# ICT2403 – Graphics and Image Processing

## Digital Image Fundamentals 2

**K.A.S.H. Kulathilake**

*Ph.D., M.Phil., MCS, B.Sc.(Hons.)IT, SEDA(UK)*

**Senior Lecturer**

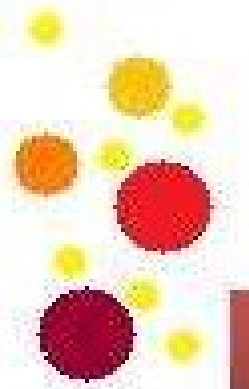
**Department of Computing**

**Rajarata University of Sri Lanka**

kule@as.rjt.ac.lk

# Learning Outcomes

- At the end of this lecture, you should be able to;
  - describe spatial resolution
  - describe intensity resolution
  - identify the effect of aliasing
  - describe image interpolation
  - describe relationships among the pixels



# Spatial Resolution

- **Spatial resolution is the smallest discernible detail in an image.**
- Or, we can describe the smallest number of discernible line pairs per unit distance
  - Example, 100 line pairs per millimeter.
- Dots per unit distance is a measure of image resolution used commonly in the printing and publishing industry.
  - 300 dpi

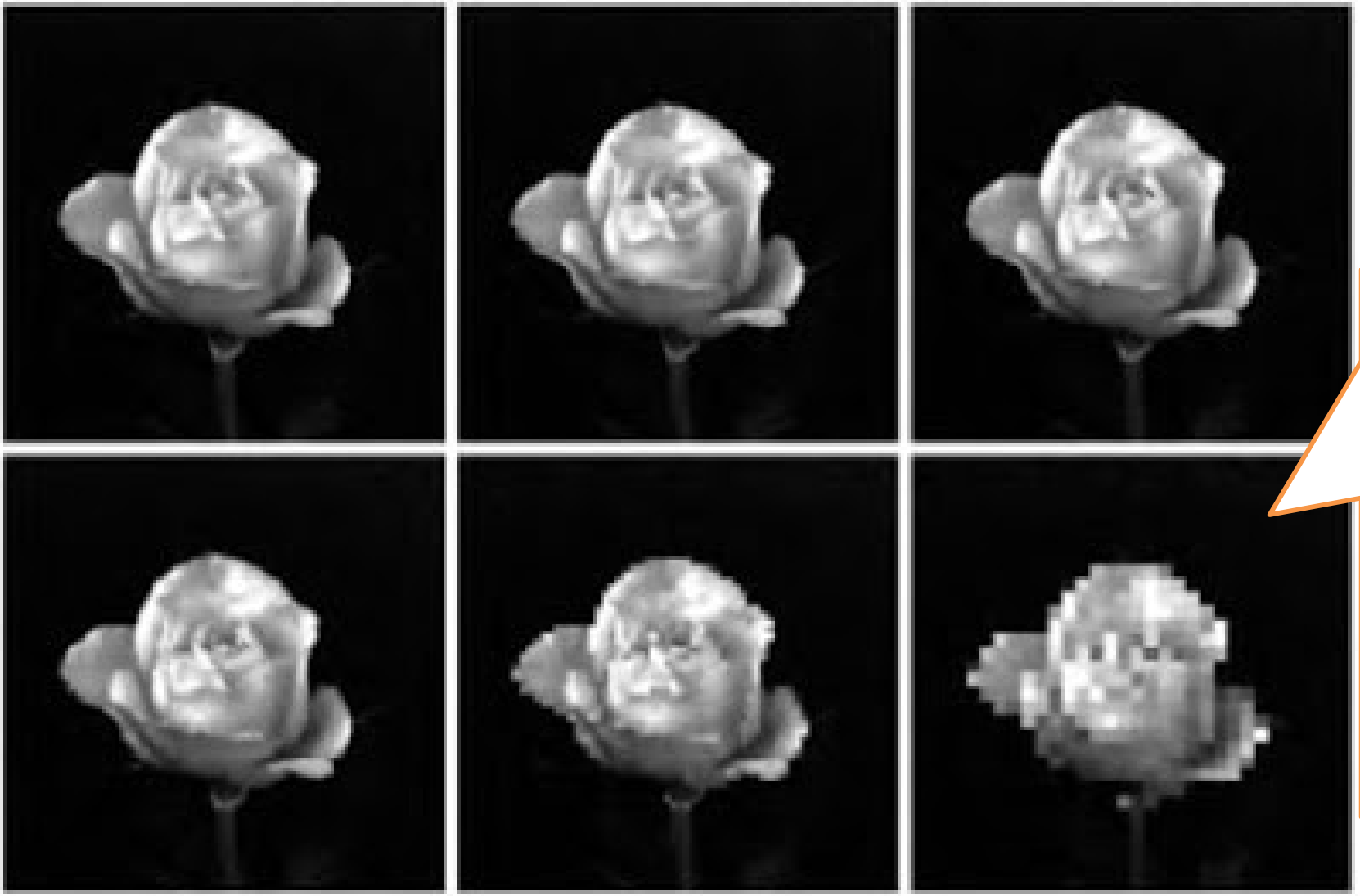
# Spatial Resolution (cont…)

- **Measuring Spatial Resolution:**
  - Since the spatial resolution refers to clarity , so for different devices , different measure has been made to measure it.
    - FOR EXAMPLE:
      - DOTS PER INCH: Dots per inch or DPI is usually used in monitors.
      - LINES PER INCH: Lines per inch or LPI is usually used in laser printers.
      - PIXEL PER INCH: Pixel per inch or PPI is measure for different devices such as tablets , Mobile phones e.t.c.

# Spatial Resolution (cont…)


Image of size 1024 * 1024 pixels whose gray levels are represented by 8 bits. The other images shown in figure are the result of sub sampling the 1024 * 1024 image. The number of allowed gray levels was kept at 256 in all of these images.

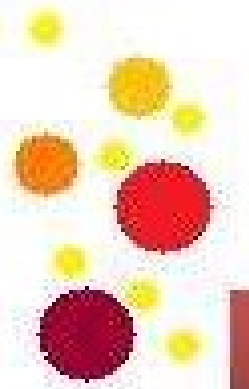
# Spatial Resolution (cont…)



Bring all the sub sampled images up to size 1024 * 1024 by row and column pixel replication.

# Intensity Resolution

- **It is a smallest discernible change in intensity level.**
- It is an integer power of two (8 bits, 16 bits)
- An 8-bit system quantizes intensity in fixed increments of 1/256 units of intensity amplitude.



# Intensity Resolution (cont…)

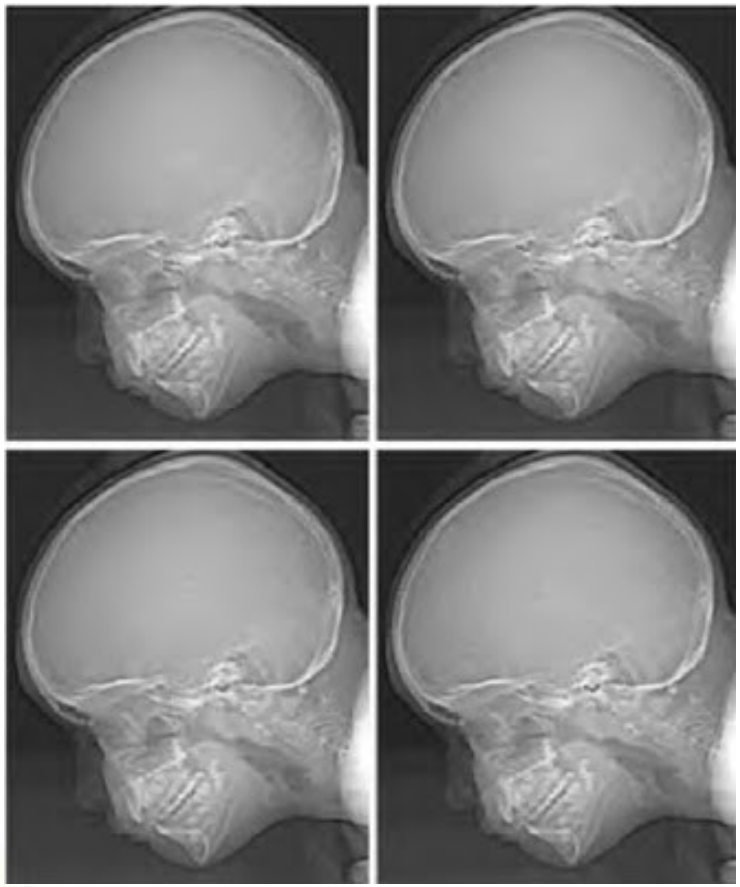
- 256 gray levels (8bits/pixel) 32 gray levels (5 bits/pixel) 16 gray levels (4 bits/pixel)

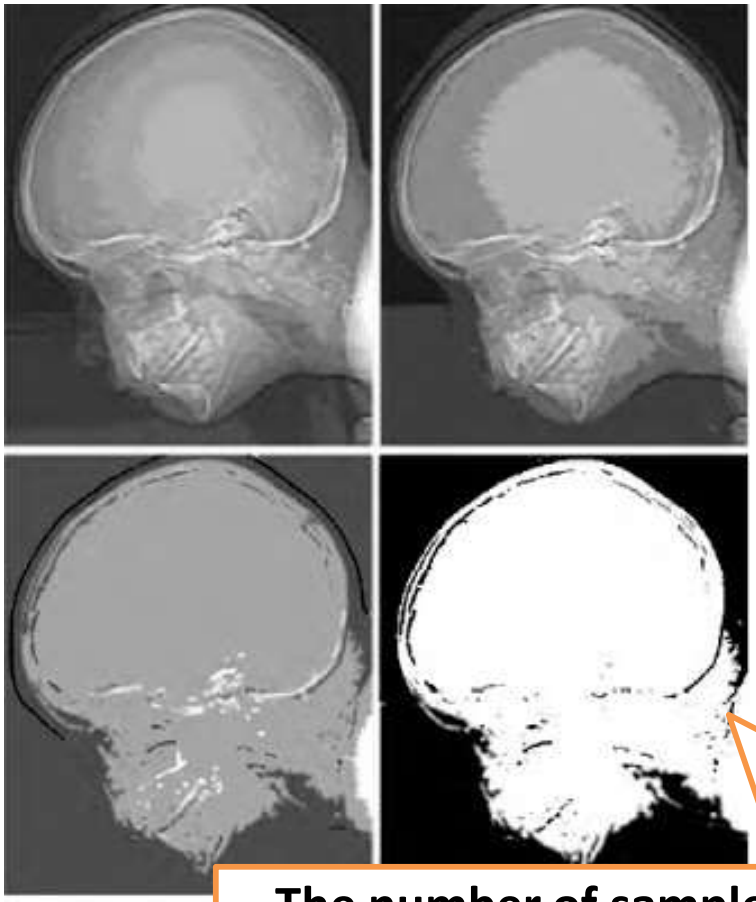


- 8 gray levels (3 bits/pixel) 4 gray levels (2 bits/pixel) 2 gray levels (1 bit/pixel)



# Intensity Resolution (cont…)

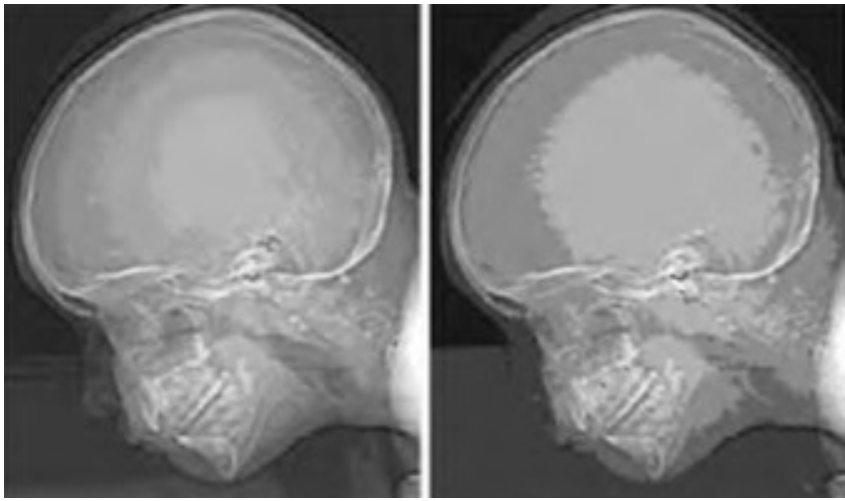




**The number of samples are constant in these images and the number of gray levels are reduced from 256 to 2, in integer power of 2.**

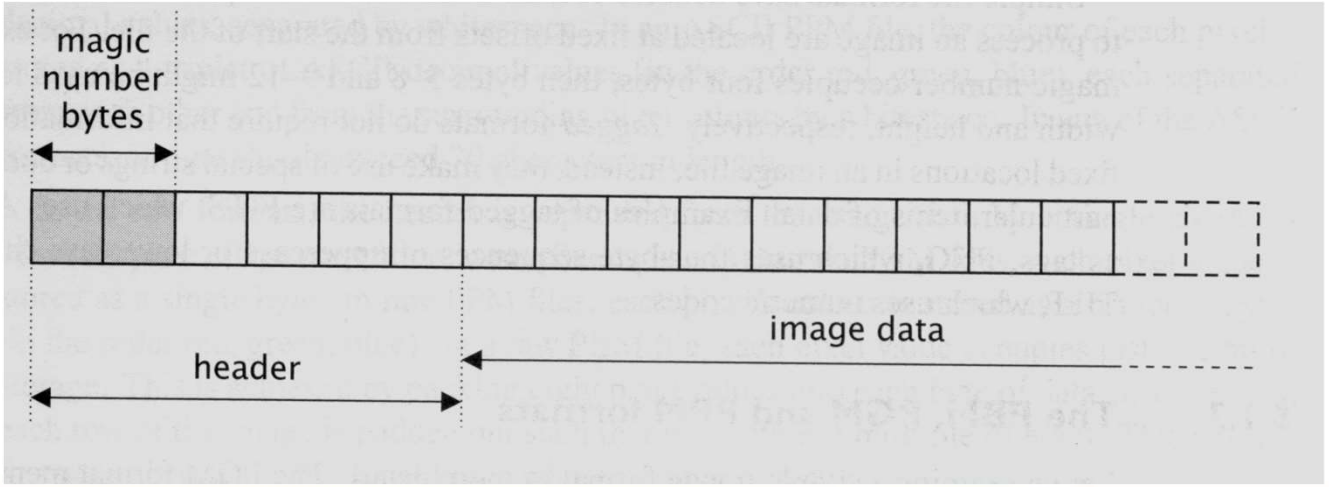
# Intensity Resolution (cont…)

- **Effect of False Contouring**
  - Under the low intensity resolution it has an imperceptible set of very fine ridge like structure in areas of smooth gray levels ( particularly in the skull).
  - This effect cause by the use of an insufficient number of gray levels in smooth areas of a digital image, is called **False Contouring.**
  - It happens because the ridges resembles topographic contours in map.
  - False contouring is generally is quiet visible in images displayed using 16 or less uniformly spaced gray levels.



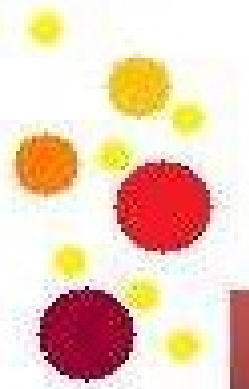
# Image File Formats

- Many image formats adhere to the simple model shown below (line by line, no breaks between lines).
- The header contains at least the width and height of the image.
- Most headers begin with a **signature** or “magic number” - a short sequence of bytes for identifying the file format.



# Image File Formats (Cont…)

- Common File Formats
  - GIF (Graphic Interchange Format)
  - PNG (Portable Network Graphics)
  - JPEG (Joint Photographic Experts Group)
  - TIFF (Tagged Image File Format)
  - PGM (Portable Gray Map)
  - FITS (Flexible Image Transport System)

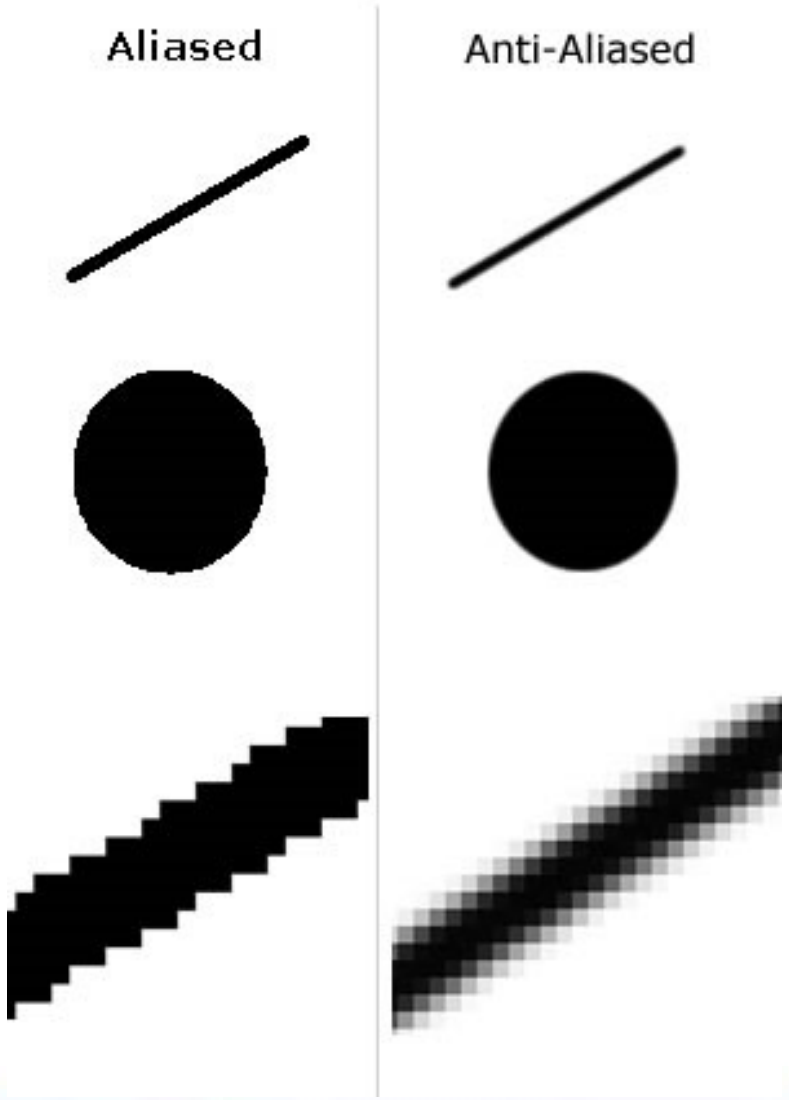


# Aliasing

- **Shannon's sampling theorem**
  - If the function is sampled at a rate equal to or greater than twice its highest frequency, it is possible to recover completely the original function from its samples.
- If the function is under sampled, then the phenomenon called **aliasing** corrupts the sampled image.
- **The corruption is in the form of additional frequency components being introduced into the sampled function.**
- **These are called aliased frequencies.**

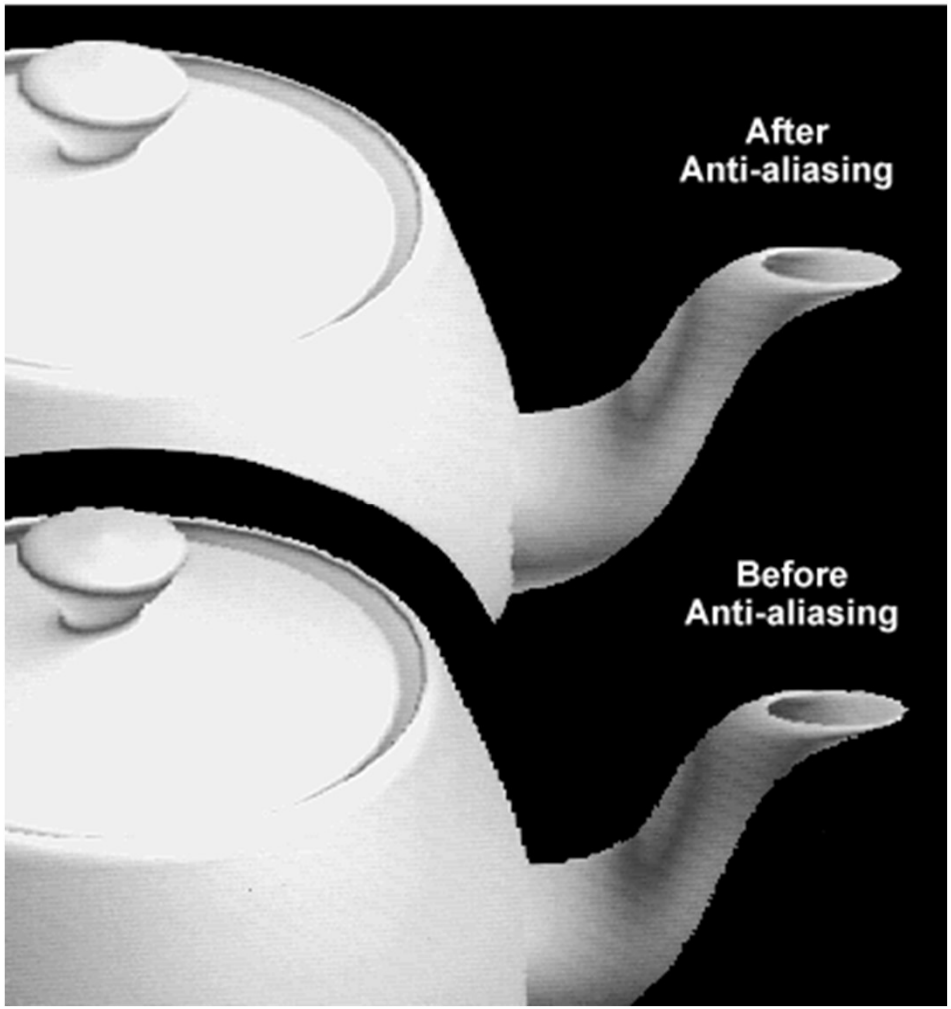
# Aliasing (Cont…)

- Note that the sampling rate in image is the number of samples taken (in both spatial direction) per unit distance.
- The principle approach for reducing the aliasing effect on an image is to reduce its high frequency components by blurring the image prior to sampling.
- However, aliasing is always present in a sampled image.



# Aliasing (Cont…)

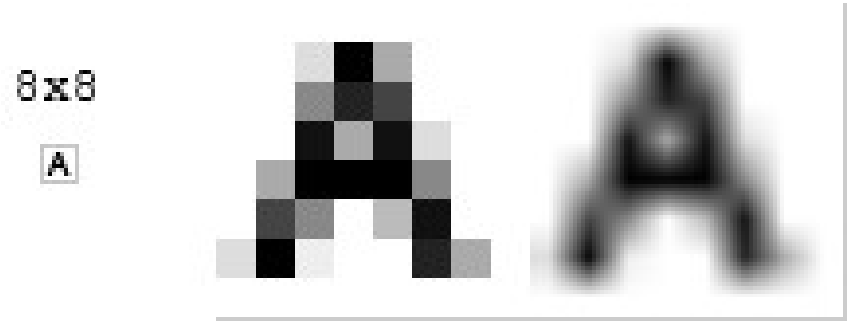
# Aliasing (Cont…)



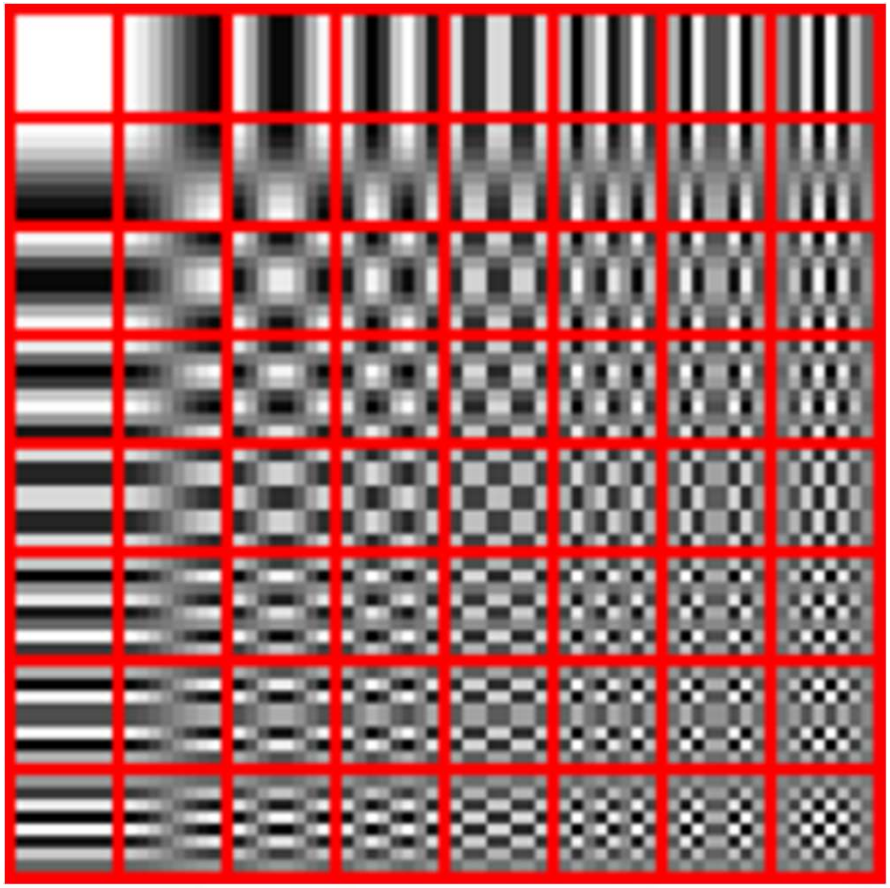

http://www.howtogeek.com/73704/what-is-anti-aliasing-and-how-does-it-affect-my-photos-and-images/

# Image Representation from Frequency Domain

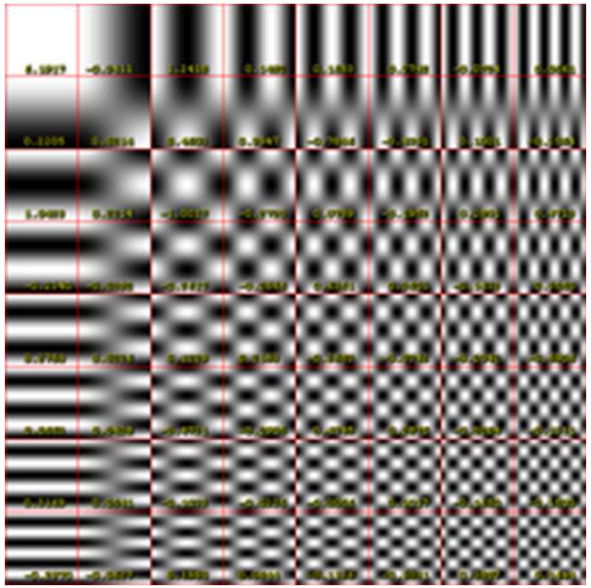
- http://upload.wikimedia.org/wikipedia/commons/5/5e/Idct-animation.gif
- https://en.wikipedia.org/wiki/Discrete_cosine_transform




Two-dimensional DCT frequencies from the JPEG DCT

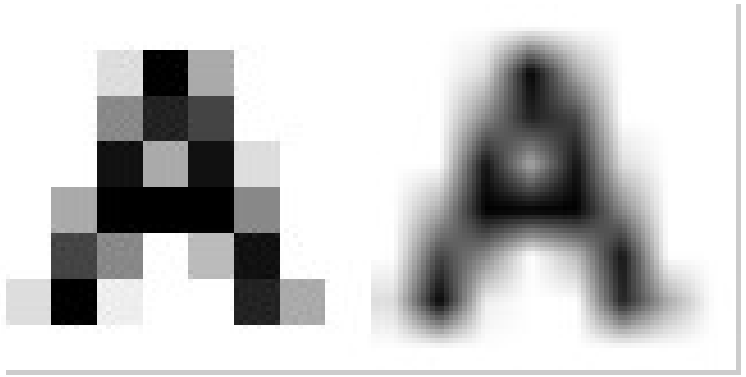


# Image Representation from Frequency Domain (Cont…)



8x8

A



Coefficients of the basis functions

$$\begin{bmatrix} 6.1917 & -0.3411 & 1.2418 & 0.1492 & 0.1583 & 0.2742 & -0.0724 & 0.0561 \\ 0.2205 & 0.0214 & 0.4503 & 0.3947 & -0.7846 & -0.4391 & 0.1001 & -0.2554 \\ 1.0423 & 0.2214 & -1.0017 & -0.2720 & 0.0789 & -0.1952 & 0.2801 & 0.4713 \\ -0.2340 & -0.0392 & -0.2617 & -0.2866 & 0.6351 & 0.3501 & -0.1433 & 0.3550 \\ 0.2750 & 0.0226 & 0.1229 & 0.2183 & -0.2583 & -0.0742 & -0.2042 & -0.5906 \\ 0.0653 & 0.0428 & -0.4721 & -0.2905 & 0.4745 & 0.2875 & -0.0284 & -0.1311 \\ 0.3169 & 0.0541 & -0.1033 & -0.0225 & -0.0056 & 0.1017 & -0.1650 & -0.1500 \\ -0.2970 & -0.0627 & 0.1960 & 0.0644 & -0.1136 & -0.1031 & 0.1887 & 0.1444 \end{bmatrix}$$

# Image Interpolation

- **Interpolation is the process of using known data to estimate values at unknown locations.**
- It happens anytime you resize or remap (distort) your image from one pixel grid to another.
- Image resizing is necessary when you need to increase or decrease the total number of pixels, whereas remapping can occur under a wider variety of scenarios: correcting for lens distortion, changing perspective, and rotating an image.

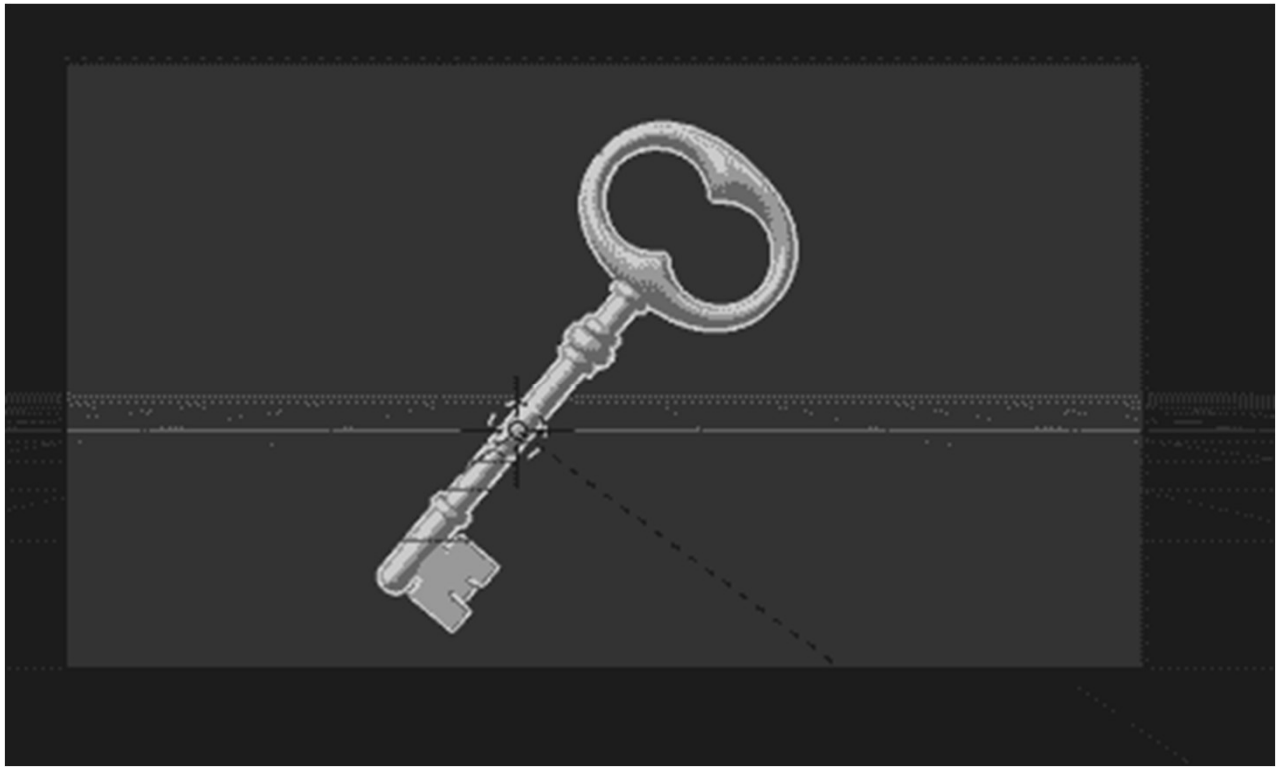
# Image Interpolation


Lense Distortion

# Image Interpolation

Changing Perspective

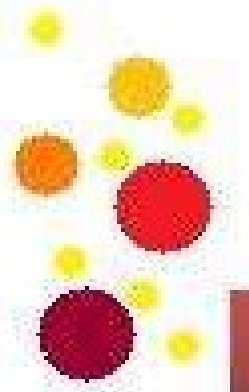
# Image Interpolation



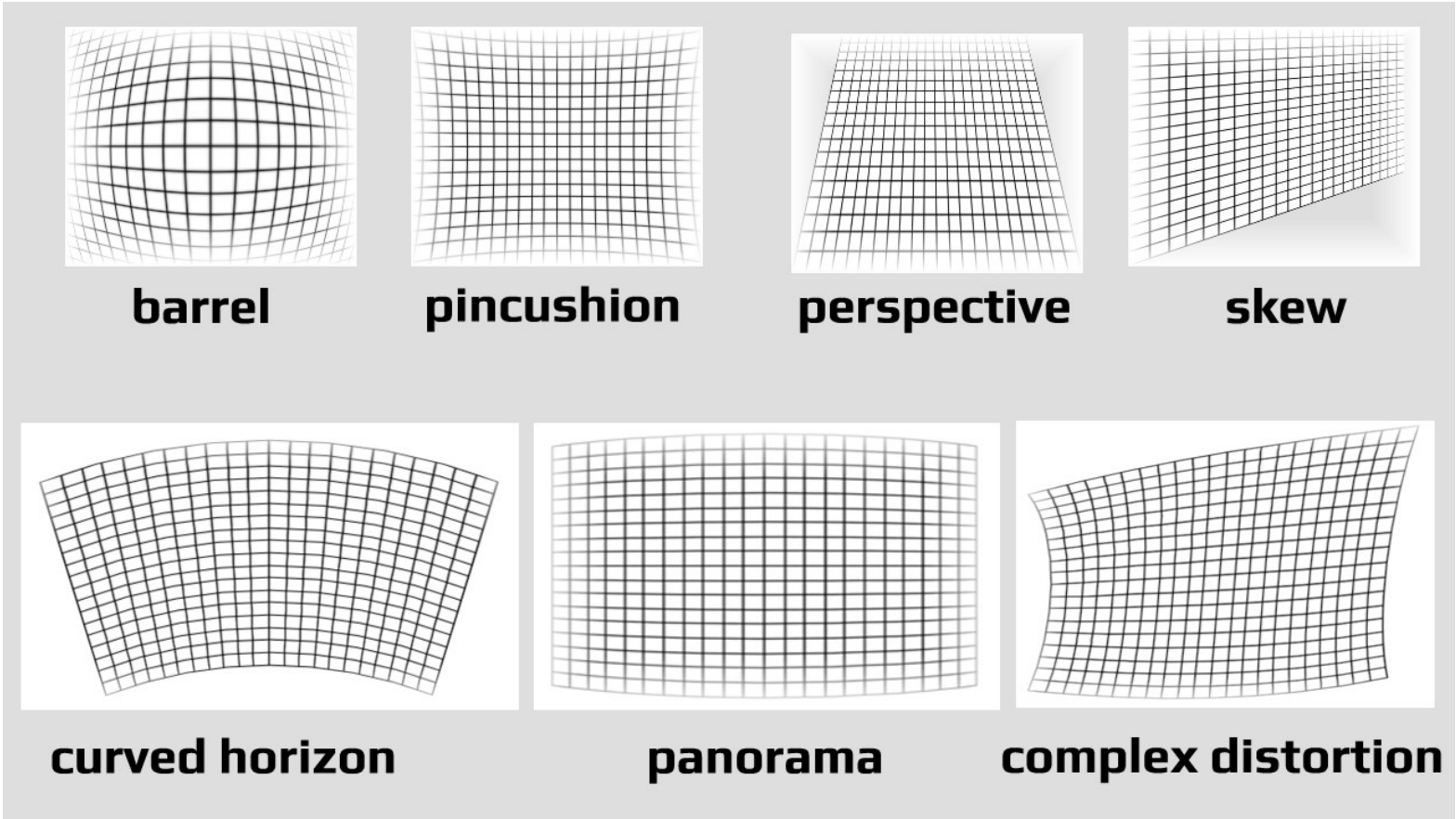
Rotating an Object

# Image Interpolation (Cont…)

- Distortion
  - In image processing, distortion refers to any deviation or alteration of an image from its original form, causing it to appear twisted, blurred, or otherwise deformed in comparison to the intended or real-life scene.
  - Distortion can occur due to various factors, ranging from the characteristics of the imaging sensor, the lens used in capturing the image, to post-processing techniques.



# Image Interpolation (Cont…)



# Image Interpolation (Cont…)

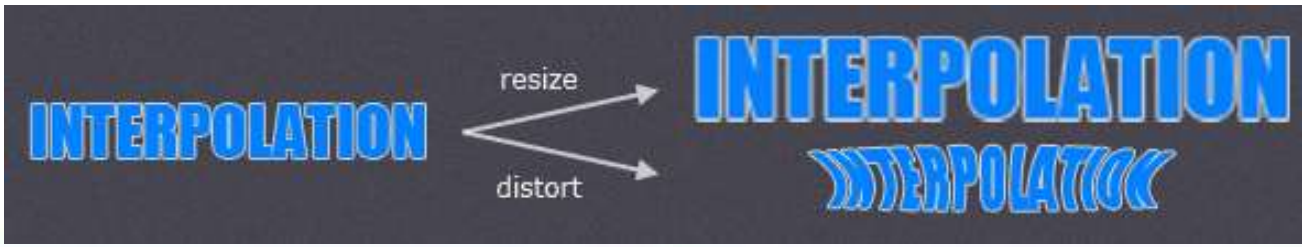
Barrel Distortion | Pincushion Distortion | Corrected Vision

https://snorpey.github.io/distort-grid/

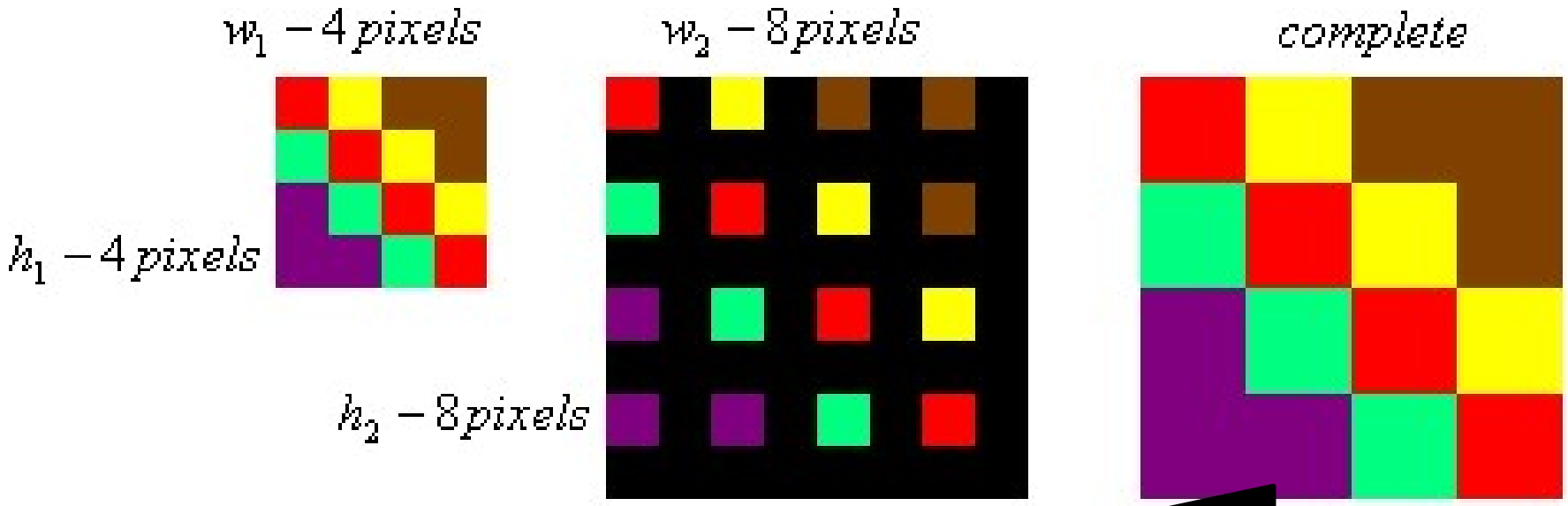
https://photographylife.com/what-is-distortion

# Image Interpolation (Cont…)

- Even if the same image resize or remap is performed, the results can vary significantly depending on the interpolation algorithm.
- It is only an approximation; therefore an image will always lose some quality each time interpolation is performed.



# Image Interpolation (Cont…)




In order to perform the gray level assignment, for any point in the overlay, we look for the closest pixel in the original image and assign its gray level to the new pixel in the grid. This method of gray level assignment is called **nearest neighbor interpolation**.

# Image Interpolation (Cont…)

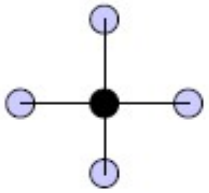
- **Pixel replication** is a special case of nearest neighbor interpolation.
- Pixel replication is applicable when we want to increase the size of an image an integer number of times.
- For instance, to double the size of an image we can duplicate each column (horizontal direction enlargement) or row (vertical direction enlargement).
- Image shrinking is done in similar manner as zooming and the equivalent process of pixel replication is row column deletion.
  - For example, to shrink an image by one half, we delete every other row and column.

# Image Interpolation (Cont…)

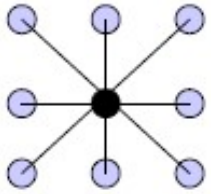
- **It is possible to use more neighbors for interpolation.**
- Using more neighbors implies fitting the points with a more complex surface, which generally gives a more smoother results.
- This is important in 3D graphics and medical image processing.
- Reading → http://www.cambridgeincolour.com/tutorials/image-interpolation.htm

# Neighbors of Pixels

Neighbors of a pixel $p=(i,j)$



$N_4(p)=\{(i-1,j),(i+1,j),(i,j-1),(i,j+1)\}$



$N_8(p)=\{(i-1,j),(i+1,j),(i,j-1),(i,j+1),$
$(i-1,j-1),(i-1,j+1),(i+1,j-1),(i+1,j+1)\}$

- A pixel *p* at coordinates *(x,y)* has 4 neighbors ( *(x+1, y), (x-1, y), (x, y+1), (x, y-1)* ). These four neighbors are denoted as $N_4(p)$
- Four diagonal neighbors of p have coordinates (*(x+1, y+1), (x+1, y-1), (x-1, y+1), (x-1, y-1)*). And are denoted by $N_D(p)$
- Eight neighbors of P denoted as;

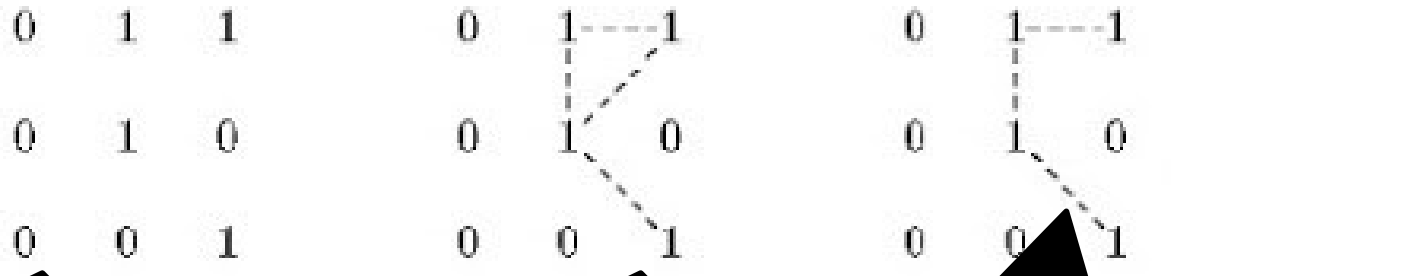
$$N_8(p) = N_4(p) + N_D(p)$$

# Adjacency of Pixels

- Two pixels are said to be connected, if they are neighbors and if their gray levels satisfy a specified criterion of similarity.

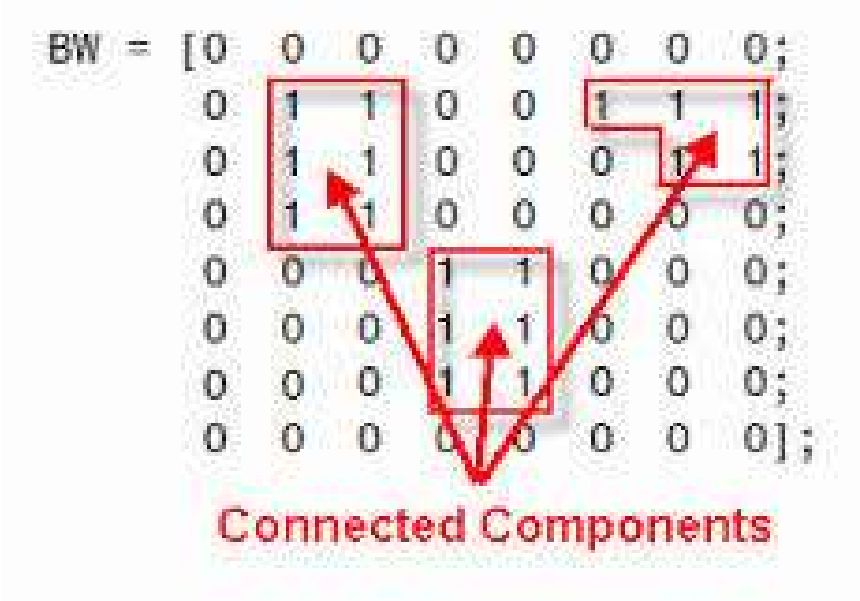
# Adjacency of Pixels (Cont…)

- There are three types of adjacency;
  - **4- adjacency** – two pixels ***p*** and ***q*** with values from ***V*** are 4-adjacent if ***q*** is in the set $N_4(p)$
  - **8-adjacancy** - two pixels ***p*** and ***q*** with values from ***V*** are 8-adjacent if ***q*** is in the set $N_8(p)$
  - **m-adjacency (mixed adjacency)** - two pixels ***p*** and ***q*** with values from ***V*** are m-adjacent if ***q*** is in $N_4(p)$ or ***q*** is in $N_D(p)$ and the set $N_4(p)$ intersect $N_4(q)$ has no pixels whose values are from ***V***.



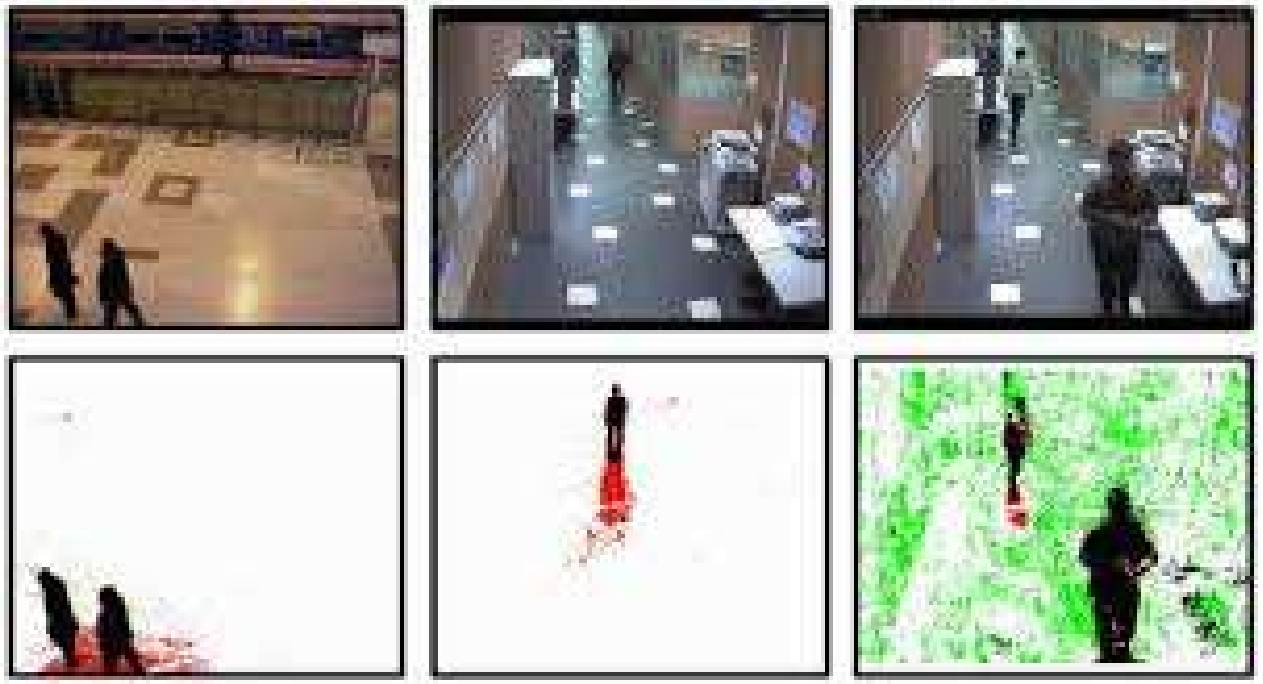
# Connectivity

- Let ***S*** represent subset of pixels in an image.
- Two pixels ***p*** and ***q*** are said to be connected in ***S*** if there exist a path between them consisting entirely of pixels in ***S***.
- For any pixel ***p*** in ***S***, the set of pixels that are connected to it in ***S*** is called **a connected component** of ***S***.
- If it only has one connected component, then set is called **connected set**.



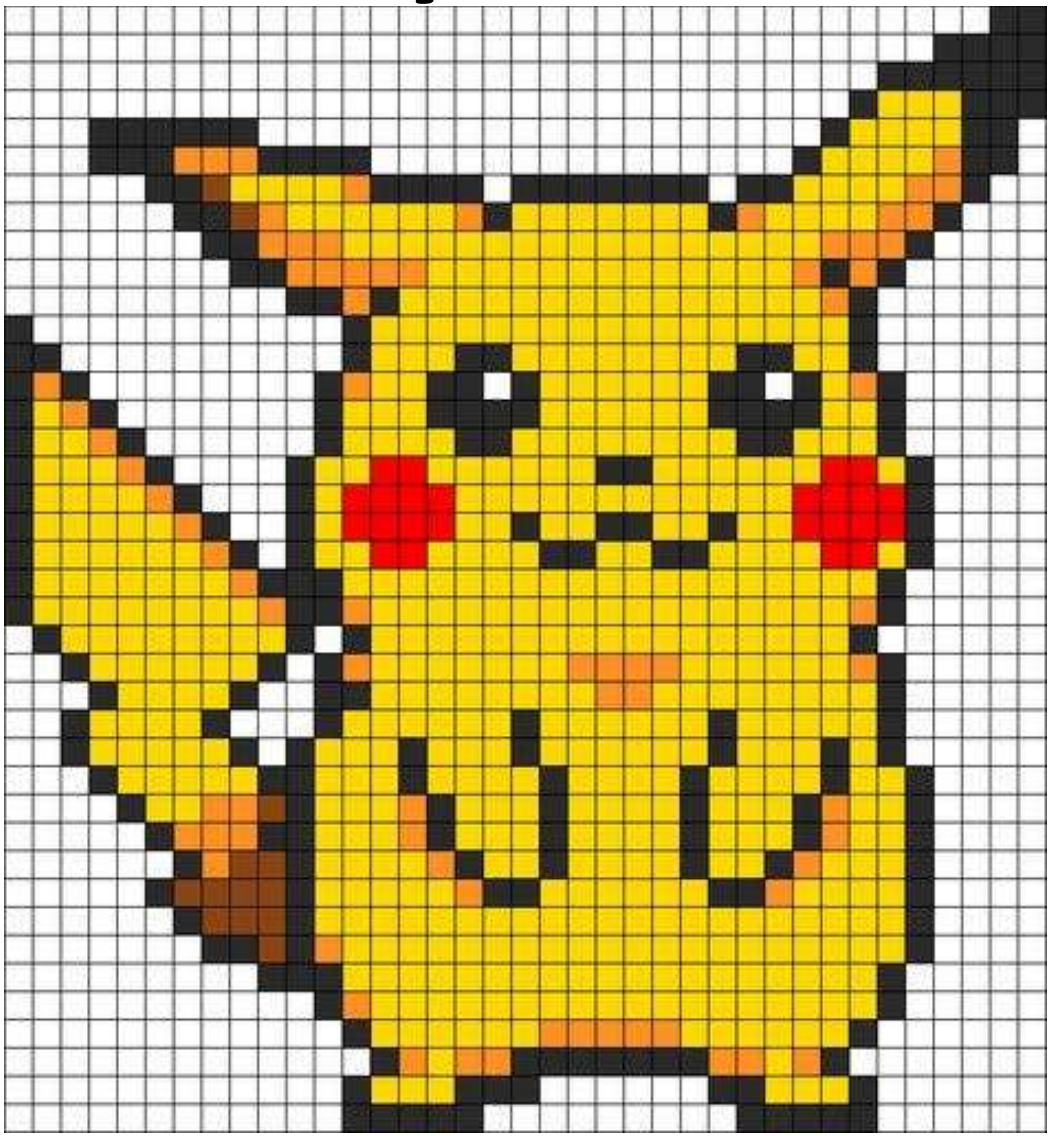
# Region

- Let ***R*** be a subset of pixels in an image.
- We call ***R*** a **region** of the image if ***R*** is a connected set.

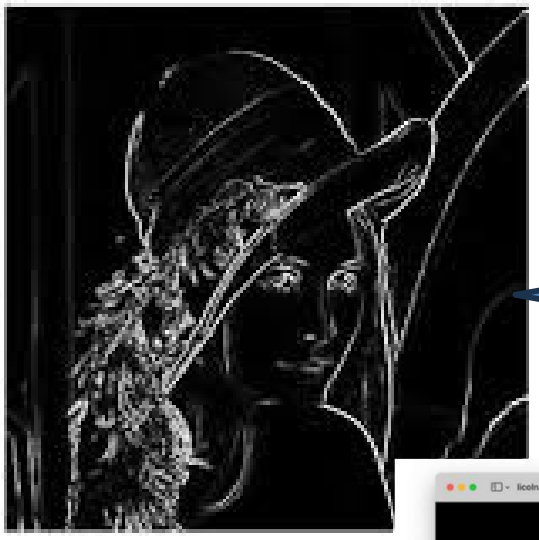


# Edge & Boundary

- **Edges** are formed from pixels with derivative values that exceed a preset threshold.
- **Thus, the idea of an edge is a local concept that is based on a measure of gray level discontinuity at a point.**
- It is possible to link edge points in to edge segments, and sometimes these segments are linked in such a way that correspond to boundaries, but this is not always the case.
- **It is helpful to think of edges as intensity discontinuities and boundaries are closed paths.**



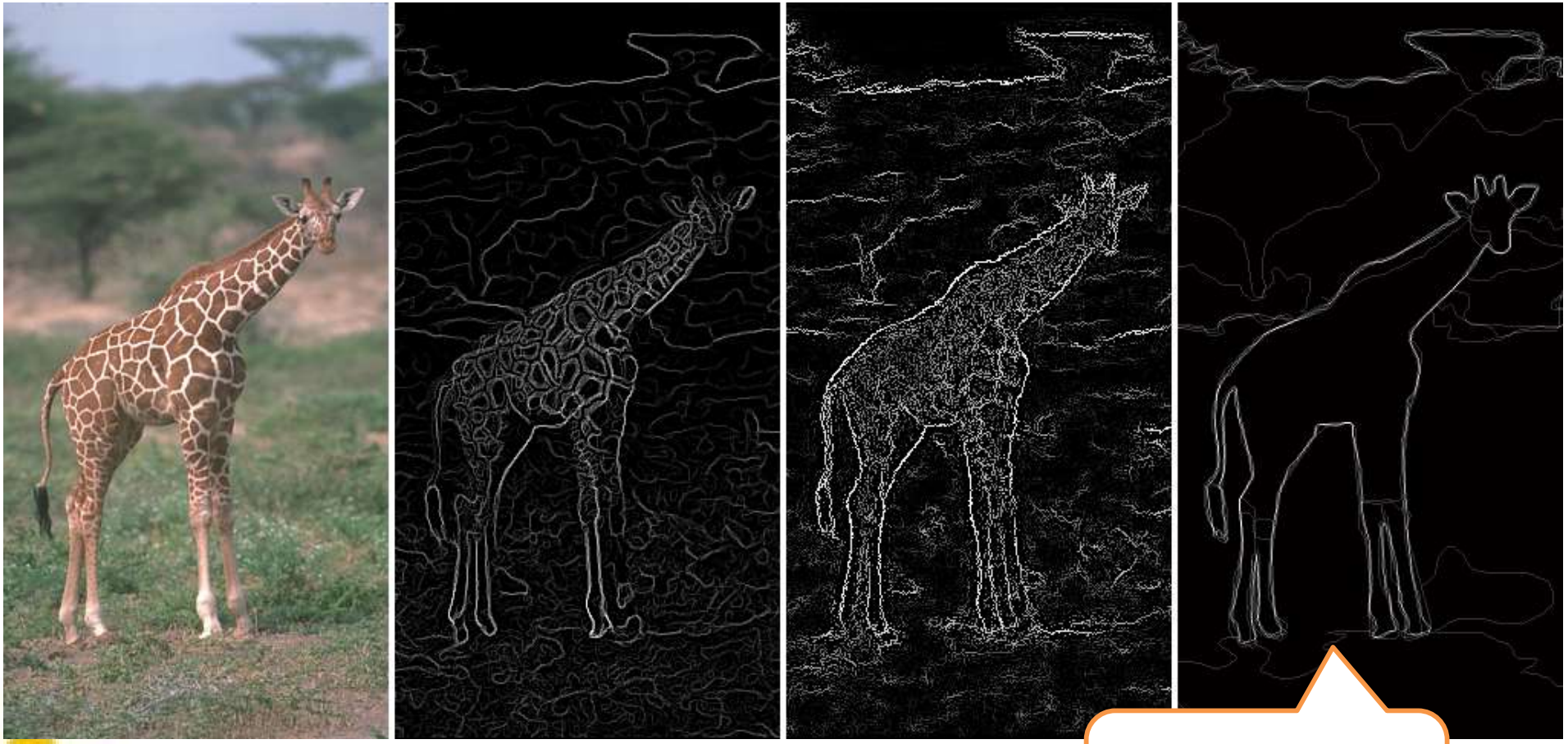
# Edge & Boundary (cont…)



Edges

Boundary


# Edge & Boundary (cont…)



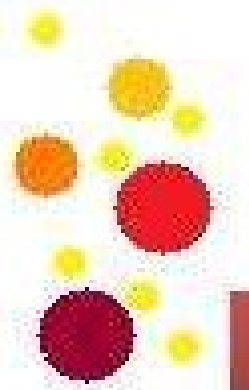
Boundary Detection

# Reference

- Chapter 02 of Gonzalez, R.C., Woods, R.E., Digital Image Processing, 3rd ed. Addison-Wesley Pub.

# Learning Outcomes Revisit

- Now, you should be able to;
  - describe spatial resolution
  - describe intensity resolution
  - identify the effect of aliasing
  - describe image interpolation
  - describe relationships among the pixels



Next Lecture – Color and Color Models

# QUESTIONS ?