Digital Image Fundamentals

Computer Science Department
CS4481b/9628b: Image Compression
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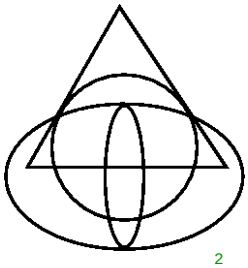
Instructor: Mahmoud R. El-Sakka
Office: MC-419
Email: elsakka@csd.uwo.ca
Phone: 519-661-2111 x86996

What Is an Image?

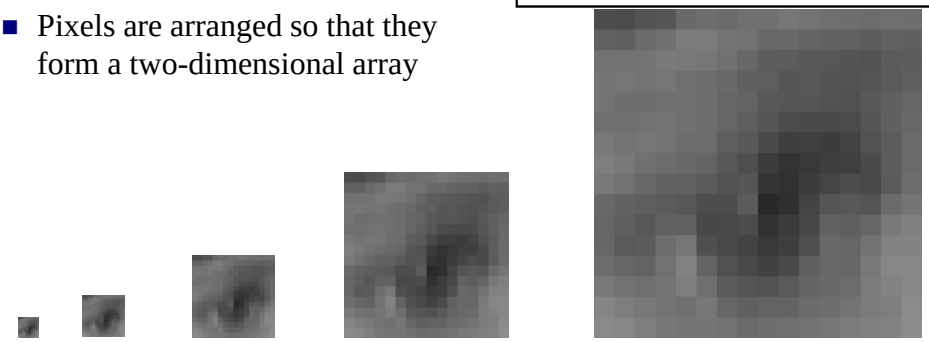
- Image is a ***representation*** of the ***visual information*** in a given object or scene
- Describe the information represented in each image
- What is the dimension of each of these two image?
  - three-dimensional image
  - two-dimensional image
  - something else



What Is an Image Composed of?

- Generally, an image is composed of discrete units called picture elements (or simply *pels*, or *pixels*)
- Each pixel occupies a small rectangular region of the image and displays *one* color at a time
- Pixels are arranged so that they form a two-dimensional array

```
 76  74  81  84 103 110 107 112 112 119 115 111 110 108 111 110
 95  94 103 109 121 122 115 114 106 106 101  99  98  93  98  97
113 113 114 121 120 119 113 105  95  93  89  88  85  83  90  93
116 118 115 118 112 110 106  97  94  87  88  84  82  85  90  94
116 110 110 112 111 109 103  99  89  86  86  82  80  87  95 101
111 112 113 116 112 109 102  95  87  78  75  74  76  84  95 103
119 115 118 116 110 108  96  90  76  64  64  61  67  81  91 105
126 121 113 109 105 102  89  80  63  53  55  62  63  74  91 105
121 115 106  98  98  92  82  85  55  49  59  67  75  73  89 107
106 100  95  92  88  79  77  91  44  46  64  83  87  84 103 115
102  96  87  95  97  74  73  77  50  57  68  95  93  99 118 127
103  90  89 107 117  81  74  68  56  60  75 102 100 112 128 131
108 102  98 113 129 100  81  73  64  72  92 103 103 118 133 135
120 114 110 115 126 112  91  84  80  88  98 105 106 122 130 135
132 125 119 116 113 119 102  94  97  98 105 109 113 122 125 138
137 133 126 120 117 117 112 105 109 110 113 118 122 127 130 140
```



What Is an Image Composed of?

- Images are constructed by adjusting the color of individual pixels
- How many pixels do we have in this image?
- How many different images (that have the same size as the picture shown) can be generated?

Number of possible colors per pixel ***Number of pixels***

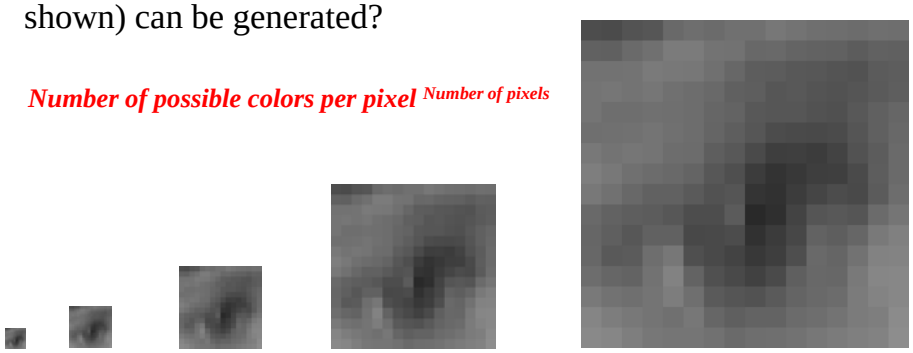


Image Formats

- Image formats can be divided into two general classes:
  - Bitmap format
  - Vector format
- During this course, we will only deal with bitmap images

Bitmap Image Format

- Bitmap images are represented as a two-dimensional array, where each array-element represents a *single* color to be displayed at a specific location
- When a bitmap image is displayed on a monitor, each element is generally mapped to a single pixel in the monitor
- When pixels are placed close enough on a monitor, or a displaying device in general, it becomes difficult for human eyes to detect the array structure that composes the image
- × The major drawback with bitmap images is the amount of data required to hold them
- × Bitmap images are size dependent
  - Reducing the size requires throwing away information
  - Enlarging the size produces blocking artifacts
- × Bitmap format is not suitable for editing
- ✓ Bitmap can produce a very high quality real-scene images

Bitmap Format Example

Original
512 × 512 image

Reduced
128 × 128 image

Enlarged
512 × 512 image

Vector Image Format

- Vector format is a descriptive representation
- It consists of a series of drawing commands to represent an image
- Computer monitors and laser printers can not *directly* deal with vector commands
  - They usually have software that converts vector commands into pixels
  - Complex images may take a longer time to display

✓ Vector images are usually small is size

✓ Vector images are size independent

✓ Vector format is suitable for editing

× Vector format is not suitable for reproducing photographs or paintings; just determining which commands to use to represent the painting would be a huge horrible task

Vector Format Example (Postscript)

```
%!ps
% the origin at the lower left corner
100 setlinewidth % the default is 1 pixel
300 300 200 0 360 arc % draw arc
closepath
gsave % save graphics state
  0.50 setgray % the default is 0, i.e., black
  fill % fill area enclosed by path
grestore % restore graphics state
stroke % perform what you have so far

/courier findfont
140 scalefont % 1 point unit = 1/72 inch
setfont

50 250 moveto
(CS4481) false charpath % char. outline
gsave % save graphics state
  16 setlinewidth % the default is 1 pixel
  .75 setgray % the default is 0, i.e., black
  stroke % perform what you have so far
grestore % restore graphics state
1.00 setgray % the default is 0, i.e., black
fill % fill area enclosed by path
stroke % perform what you have so far
showpage %print page
```

Vector Format Example (Postscript)

```
%!ps
% the origin at the lower left corner
100 setlinewidth % the default is 1 pixel
300 300 200 0 180 arc % draw arc
closepath
gsave % save graphics state
  0.50 setgray % the default is 0, i.e., black
  fill % fill area enclosed by path
grestore % restore graphics state
stroke % perform what you have so far

/courier findfont
140 scalefont % 1 point unit = 1/72 inch
setfont

50 250 moveto
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1.00 setgray % the default is 0, i.e., black
fill % fill area enclosed by path
stroke % perform what you have so far
showpage %print page
```

Vector Format Example (Postscript)

```
%!ps
% the origin at the lower left corner
100 setlinewidth % the default is 1 pixel
300 300 200  45 315 arc % draw arc
closepath
gsave % save graphics state
  0.50 setgray % the default is 0, i.e., black
  fill % fill area enclosed by path
grestore % restore graphics state
stroke % perform what you have so far

/courier findfont
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```

Vector Format Example (Postscript)

```
%!ps
% the origin at the lower left corner
100 setlinewidth % the default is 1 pixel
300 300 200 315  45 arc % draw arc
300 300 200 135 225 arc % draw arc
closepath
gsave % save graphics state
  0.50 setgray % the default is 0, i.e., black
  fill % fill area enclosed by path
grestore % restore graphics state
stroke % perform what you have so far

/courier findfont
140 scalefont % 1 point unit = 1/72 inch
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fill % fill area enclosed by path
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showpage %print page
```

Digitization

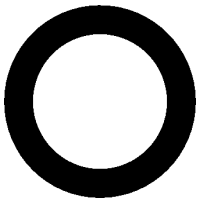
- Digitization is the process of converting an ***analog signal*** to a ***digital signal***
- A digitizing device is an instrument that creates a digital version (a bitmap version) of a physical representation
- Digitizing devices include scanners and image grabbers

Resolution Versus Density

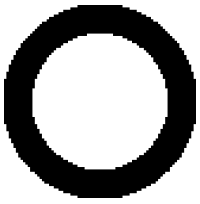
- *Resolution* is a measure of details
  - *The resolution of an image* is its physical size in pixels; i.e., number of pixels wide × number of scan lines long
  - *The resolution of a monitor* is the number of pixels per a scan line × the number of scan lines it may display, e.g., 800 × 600
- *Density* is the quantity per unit
  - *Pixel Density* is number of dots, or pixels, per unit length
  - The pixel density of reasonable quality laser printers is 1200 dots per inch (dpi)

Jagging

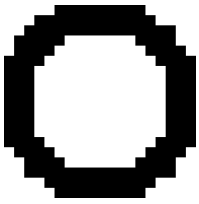
- The pixels may have jagged edges, which is not pleasing to the human eyes
- The more densely pixels are packed together, the less noticeable the jagged edge becomes; also the more storage space is required to save, and/or the more time to transmit, the image (i.e., more cost)



Resolution: *320 × 320*
Density: *160 pixels per inch*



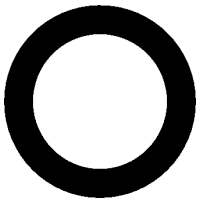
Resolution: *80 × 80*
Density: *40 pixels per inch*



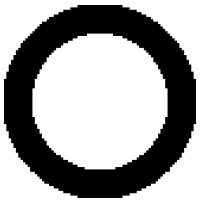
Resolution: *20 × 20*
Density: *10 pixels per inch*

Jagging

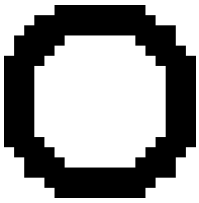
- How does the first image look like if I change its density to 40 pixels per inch?
- How does the third image look like if I change its density to 40 pixels per inch?



Resolution: *320 × 320*
Density: *160 pixels per inch*



Resolution: *80 × 80*
Density: *40 pixels per inch*



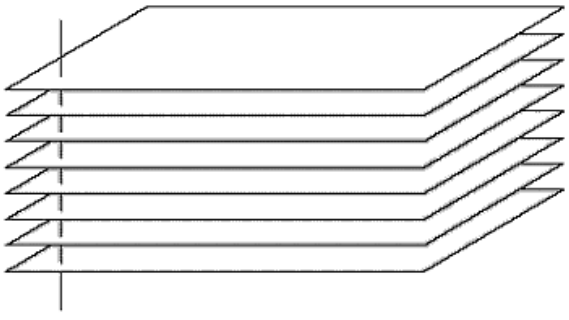
Resolution: *20 × 20*
Density: *10 pixels per inch*

Pixel Depth

- Pixel depth is the number of bits used to form individual pixel values
- $2^{\text{Pixel\_Depth}}$ specifies the maximum number of different values a pixel can assume, e.g., for 8 bits per pixel (bpp), 256 is the maximum number of different values a pixel can assume

Bit Plane

- Bit Plane is a two-dimensional array of bits, one bit deep
- An 8 bpp bitmap image contains 8 bit planes
- A binary image has a single bit plane



Displaying an Image

- Display devices can be divided into two general groups:
  - Computer monitors
  - Computer printers

Computer monitors

- Typically about 100 pixels per inch
- Each *monitor controller* has its own memory
- Each pixel on the monitor has a corresponding memory location in this memory
- The *monitor controller* converts the values in the memory to a signal that can be displayed by the monitor
- This memory can be read from, or written to, just like any other memory location
- An application can change the color displayed on the monitor just by changing a memory value

Computer Printers

- Much higher density than a computer monitor has; Typically 600, 1200, or even higher, pixels per inch
- Similar to the monitor controllers, printers do contain memory
- However, data is transmitted over a serial cable, parallel cable, or even over the network, rather than directly through the system bus
- The image gets built in the printer's memory and then gets written to the printer page
- Plotters can be considered as printers

Frame

- A single image sometime is called a single frame, a.k.a. *still image*
- Multiple (two or more) frames of slightly differing images displayed in rapid sequence may provide the illusion of continuous motion (animation), a.k.a. *moving sequence*
- Typically, cartoon animations are played back at a rate of 12 to 15 frames per seconds
- Video animations usually require a display rate of 20 frames per second, or better, to produce a smoother motion
- ***What is the size of a 30 frames per second 1 hour color movie if the single frame is 1000×1000 pixels?***

Color components in Images

- Images can be
  - Binary (each pixel displays one of two colors black/white)
  - Gray (each pixel displays one shade of gray)
  - Color (each pixel displays one multi-color value)