Lecture 03

Pixel Graphics

Abbreviations

dpi = dots per inch
ppi = pixels per inch
FAQ = frequently asked questions
lpi = lines per inch
RWS&HT = Real World Scanning and Halftones
NDWB = The Non-Designer’s Web Book

Optional background reading

“Beyond the Mac is not a typewriter,” by Robin Williams (http://www.ratz.com/robin/realbio.html)
Remember . . .
UNDERSTANDING what you’re doing in lab, and why, is more important than how to do it

So in lecture today
• focus on WHAT we’re doing, not how

This week’s reading
• both supplements and complements this week’s lecture
• from Learning Web Design

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• Please ask questions!

Assumptions
• You have used a camera.
• You may have done some photo editing.
• Terminology in this lecture may be brand new.
Things to Think About

• What are the data objects in a Pixel Graphics program?
• Is there more than one way to do any given task?
• What are the deficiencies of the interface?
• What are the efficiencies of the interface?

What is “Pixel Graphics?”

Everything you see on the screen is composed of “pixels”
• imagine the screen as a piece of graph paper
• draw an object by colouring in squares
  “painting” with a “brush” (ie the “tracker”)
• the squares are called “pixels”
• “pixel” is short for PICture ELement (from “pix” for picture)

Each pixel (usually) has
• a red intensity (0...255)
• a green intensity (0...255)
• a blue intensity (0...255)
— vary these to get a variety of colours
Thus typically $0 \leq R, G, B \leq 255$
• 255 is the largest integer that fits in a byte (character) of memory
EVERYTHING displayed is represented by a pattern of pixels

For more information on how LCDs — and CRTs — actually work, see
http://www.bit-tech.net/hardware/2006/03/20/how_crt_and_lcd_monitors_work/3.html
or Wikipedia
**Why does pixel graphics work?**

RGB-based colour is “additive colour”

As distinct from the “subtractive (CMY-based) colour” you may have seen in an art class

Additive colour is based on the red-, green-, & blue-sensitive “cones” in your eye
red, green and blue are said to be the “primary colours”

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**Some facts about additive colour**

Some colour facts & terminology

- red + green = yellow  \( \text{ie} \ R + G = Y \)
- green + blue = cyan  \( \text{ie} \ G + B = C \)
- red + blue = magenta  \( \text{ie} \ R + B = M \)

- for us, yellow, cyan and magenta are said to be “secondary colours”
- red + green + blue = white  \( \text{ie} \ R + G + B = W \)

The “Colour Wheel” — a model for mixing colour
More facts about additive colour

Therefore: white – blue = red + green = yellow (etc)

“nothing” is black, represented by $K$ (because B is already taken for blue...)

“equal” amounts of red, green and blue combine to form grey

“hue” is what we usually think of as “colour”

as in reddish, greenish, etc

“saturation” refers to how “pure” or “vivid” the colour is

ie how much a colour departs from gray

“brightness,” “lightness,” & “luminance” refer to overall intensity

you can specify colour in terms of hue, saturation, & brightness

there’s an arithmetic transformation between the two

similarly for cyan, magenta and yellow, the (subtractive printing primaries)

or CMYK (printing with the four inks cyan, magenta, yellow and black gets better results)

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A Hue, Saturation & Brightness Model for Mixing Colour

In Gimp

- click on foreground or background colour in the Tools Palette

  “paint colour” = “foreground colour”

  “paper colour” = “background colour”

Desaturate by moving down, saturate by moving up

Darken by moving left, brighten by moving right

Click on the spectrum to change the hue

Or ... type R, G, B or H, S, B values into the text edit boxes
2^N Patterns for N Bits

<table>
<thead>
<tr>
<th>N bits</th>
<th>0</th>
<th>1</th>
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<tbody>
<tr>
<td>1 bit</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2 bits</td>
<td>00</td>
<td>01</td>
</tr>
<tr>
<td>3 bits</td>
<td>000</td>
<td>001</td>
</tr>
<tr>
<td>4 bits</td>
<td>0000</td>
<td>0001</td>
</tr>
<tr>
<td>5 bits</td>
<td>00000</td>
<td>00001</td>
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Typical Display “Resolutions” (“Addressability” Would Be Better)

“Spatial Resolution”
- \( h \times v \): eg 1024 \( \times \) 768, 1152 \( \times \) 870, 1280 \( \times \) 1024, 1600 \( \times \) 1200, 2048 \( \times \) 1536
- \( h \) = horizontal, \( v \) = vertical
- pixels per inch (aka dots per inch, or dpi) is then determined by the screen’s actual size

“Pixel Resolution” (bits per pixel)
- 24 bits per pixel — 8 for red, 8 for green, 8 for blue
  - 8 bit => 256 different values (intensities), so
  - 256 reds \( \times \) 256 greens \( \times \) 256 blues
    \( = 16,772,160 \) combinations — “millions” of colours in Apple-speak
    \( = “true colour” \) in Microsoft-speak
- 16 bits per pixel — 5 for red, 5 for green, 5 for blue
  - 5 bits => 32 different values (intensities), so
  - 32 reds \( \times \) 32 greens \( \times \) 32 blues
    \( = 32,768 \) combinations — “thousands” of colours in Apple-speak
    \( = “high colour” \) in Microsoft-speak
- 8 bits per pixel — is different: 256 “colour numbers” defined elsewhere in a “colour table” or “palette”
  - each pixel consists not of an (R,G,B) triplet of intensities, but instead specifies an entry in the colour table
### Changing Display Settings on a Mac

Let's you choose
- how many pixel bits to use ("colour depth")
- among available spatial resolutions & "display rates"

The higher the resolution, the longer it takes to scroll
- more bits to move around in display memory!

For Windows
- use the Settings tab in the Display control panel

Multiple displays (both Mac & Windows now)

### Pixel Graphics File Formats

Stored paintings/images are large and take a long time to transmit over the internet
- $640 \times 480 \times 3$ bytes = 0.92 Megabytes
  - roughly analog TV resolution
- $1280 \times 1024 \times 3$ bytes = 3.75 Megabytes
- $1600 \times 1200 \times 3$ bytes = 5.76 Megabytes
- If you scan an 8.5" by 11" page in colour at 300 dpi ...
  - $2550 \times 3300 \times 3$ bytes = 22.275 Megabytes

So often you compress them

There are lots of different file formats for storing pixel images
- of varying appropriateness for different kinds of images
- some reflect different compression techniques
- others reflect a programmer’s choice
Some Common Graphics File Formats (1)

GIF (Graphics Interchange Format)
- common on the internet (the “original” internet format)
- “loss-less compression”
- 8-bit colour only, & supports simple animation
  each “8-bit colour” actually refers to an entry in a separate 256-entry “colour table” that defines each colour to be some particular 24-bit (R,G,B) triple
- was licensed by Unisys, and use required a fee
  (paid by the software vendor; included in the purchase price of software)
  — however, the patent expired in 2004

PNG (Portable Network Graphics)
- invented in 1996 because of the GIF licensing fee
- true-colour capable
- loss-less compression
- very flexible & cross-platform, but no animation (which GIF supports)
- current and recent browsers support it; really old browsers didn’t (eg IE 3)

JPEG (Joint Photographic Experts Group, aka JPG)
- true-colour
- supports “lossy compression”; variations trade smaller file size for loss of detail

PNG vs JPEG Example (1) — Actual Size

The original “raw” data: 1,350 KB becomes an 887 KB png file. (1.5x)

The same data as a “lowest quality” 56 KB jpeg file. (24x)
PNG vs JPEG Example (1) — The Selected Area Zoomed 2885 %

The highlighted raw pixels

The highlighted jpeg-compressed pixels

PNG vs JPEG Example (2)

The original – a perfectly sharp boundary.
219 KB of raw data;
728 bytes of **png**-compressed data. (309x)

Minimum jpeg quality - border artifacts.
219 KB of raw data;
2,500 bytes of **jpeg**-compressed data. (89x)
Some Common Graphics File Formats (2)

TIFF (Tagged Image File Format)
- both 8-bit & true-colour
- loss-less compression
- a cross-platform standard
- some browsers don’t support

BMP (Windows Bitmap)
- both 8-bit & true-colour
- loss-less compression
- standard Windows format

“Raw” digital camera format
- just the RGB pixel intensities measured by camera
  (as distinct from JPEG, which is always an option) and w/o in-camera image processing (eg noise reduction)
- the file format produced is typically proprietary, however

Final words
- “Different file format” means “the bit representation of the data is different.”
- *Renaming foo.png to foo.jpg doesn’t change the file’s format.*

Pixel Graphics with Gimp — Painting (1)

You “paint” by click-dragging the mouse
- which controls a “brush” (the tracker) (Paintbrush Tool)
- whose width, shape, colour, etc, you control
  - (see “Paintbrush Tool” in online Help)

As you move the mouse
- pixels over which the brush passes are modified
- may be completely replaced by the brush colour
- may be combined with the brush colour
  - in Adobe-speak, according to the painting “mode”

applies the “Paint” colour (aka the “foreground” colour)

erases to the “Paper” colour (aka the “background” colour)

(Bucket Fill Tool) pours the “Fill” colour (which is, in fact, the current foreground colour)

Both and are applied with a brush you can reshape

How do you select a Paint / Paper / Fill colour?
Brush “transparency” (the reverse of “opacity”)
• the percentage of what’s underneath that shows through

“Wet” or “soft” edges
• ~ transparency is added to the edge of a brush stroke
• 0% for none (a “hard” or “sharp” edge)

Painting or filling a region: use the “marquee tool”
• then you can only paint within the “selected” region
• the remainder of the image is “masked”

“Feathering” a mask by some number of pixels causes smooth blending across the mask boundary; the number of pixels controls the width of the blending

To feather a selection, right click and then click Select >

Image Manipulation

Examples
• Level (Re)mapping
• Sharpening
• Colour Balance
• Brightness / Contrast
• Hue / Saturation / Lightness

These may be applied
• to the image as a whole
• to a selected portion of the image

There are a variety of tools and techniques for selecting portions of an image.
We will mostly use direct rectangular or elliptical selections
Other useful tools include the “fuzzy select tool” and the “scissors select tool”

For the images used to illustrate these, see
• Learn/ Week 3: Pixel Graphics: Files from Pixel Graphics Lecture
• NB: the manipulations we discuss don’t print accurately (the “colour matching problem”)
Retouching Scanned Images & Digital Photographs

Can be digitally manipulated in many interesting & useful ways

“Retouching” consists of such operations as manually

- moderating highlights (eg from flash reflection)
- painting (or cloning) over blemishes
- generally speaking, using a mouse to point to pixels that should be altered in some way, often based on the color of the pixels underneath the tracker
- perhaps just changing the hue, the saturation, the brightness, etc (the painting “mode” again)

Demo!

Irrelevant aside: for lot’s more interesting stuff about vision & the eye, see “The Eye—A Natural History,” by Simon Ings, $15 at Chapters.
(Ings is an excellent science writer.)

Scanned Images & Digital Photographs (Channels in Color)

Are arrays of pixel intensities

- that come from a scanner or digital camera
- that MEASURES (R,G,B) pixel intensities on a rectangular grid, usually producing one byte (8 bits) for EACH of R, G and B at each grid position

In the rightmost of these three images, which shows only the blue channel, the red and green intensity values at each pixel are temporarily set to zero while generating the display. The red and green channels are handled similarly.
Scanned Images & Digital Photographs (Channels in Gray)

Are arrays of pixel intensities that come from a scanner or digital camera that MEASURES (R,G,B) pixel intensities on a rectangular grid, usually producing one byte (8 bits) for EACH of R, G and B at each grid position.

In the rightmost of these three images, which shows only the blue channel, the blue intensity value at each pixel temporarily replaces the red and green intensity values for that pixel while generating the display. The red and green channels are handled similarly.

Recall that a selection

• is a “mask”
• is an 8-bit grey-scale image in which
  • white represents complete selection,
  • black represents no selection, and
  • gray represents partial selection

When you apply color (“paint”), the more fully selected a pixel is, the more paint is applied.

In Gimp you can

• save a selection as a “channel,” (aka an “alpha channel”)

and you can select and manipulate such an alpha channel just as if it were a “normal” image.

There are many ways of creating / editing / manipulating a selection; we will barely scratch the surface.
Selections (2)

The complete image.

The red selection mask.

The blue selection mask. Note the gradual transition, which results from feathering.

Pixel Histograms

Colors > Levels

The graph plots the number of pixels having each intensity value

How many pixels have that intensity

Intensity
Colors > Levels…
Note the unused values at both ends.

A has been moved right to pixel intensity 7.
B has been moved left to pixel intensity 210.

The effect of these particular changes to A and B is to use the full range of available intensities

- pixels with intensity 0, 1, ...,7 take on intensity 0
  - blacks become blacker
- pixels with intensity 210, 211, ... 255 take on intensity 255
  - whites become whiter
- pixels with intermediate intensities shift accordingly
  - the graph is “stretched uniformly”
- In other words, for the image as a whole, there’s more contrast and more dynamic range
Shifting Midtones

Move slider C…

- *left to lighten* intermediate intensities or “*midtones*”
  
  “stretch left, compress right”

- *right to darken* intermediate intensities
  
  “compress left, stretch right”

— either results in a NON-uniform change to the histogram

Lightened

Sharpening

Filters > Enhance > Unsharp Mask…

*each pixel value is replaced*

*by a weighted sum of its neighbours,*

*in such a way as to*

*sharpen the appearance of the image*

*by making edges more visible*

Amount (%)

- how much to sharpen (start with 30%)

Threshold

- by how much adjacent pixels must differ
  
  before sharpening occurs (start with 4)

- an effort at edge detection

- increase the threshold to focus on “real” edges

Radius

- is the width in pixels of the effect on either side of an edge
Unsharp Masking—What’s Happening

Before: RGB = (100,100,100) on the left & (200,200,200) on the right

After sharpening with amount = 100, radius = 2.0, threshold = 0

The contrast immediately to left and right of the boundary has been increased—when not enlarged, the eye sees this as a sharper edge

What About Colour?

Apply Level and Sharpening adjustments
  • to the R, G and B channels simultaneously (RGB)
  • or individually

The Gimp “Curves” tool provides for very flexible adjustment of
  • levels
  • colour balance
  • contrast

Unfortunately it’s use is a bit beyond the scope of CS200.

For more, see: http://www.cambridgeincolour.com/tutorials/photoshop-curves.html (strongly recommended...)

Transformations specifically for colour:
  • Colour Balance
  • Hue / Saturation / Lightness
  • Brightness / Contrast
Hue, Saturation and Lightness (aka Brightness, Luminance)

Image > Adjustments > Hue/Saturation...

The Hue slider rotates colour around the colour wheel

Saturation
• increasing saturation makes colours more vivid
• fully desaturated colours are gray

Increasing lightness lightens the entire image

Brightness-Contrast

Image > Adjustments > Brightness/Contrast...
Select a Marquee Tool

Use the tool to select a part of the image & apply an image transformation

Feather the selection (remember feathering?) and apply the same image transformation

• pixels inside a selection can be modified
• pixels outside the selection are “masked” (remember masking?)
• “Feathering” results in a gradual transition from full to no effect as you move outwards across the selection boundary

We’ve seen this before, when filling selections

Hint: Use Select > Feathering... to increase the feathering for an existing selection.

The Layers Palette (Another Data Model)

Each “layer” is a pixel grid (effectively, an individual & distinct painting)

• stacking order determines visibility (painting order)
  — the net effect is built up by painting the layers in order from bottom to top — though objects may be partially transparent
• each layer is ONLY a pixel grid (compare with the lecture on Geometric Graphics)
• click-drag in the Layers palette to change a layer’s stacking (ie painting) order
• when you draw on the canvas, ink goes into (onto?) the selected layer
• you can control whether a layer is visible
• you can “lock” a layer so that it cannot be modified
• click-drag the ink in an object to move the object in x and y
  Gimp identifies the object to be moved by whose ink is frontmost
Using Layers to Control the Stacking Order (aka “Z-Depth”) 

Layer > New Adjustment Layer > …

An “adjustment layer” is a “layer” with an attached image transformation
the adjustment may affect the entire image, or only a selected (“masked”) portion
you can alter the transformation later

•Layer > Change Layer Content
to change transformation parameters
or apply a different transformation

Adjustment Layers

Warning

• You can apply image manipulations directly to an image via the Image > Adjustments submenu.
• It’s nearly always better to create an adjustment layer.
• Directly adjusting an image alters the image pixels themselves, whereas altering an adjustment layer changes only what's displayed on the screen. (The adjustment layer is stored separately, and the transformation applied to the image whenever it is rendered.)
Adjustment Layers Example 1

You can (also) alter the transformation’s settings by double-clicking on the “adjustment layer icon” in the relevant row of the Layers palette.

If adjustments are made via multiple layers you can alter them at any time and in any order; you can’t do that if you directly adjust the image.

Layers, Layer Masks, and Selections

Selections can be converted to "layer masks"

- create a new adjustment layer while something’s selected
- click on the layer in which you want the selection, then command-click on the layer mask

You can edit a layer mask with all of Photoshop’s tools, just as you edit an image

- option-click on the layer mask

You can disable (turn off) a layer mask

- shift-click on the layer mask
Half-Tone Dots—"Traditional" Printing

(A) Traditional print media print solid black dots of varying size to imitate gray

![Darker to Lighter](example-image)

and of solid Y/C/M/K dots of varying size to obtain colour, again when viewed from a sufficient distance

(B) Compared to a monitor — “true” intensity variation (ie no half-toning)

Faking Half-Tone Dots on a Bi-Level Printer

(C) Digital half-toning for bi-level printers, solid black or white dots (most, but not all printers)

“Lines Per Inch” = # of rows / pixel
An NxN square yields $1+N^2$ grey levels

- (eg 2x2 squares can have 0, 1, 2, 3, or 4 black pixels, & thus be black

So to print an image the same size as the original ...

if your scanned photo has 72 pixels per inch (dpi) with 8 bits per pixel (256 intensities) and your bi-level printer has 1200 dots per inch (dpi) (eg the HP 2300 in my office)
you’ll have about $1200 / 72 \approx 16.7$ rows of printer pixels / image pixel

- & 16 x 16 squares are available to mimic half-tone dots on the printer (257 intensity levels—just right!)

![Image of rows and intensity levels](example-image)
Digital Printing—Variations on a Theme

“Regular-pattern halftones”
what’s important is actually that the right fraction of the dots be inked in,
not whether they’re clustered in the middle as a dot

“Stochastic screening” = “dithering”
randomly select which pixels to ink in,
in such a way that the right percentage of pixels are inked in
eg 33% gray could be presented by many different patterns
— in every 3x3 squares, there are 9*8*7 possible patterns with 0.33*9 = 3 dots inked:

Final Words

Gimp is an extremely rich application
• rich both in features
• and in the variety of useful ways in which you can combine features
we’ve only scratched the surface / given you a skeleton to flesh out on your own
• esp wrt making selections and masking

Places to go for more information
Real World Adobe Photoshop CS3 (© 2005)
  by David Blatner, Conrad Chavez and Bruce Fraser

  by David Blatner, Conrad Chavez, Glenn Fleishman and Steve Roth

The Non-Designer’s Scan and Print Book (© 1999)
  by Sandee Cohen and Robin Williams

resources > Drop Shadows & Masks on the cws

(Like O’Reilly, Peachpit is a quality publisher whose books are generally recommended.)