INTRODUCTION TO DIGITAL IMAGE PROCESSING

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LEARNING OUTCOME

1. Able to describe steps in image processing
2. Able to identify image processing application domain
3. Able to explain process of image acquisition.
4. Able to understand and modify sampling and quantization rate.
5. Able to describe the mathematical representation and mathematical function of a digital image.

IMAGE PROCESSING STEPS

1. **Image Acquisition**
   - Image is acquired and brought into the system (e.g. digital camera, CAT scan)
   - Usually requires preprocessing, (e.g., scaling, sampling)
2. **Image Enhancement**
   - Image is made clearer to the user by enhancing some features of the image
   - This is a subjective operation, enhancement depends on users satisfaction

IMAGE PROCESSING STEPS (CONT.)

3. **Image Restoration** (this topic is not covered)
   - Image is improved
   - This operation is objective evaluated using mathematical model

4. **Color Processing**
   - Image colors and color transformation e.g., from display color space (red green and blue) into hardcopy printing space (cyan, magenta and yellow)

IMAGE PROCESSING STEPS (CONT.)

5. **Compression** (this topic is not covered**)**
   - Image archive size is reduced (storage, transmission)
   - Error free, and error prune compression

6. **Segmentation**
   - Image is partitioned into features (e.g. boundary of objects)

IMAGE PROCESSING STEPS (CONT.)

7. **Representation**
   - Color, shape or texture features are extracted to represent the objects in the image.

8. **Recognition**
   - Image objects are being identified based on their feature representations.

IMAGE PROCESSING IN MEDICAL DOMAIN

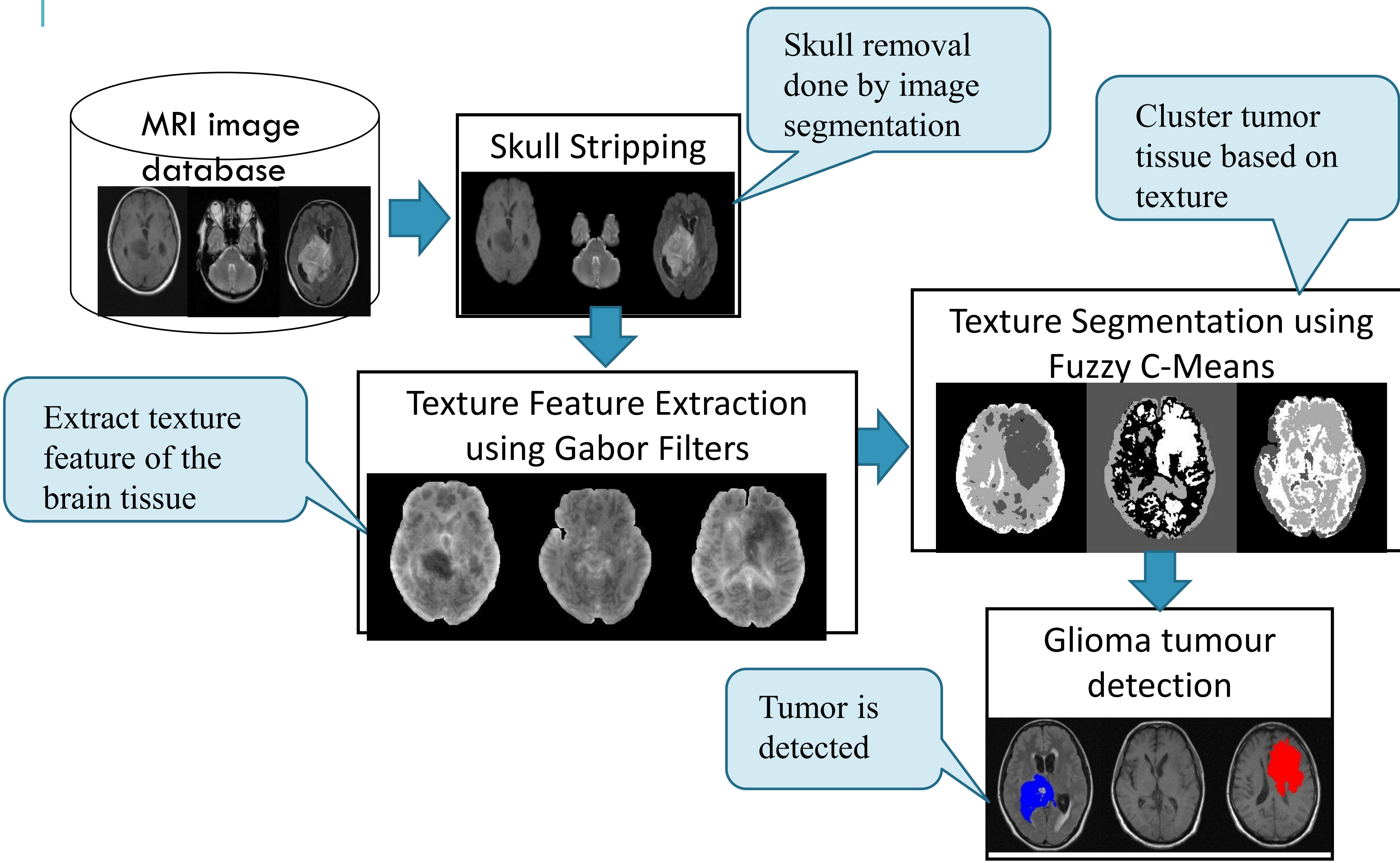


IMAGE PROCESSING IN TEXTILE DOMAIN

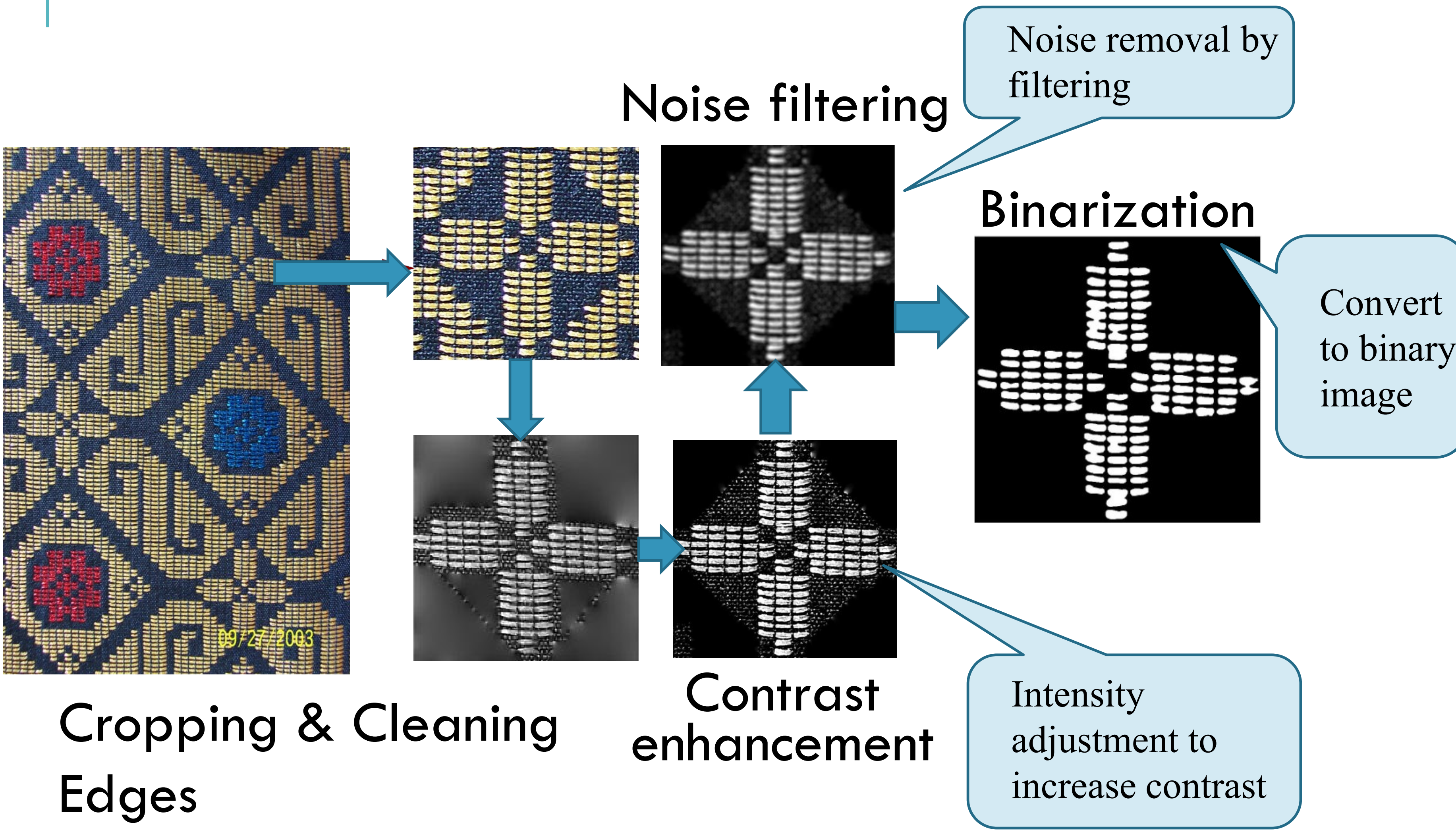
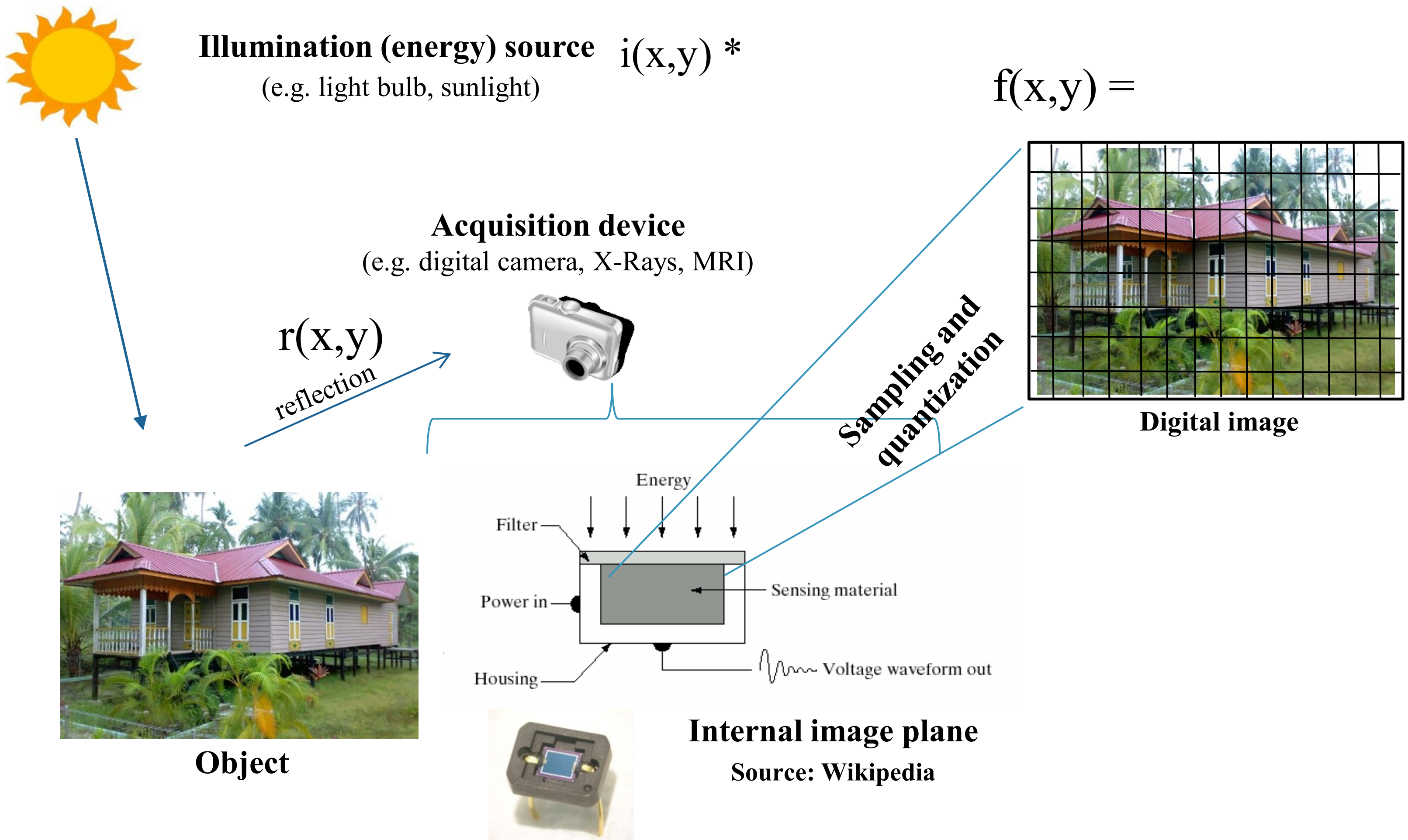
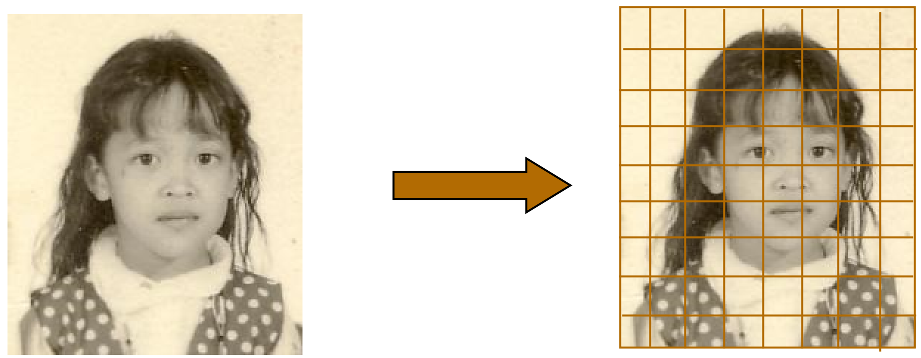


IMAGE ACQUISITION



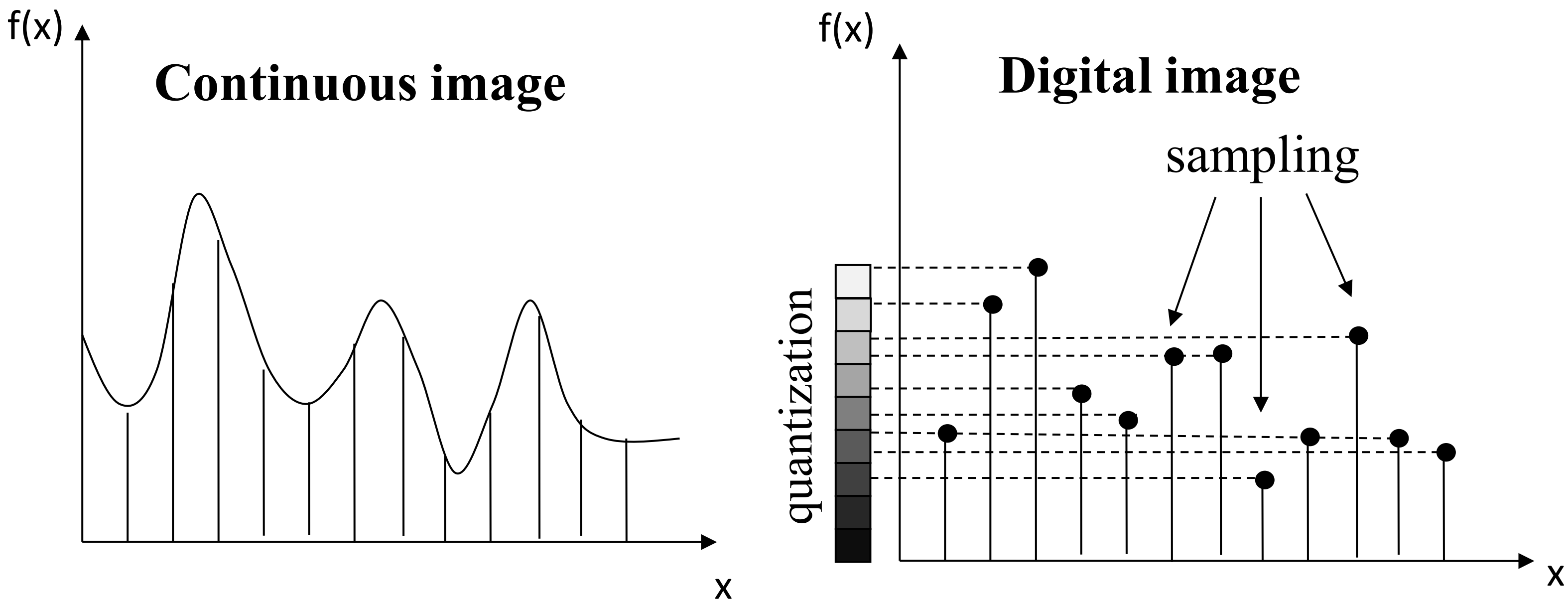
SAMPLING AND QUANTIZATION



Continuous image | Digital image

- Sampling is process of digitizing an analog image in a continuous space to a digital image in a discrete space. **Digitizing the coordinate values is called sampling.**
- The process of representing the amplitude of the continuous signal at a given coordinate as an integer value with different gray levels is usually referred to as quantization. **Digitizing the amplitude of the frequency is quantization.**

SAMPLING



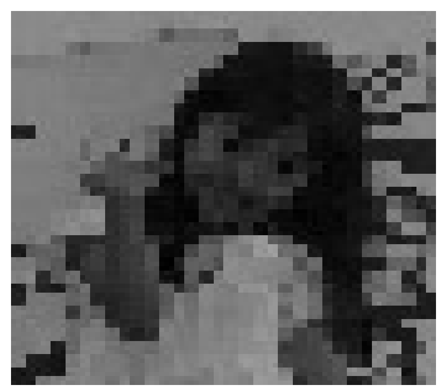
- Sampling determines the **spatial resolution** of the image. (i.e. image size)
- Each sample makes up a **pixel**. The higher the sampling rate, the more number of pixels, thus the bigger the size of the image.
- Each pixel has a gray level intensity, determined by quantization rate.

CHECKERBOARD EFFECT

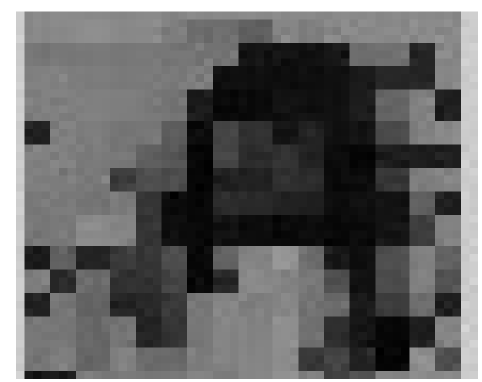
When a digital image is resize, the numbers of samples (i.e. pixels) are increase or decrease accordingly. An image is undersampled when too few samples, ***N*** are used to represent the image. This may cause the problem of **checkerboard effects** as new pixels are interpolated from existing pixels.

N=256

N=64



N=32



N=16

QUANTIZATION

- Quantization determines the Intensity resolution of the image (i.e. bit depth)
- Bit depth determines the gray levels allowed for each pixel. The higher the quantization rate, the bigger the bit depth, thus the more gray levels (i.e. colours) the image has.
- Gray levels are integer powers of two: $G = 2^{k}$, where k = number of gray levels. Therefore, if $k = 3$, $G = 2^3 = 8$. Therefore, an image with bit depth of 3 has 8 gray level values or 8 colours.

FALSE CONTOUR

Upon reducing the quantization rate to save storage space, false contouring may occur in the resulting image.

5-bit depth

4-bit depth

3-bit depth

2-bit depth

SPATIAL VS. INTENSITY RESOLUTION

- Sampling determines the smallest discernible detail in the image : spatial resolution
- Quantization determines the smallest discer gray level : intensity resolution

Point to ponder?

- How many samples and gray levels are required for a good approximation?
  - Resolution (the degree of discernible detail) of an image depends on sample number and gray level number.
  - i.e. the more these parameters are increased, the closer the digitized array approximates the original image.
  - But: storage & processing requirements increase rapidly as a function of N, M, and k

IMAGE FUNCTION

- Function f(x,y) can be characterized by two functions
  - illumination function $i(x,y)$, determined by illumination source
  - reflectance function $r(x,y)$, determined by objects in scene

- These two functions form:

$$f(x,y) = i(x,y)r(x,y)$$

  - where $0 < i(x,y) < \propto$ and
  - $0 < r(x,y) < 1$, 0 = total absorption, 1 = total reflectance

DIGITAL IMAGE REPRESENTATION

An image is represented as a matrix of size MxN

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

Digital Image

Image Elements
(Pixels)

ZOOMING AND SHRINKING

Zooming is oversampling while shrinking is undersampling for digital image.

Zooming:

1. Create new pixels.
2. Assign gray levels using nearest-neighbor or bilinear interpolation to these new pixel.

Shrinking:

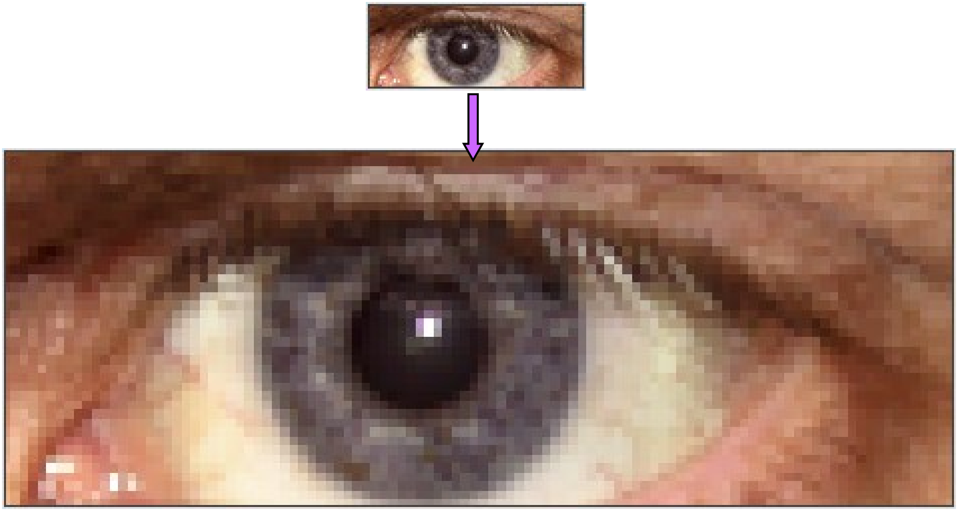
1. Select pixels using nearest-neighbor or bilinear interpolation to delete.
2. Delete pixels

PIXEL REPLICATION

- Simplest method, zooming factor is an integer
- Duplicating rows and columns of the original image.
- Produces checkerboard effects.

NEAREST NEIGHBOR INTERPOLATION

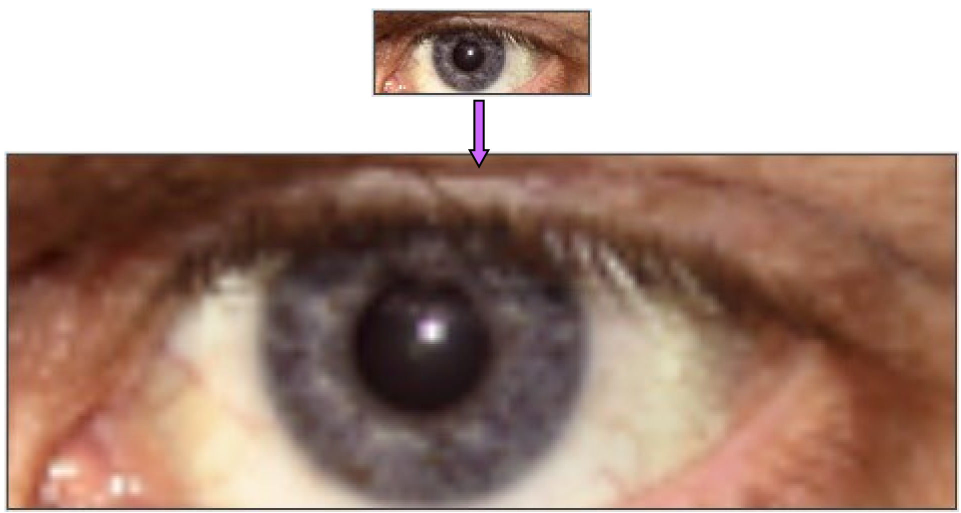
- Nearest neighbor interpolation is the simplest method of making the pixels bigger. The color of a pixel in the new image is the color of the nearest pixel of the original image.
- If you enlarge 200%, one pixel will be enlarged to a 2 x 2 area of 4 pixels with the same color as the original pixel.
- May produce severe distortions of straight edges.



Source: http://www.dpreview.com

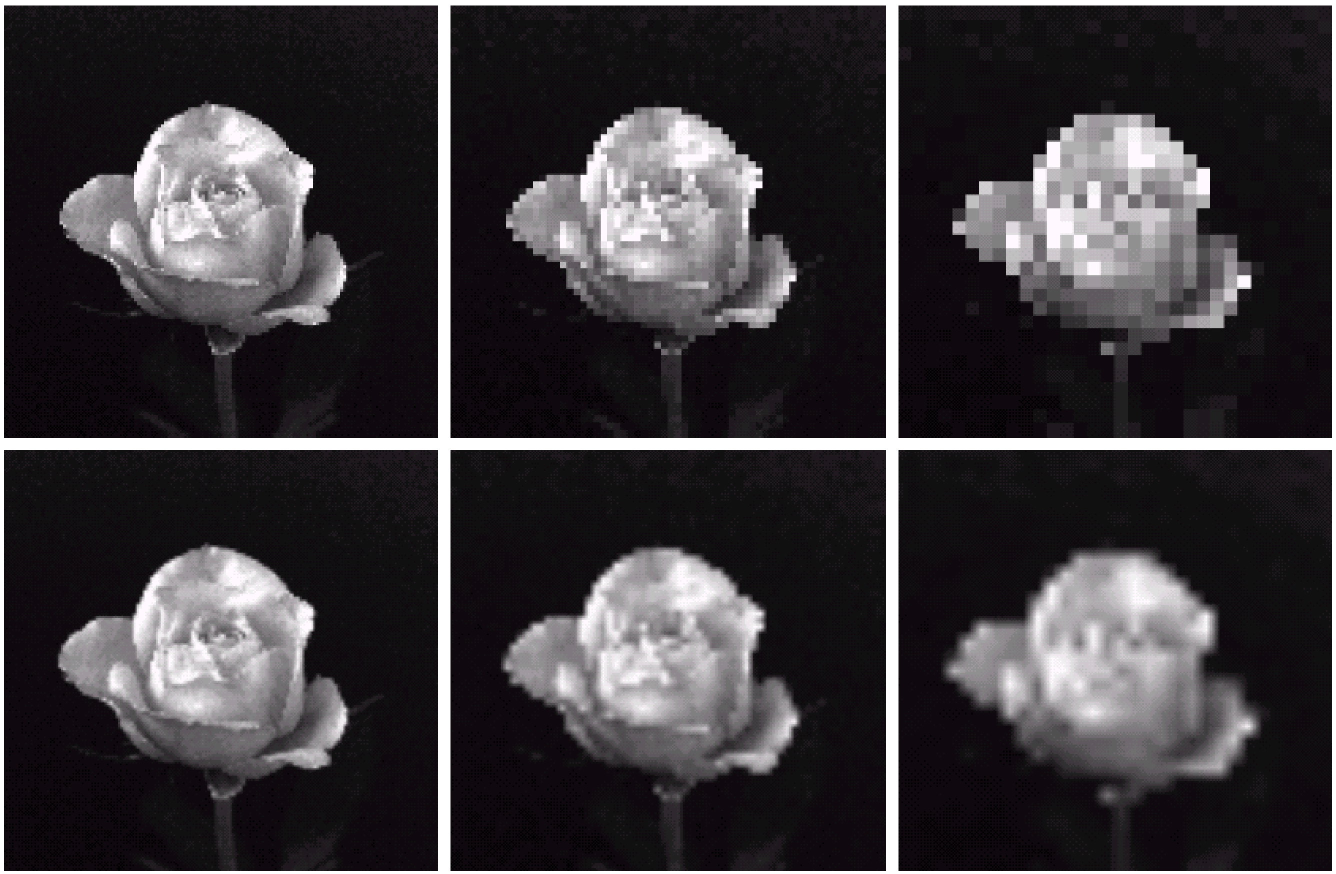
BILINEAR INTERPOLATION

- Bilinear interpolation determines the value of a new pixel based on a weighted average of the 4 pixels in the nearest 2 x 2 neighborhood of the pixel in the original image.
- The averaging has an anti-aliasing effect and therefore produces relatively smooth edges with hardly any jaggies.



Source: http://www.dpreview.com

BILINEAR VS. NEAREST-NEIGHBOR INTERPOLATION

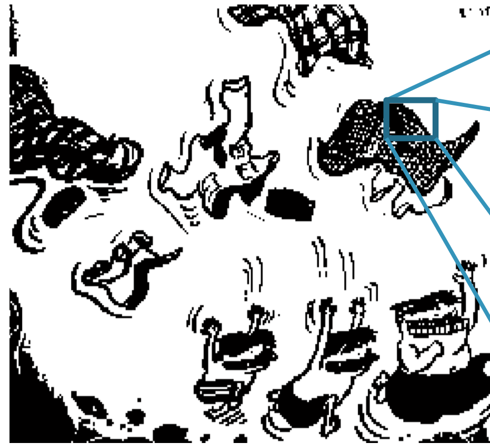


Source: Gonzales & Woods

IMAGE TYPES

Image type	**Data type**
Binary images	{0, 1}
Intensity (grayscale) images	{0, 1}, uint8, or uint16
Indexed images:	m-by-3 colour map matrix
RGB images	m-by-n-by-3 matrix

IMAGE TYPES (CONT.)



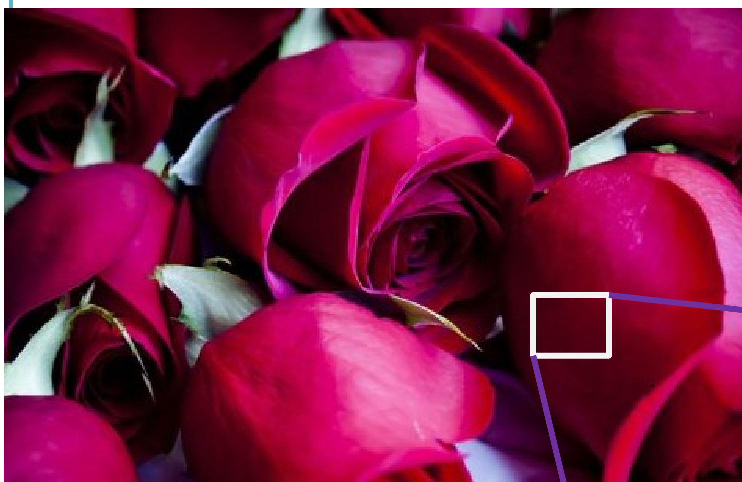
1	1	1	1	1	1	1	1	1	1
1	1	1	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1

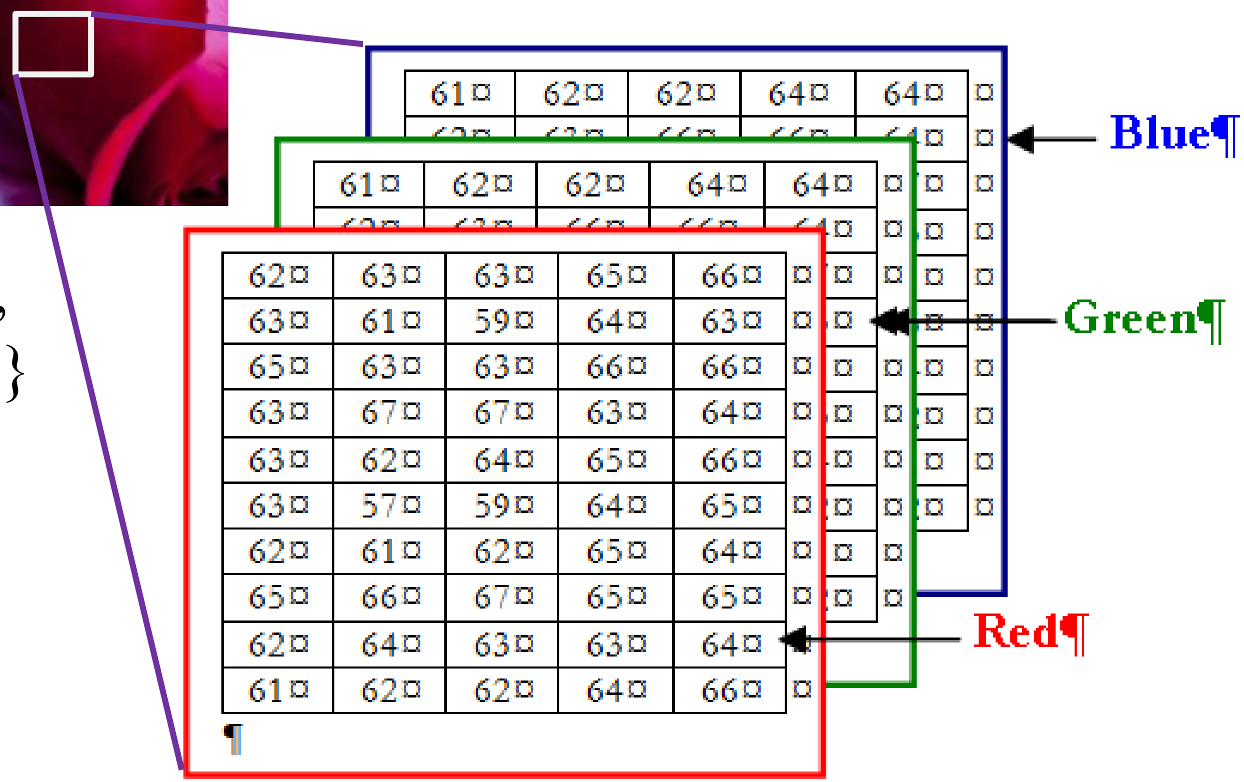
Binary images, row * col {0,1}

30	38	53	79	98	136	138	140	139
52	72	93	112	121	138	136	136	136
90	110	130	136	135	138	136	135	135
120	133	137	141	139	137	138	137	139
138	139	135	136	134	137	127	111	95
134	137	138	137	138	110	94	74	57
139	137	141	138	138	85	66	50	43
135	139	145	134	120	51	44	42	36

Grayscale images, row * col {0..255}

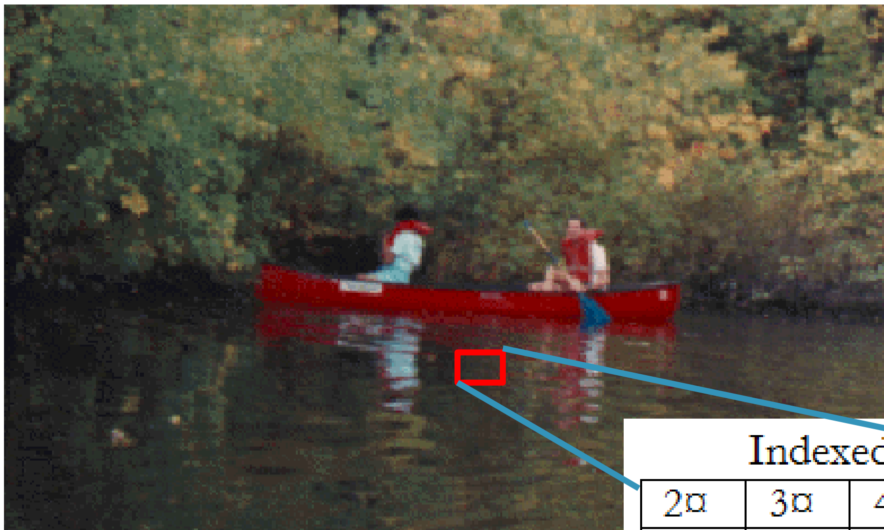
IMAGE TYPES





RGB color image, row*colx3 {0..255}

IMAGE TYPES (CONT.)



Indexed image, row*3 ,{0,255}

Indexed image

2	3	4	56	45
12	14	78	5	4
5	4	3	2	1
10	55	66	88	57
255	12	100	88	44
99	77	54	12	5
3	100	90	55	45
4	74	57	12	63
47	84	21	64	250
100	88	99	66	44

Colour map

1	121	62	25
2	65	45	33
3	2	45	78
4	126	15	66
5	215	14	36
6	69	68	61
:	:	:	:
:	:	:	:
255	60	20	145
256	88	54	122

Red Green Blue