Image Fundamentals

Digital image

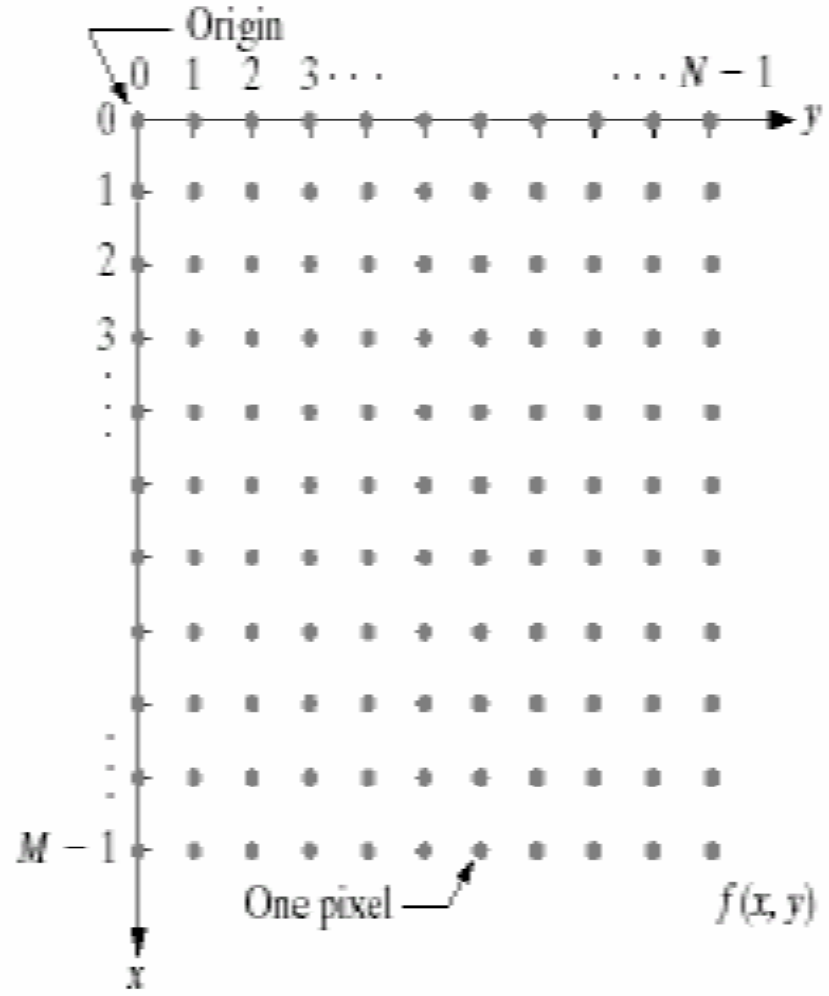


Image Matrix

Image

Digital Image

- An image is a 2D array of pixels
  - N pixels wide (columns)
  - M pixels high (row)
- Each **pixel** is a small square on the screen
- For gray image, each pixel has intensity associated with it (3^{rd} Dimension)
- For color image each pixel has a **color** associated with it
- Image requires 3D representation (row, column and pixel value)
- Digital image requires sampling and quantization of Camera Image

Image Resolution

- Gives the degree of distinguishable details of image
- Depends on sampling and quantization
- Broadly classified into

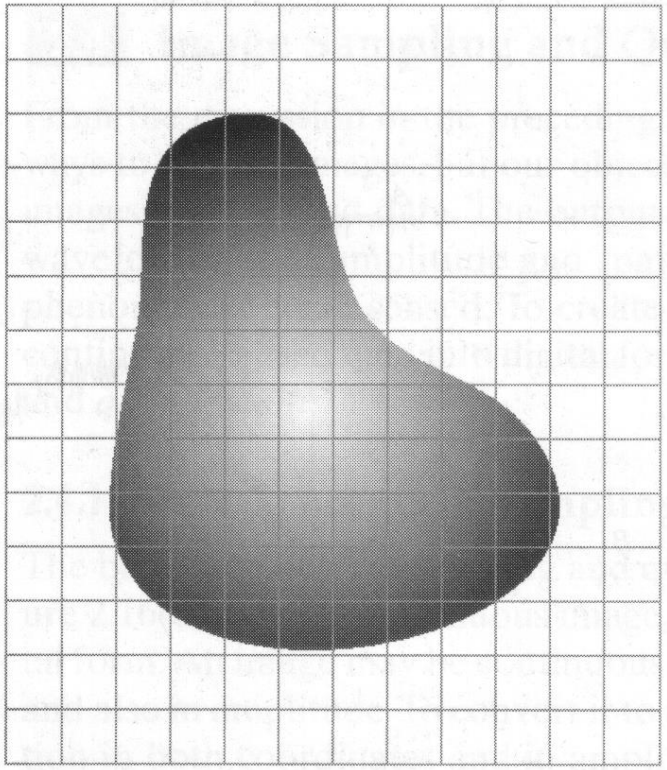
  (i) spatial resolution
  - smallest discernible detail in an image
  - depends on the number of pixels

  (ii) gray-level resolution
  - refers to the smallest discernible change in the gray level of pixels
  - depends on the number of gray levels

Image Sampling and Quantization

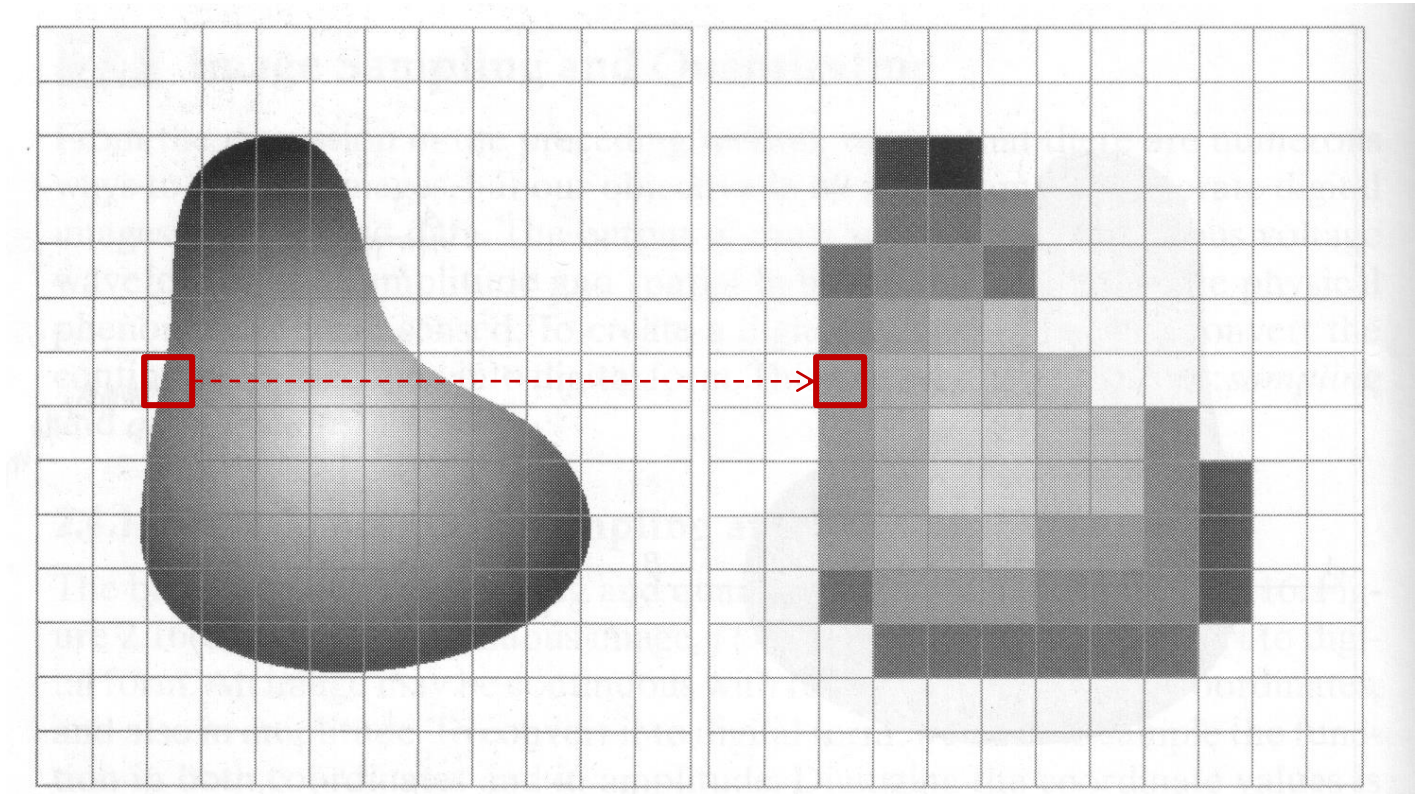
- Formation of digital image involves two processes:
  - sampling
  - quantisation
- Digitizing coordinates is called sampling
- Digitizing the amplitude values is called quantization

Image Sampling and Quantization



(a) Continuous image sampled in coordinates

Image Sampling and Quantization



(a) Continuous image to be sampled in coordinates

(b) Result of image sampling (14×12)

Intensity is assumed to be constant within each pixel (quantization)

Intensity Resolution of Image (n-bit image)

- Also called Gray level Resolution
- Represents value of each pixel

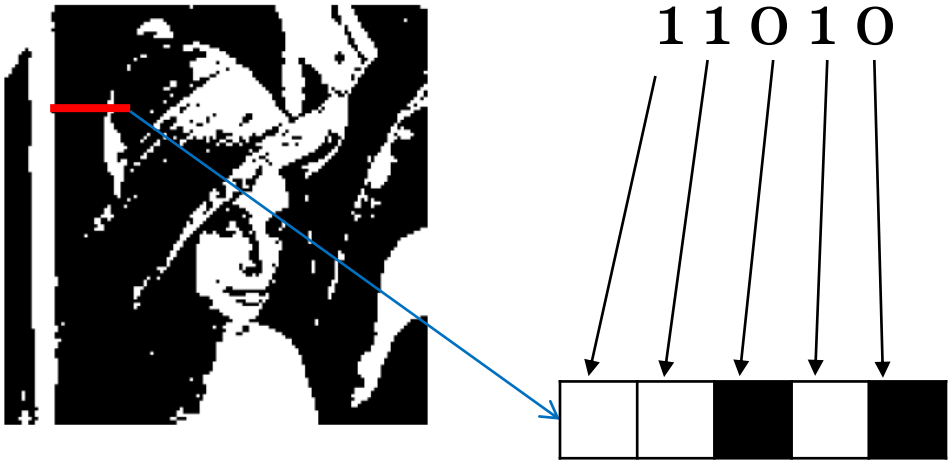
- Binary image (1-bit)

- Monochrome images (8 bit grey scale)

- Colour images (24 bit colour scale)

Binary Image (1bit/pixel)

- One bit to represent each pixel
- Pixel values are 0 or 255 ('0' or '1' if normalized)



A part of single row of image

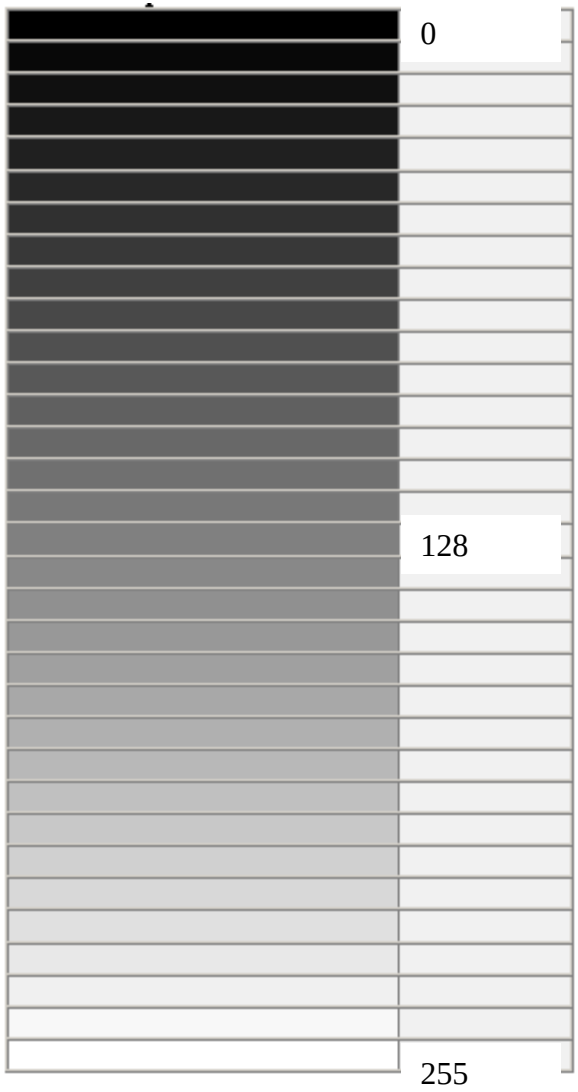
Image matrix (normalized)

1	0	…	1
0	1	…	1
:	:	…	:
1	1	…	1

Binary Image (1 bit/pixel)

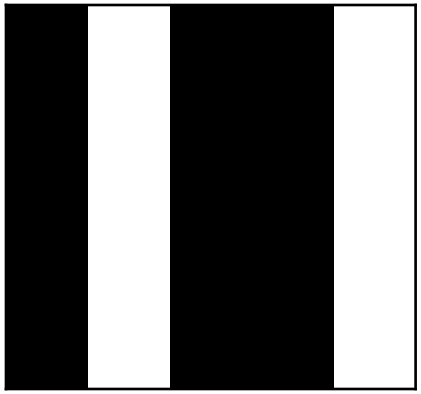
- Example: width 800 pixels (columns)
  height 600 pixels (rows)
- Size = 800*600 bits
  = 60,000 bytes

Pixel Intensity of Grey Image



For 8-bit image,
intensity range is 0-255

Digital Image and Image Matrix



Binary Image

0	255	0	0	255
0	255	0	0	255
0	255	0	0	255
0	255	0	0	255
0	255	0	0	255

Image matrix

Grey Image

255	255	255	255	255
100	100	100	100	100
50	50	50	50	50
0	0	0	0	0
50	50	50	50	50

Image matrix

Grey-scale 8-bit image

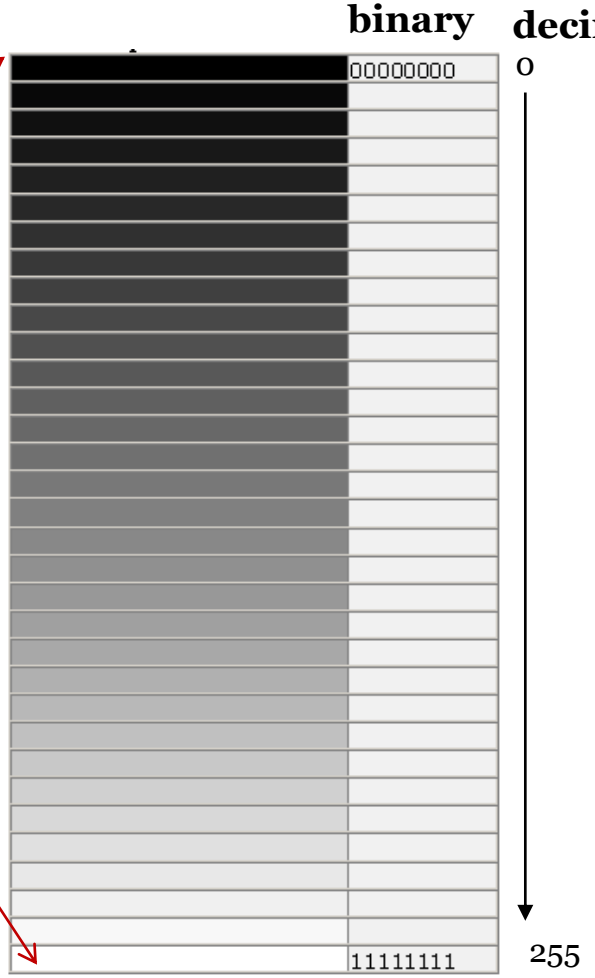
Image matrix (m×n)

10	0	…	86
22	33	…	75
:	:	…	:
255	51	…	100

Intensity range is 0-255

Grey-scale image (8 bits/pixel)

Grayscale image of Lena.



256 shades of grey

Gray Image (8 bits/pixel)

- Example: width 800 pixels (columns)
  height 600 pixels (rows)
- Size = 800×600×8 bits
  = 480,000 bytes

Compare binary and grey image

Size of image: 800×600

grey

Binary

1 pixel = 8 bits

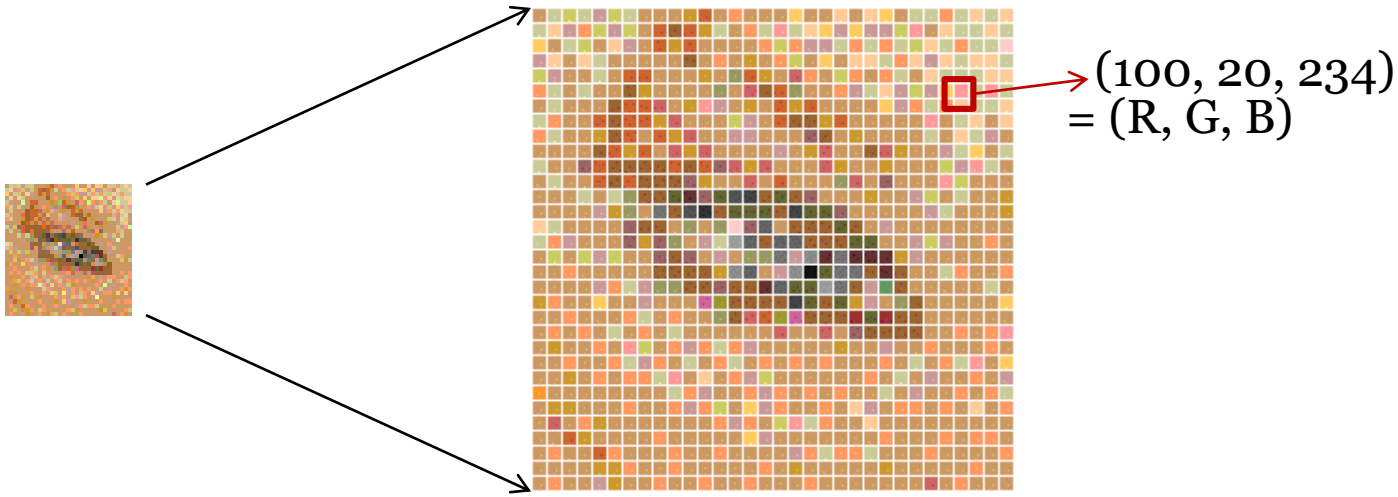
Image size= 480,000 bytes

1 pixel = 1 bit

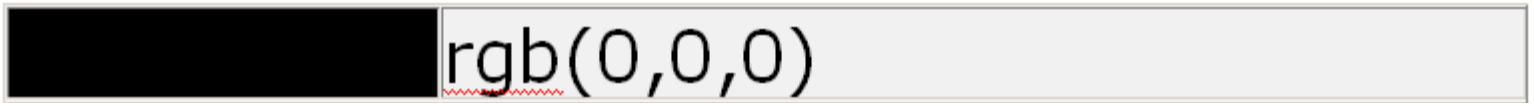
Image size = 60,000 bytes

Color Image Representation

- Each pixel is a combination of Red, Blue and Green color
- Each pixel is a combination of 3 colors (Red, Green, Blue)
- Therefore there are 3 values for each pixel
- Ex: at location (6,75), pixel value is (100, 20, 234)



RGB Colours (Red Green Blue)



RGB Colours (Red Green Blue)

	rgb(0,0,0)
	rgb(255,0,0)

RGB Colours (Red Green Blue)

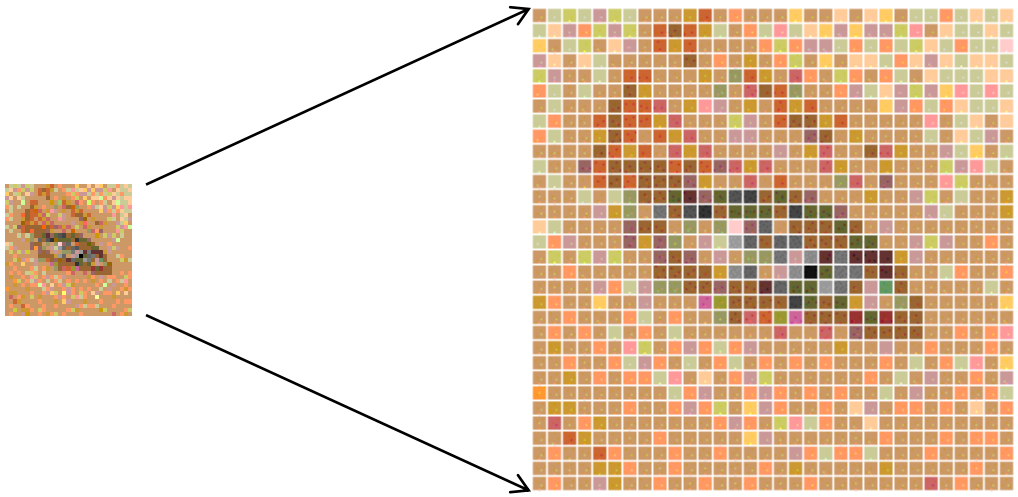
	rgb(0,0,0)
	rgb(255,0,0)
	rgb(0,255,0)

RGB Colours (Red Green Blue)

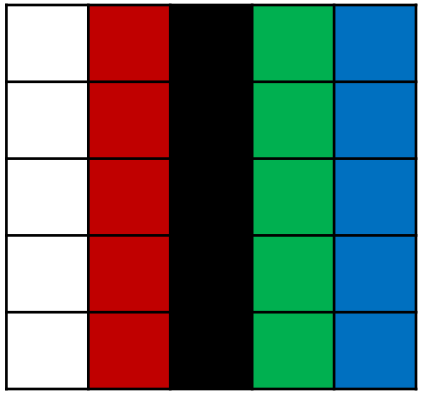
	rgb(0,0,0)
	rgb(255,0,0)
	rgb(0,255,0)
	rgb(0,0,255)
	rgb(255,255,0)
	rgb(0,255,255)
	rgb(255,0,255)
	rgb(192,192,192)
	rgb(255,255,255)

Color Image Representation

- Three planes (R, G and B) for each image
- Each plane uses 8 bits for each pixel
- Therefore each pixel is represented by 24 bits



Digital Color Image and Image Matrix



Image

255	255	0	0	0
255	255	0	0	0
255	255	0	0	0
255	255	0	0	0
255	255	0	0	0

Red component

255	0	0	0	255
255	0	0	0	255
255	0	0	0	255
255	0	0	0	255
255	0	0	0	255

Blue component

255	0	0	255	0
255	0	0	255	0
255	0	0	255	0
255	0	0	255	0
255	0	0	255	0

Green component

Size for grey (M x N) Image

- If k bits are is used to represent gray levels
- Then number of intensity levels

$$L = 2^k \text{ where } k = 1, 2, \ldots, 8$$

- Number of bits required to store a digitised image

$$= M \times N \times k$$

- It is a common practice to refer to the image as a "k-bit image"

Change 8-bit Image to b-bit Image

- 8 bits have 256 values with the range, {0, 1, 2,…,255}
  step size, S = 1 (=difference between 2 consecutive values)
  $S = 255/(2^b - 1) = 255/(2^8 - 1) = 1$
- For 8-bit (256 values) to 1 bit (2 values),
- $S = 255/ (2^1 - 1) = 255$
  256 values are converted to two values, {0, 255} → '0', '1'
- For 8-bit (256 values) to 2 bits
- $S = 255/ (2^2 - 1) = 85$
  256 values are converted to four values,
  {0, 85, 170, 255} → '00', '01', '10', '11'
- b bits have 2^b values, {0, S, 2S, …, 255},
  $S = 255/(2^b - 1)$

Ex: Change 8-bit Image to 3-bit Image

- Number of intensity levels for original 8-bit image= 256 = 2^8
- Number of intensity levels for new 3-bit image= 2^3
  - S = 255/(2^3-1) = integer(255/7) =36
  - New intensity values are
    {0, 36, 72, 108, 144, 180, 216, 252(or 255)}
  - Pixels in original image are mapped to new pixel value
  - Choose middle value for each range (for 0 to 36, middle value is 18)
  - First and last range has difference of 18

Pixel value in 8-bit image	0-18	19 -54	55-90	91-126	127-162	163-198	199-234	235-255
Mapped values for 3-bit image	0	36	72	108	144	180	216	255

0-18-36-54-72-90-.....235-255

Change 8-bit Image to 3-bit Image

Intensity values of 3-bit image {0, 36, 72, 108, 144, 180, 216, 252}

Pixel value in 8-bit image	0-18	19 -54	55-90	91-126	127-162	163-198	199-234	235-255
Mapped values for 3-bit image	0	36	72	108	144	180	216	255
Mapped to Binary	000	001	010	011	100	101	110	111

10	29	0	230
236	35	12	37
200	21	38	240
235	255	16	15

8-bit image

0	36	0	255
255	36	0	36
216	36	36	255
255	255	0	0

Mapped values for 3-bit image

Change 8-bit Image to 3-bit Image

Intensity values of 3-bit image {0, 36, 72, 108, 144, 180, 216, 252}

Pixel value in 8-bit image	0-18	19 -54	55-90	91-126	127-162	163-198	199-234	235-255
Mapped values for 3-bit image	0	36	72	108	144	180	216	255
Mapped to Binary	000	001	010	011	100	101	110	111

0	36	0	255
252	36	0	36
216	36	36	252
255	255	0	0

Mapped values for 3-bit image

000	001	000	111
111	001	000	001
110	001	001	111
111	111	0	0

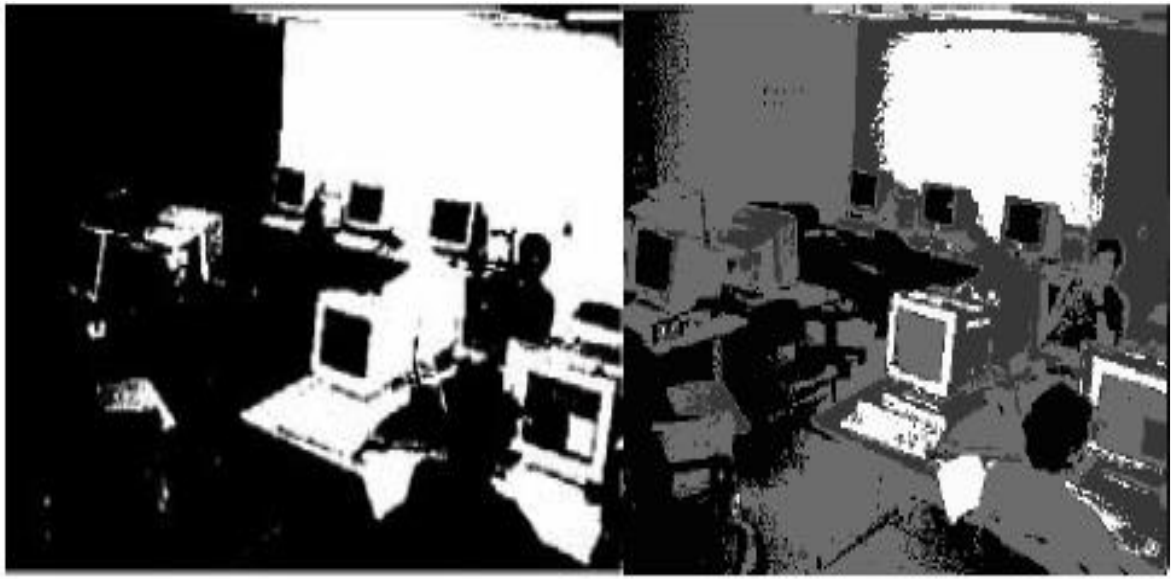
3-bit image

Various Grey Levels of monochrome/grey images

2 levels

1 bit/pixel

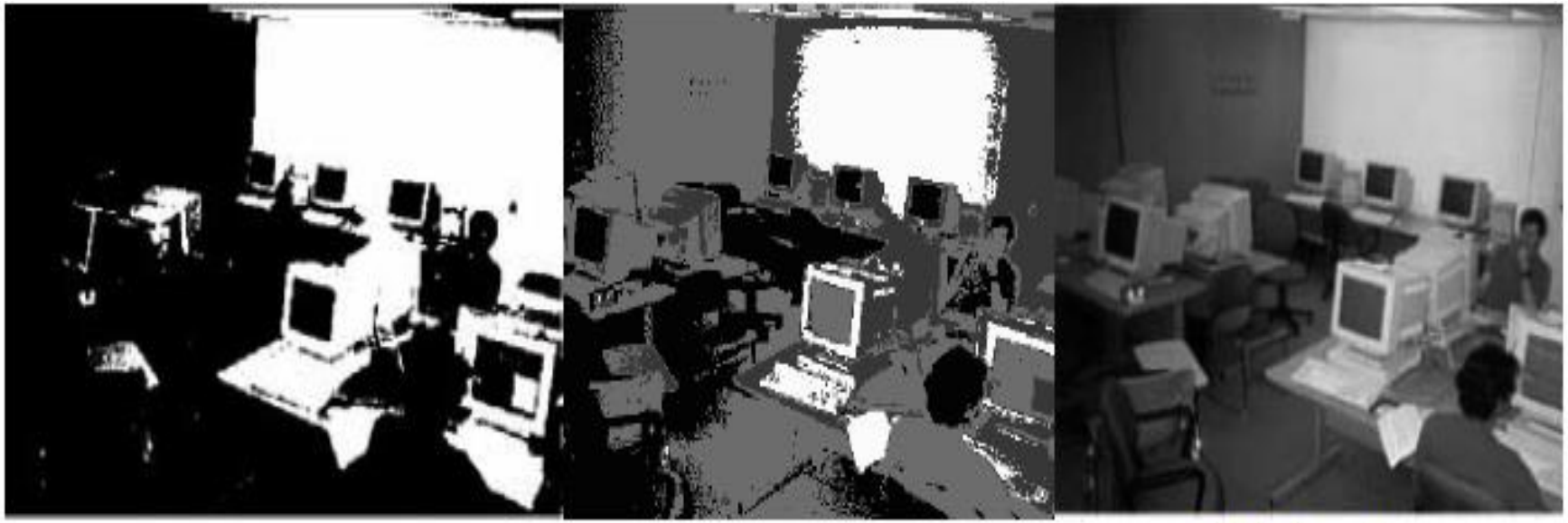
Various Grey Levels of monochrome images



2 levels
1 bit/pixel

4 levels
2 bits/pixel

Various Grey Levels of monochrome images



2 levels
1 bit/pixel

4 levels
2 bits/pixel

256 levels
8 bits/pixel

Intensity Resolution (number of bits/pixel)

- Good resolution
- useful for reading number plate

Intensity Resolution (number of bits/pixel)

- Good resolution
- Useful for reading number plate

- Poor resolution
- Useful for counting number of cars

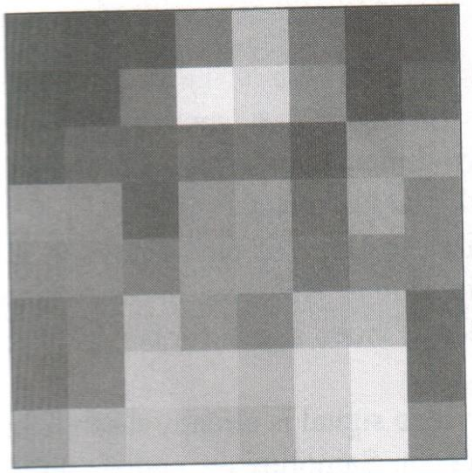
File Size for color image (800 x 600)

- 1 pixel = 24 bits = 3 bytes
- Image requires 800×600×3= 1,440,000 bytes
- Therefore files for colour images are large
- Since 24 bits are used to represent each pixel
- 2^{24} = 16 million colours are possible
- However, human eye can only perceive 10 million colors
- Therefore some levels can be avoided to compress image

Spatial Resolution (M x N)

Spatial Resolution (M x N)

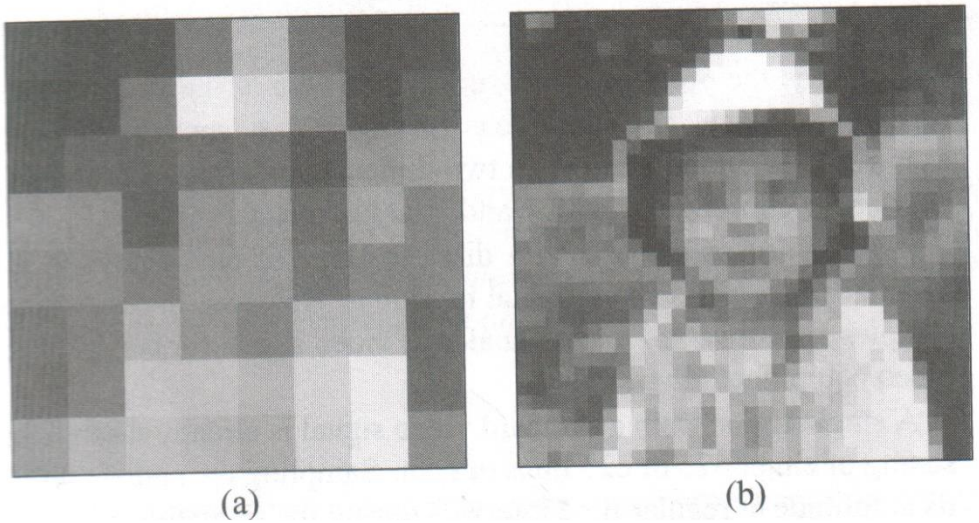
8x8 image



(a)

Spatial Resolution (M x N)

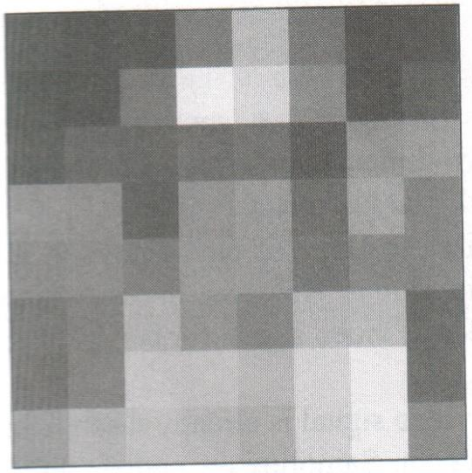
8x8 image



32x32 image

Spatial Resolution (M x N)

8x8 image



(a)

(b)

32x32 image

(c)

64x64 image

Spatial Resolution

- Depends on the number of pixels in an image
- It depends on the rows and columns
- An image can be either down sampled to reduce resolution or
- upsampled to increase resolution in spatial domain

Down sampling

2	1	0	2	2	5
0	1	6	1	1	6
4	0	6	0	6	4
6	2	5	1	7	6
7	5	7	0	4	0
1	3	3	0	5	7

Original Image Matrix

2	1	0	2	2	5
0	1	6	1	1	6
4	0	6	0	6	4
6	2	5	1	7	6
7	5	7	0	4	0
1	3	3	0	5	7

Delete highlighted rows/columns for sampling rate 2

2	0	2
4	6	6
7	7	4

Down sampled Image Matrix

For color image, each plane is sampled

Up sampling

2	0	2
4	6	6
7	7	4

Original Image Matrix

2	0	0	0	2	0
0	0	0	0	0	0
4	0	6	0	6	0
0	0	0	0	0	0
7	0	7	0	4	0
0	0	0	0	0	0

To be up sampled with sampling rate 2

2	0	0	0	2	0
3	0	3	0	4	0
4	0	6	0	6	0
6	0	6	0	5	0
7	0	7	0	4	0
0	0	0	0	0	0

Up sampled Image Matrix using averaging Method on columns

2	1	0	1	2	0
3	3	3	3	4	0
4	5	6	6	6	0
6	6	6	5	5	0
7	7	7	5	4	0
0	0	0	0	0	0

Up sampled Image Matrix using averaging Method on rows

Image file Formats

- Raster image files
  - Images are constructed by a series of pixels
  - or individual blocks, to form an image
- Vector image files
  - Far more flexible
  - Constructed using proportional formulas rather than pixels

Raster Image Files

- JPEG, GIF, and PNG
- Photo available online or in print is a raster image
- Pixels have a defined proportion based on their resolution (high or low)
- Cannot resize raster images without compromising their resolution

Vector image files

- EPS, AI and PDF are useful for creating graphics that require frequent resizing
- Logo and brand graphics are created as a vector image
- Can be resized as small as a postage stamp, or large enough to fit a large screen

Common file formats

- Numerous image file types are available
- Difficult to know which file type best suits the application
- Some image types such a TIFF are useful for printing
- Others, like JPG or PNG, are best for web graphics

Common file formats

- JPEG (or JPG) - Joint Photographic Experts Group
- Most common file type on the web
- known for their "lossy" compression,
  quality of the image decreases as the file size decreases
- There is no difference between the .jpg and .jpeg filename extensions
- Two extensions exist for the same format
- .jpeg was shortened to .jpg to accommodate the three-character limit in early versions of Windows
- .jpg remains the standard and default on many image software programs

PNG - Portable Network Graphics

- Useful for interactive documents such as web pages but are not suitable for print
- Lossless format
- can edit images and do not lose quality
- Used in most web projects because
- you can save image with more colors
- This makes for a much sharper, web-quality image

GIF - Graphics Interchange Format

- Most common in their animated form
- Formed from up to 256 colors in the RGB colorspace
- Due to the limited number of colors, the file size is drastically reduced
- Useful when an image needs to load very quickly with lower level of quality

TIFF - Tagged Image File

- Large raster file that doesn't lose quality
- lossless compression
- original image data is maintained regardless of how it is copied, re-saved, or compress the original file

PDF - Portable Document Format

- Invented by Adobe with the goal of capturing and reviewing rich information from any application on any computer, with anyone, anywhere
- This is by far the best universal tool for sharing graphics

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