



## Pictures are "Pixels"



- Every Digital Picture is made up of "Pixels"
- A "Pixel" is a "Picture Element"



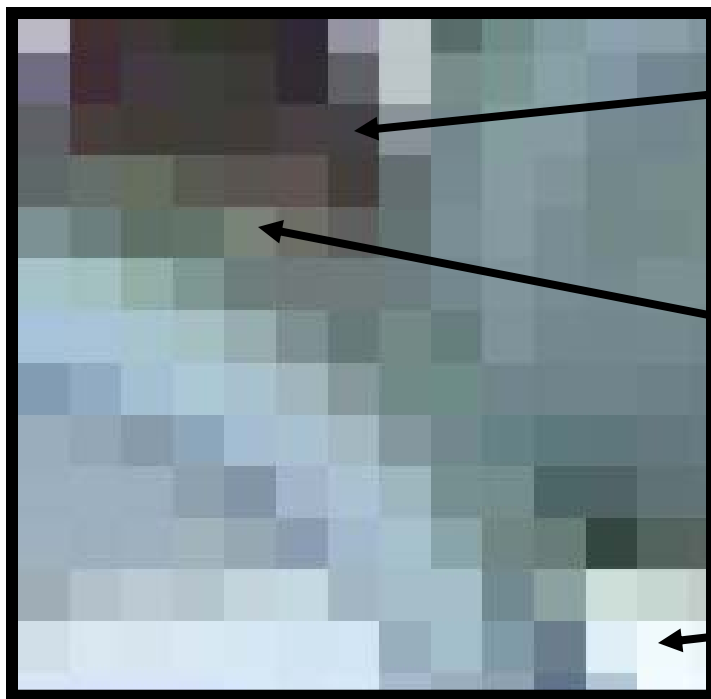
# Pixels are Numbers

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- A Computer stores each pixel as a numerical value
- A Color Pixel will have 3 values
  - Red
  - Green
  - Blue

# Big Numbers – Bright Shades



- Red 67
- Blue 69
- Green 65

- Red 121
- Blue 120
- Green 131

- Red 238
- Blue 250
- Green 254

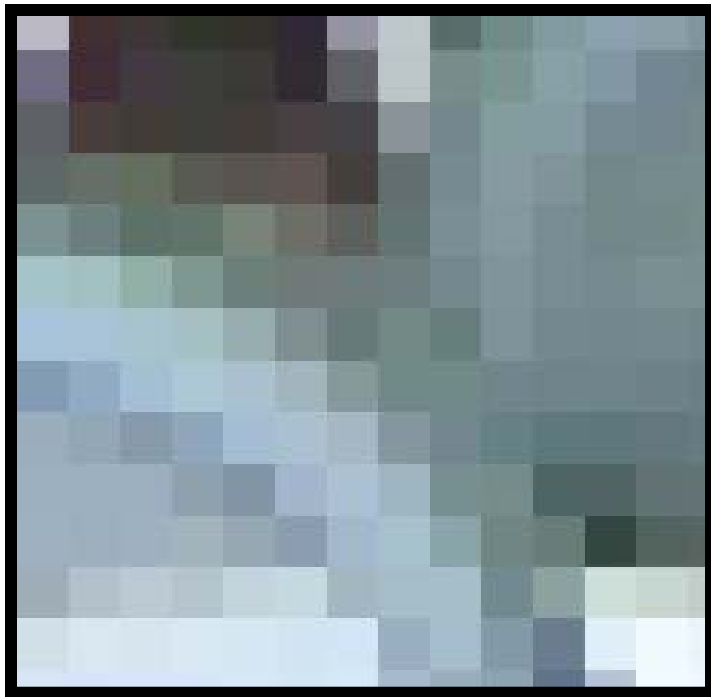


# From 0 to 255

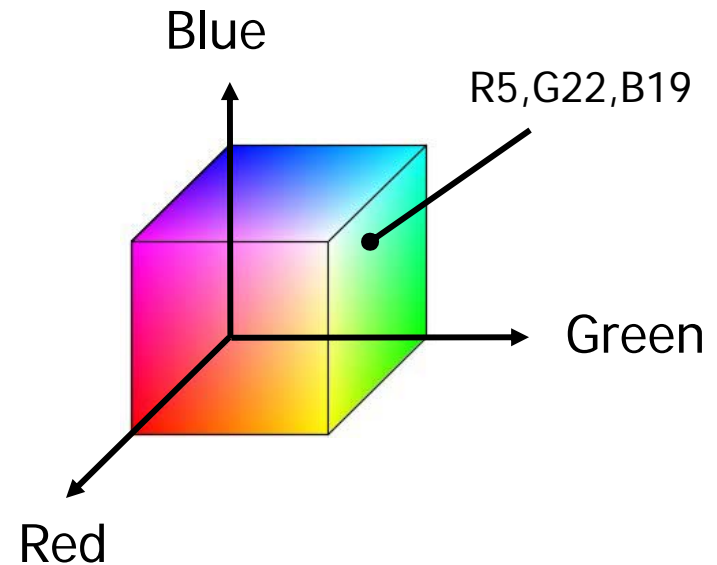
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- Computers store Pixel values as “Bytes”
  - A Byte is the smallest storage unit for numbers.
  - Computer math using Bytes is very fast.
  - A Byte can only store values from 0 to 255
- Pixels are generally stored as Byte values

# Color Pixel



- Colors get 3 Bytes
  - One for each primary

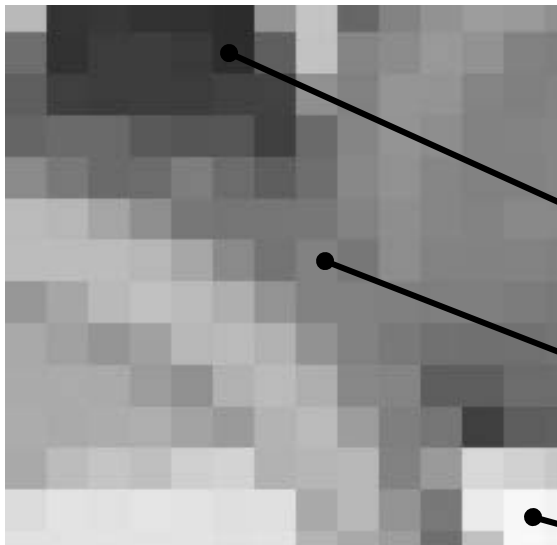




# Monochrome Pixel

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- Monochrome Pixel (Black and White) needs only 1 byte



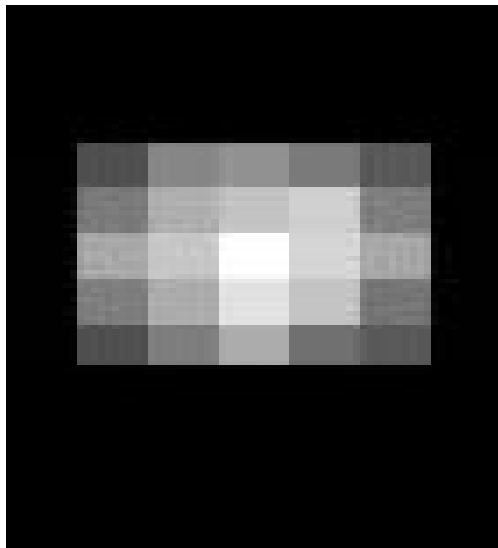
Black = 0

50% Grey = 128

White = 255

# Machine Vision

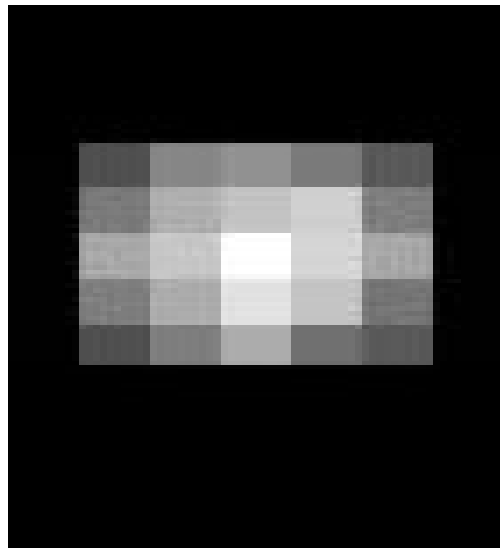
- A Computer sees the picture as an array of numbers



0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	4	0	0	0
0	0	12	24	12	0	0
0	12	48	84	48	12	0
4	24	84	128	84	24	4
0	12	48	84	48	12	0
0	0	12	24	12	0	0
0	0	0	4	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

# All is Math

- Every Inspection is based on some math using the pixel values



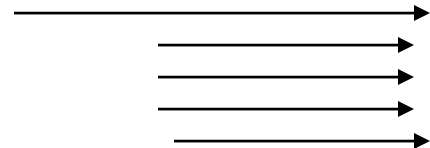
	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- Is Pixel D6 > 100 ?  
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# On Every Pixel

- The Computer Looks at every pixel in the image.
- A decision for each pixel is made based its value and often the value of surrounding pixels.



	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

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Inspection System



# Contrast Value

- The Contrast value sets the threshold at which a pixel will be “counted”

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

Contrast = 100: Count = 1

Contrast = 50: Count = 5



# Contrast Value

- A Lower Contrast Value will “count” More Pixels.
- A Lower Contrast will count more defects

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

Contrast = 100: Count = 1

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

Contrast = 50: Count = 5



# Sharpness Value

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- To find edges the computer looks at several pixels at once
- The idea is to see how quickly the values are changing
  - Is the image suddenly getting brighter or darker?



# Sharpness of 1

- Pixels 1 away (vertical and horizontal) are compared.
- The Difference is computed.

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- Is D5-D7 > Contrast ?
- Is C6-E6 > Contrast ?



# Sharpness of 2

- Pixels 2 away (vertical and horizontal) are compared.
- The Difference is computed.

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- Is D4-D8 > Contrast ?
- Is B6-F6 > Contrast ?



# Sharpness Setting

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- A Low (small) Sharpness value will skip all but the most abrupt changes.
- A High (big) Sharpness value will detect more gradual changes.
  - A Sharpness value of 2 or 3 is typical for surface inspections
  - NOTE: Sharpness and Contrast work together.



# Neighborhood and Neighbors

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- The Neighbors function is performed AFTER the Sharpness and Contrast operations have “Marked” pixels for counting.
- The tool is used to ignore small isolated “Marked” pixels
  - An isolated marked pixel may be a tiny defect or just noise in the image.



# The Neighborhood

- The neighborhood value selects how many adjacent pixels will be examined.

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- A neighborhood of 1 looks 1 pixel in each direction
  - A 3x3 block
  - 9 Pixels Total



# The Neighborhood

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- A neighborhood of 2 looks 2 pixel in each direction
  - A 5x5 block
  - 25 Pixels Total

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- A neighborhood of 3 looks 3 pixel in each direction
  - A 7x7 block
  - 49 Pixels Total



# Neighbors

- The Neighbors value selects the number of “Marked” pixels needed in the Neighborhood box in order for the pixel to be “counted”.

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- A neighborhood of 1
- Neighbors set to 3
- Single Pixel NOT COUNTED
  - Small defect ignored



# Neighbors

- The Neighbors value selects the number of “Marked” pixels needed in the Neighborhood box in order for the pixel to be “counted”.

	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- A neighborhood of 1
- Neighbors set to 3
- 4 marked Pixels in the box
- Pixel “D6” is counted
  - bigger defect found



# Neighborhood and Neighbors

- Typical setting for Surface Inspection is Neighborhood 1 : Neighbors 3 or 4

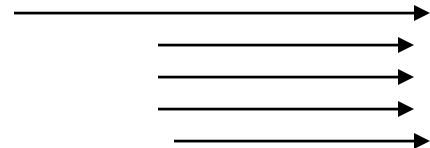
	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

- A neighborhood of 1
- Neighbors set to 3
- 4 marked Pixels in the box
- Pixel "D6" is counted
  - bigger defect found



# On Every Pixel

- For Neighbors and Neighborhood, the Computer Looks at every pixel in the image.
- A decision for each pixel is made based it's value and value of surrounding pixels.



	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	4	0	0	0
4	0	0	12	24	12	0	0
5	0	12	48	84	48	12	0
6	4	24	84	128	84	24	4
7	0	12	48	84	48	12	0
8	0	0	12	24	12	0	0
9	0	0	0	4	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0

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