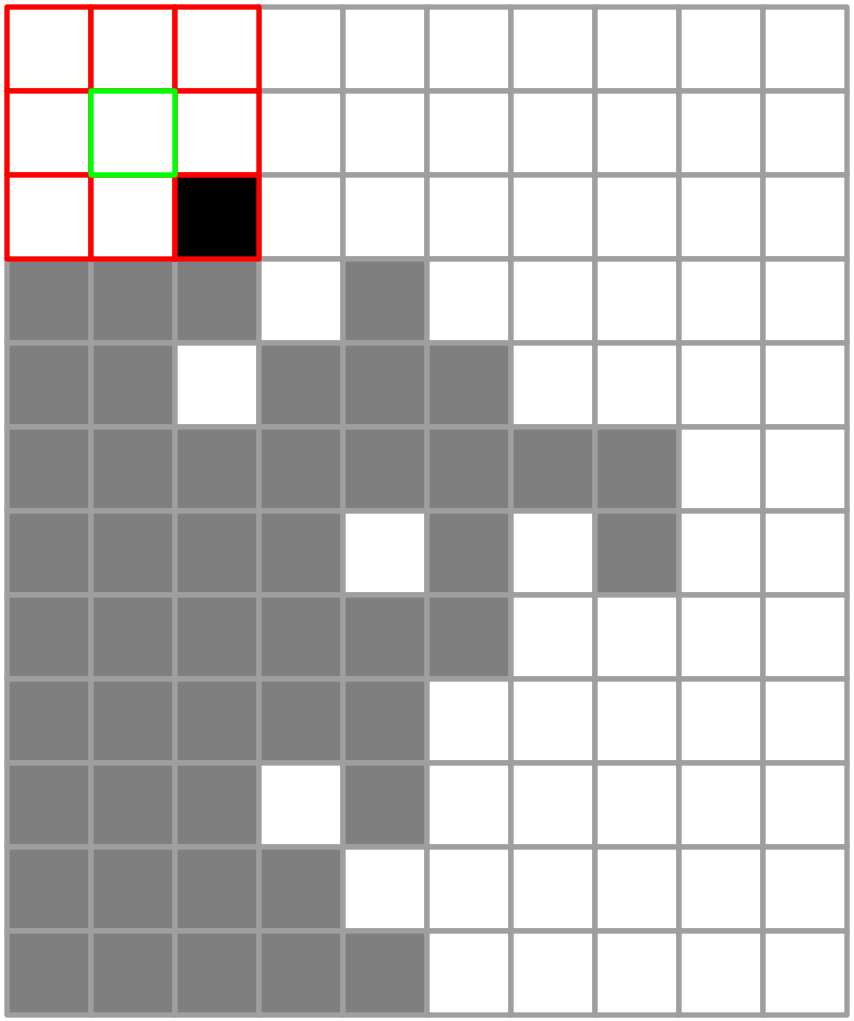
3x3 Kernel

0	0	0
0	0	0
0	0	1

We will evaluate the center pixel and assign a new value based upon the pixels in its “neighborhood”

Dilate Function

Original Image



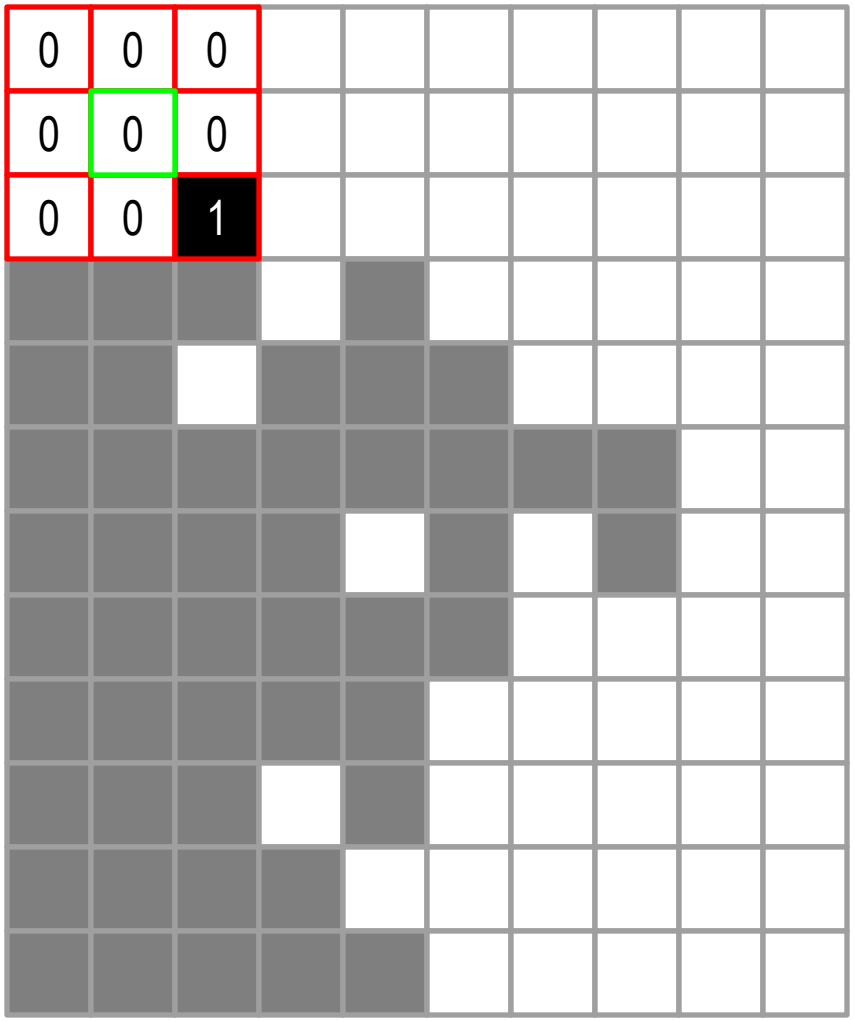
3x3 Kernel

0	0	0
0	0	0
0	0	1

For the DILATE method, we will assign the center pixel value to the MAXIMUM value of any pixel in the neighborhood, in this case 1

Dilate Function

Original Image

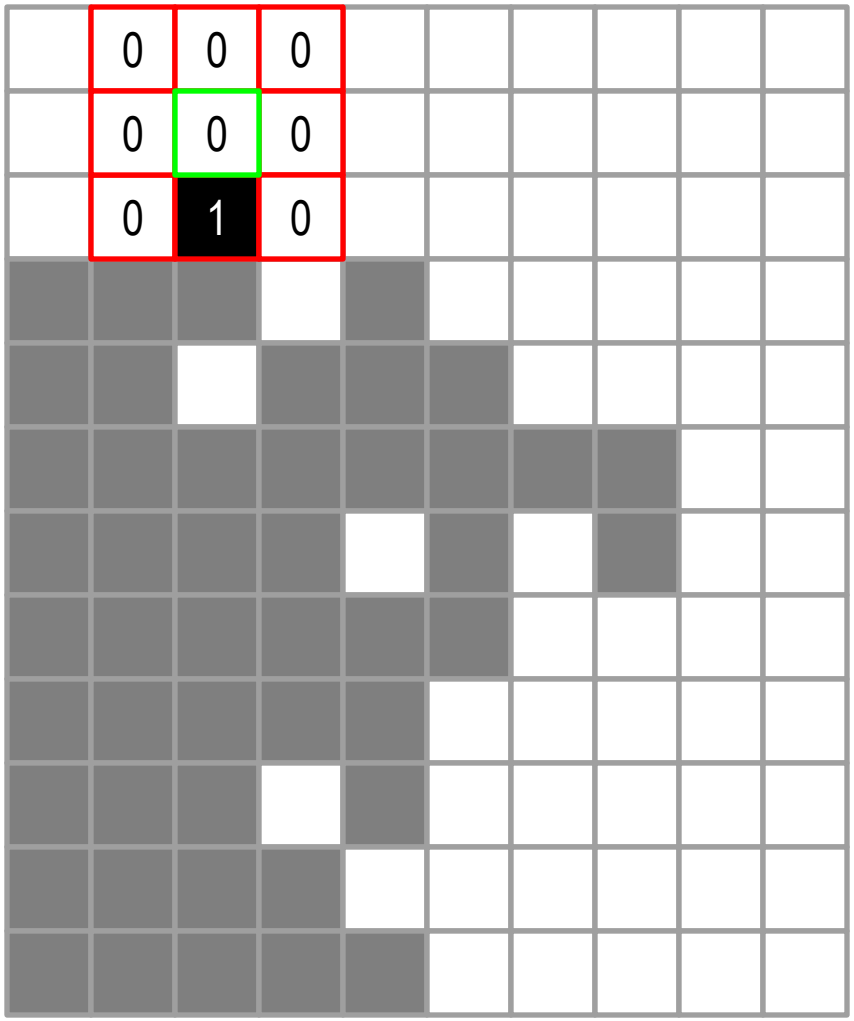


Buffer (new Image)

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

Dilate Function

Original Image



3x3 Kernel

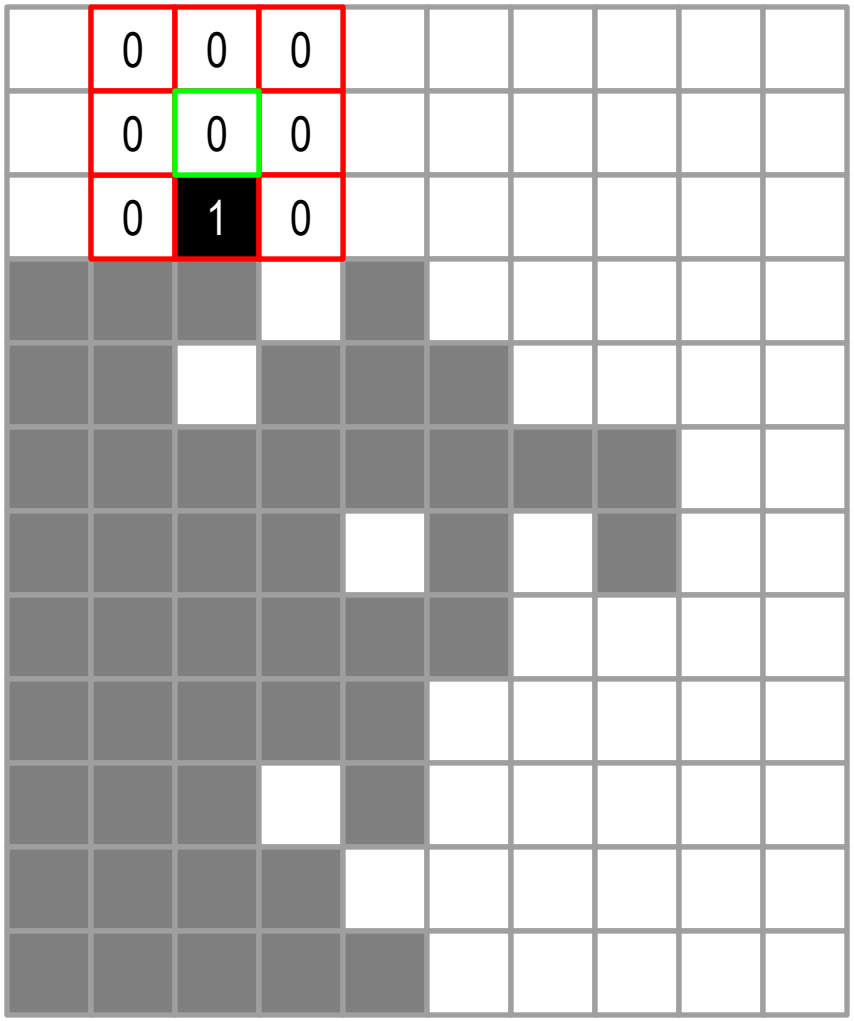
0	0	0
0	0	0
0	1	0

We have now moved to the next pixel and again will evaluate the center pixel assigning a new value based upon the pixel in its “neighborhood”

In this case we are going to change the pixel value to be 1

Dilate Function

Original Image

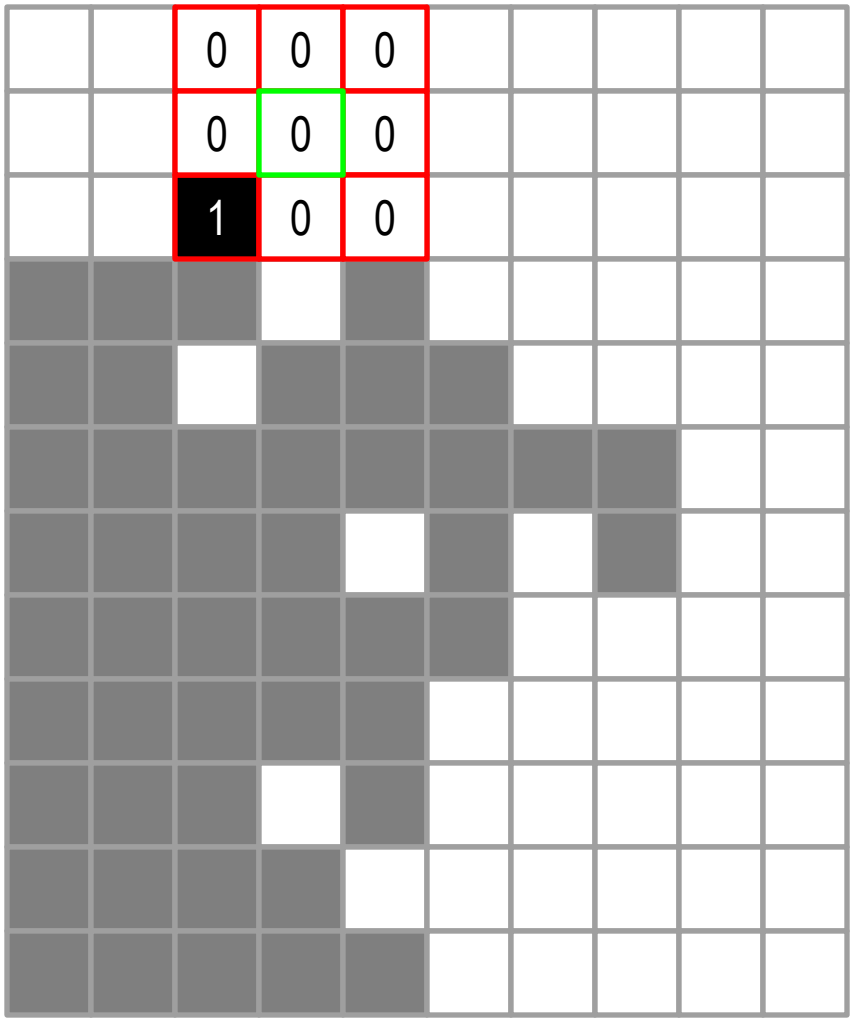


Buffer (new Image)

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

Dilate Function

Original Image

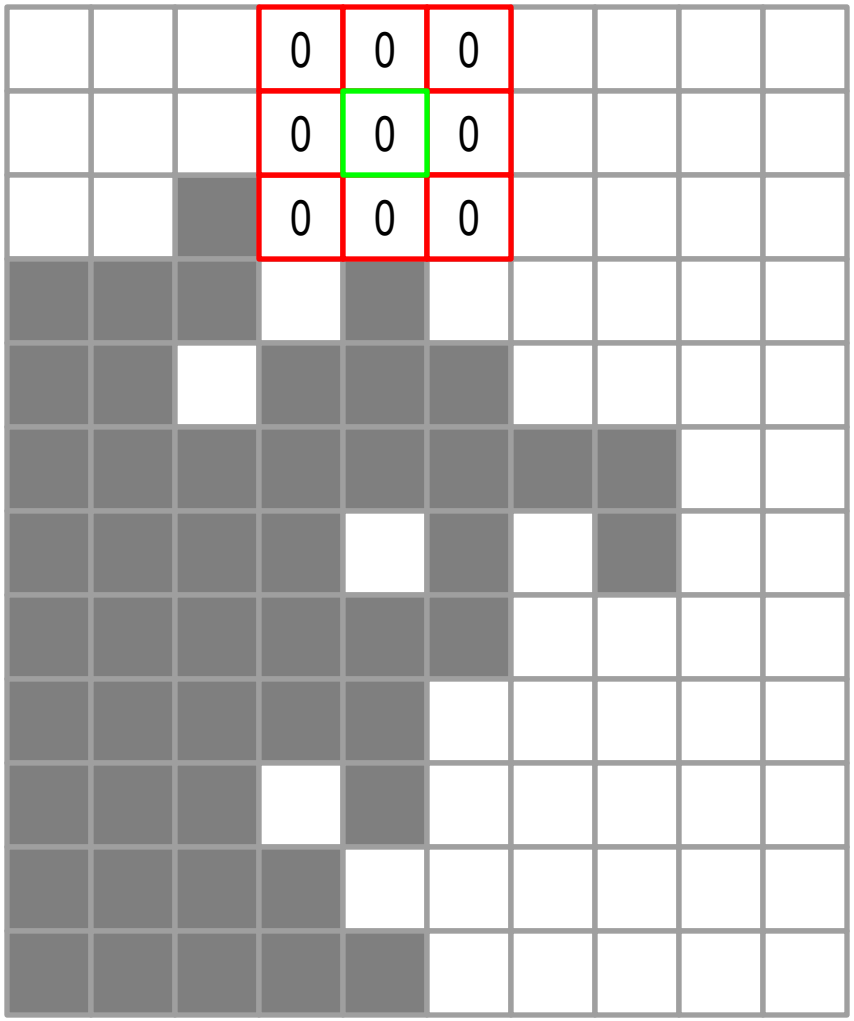


Buffer (new Image)

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

Dilate Function

Original Image



Buffer (new Image)

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

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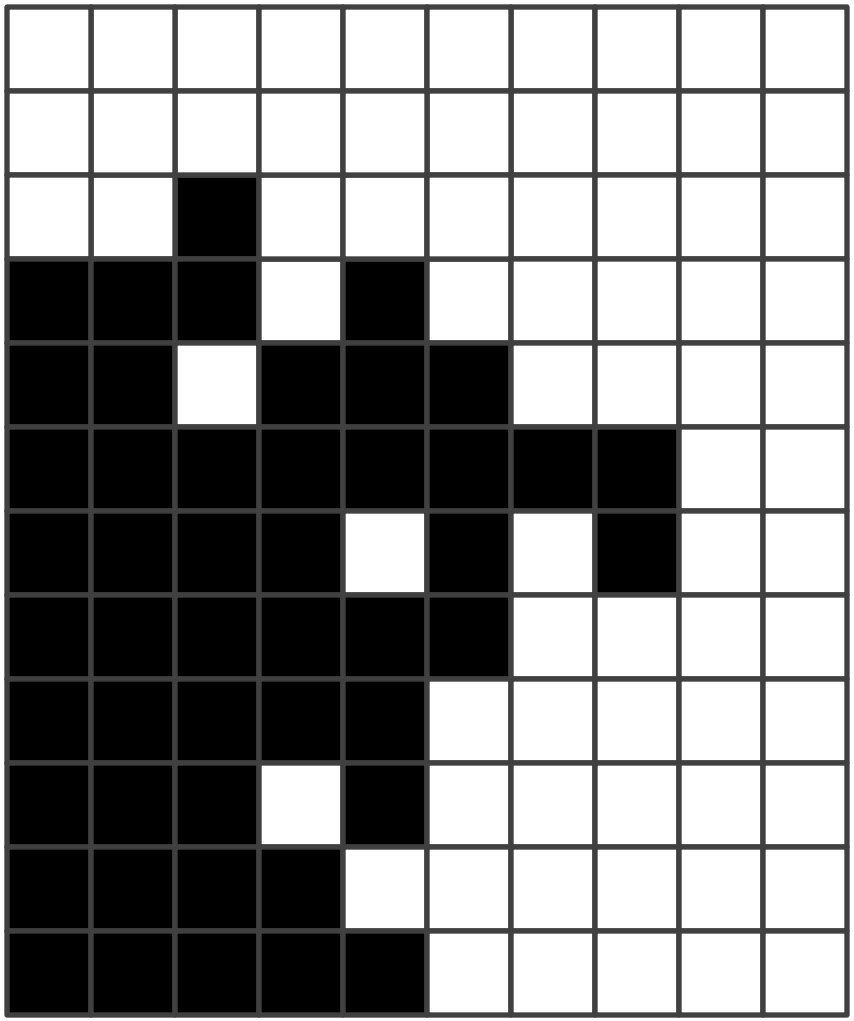
Dilate Function

Original Image

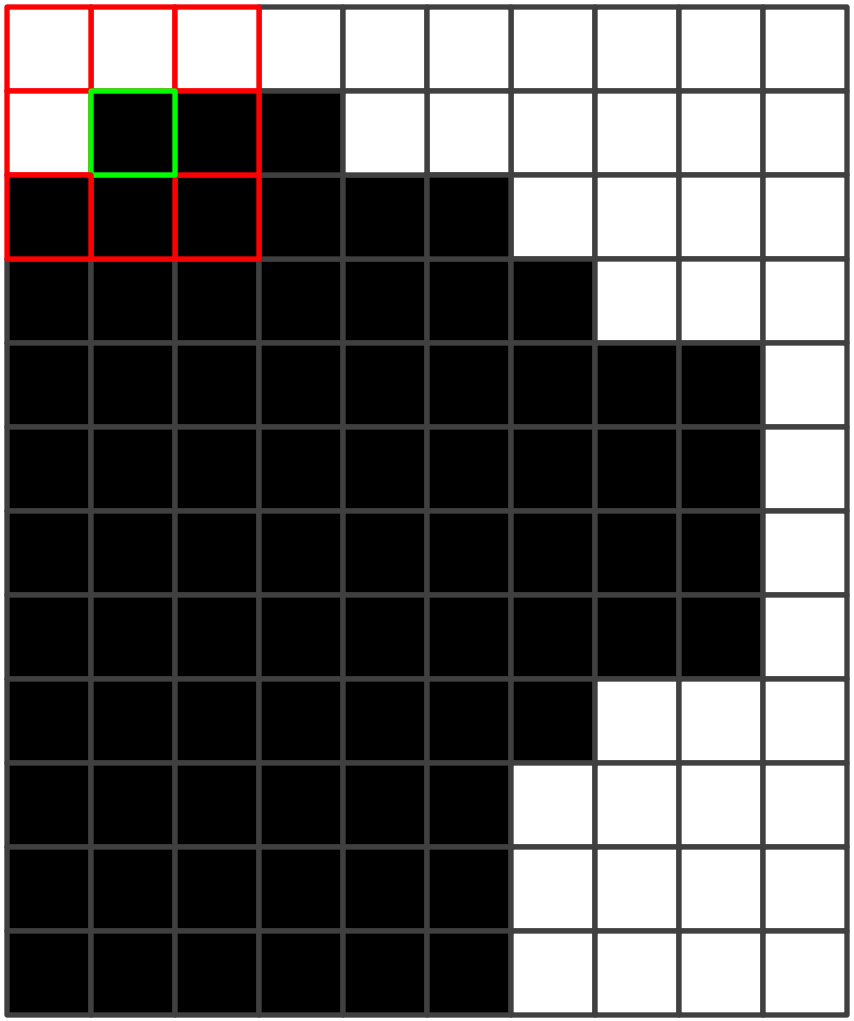


Dilated Image in Buffer

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

Erode Function

New Dilated Image



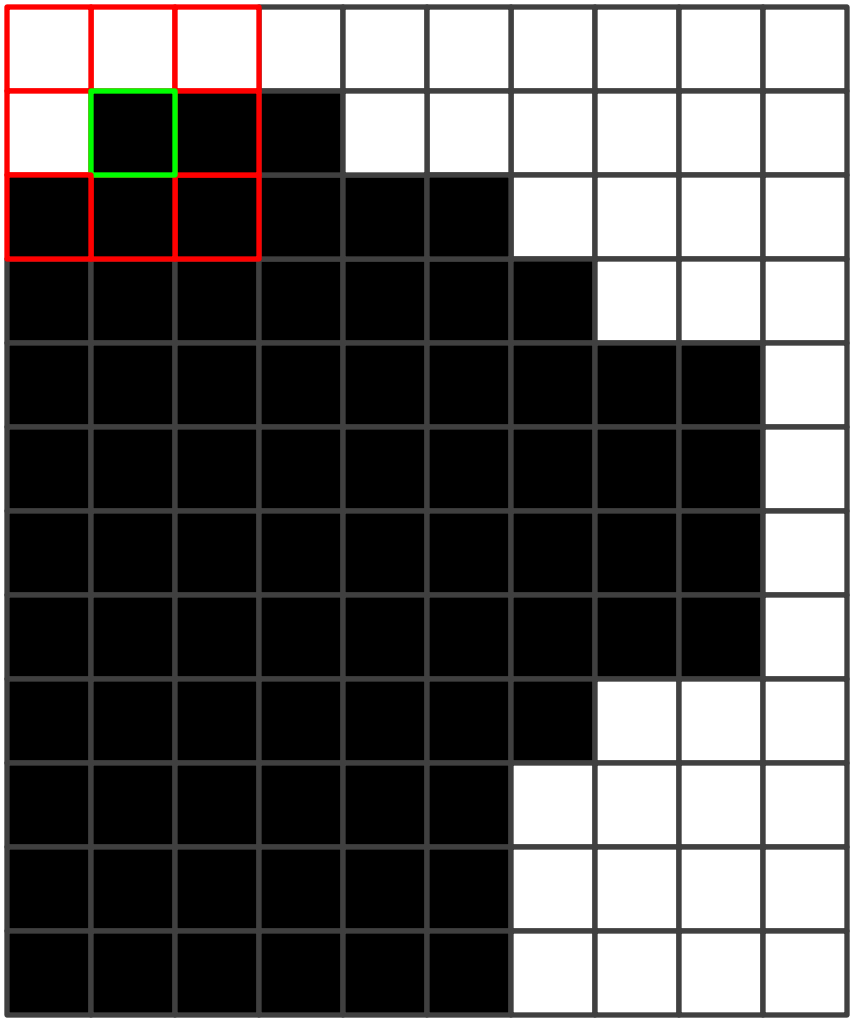
3x3 Kernel

0	0	0
0	1	1
1	1	1

We will evaluate the center pixel and assign a new value based upon the pixels in its “neighborhood”

Erode Function

New Dilated Image



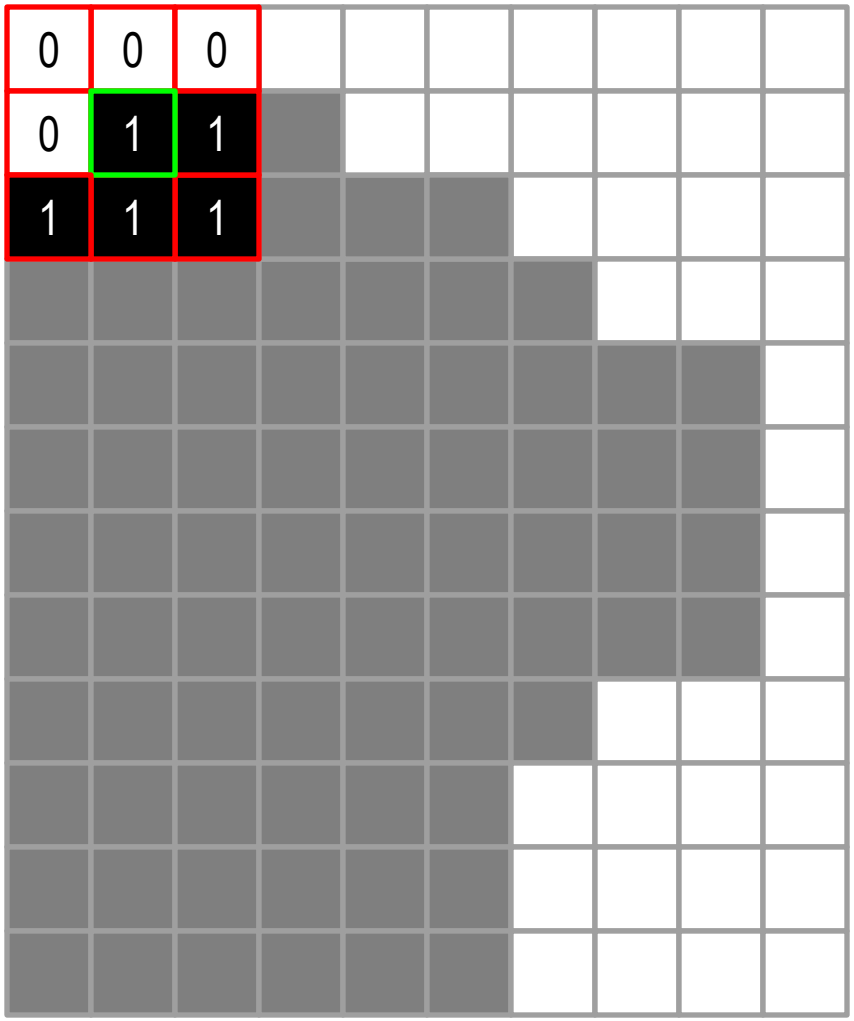
3x3 Kernel

0	0	0
0	1	1
1	1	1

For the ERODE method, we will assign the center pixel value to the MINIMUM value of any pixel in the neighborhood, in this case 0

Erode Function

New Dilated Image



Buffer (new Image)

0	0	0	0	0	0	0	0	0	0
0	0								

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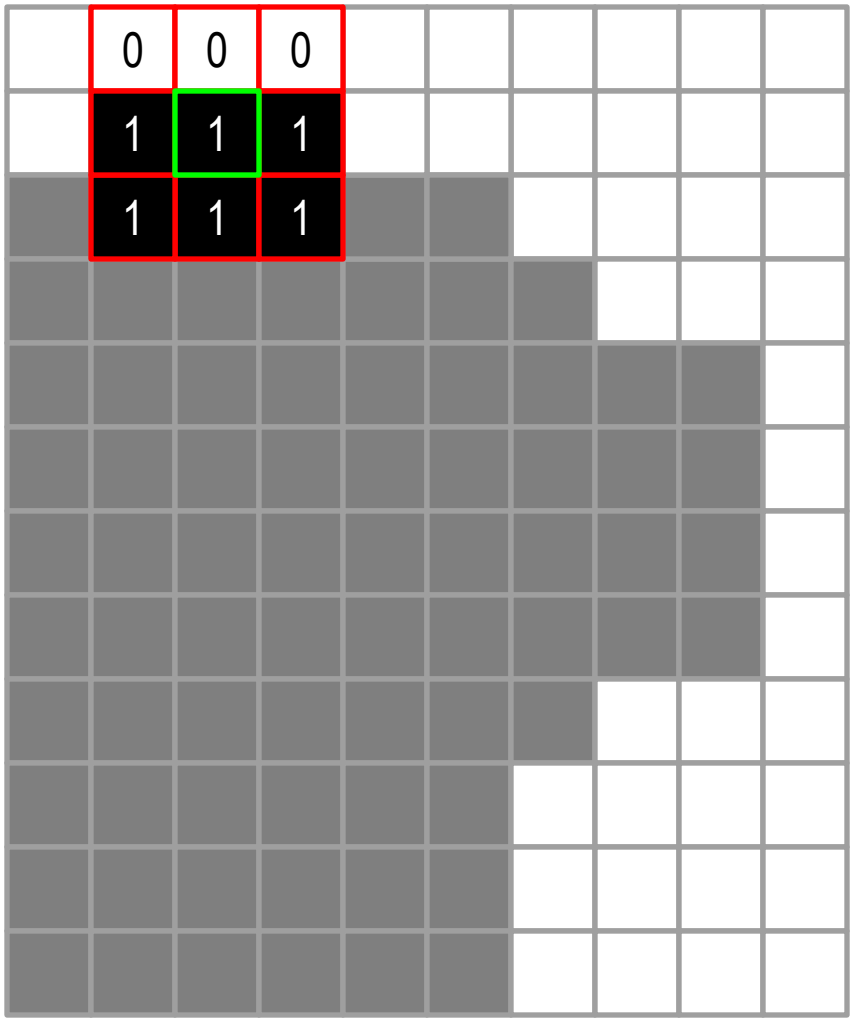
Erode Function

New Dilated Image

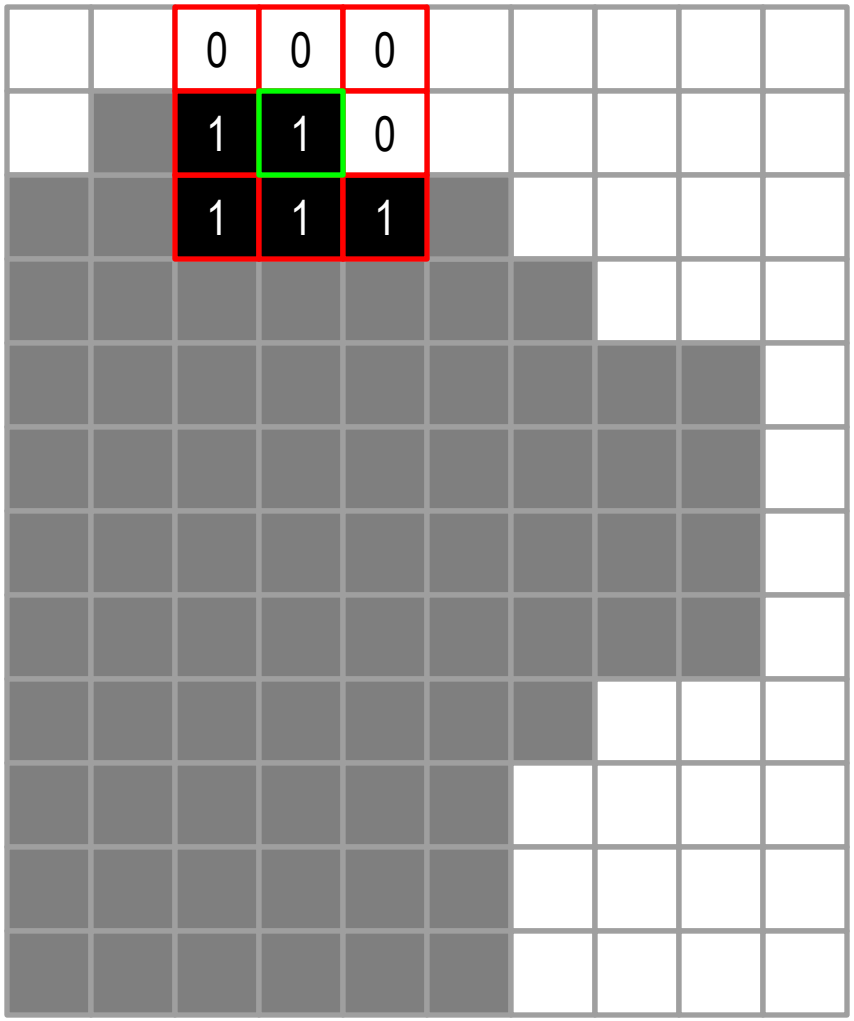


Buffer (new Image)

0	0	0	0	0	0	0	0	0	0
0	0	0							

Erode Function

New Dilated Image



Buffer (new Image)

0	0	0	0	0	0	0	0	0	0
0	0	0	0						

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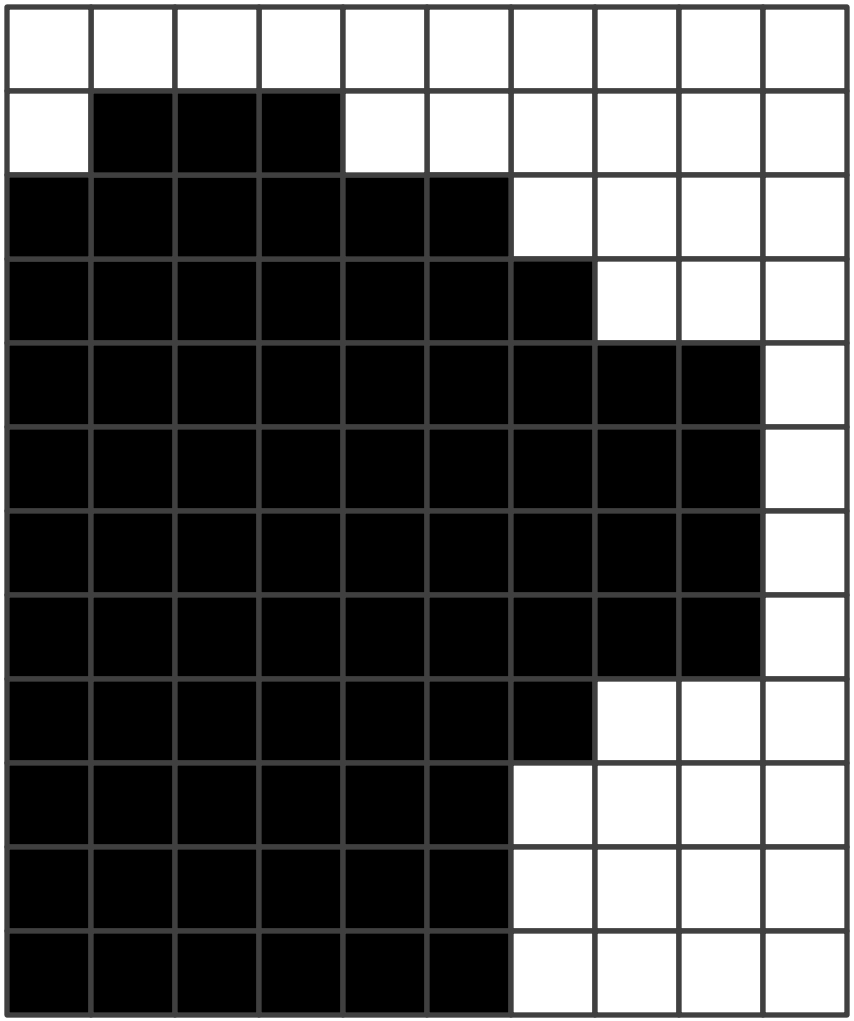
Erode Function

New Dilated Image



Eroded Image in Buffer

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

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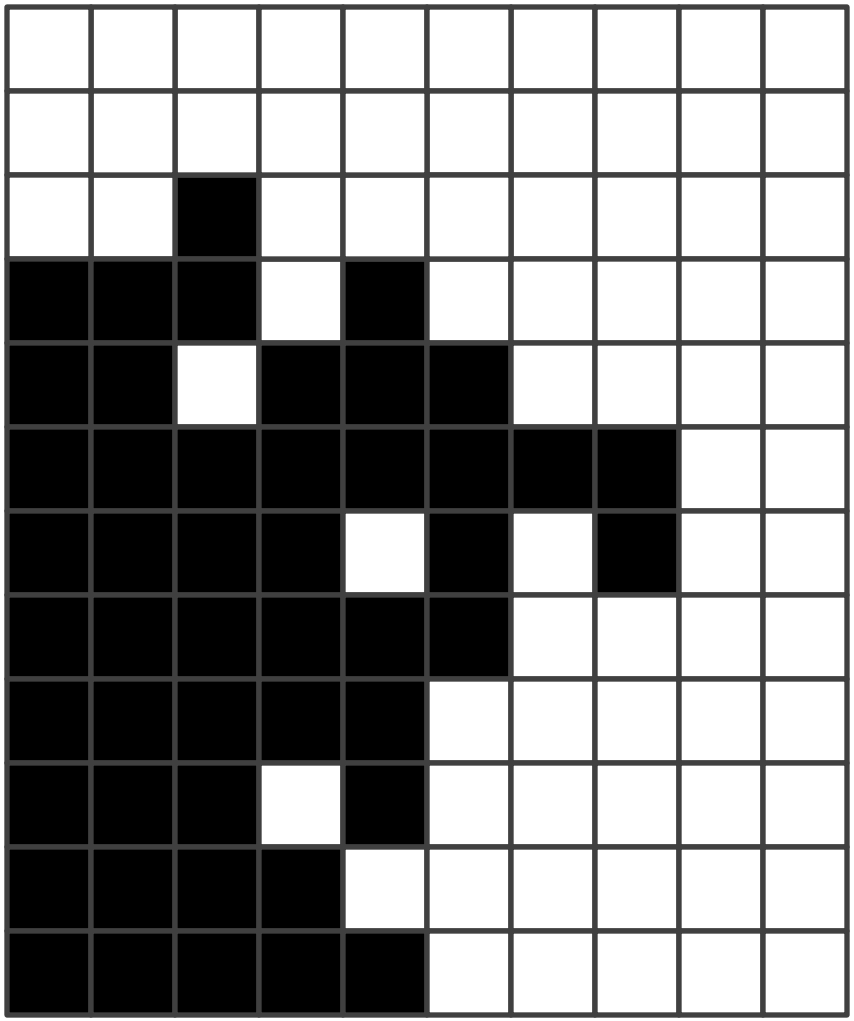
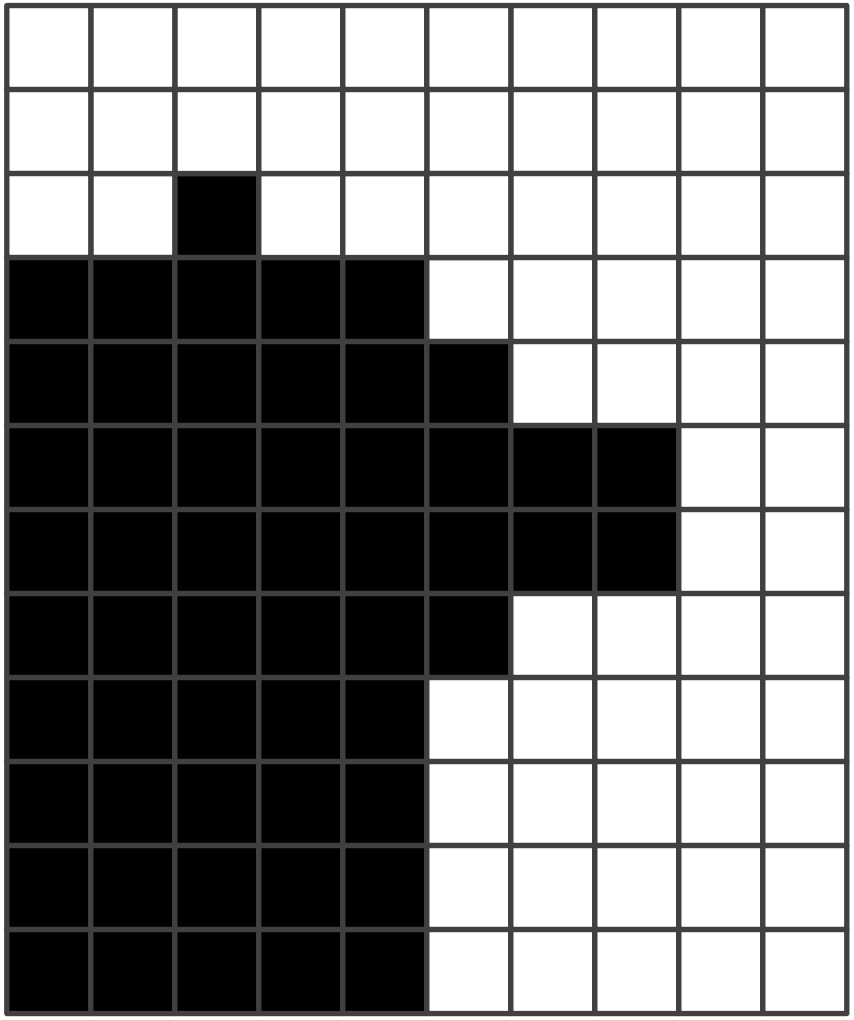
Dilate / Erode Functions

Original Image

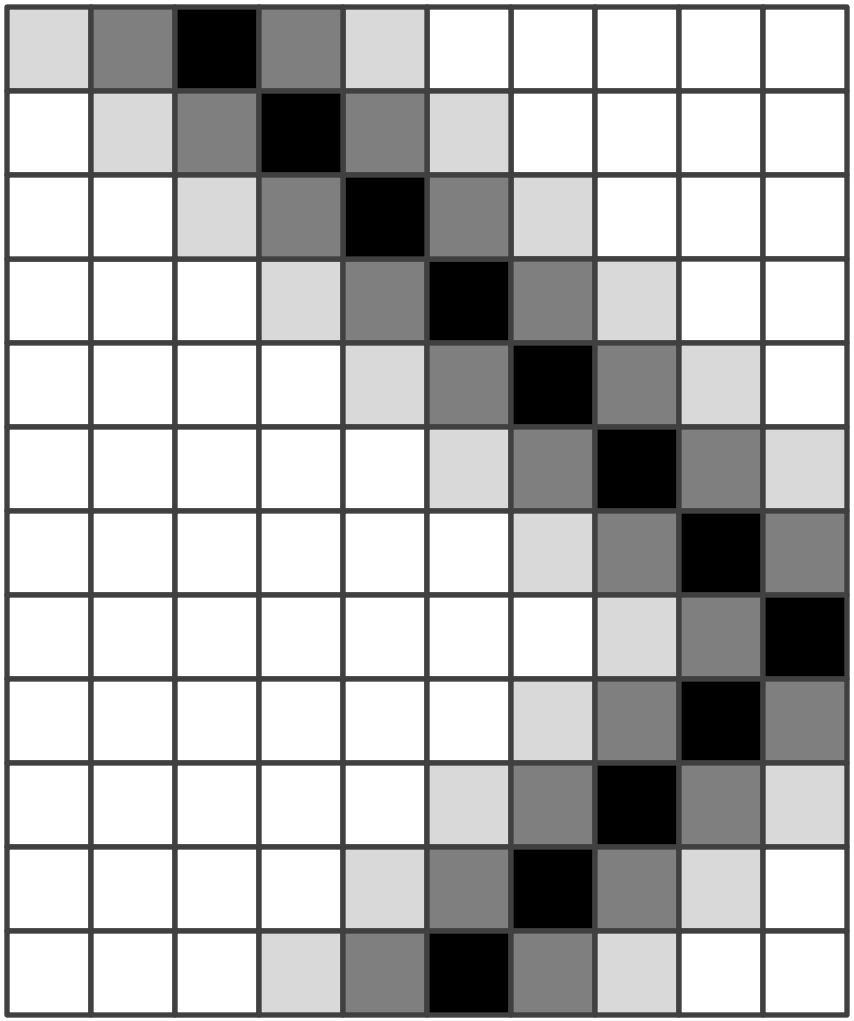


Dilated and Eroded Image



Mean Filter Function

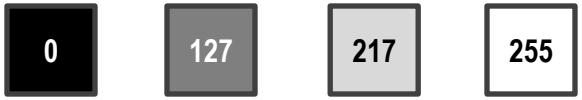
Original Image



A mean filter will change the value of our pixel to the average value for the entire neighborhood

$$a_{i,j} = \frac{1}{nm} \sum_{i=1}^{n} \sum_{j=1}^{m} a_{i,j}$$

For this example we will evaluate a group of pixels, each beginning with one of only four values



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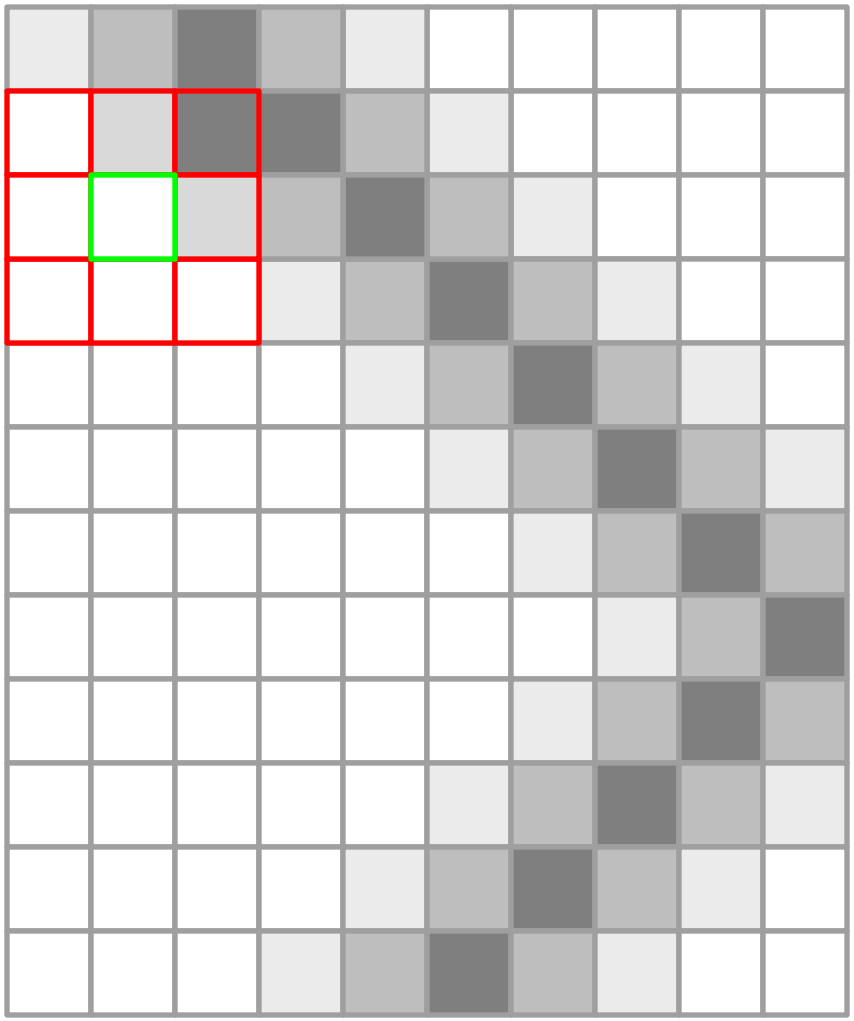
Mean Filter Function

Original Image



3x3 Kernel

255	217	127
255	255	217
255	255	255

We will evaluate the center pixel and assign a new value based upon the pixels in its “neighborhood”

In this case, we are going to apply a convolution matrix for a mean filter

Mean Filter Function

3x3 Mean Filter Kernel

$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

X

Image Pixel Neighborhood

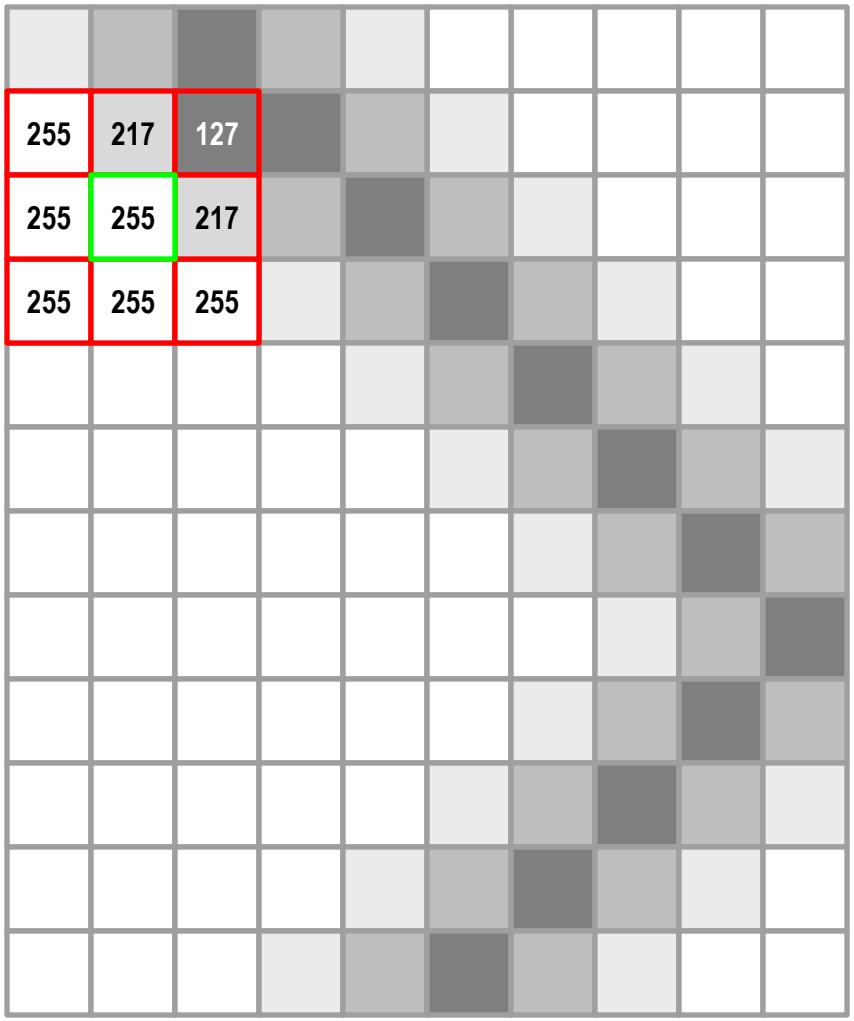
255	217	127
255	255	217
255	255	255

The new pixel value will be:

$$1/9 * (255 + 217 + 127 + 255 + 255 + 217 + 255 + 255 + 255) = 232$$

Mean Filter Function

Original Image

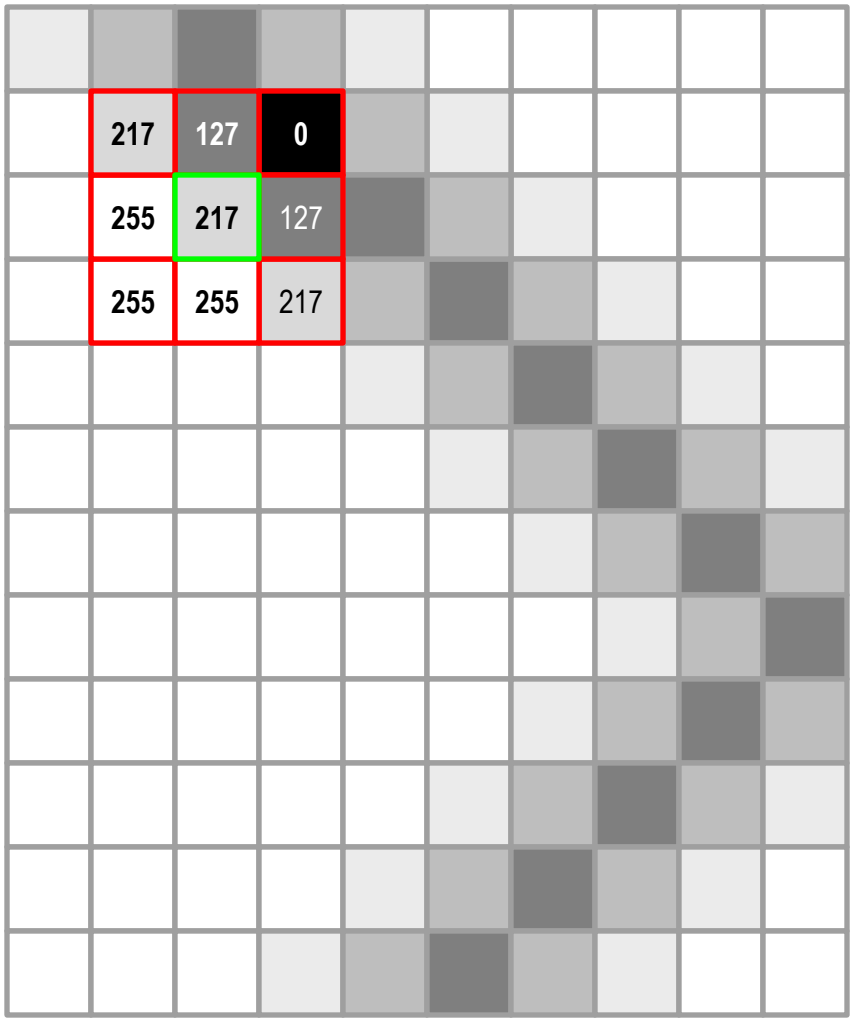


Buffer (new Image)

186	133	105	133	186	232	251	255	255	255
232	186	133	105	133	186	232	251	255	255
251	232								

Mean Filter Function

Original Image



3x3 Kernel

217	127	0
255	217	127
255	255	217

This pixel's new value will be:

1/9 * (3*(255+217) + 2*127 + 0) = 186

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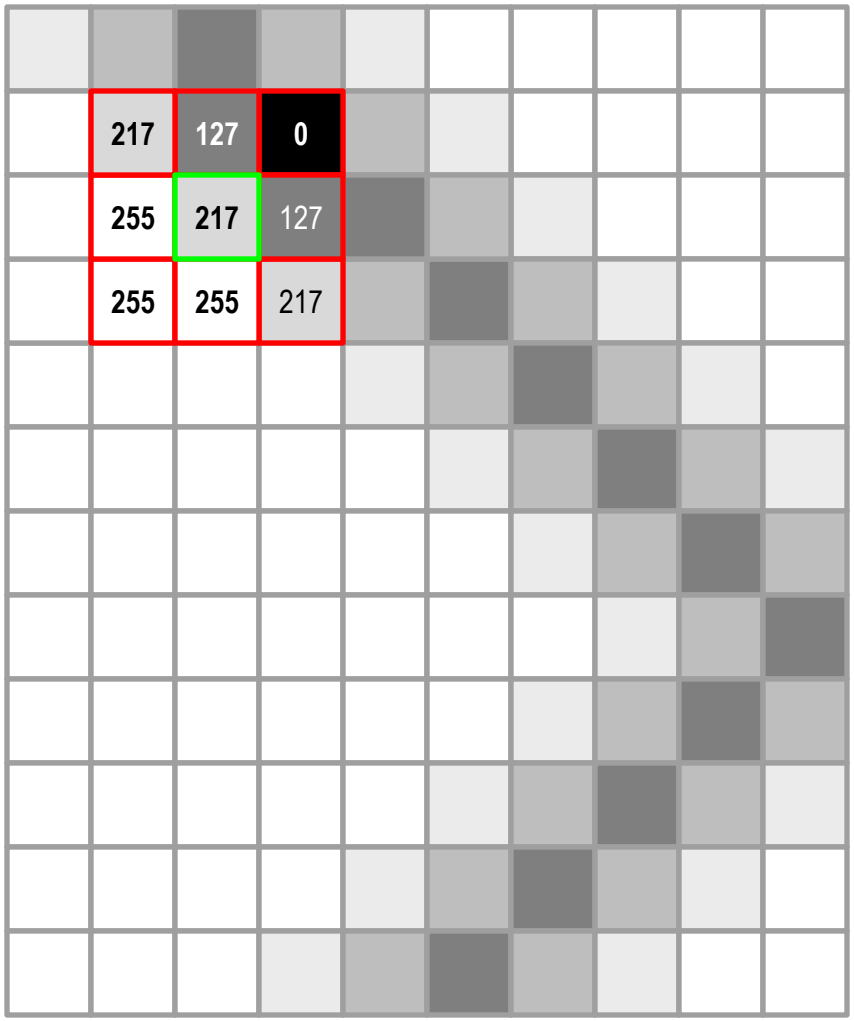
Mean Filter Function

Original Image

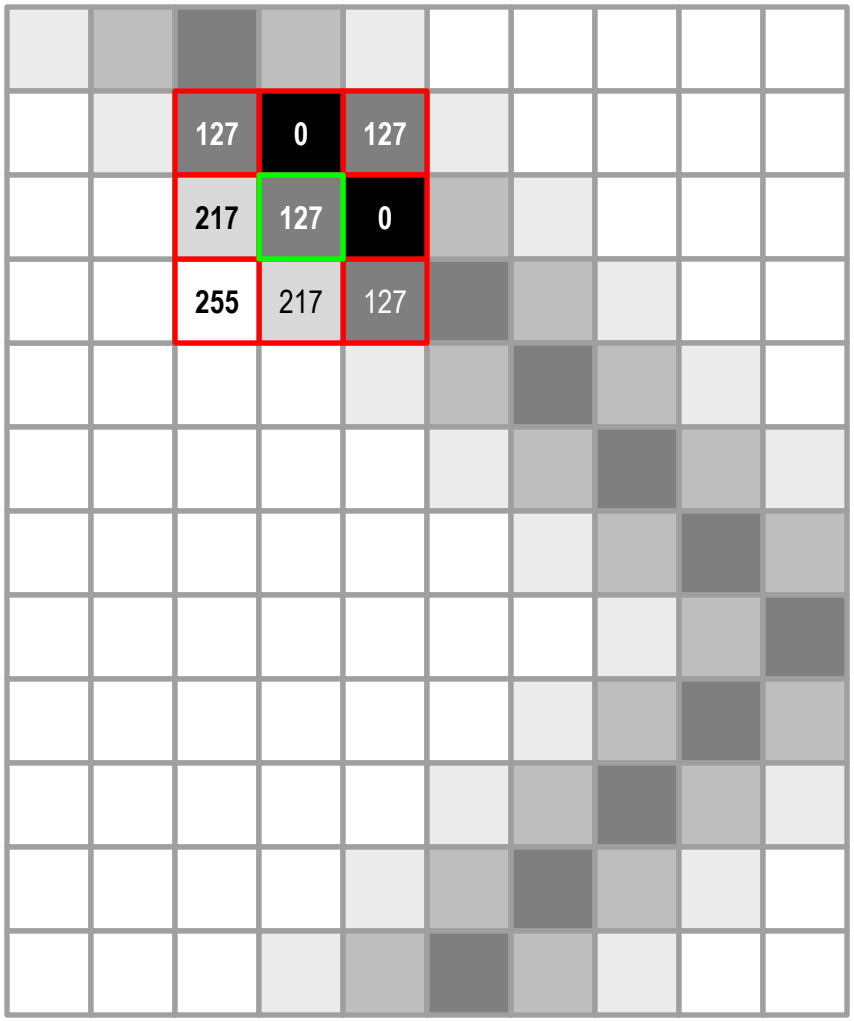


Buffer (new Image)

186	133	105	133	186	232	251	255	255	255
232	186	133	105	133	186	232	251	255	255
251	232	186							

Mean Filter Function

Original Image

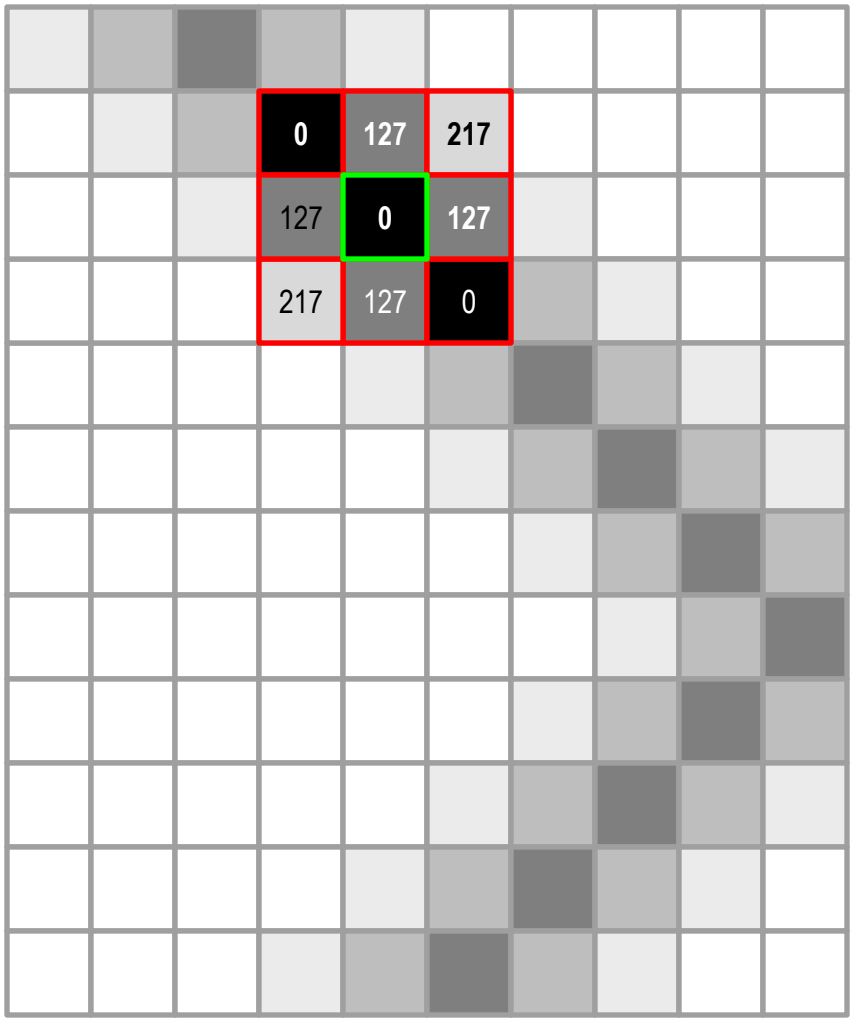


Buffer (new Image)

186	133	105	133	186	232	251	255	255	255
232	186	133	105	133	186	232	251	255	255
251	232	186	133						

Mean Filter Function

Original Image



Buffer (new Image)

186	133	105	133	186	232	251	255	255	255
232	186	133	105	133	186	232	251	255	255
251	232	186	133	105					

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Mean Filter Function

Original Image

217	127	0	127	217	255	255	255	255	255
255	217	127	0	127	217	255	255	255	255
255	255	217	127	0	127	217	255	255	255
255	255	255	217	127	0	127	217	255	255
255	255	255	255	217	127	0	127	217	255
255	255	255	255	255	217	127	0	127	217
255	255	255	255	255	255	217	127	0	127
255	255	255	255	255	255	255	217	127	0
255	255	255	255	255	255	217	127	0	127
255	255	255	255	255	217	127	0	127	217
255	255	255	255	217	127	0	127	217	255
255	255	255	217	127	0	127	217	255	255

Buffer (new Image)

186	133	105	133	186	232	251	255	255	255
232	186	133	105	133	186	232	251	255	255
251	232	186	133	105	133	186	232	251	255
255	251	232	186	133	105	133	186	232	251
255	255	251	232	186	133	105	133	186	232
255	255	255	251	232	186	133	105	133	186
255	255	255	255	251	232	186	133	105	133
255	255	255	255	255	218	214	143	95	105
255	255	255	255	251	232	186	133	105	133
255	255	255	251	232	186	133	105	133	186
255	255	251	232	186	133	105	133	186	232
255	251	232	186	133	105	133	186	232	251

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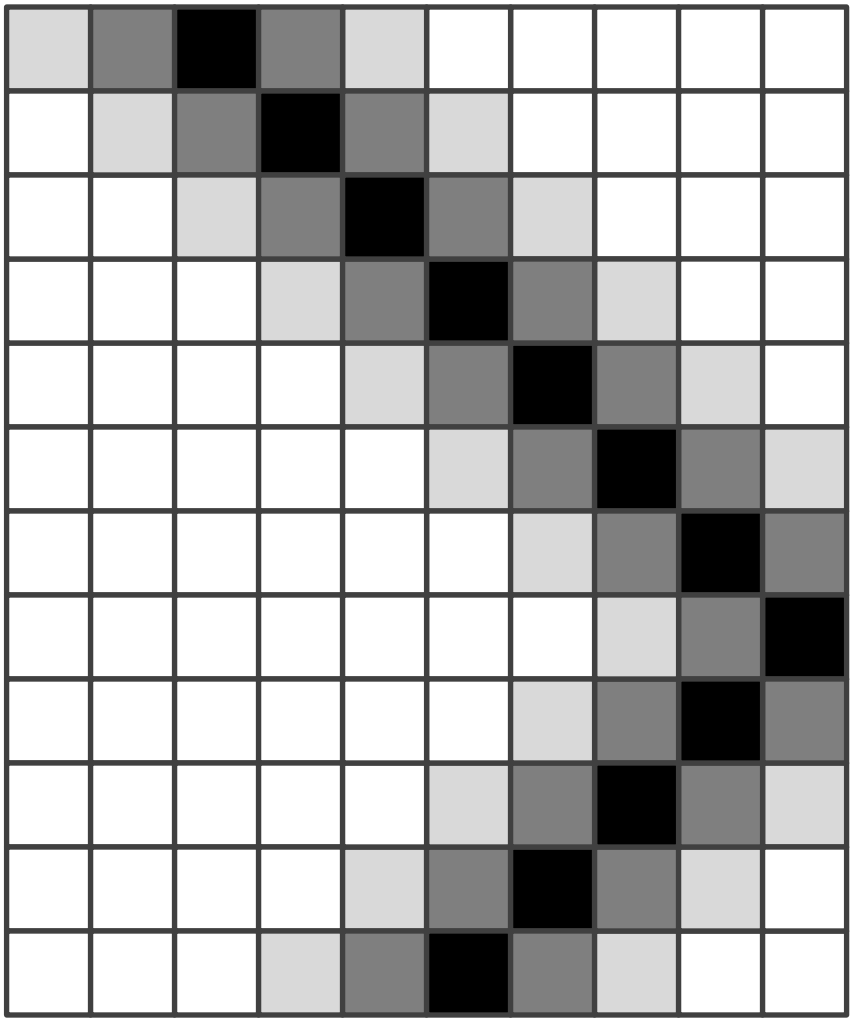
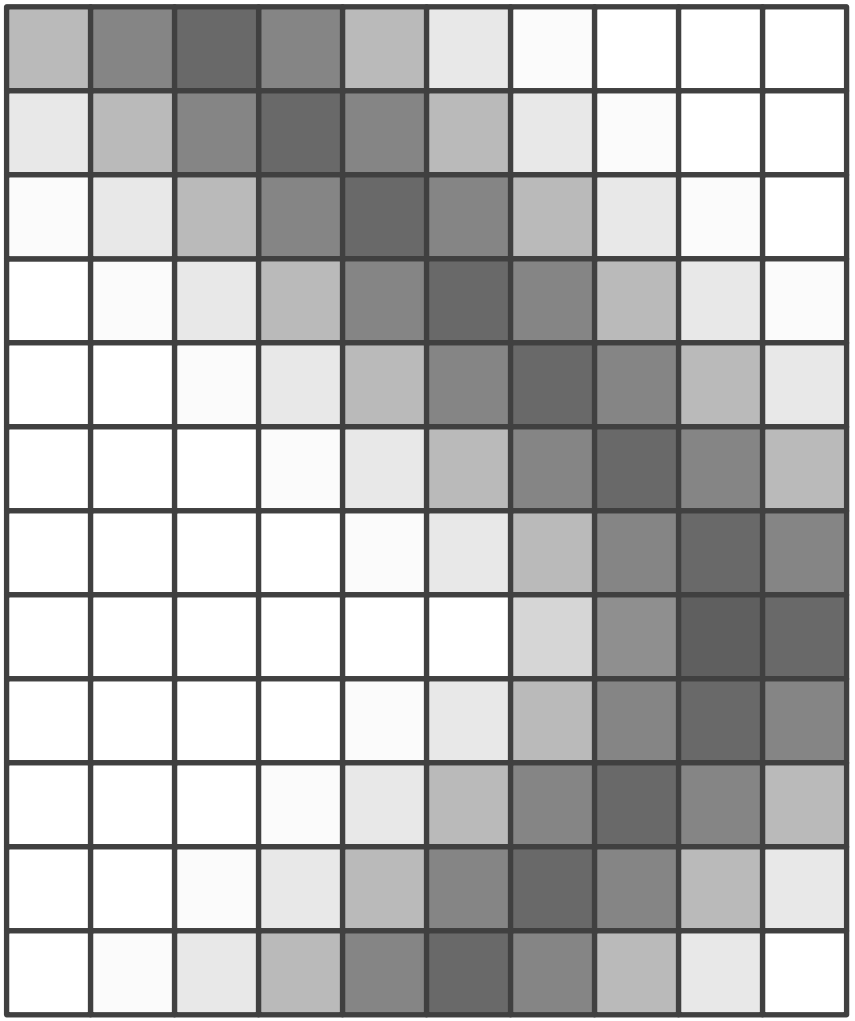
Mean Filter Function

Original Image



3x3 Mean Filtered Image



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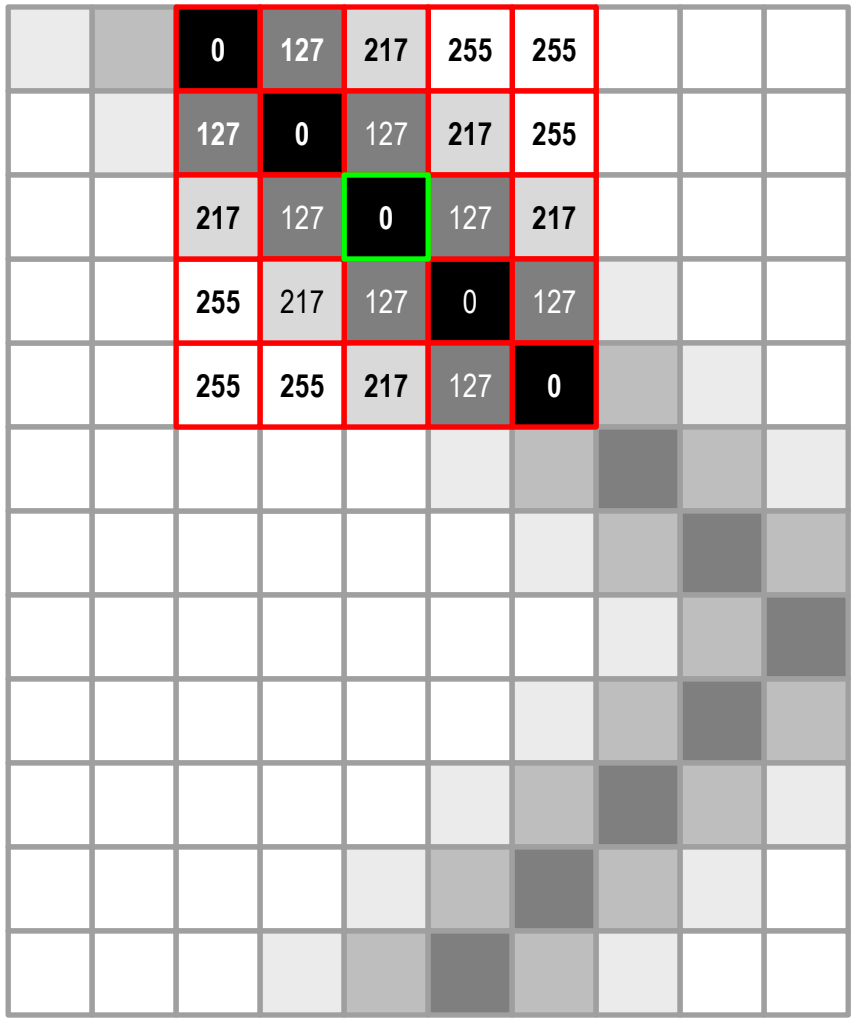
Mean Filter Function

Original Image



5x5 Kernel

0	127	217	255	255
127	0	127	217	255
217	255	0	127	217
255	217	255	0	127
255	255	217	255	0

A 3x3 Kernel will evaluate this pixel as
1/9 * (4*127 + 2*217 + 3*0) = 105

A 5x5 Kernel evaluates this pixel as
1/25 * (8*127 + 6*(255+217) + 5*0) = 155

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Mean Filter Function

Original Image

217	127	0	127	217	255	255	255	255	255
255	217	127	0	127	217	255	255	255	255
255	255	217	127	0	127	217	255	255	255
255	255	255	217	127	0	127	217	255	255
255	255	255	255	217	127	0	127	217	255
255	255	255	255	255	217	127	0	127	217
255	255	255	255	255	255	217	127	0	127
255	255	255	255	255	255	255	217	127	0
255	255	255	255	255	255	217	127	0	127
255	255	255	255	255	217	127	0	127	217
255	255	255	255	217	127	0	127	217	255
255	255	255	217	127	0	127	217	255	255

5x5 Mean Filtered Image

185	164	154	164	186	210	232	248	255	255
208	185	164	154	166	186	210	232	248	253
230	208	185	164	155	166	186	210	232	247
247	230	208	185	166	155	166	186	210	230
253	247	230	208	186	166	155	166	186	208
255	253	247	230	208	185	164	154	164	185
255	255	253	247	228	201	169	149	147	164
255	255	255	252	239	207	171	147	142	154
255	255	253	247	228	201	169	149	147	164
255	253	247	230	208	185	164	154	164	185
253	247	230	208	185	164	154	164	185	208
247	230	208	185	164	154	164	185	208	230

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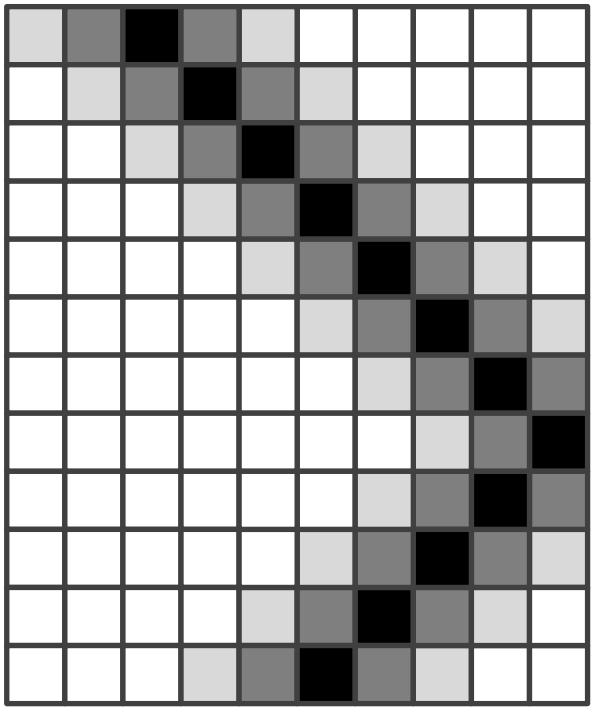
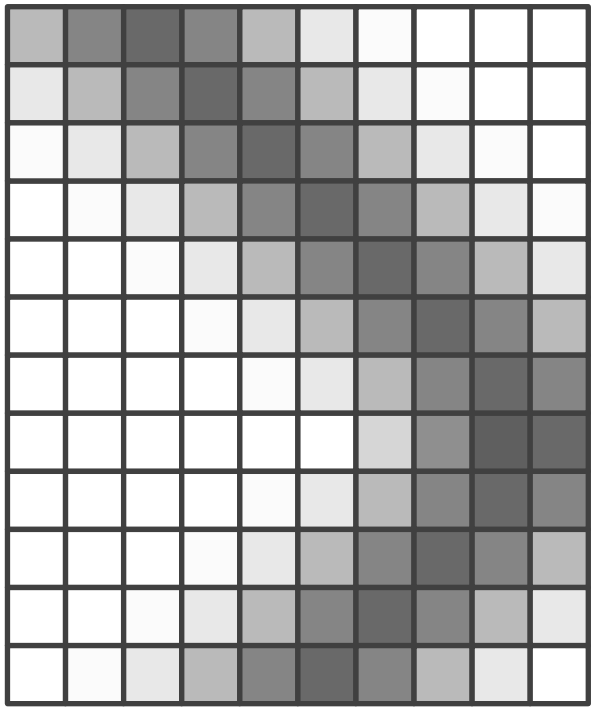
Mean Filter Function

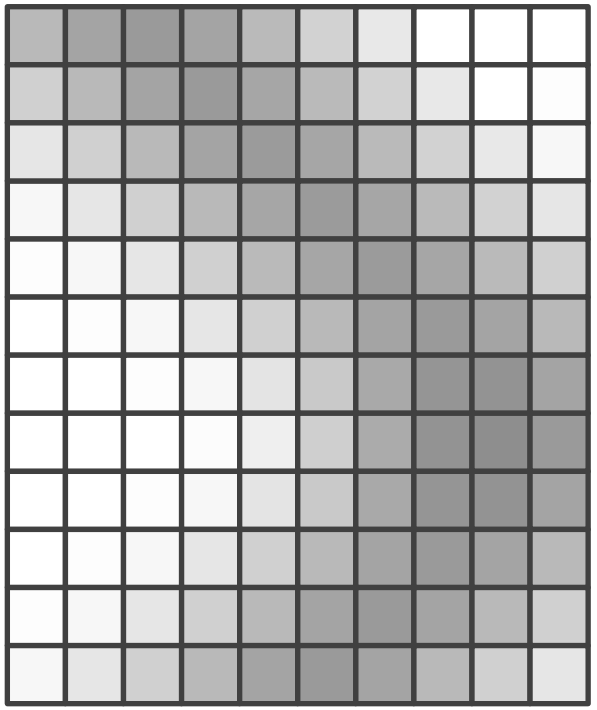
Original Image



3x3 Mean Filtered Image



5x5 Mean Filtered Image



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Overview of Presentation

- What is a kernel and how does it work?
- A variety of different kernels
- Dilate and Erode Example
- Mean Filter Example

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Questions?