Digital Images

Agenda

- Images can be stored as bitmaps or be vector-based
- The points at which an image is sampled are known as picture elements (pixels)
- Colour bitmap images can be true-colour or index-based

Images can be stored as bitmaps or be vector-based

Image Files

All images are displayed on a computer screen as a grid of "pixels" of various colours. The image files that contain these images store that image data in one of **two** fundamentally different ways:

Bitmapped images: map of individual pixels (GIF or JPEG)

Vector-based images: a set of mathematical formulas to instruct how to draw the image

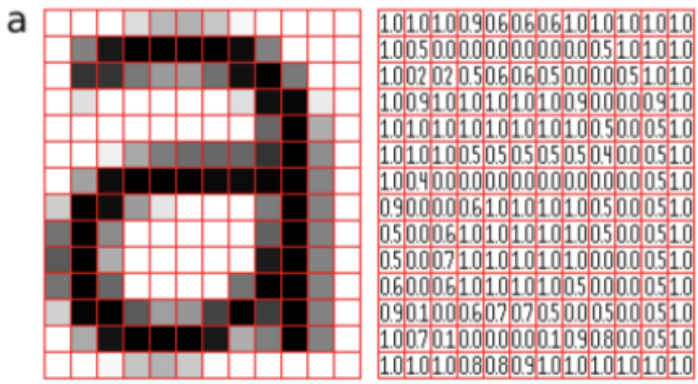
Bitmapped Vs. Vector-based

Bitmap images (also called pixmaps or raster graphics): created with a pixel-by-pixel specification of points of color.

- Bitmaps are commonly created by digital cameras, scanners, paint programs like Corel Paint Shop Pro, and image processing programs like Adobe Photoshop

Vector graphic images: use object specifications and mathematical equations to describe shapes to which colours are applied.

```
draw circle
     center        0.5, 0.5
     radius        0.4
     fill-color    yellow
     stroke-color  black
     stroke-width  0.05
draw circle
     center        0.35, 0.4
     radius        0.05
     fill-color    black
draw circle
     center        0.65, 0.4
     radius        0.05
     fill-color    black
draw line
     start         0.3, 0.6
     end           0.7, 0.6
     stroke-color  black
     stroke-width  0.1
```



Advantages & Disadvantages

Bitmapped disadvantage:

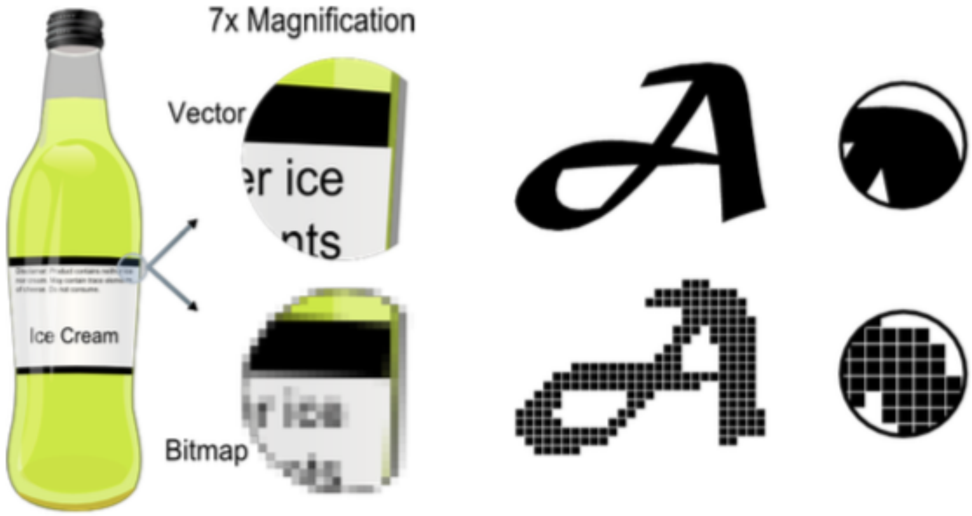
1. bigger
2. less scalable
3. when zooming, you can see individual pixels
4. store color info. for each individual pixel

Vector-based advantage:

1. Can be displayed in any size without losing quality

BP images will loss quality because the samples are fixed — numbers and they can't streched without compromising their appearance

2. Easy to be edited by changing instructions space
Vector-based disadvantage:
1. Only contain instructions
2. Can only deal with simple images



Pixels

Image Sampling and Quantization (gray scale images)

A digital image is represented by a matrix of numeric values, each representing a quantized intensity value. e.g. I (row, column)
The intensity at each pixel is represented by an integer and is determined from the continuous image by averaging over a small neighbourhood around the pixel location

- E.g. when 8-bit integers are used to store each pixel value, the gray scale levels range from 0 (black) to 255 (white)

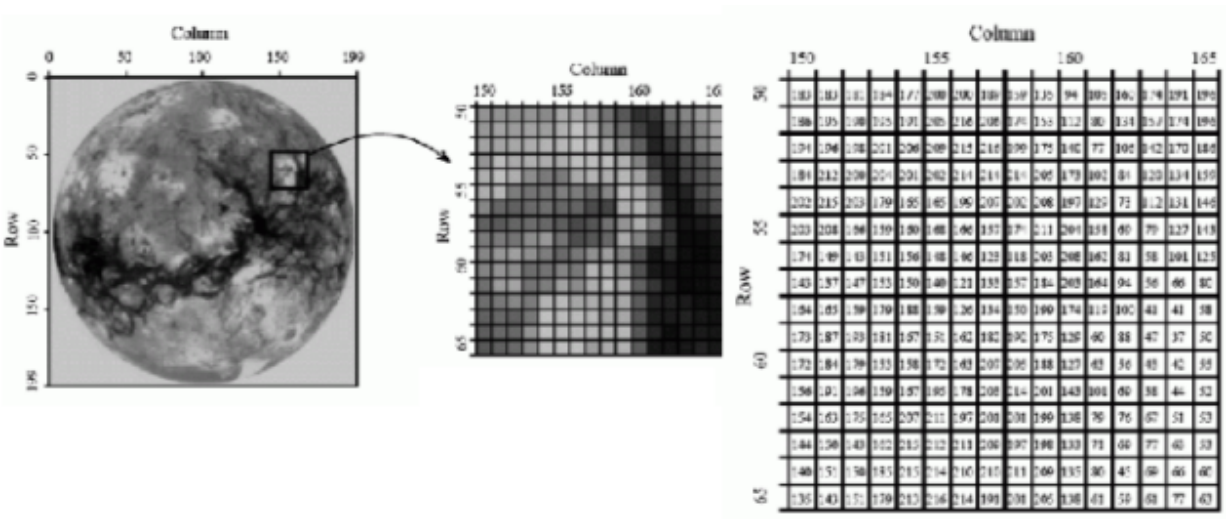


Image sampling

square sampling grid with pixels equally spaced along the two sides of the grid

Sampling error and quantization error

Images undersampled - distortion (Sampling error)

Reduced bit depth - lack of precision (Quantisation error)

Digital cameras

Digital cameras use the same digitisation process discussed already: sampling and quantisation

Sampling rate is a matter of how many points of color are sampled and recorded in each dimension of the image

- A digital camera might allow you to choose from: 1600x1200, 1280x960, 1024x768, 640x480

Quantization is a matter of the color model used and the corresponding bit depth

Digital cameras generally use RGB, which saves each pixel in three bytes, one for each of the color channels: red, green, and blue. Since three bytes is 24 bits, this makes it possible for $2^{24} = 16,777,216$ colors to be represented

Example: image file

Sampling: 1024 pixels x 768 pixels (samples) Bits per pixel: 24

Solution:

$$\text{File size} = \frac{1024 \cdot 768 \cdot 24}{8} = 2359296 \text{ bytes} = 2.36 \text{ MB}$$

Pixel dimensions

For an image file, **pixel dimensions** is defined as the number of pixels (the "**logical pixels**") horizontally and vertically, e.g. 1600x1200 (logical pixels)

- **computer screen** has a fixed maximum pixel dimensions (the "**physical pixels**"), e.g. 1024x768 or 1400x1050 (physical pixels)

When you display a bitmap image on your computer, the logical pixel is mapped to a physical pixel on the computer screen

Image resolution

- The number of pixels per inch is the **image resolution**.
- It is assumed that the same number of pixels are used in the horizontal and vertical directions.
- Typically, monitors have a screen resolution of 72 ppi (pixels per inch).

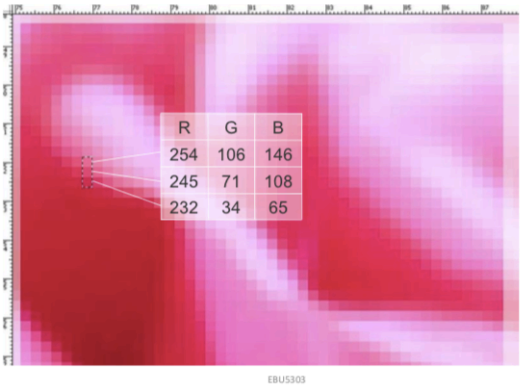
(The image resolution is depended on both the pixel dimension and the physical size of the monitor)

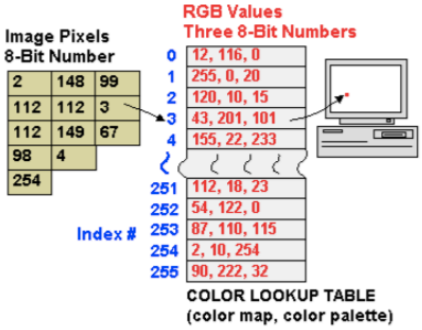
Colour bitmap images can be true-colour or index-based

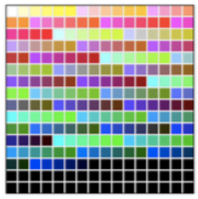
Stored Image Formats (2 formats)

RGB formats: true-colour, use 8 bits of data for each Red, Green, and Blue value. Together, this forms a 24-bit pixel palette which has 16.7 million colours

Indexed formats: are mapped to a smaller colour palette (CLUT): 256-colours or less (normally). The indexed image's palette contains all of the colours that are available for the image.







CLUT (Colour Look Up Table)

Digital Image File Type:

If you take a picture with a digital camera, you need to choose of file types, in which to save the image

Not all color models can be accomodated by an file types. Some file types require the image be compressed while some do not

4 important things for bitmap filetype:

- Color model
- Bit depth
- Compression type, if any
- Operating system, browser, application software that support it

Exercise

A 200 by 300 pixel image is stored in different formats. Calculate its size in Kbytes in the following cases:

- True colour image
- Greyscale (8 bits image)
- 4 bits indexed format

Solution:

1. $\dfrac{200 \cdot 300 \cdot 24}{8} = 180\text{ KB}$
2. $\dfrac{200 \cdot 300 \cdot 8}{8} = 60\text{ KB}$
3. $\dfrac{200 \cdot 300 \cdot 4}{8} = 30\text{ KB}$

Give two possible strategies for reducing the colour depth of a true colour image to just a third of its original one.

1. Convert the true colour image to the grayscale image
2. Using a CLUT with 8 bits colours (256 colours) for the image

A Colour Look-Up Table with 256 entries is used.

- Calculate the reduction in the size of the bitmap when a CLUT is used instead of true colour.
- Comment on how use of the CLUT will affect the appearance of the image on the screen.

- If the first entry in the CLUT has value 0,0,0, what colour would be stored there?

Solution:

1. 8 bits/sample are used instead of 24/sample bits for quantization rate
2. The precision is lower than the original image, since some colors that are needed in the image are missing
3. Black

Questions in test:

c) Consider a video with the following properties: frame size is 1280-by-720-pixels; colour depth is 24-bits; frame rate is 30 fps; duration is 1 minute.

[5 marks]

i) How much data rate reduction can be achieved by reducing the width and height of this video to half? Prove your answer by calculating the data rates.

(3 marks)

ii) Give two possible strategies for reducing the colour depth of the video to just a third of its original depth.

(2 marks)

(1) original data rate: $1280 \cdot 720 \cdot 24 \cdot 30 = 663.552$ Mbps
Data rate after reduction: $640 \cdot 360 \cdot 24 \cdot 30 = 165.888$ Mbps
Data rate reduction = 663.552 - 165.888 = 497.664 Mbps
(2) First, convert the each frame of the video to its grayscale version
Second, mapped each frame into a CLUT with 256 colours (8 bits) of the video

c) This question is about image encoding.

[5 marks]

i) Calculate the size in kilo bytes (KB) of a 200 x 300 pixels true colour image.

(3 marks)

ii) Now calculate the size of the grayscale version of the same image.

(2 marks)

(1) File size $= \dfrac{200 \cdot 300 \cdot 24}{8} = 180$ KB

(2) Grayscale File size $= \dfrac{200 \cdot 300 \cdot 8}{8} = 60$ KB

c) Consider the three images shown in Figure 1. Image 1(a) is the original grayscale image.
i) Image 1(b) is the same image as in 1(a) obtained with a lower sampling rate. Explain its appearance. (3 marks)
ii) Image 1(c) is the same image as in 1(a) obtained with a lower quantisation rate. Explain its appearance. (3 marks)

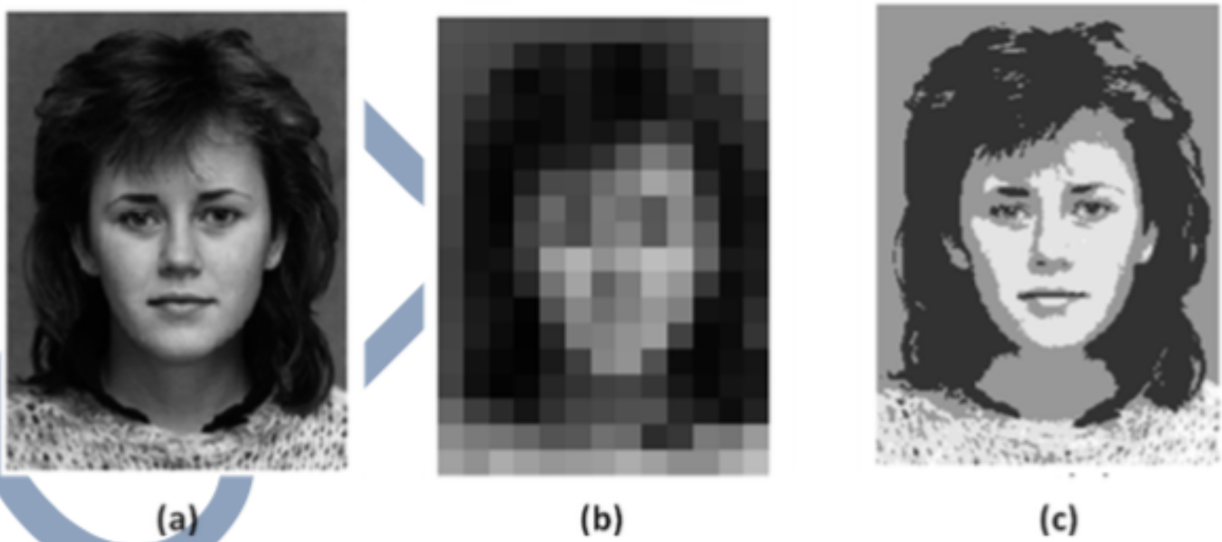


Figure 1

(1) The image appears blocky, because it losses pixel information, which is a case of aliasing.
(2) The iamges show that the colors are not gradually changed. Since the bit depth is not enough, the limited number of gray colours cannot cover all the gray colours needed by every pixels. It can be improved by dithering or noise shaping.

Solution:

i) The image appears blocky because missing pixel information must be interpolated over a number of pixels. This is a case of aliasing.

ii)The image shows large areas of uniform gray level, this is because there is not enough bits to encode all the different shades of gray of the original image. Using dithering could improve its appearance.