

EBU5303

Multimedia Fundamentals

Digital Images

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Learning Objectives

- Discuss and compare image representations (bitmaps versus vector-based).
- Define image resolution.
- Explain how colour information can be stored in bitmaps.
- Compare image file types.

Reading



<http://burg.cs.wfu.edu/TheScienceOfDigitalMedia/Chapter2/ch2scienceofdigitalmedia.pdf>

2.2 Bitmap

<http://burg.cs.wfu.edu/TheScienceOfDigitalMedia/Chapter3/Ch3ScienceOfDigitalMedia.pdf>

3.2 Digital Image File Types

3.3 Indexed Color

Reading



[Fundamentals of Multimedia](#), by Ze-Nian Li, Mark S. Drew, Jiangchuan Liu (3rd edition)

Chapter 3: Graphics and Image Data Representations

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

Bitmapped Vs. Vector-based

- 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 image files store image data as a **map of individual pixels** (e.g. GIF and JPEG).
 - Vector-based image files store image data as a set of **mathematical formulas** that instruct the computer how to draw the image.
- Some file formats, such as PNG, contain both bitmapped and vector-based image data.

Bitmapped Vs. Vector-based

- ***Bitmap images*** (also called ***pixmaps*** or ***raster graphics***) are created with a pixel-by-pixel specification of points of colour. ***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***—created in programs such as Adobe Illustrator and Corel Draw—use object specifications and mathematical equations to describe shapes to which colours are applied.

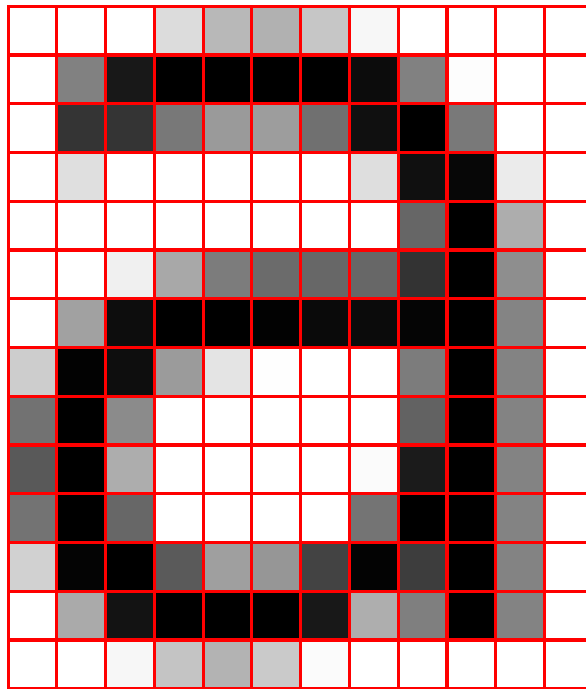
Vector-based image

```
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
```



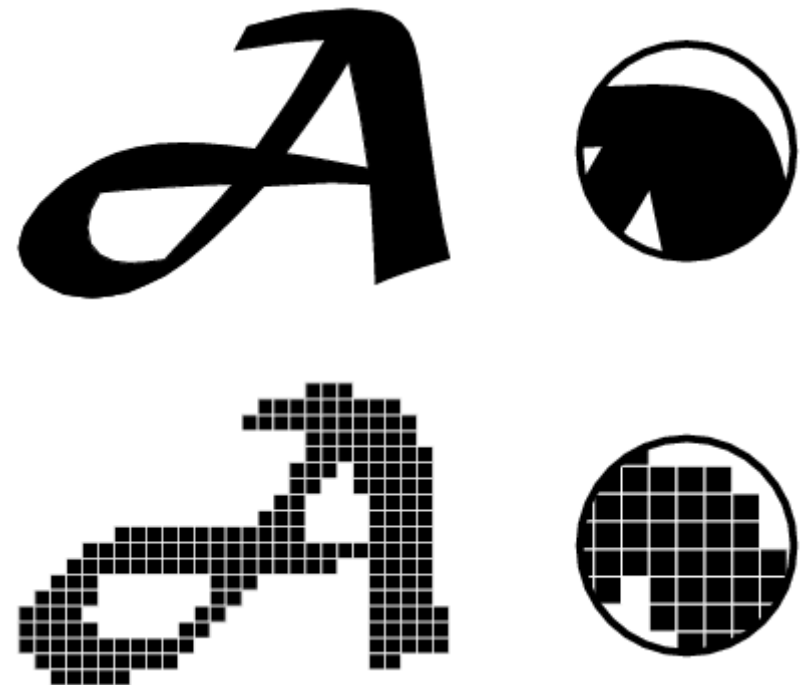
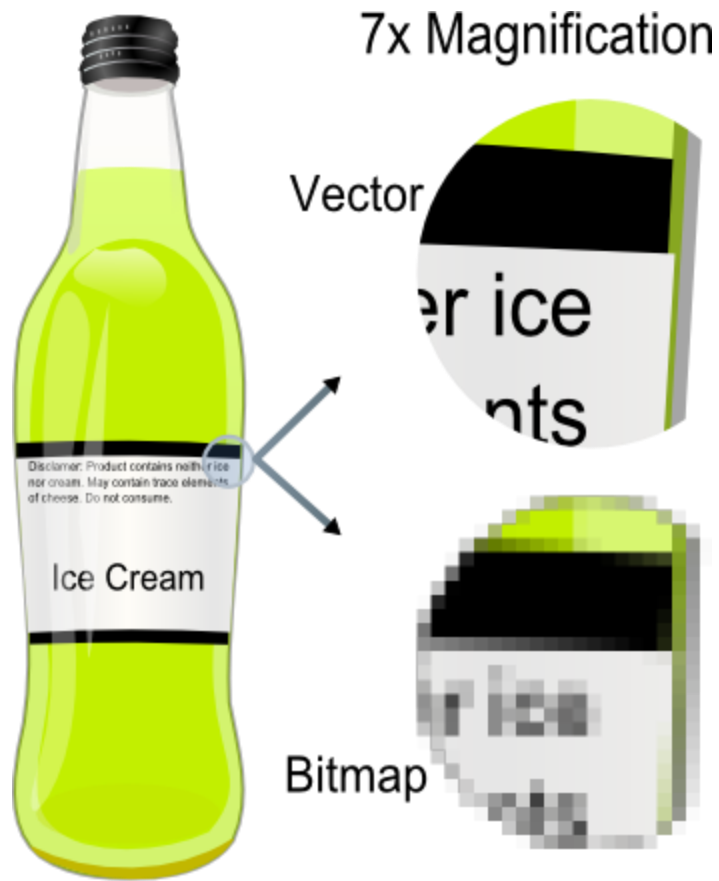
Bitmapped image (raster)

a

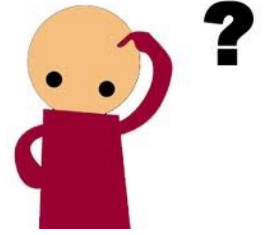


1.0	1.0	1.0	0.9	0.6	0.6	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0	1.0	1.0	1.0
1.0	0.2	0.2	0.5	0.6	0.6	0.5	0.0	0.0	0.5	1.0	1.0	1.0	1.0	1.0
1.0	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.0	0.0	0.9	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0	1.0	1.0	1.0
1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0.4	0.0	0.5	1.0	1.0	1.0	1.0
1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0	1.0
0.9	0.0	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0	1.0	1.0	1.0
0.5	0.0	0.6	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0	1.0	1.0	1.0
0.5	0.0	0.7	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	1.0	1.0	1.0	1.0
0.6	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.0	0.5	1.0	1.0	1.0	1.0
0.9	0.1	0.0	0.6	0.7	0.7	0.5	0.0	0.5	0.0	0.5	1.0	1.0	1.0	1.0
1.0	0.7	0.1	0.0	0.0	0.0	0.1	0.9	0.8	0.0	0.5	1.0	1.0	1.0	1.0
1.0	1.0	1.0	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Bitmapped Vs. Vector-based



Questions...



- What is a bitmap image?
- What is a vector based image?
- What are the differences?

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

Image Sampling and Quantisation (grayscale images)

- A digital image is represented by a matrix of numeric values, each representing a quantised intensity value. e.g. $I(r, c)$
- 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 grayscale levels range from 0 (black) to 255 (white).

Image Sampling and Quantisation (grayscale images)

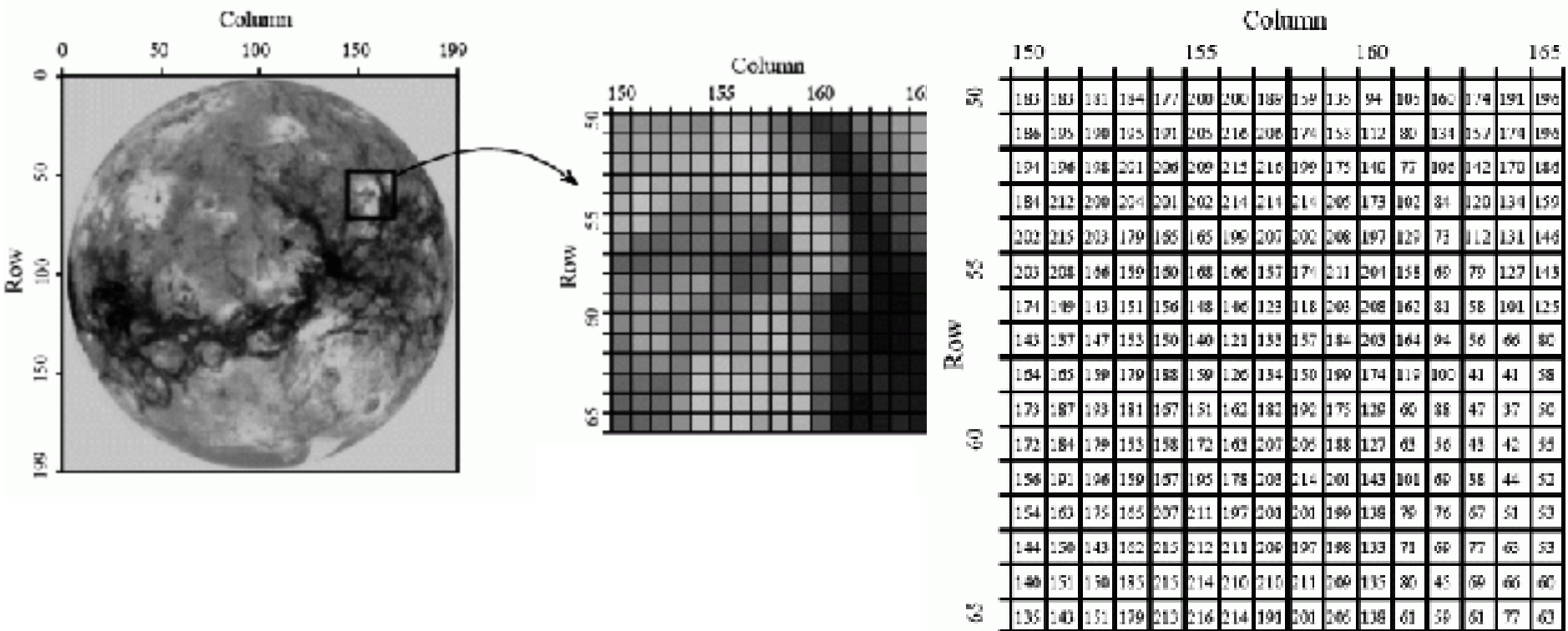
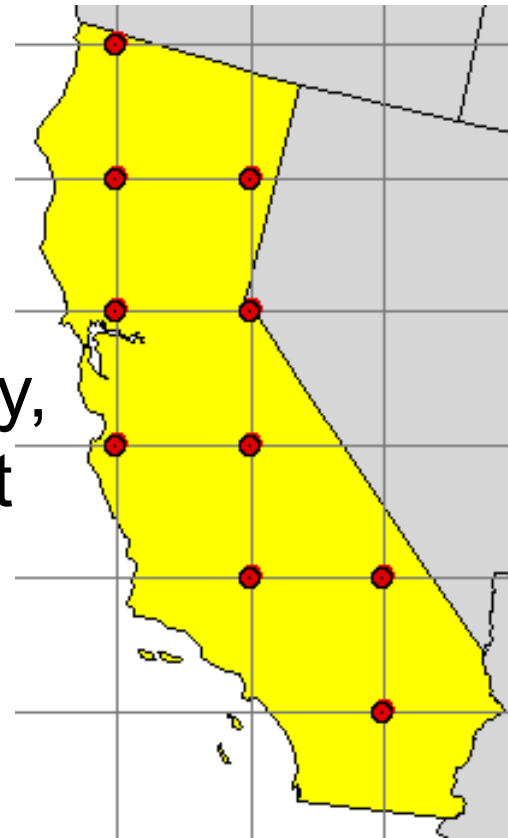
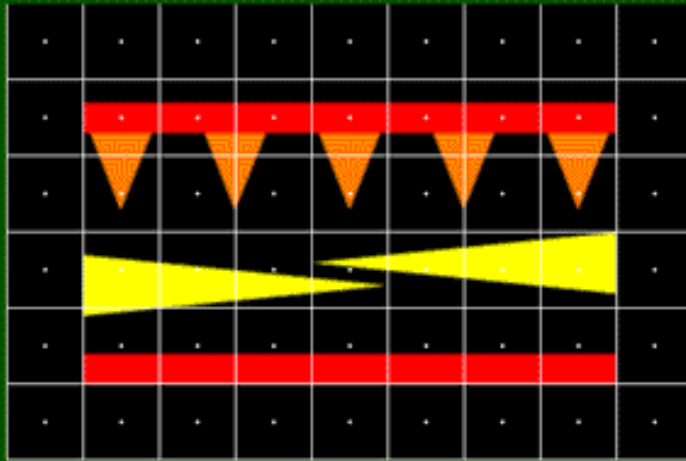


Image sampling

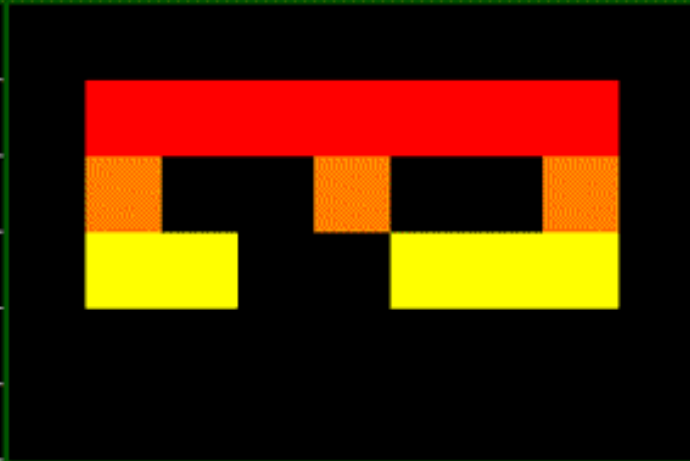
It is common to use a **square sampling grid** with pixels equally spaced along the two sides of the grid.

Both sampling and quantisation can introduce error in the sense that the image captured does not represent, with perfect fidelity, the original scene or objects that were photographed.





Original



Rendered

The effect of sampling reduction

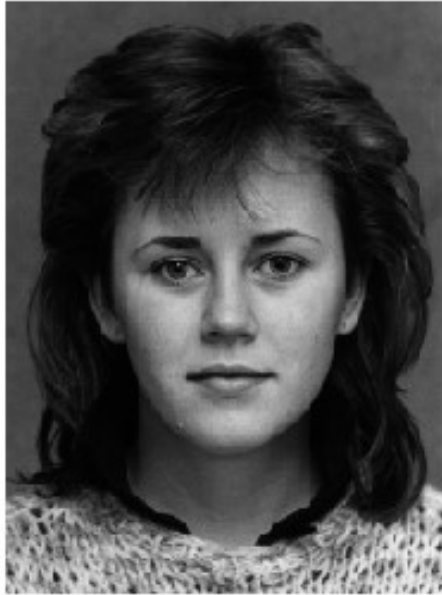
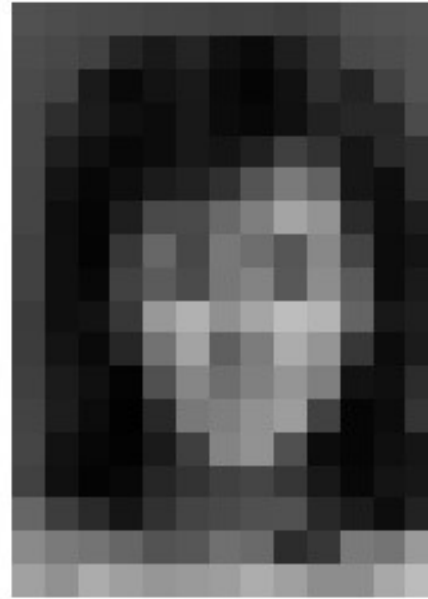


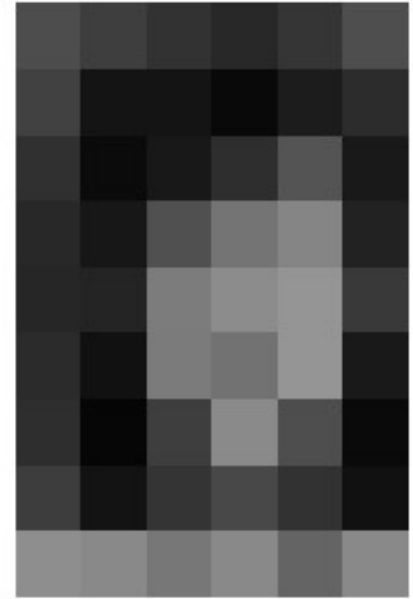
Image of girl



Reduction by 4



Reduction by 16



Reduction by 32

The effects of sampling and quantisation



Image undersampled



Reduced bit depth

Digital cameras

- Digital cameras use the same digitisation process discussed already: sampling and quantisation.
- Sampling rate is a matter of how many points of colour are sampled and recorded in each dimension of the image.
- A digital camera might allow you to choose from:
1600x1200, 1280x960, 1024x768, 640x480

Digital cameras

- Quantisation is a matter of the colour model used and the corresponding bit depth.
- Digital cameras generally use RGB, which saves each pixel in three bytes, one for each of the colour channels: red, green, and blue. Since three bytes is 24 bits, this makes it possible for $2^{24} = 16,777,216$ colours to be represented.

Data size : image file

Example:

Sampling: 1024 pixels x 768 pixels (samples)

Bits per pixel: 24

$1024 \times 768 = 786,432$ pixels

$786,432 \times 24 = 18,874,368$ bits

$18,874,368 / 8 = 2,359,296$ bytes

File size ~ 2.36 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.
- Similarly, your computer screen has a fixed maximum pixel dimensions (the “physical pixels”), e.g. 1024x768 or 1400x1050.
- 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).



Image resolution

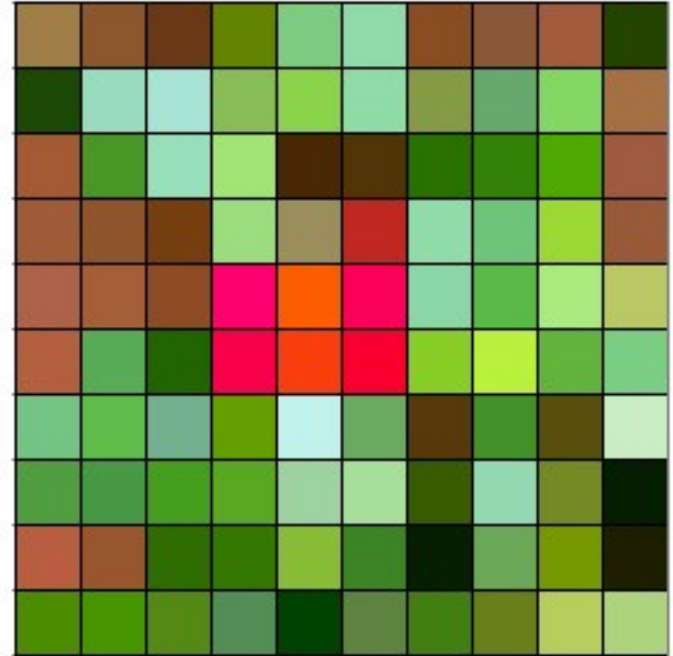
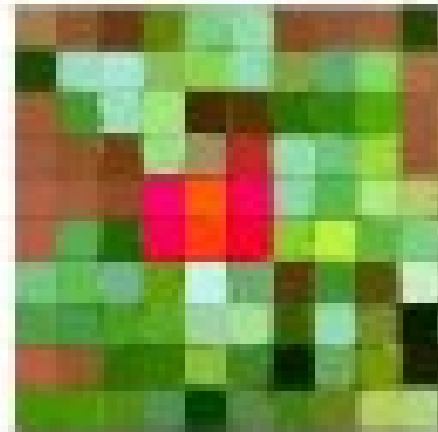
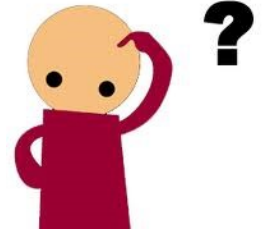


Image resolution & image size



Questions...



- What is image resolution?
- How are image resolution and displayed size related?

Problem

You decide that the best way to share the digital images with the rest of your family is via social media, and you expect that most of your relatives will watch the images on their mobile phone.

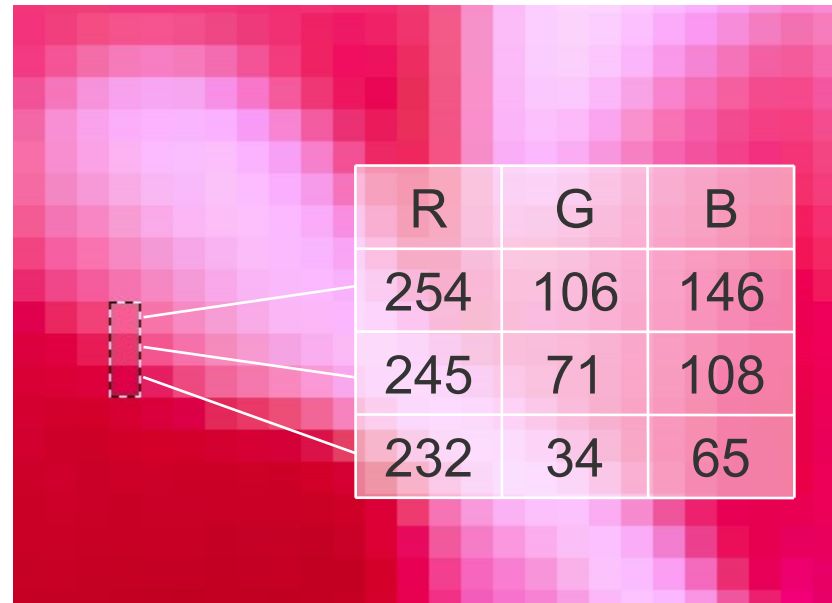
Q4: What image resolution should you aim for?



Image quantisation

The quantisation level is called image depth.

1	1	1	1	1
1	2	2	2	1
1	2	5	2	1
1	2	2	2	1
1	1	1	1	1



The effect of quantisation reduction

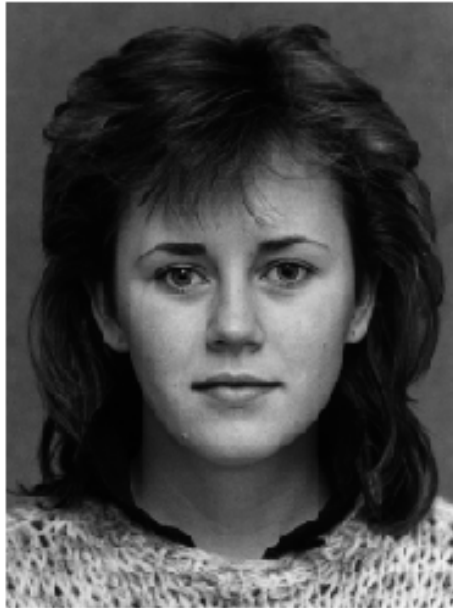


Image of girl: 256 levels



8 levels



4 levels



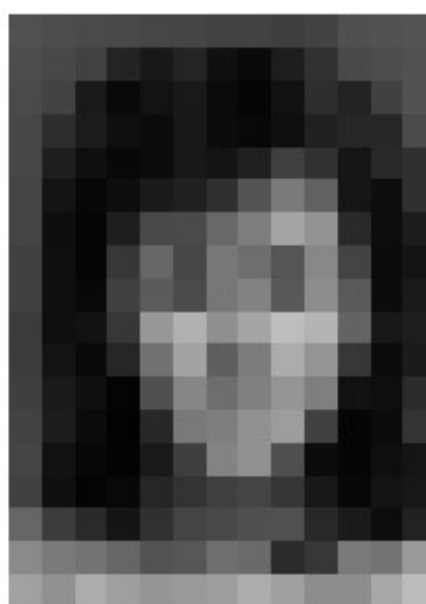
2 levels



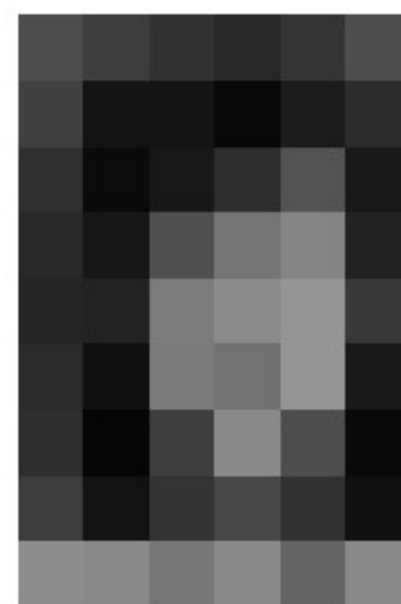
Image of girl



Reduction by 4



Reduction by 16



Reduction by 32



Image of girl: 256 levels



8 levels



4 levels



2 levels

Summary so far ...

- The points at which an image is sampled are known as picture elements (pixels)
- The number of pixels per inch is the image resolution
- The image resolution varies with its size
- The quantisation rate is the image depth

Agenda

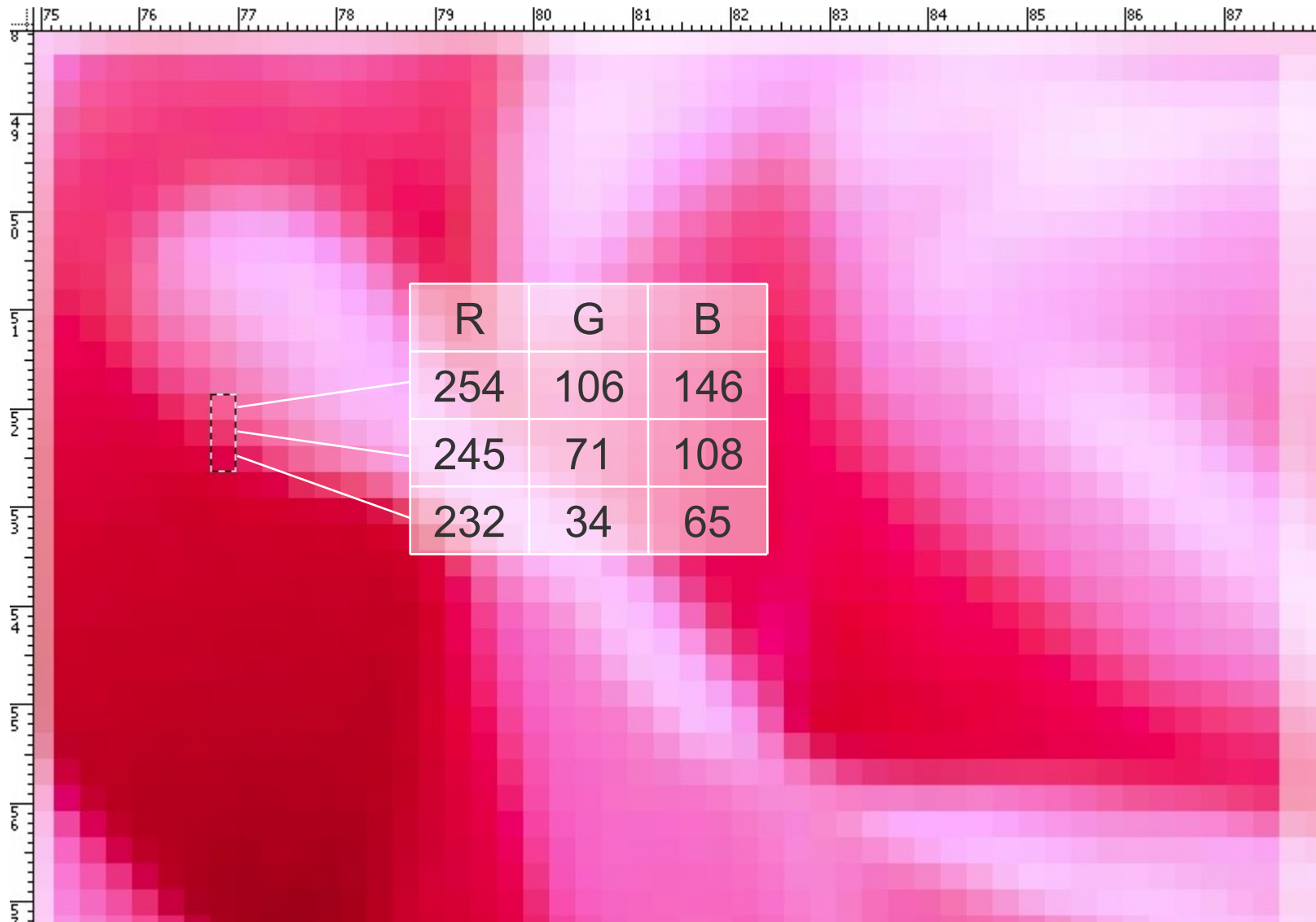
- Images can be stored as bitmaps or be vector-based
- The points at which an image is sampled are known as picture elements (pixels)
- Colour bitmap images can be true-colour or index-based

Stored Image Formats

- **RGB formats**, also known as 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.



RGB format (true colour)



Indexed format

Image Pixels
8-Bit Number

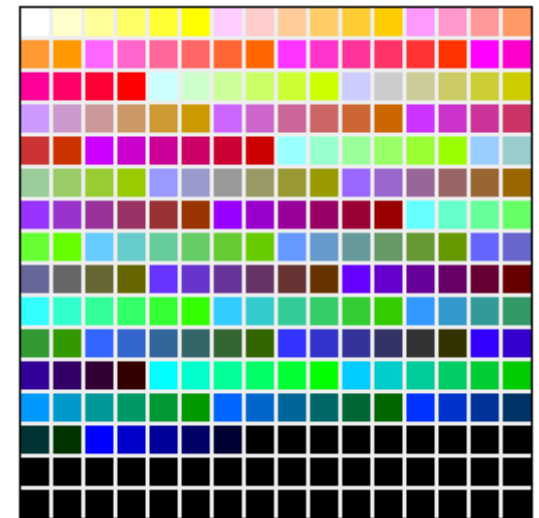
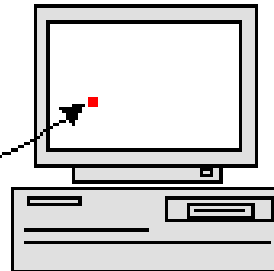
2	148	99
112	112	3
112	149	67
98	4	
254		

Index #

RGB Values
Three 8-Bit Numbers

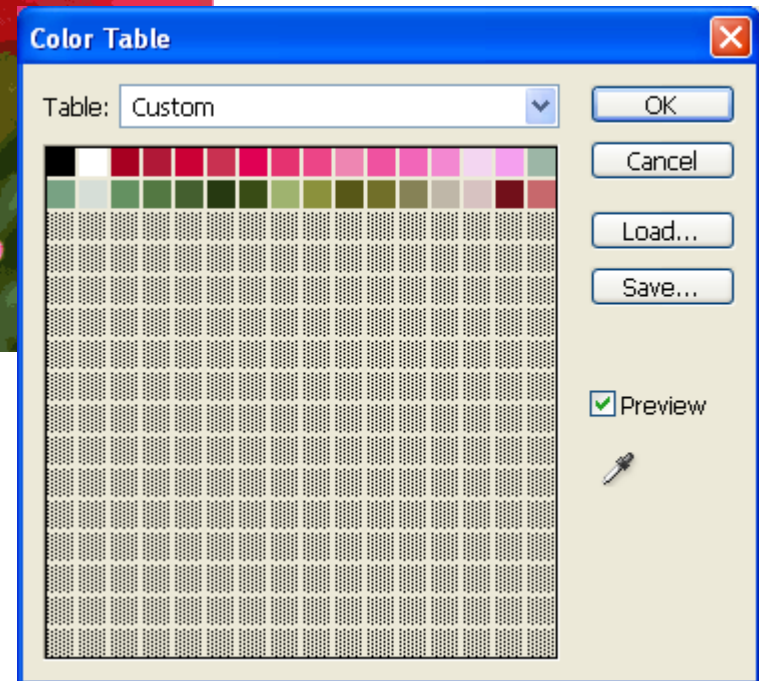
0	12, 116, 0
1	255, 0, 20
2	120, 10, 15
3	43, 201, 101
4	155, 22, 233
...	
251	112, 18, 23
252	54, 122, 0
253	87, 110, 115
254	2, 10, 254
255	90, 222, 32

COLOR LOOKUP TABLE
(color map, color palette)



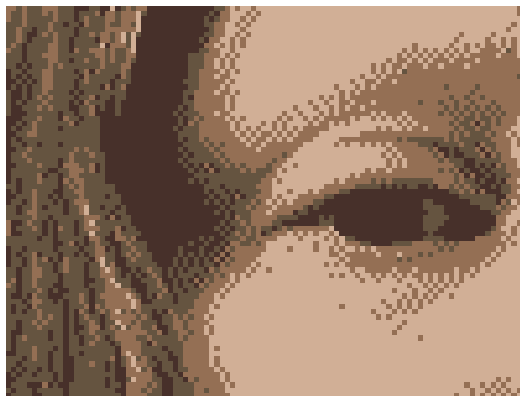
CLUT (Colour Look Up Table)

32 Colours (Indexed format)



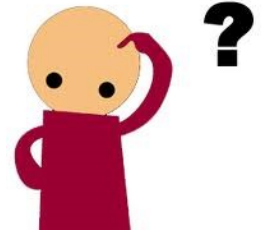
Indexed formats

8bits/256 colours



2bits/4 colours

Questions...



- What true-colour images?
- What are grayscale images?
- What are index-based images?
- When changing an image from true-colour to index-based, what is the most likely to happen?

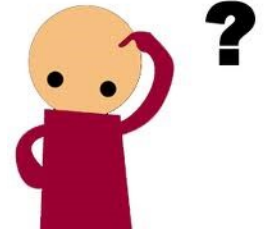
Exercise



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

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

Question



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

Exercise



A 300 by 400 pixel image has a size of 120 Kbytes. How is it encoded?

Exercise



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?

Problem

85% of the photographs are black and white, the remained 15% are coloured.

Q5: What colour depth should you choose?



Digital Image File Types

- If you take a picture with a digital camera or scan a photograph with a digital scanner, you'll have a choice of file types in which to save the image.
- Not all colour models can be accommodated by all file types, and some file types require that the image be compressed while some do not.
- The four most important things to know about a bitmap filetype are: its colour model; its bit depth; its compression type, if any; and the operating systems, browsers, and application software that support it.
- The possible bit depths for bitmap images include 1, 4, 8, 16, 24, 32, 48, and 64 bits.

Digital Image File Types

File Suffix	Our Abbreviation	File Type	Characteristics
Bitmap Images			
<i>.bmp</i>	BMP	Windows bitmap	1 to 24-bit color depth, 32-bit if alpha channel is used. Can use lossless RLE or no compression. RGB or indexed color.
<i>.gif</i>	GIF	Graphics Interchange Format	Used on the web. Allows 256 RGB colors. Can be used for simple animations. Uses LZW compression. Originally proprietary to CompuServe.
<i>.jpeg</i> or <i>.jpg</i>	JPEG	Joint Photographic Experts Group	For continuous tone pictures. Lossy compression. Level of compression can be specified.
<i>.png</i>	PNG	Portable Network Graphics	Designed as an alternative to <i>.gif</i> files. Compressed with lossless method. 1 to 64-bit color with transparency channel.
<i>.psd</i>	PSD	Adobe Photoshop	Supports a variety of color models and bit depths. Saves image layers created in photographic editing.
<i>.psp</i>	PSP	Corel Paint Shop Pro	Similar to <i>.psd</i> .
<i>.raw</i>		Photoshop	Uncompressed raw file. Could be black and white, grayscale, or RGB color.
<i>.tif</i> or <i>.tiff</i>	TIFF	Tagged Image File Format	Often used for traditional print graphics. Can be compressed with lossy or lossless methods, including RLE, JPEG, and LZW. Comes in many varieties.

Problem

Q6: What format will you use to encode and store your images?



Summary

- Bitmap images can be true-colour or index-based
- A true colour image pixel is represented with 24 bits (8 bits for each colour channel)
- 16.7 million colours can be represented with 24 bits
- A grayscale image has an image depth of 8
- An indexed image uses a Colour Look Up Table (CLUT)
- In an indexed image, each pixel is represented by an index, which refers to a colour in the CLUT
- The number of bits needed for each pixel depends on the size of the CLUT