Compsci 101
Images, Tuples

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P is for …

- **Python**
  - Whatever you want it to be? Language!!!
- **Parameter**
  - When an argument becomes a variable
- **Power Cycle**
  - Not the last resort. But works
- **P2P**
  - From networking to collaboration

Cynthia Rudin

- **Duke CompSci Professor**
  - Univ Buffalo, BS Mathematical Physics, BA Music Theory
  - Princeton, PhD.
- **Works in interpretable machine learning, which is crucial for responsible and trustworthy AI**
- **Winner of Squirrel AI Award for AI for the Benefit of Humanity – 1 million**
  - Detecting crime series
  - Con Edison NYC – underground electrical distribution network

She uses AI's power to help society.

Announcements

- **Assign 4 due Thursday, March 23**
  - Assign 4 Sakai Quiz due tonight!
- **Prelab 8 – do before lab this week**
- **Assign 5 and Apt 5 out on Thursday**

- **Exam 2 coming back soon**
- **APT Quiz 2 starts at end of next week**
  - March 30-April 3

PFTD

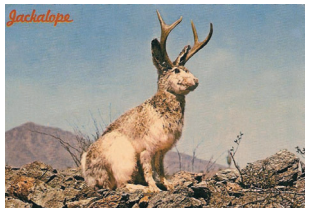
- **Exam 2**
- **Images**
- **Classes and Objects**
- **Tuples sprinkled about**

Images

What is photoshop?

Image Processing

- **Convert image into format for manipulating the image**
  - Visualization, Sharpening, Restoration, Recognition, Measurement, more
  - Resizing, Red-eye Removal, more
  - CrashCourse: Navigating Digital Info
    - http://bit.ly/dukecs101-cc-images



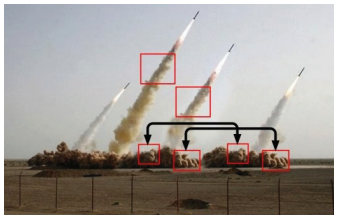
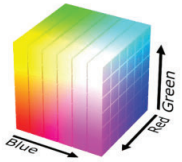


Image Library

- **PIL: Python Image Library -> Pillow**
  - To install run the command below in a terminal
    - Terminal in PyCharm, not "Python Console"
    - `pip install Pillow`
      - `If that doesn't work try:`
      - `Python3 -m pip install Pillow`
- **Library has extensive API, far more than we need**
  - Concepts often apply to every image library
  - Realized in Python-specific code/functions

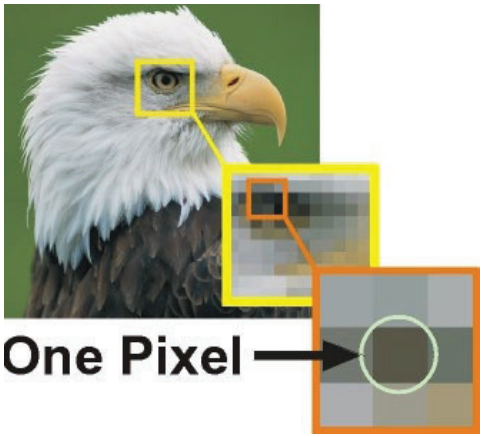
Color Models

- **Cameras, Displays, Phones, JumboTron: RGB**
  - Additive Color Model: Red, Green, Blue
  - https://en.wikipedia.org/wiki/RGB_color_model
- **Contrast Printers and Print which use CMYK**
  - Subtractive: Cyan, Magenta, Yellow, Key/Black



An image is made up of Pixels

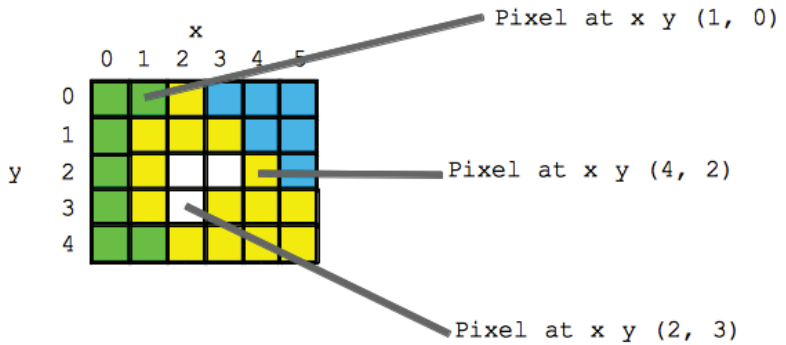
- **A pixel is a square of color**



Images and Pixels

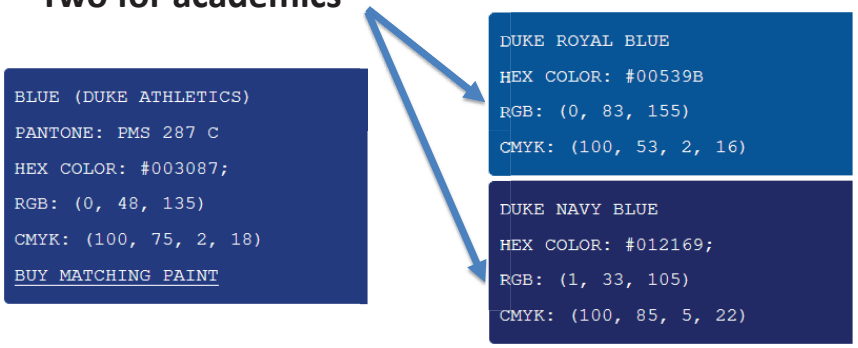
- **Image is a collection of pixels**
  - Organized in rows: # rows is image height
  - Each row has the same length: image width
- **Pixels addressed by (x, y) coordinates**
  - Upper-left (0,0), Lower-right (width-1,height-1)
  - Typically is a single (x, y) entity: tuple
- **Remember: Tuple is immutable, indexed sequence (a, b, c)**

Each pixel has a location in Image



Each pixel has an RGB color

- **Duke has three Duke blues**
- **Duke Athletics RGB: (0, 48, 145)**
- **Two for academics**



SimpleDisplay.py

- **Access to PIL and Image module**
  - What type is img?
  - https://pillow.readthedocs.io/en/latest/

```
6   from PIL import Image
7
8   if __name__ == '__main__':
9       img = Image.open("images/bluedevil.png")
10      img.show()
11      print("type is:", type(img))
12      print("width %d height %d" % (img.width, img.height))
```

OUTPUT:

SimpleDisplay.py

- **Access to PIL and Image module**
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12      print("width %d height %d" % (img.width, img.height))
```

OUTPUT:

```
type is: <class 'PIL.PngImagePlugin.PngImageFile'>
width 397 height 337
```


String formatting with % operator

- **Use formatted string with % in string to show where to put values**
  - Followed by % and tuple of values
  - %d is for an int
  - %f is for a float
  - %.xf is to specify x digits past the decimal
  - %s is for a string or something that could be shown as a string

String Formatting Examples

```
name = "Xiao"
age = 19
print("%s is %d years old" % (name, age))
alist = [6, 7.8643, 2]
print("%f is a list %s" % (alist[1], alist))
print("fav in %s is %.2f" % (alist, alist[1]))
```

OUTPUT:

String Formatting Examples

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name = "Xiao"
age = 19
print("%s is %d years old" % (name, age))
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print("%f is a list %s" % (alist[1], alist))
print("fav in %s is %.2f" % (alist, alist[1]))
```

OUTPUT:

```
Xiao is 19 years old
7.864300 is a list [6, 7.8643, 2]
fav in [6, 7.8643, 2] is 7.86
```


WOTO-1 Images

http://bit.ly/101s23-0321-1

What is a class in Python?

- **Class ≈ module ≈ library (for this CS101)**
- **Class – Also blueprint/Factory for creating objects**
  - We've used int, float, str
  - **<class 'int'>, <class 'list'>**
  - Everything is a class in Python3
- **Objects are created from a class**
  - x = [5, 6, 7]
  - b = “Moe”
  - c = “Charlotte”

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  - `<class 'int'>, <class 'list'>`
  - Everything is a class in Python3
- **Objects are created from a cla**
  - x = [5, 6, 7]
  - b = “Moe”
  - c = “Charlotte”

x is a list object from the <class ‘list’>

b and c are string objects from the <class ‘str’>

Types

```
print(type(6))
print(type([1,1]))
print(type('blue'))
print(type((6,[7]))
```

```
img = Image.open("images/bluedevil.png")
print(type(img))
```

```
img = Image.open("images/eastereggs.jpg")
print(type(img))
```


Types

```
print(type(6))          <class 'int'>
print(type([1,1]))      <class 'list'>
print(type('blue'))     <class 'str'>
print(type((6,[7]))     <class 'tuple'>
```

```
img = Image.open("images/bluedevil.png")
print(type(img))
<class 'PIL.PngImagePlugin.PngImageFile'>
```

```
img = Image.open("images/eastereggs.jpg")
print(type(img))
<class 'PIL.JpegImagePlugin.JpegImageFile'>
```


What is a class in Python?

- **Use . dot notation to access object's innards**
  - `word = "Hello"`
    - word is an **object** from the String class
  - `word.lower()`
    - `.lower()` is a function, but don’t call it that!
    - Function that goes with a class is called a **method**
    - `.lower()` is a **method** from the String class
  - `img.width` is an attribute aka field/property
    - Note there are no ()’s, like a variable

What is a class in Python?

- **Use . dot notation to access object's fields**
  - `word = "Hello"`
    - word is an **object** from "
  - `word.lower()`
    - `.lower()` is a function, but don't call it that!
    - Function that goes with a class is called method
    - `.lower()` is a **method** from the String class
  - `img.width` is an attribute aka field/property
    - Note there are no ()'s, like

Word is object from String class

Use "dot" to access a String method lower()

Use "dot" to accesss part of object, width

Image Library Basics

- **Library can create/open images in different formats, e.g., .png, .jpg, .gif, …**
- **Images have properties: width, height, type, color-model, and more (variables associated with class)**
  - Functions and fields access these properties, e.g., `im.width`, `im.format`, and more
- **Pixels are formed as triples (255,255,255), (r,g,b)**
  - In Python these are tuples: immutable sequence

Types

```
img = Image.open("images/bluedevil.png")
print(img.format)
```

```
img = Image.open("images/eastereggs.jpg")
print(img.format)
```


Types

```
img = Image.open("images/bluedevil.png")
print(img.format)
```

```
PNG
```

```
img = Image.open("images/eastereggs.jpg")
print(img.format)
```

```
JPEG
```

WOTO-2 Classes
http://bit.ly/101s23-0321-2

Demo: Convert Color to Gray

Process each pixel
Convert to gray

main

```
36  if __name__ == '__main__':
37      img = Image.open("images/eastereggs.jpg")
38      start = time.process_time()
39      gray_img = grayByPixel(img,True)
40      #gray_img = grayByData(img,True)
41      end = time.process_time()
42      img.show()
43      gray_img.show()
44      print("Time = %1.3f" % (end-start))
```


grayByPixel Function

```
13  def grayByPixel(img, debug=False):
14      width = img.width
15      height = img.height
16      new_img = img.copy()
17      if debug:
18          print("creating %d x %d image" % (width,height))
19      for x in range(width):
20          for y in range(height):
21              (r,g,b) = img.getpixel((x,y))
22              grays = getGray(r,g,b)
23              new_img.putpixel((x,y),grays)
24      return new_img
```

getGray function

```
12  def getGray(r,g,b):
13      gray = int(0.21*r + 0.71*g + 0.07*b)
14      return (gray,gray,gray)
```


WOTO-3 GrayScale
http://bit.ly/101s23-0321-3

Make Gray: Notice the Tuples!

```
13  def grayByPixel(img, debug=False):
14      width = img.width
15      height = img.height
16      new_img = img.copy()
17      if debug:
18          print("creating %d x %d image" % (width,height))
19      for x in range(width):
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```


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21              (r,g,b) = img.getpixel((x,y))
22              grays = getGray(r,g,b)
23              new_img.putpixel((x,y),grays)
```

How does this code make a grey image?

New stuff here, what and where?

Revisiting nested Loops

- **What is printed here? y varies first**
  - Value of x as inner loop iterates?

```
>>> for x in range(5):
...     for y in range(3):
...         print(x, y)
```

```
0 0
0 1
0 2
1 0
1 1
1 2
2 0
2 1
2 2
3 0
3 1
3 2
4 0
4 1
4 2
```


Revisiting nested Loops

- **What is printed here? y varies first**
  - Value of x as inner loop iterates?

```
>>> for x in range(5):
...     for y in range(3):
...         print(x, y)
```

Why is the first column have the number repeated like that? What if the print became: `print(y, x)`?

print(y, x)

```
0 0
0 1
0 2
1 0
1 1
1 2
2 0
2 1
2 2
3 0
3 1
3 2
4 0
4 1
4 2
```

```
0 0
1 0
2 0
0 1
1 1
2 1
0 2
1 2
2 2
0 3
1 3
2 3
0 4
1 4
```


Make Gray cont.

```
13  def grayByPixel(img, debug=False):
14      width = img.width
15      height = img.height
16      new_img = img.copy()
17      if debug:
18          print("creating %d x %d image" % (width,height))
19      for x in range(width):
20          for y in range(height):
21              (r,g,b) = img.getpixel((x,y))
22              grays = getGray(r,g,b)
23              new_img.putpixel((x,y),grays)
```


Make Gray cont.

```
13  def grayByPixel(img, debug=False):
14      width = img.width
15      height = img.height
16      new_img = img.copy()
17      if debug:
18          print("creating %d x %d image" % (width,height))
19      for x in range(width):
20          for y in range(height):
21              (r,g,b) = img.getpixel((x,y))
22              grays = getGray(r,g,b)
23              new_img.putpixel((x,y),grays)
```

If stop code halfway, what half of image is gray?

Tuple

Tuple

Nested Loops

Tuple

How many parameters does putpixel have?

Accessing Individual Pixels is Inefficient

- **Accessing each one one-at-a-time is inefficient**
  - Python can do better "under the hood"
- **PIL provides a function `img.getdata()`**
  - Returns list-like object for accessing all pixels
  - Similar to how file is a sequence of characters
  - Symmetry: `img.putdata(sequence)`

Processing all Pixels at Once

- **Treat `img.getdata()` as list, it's not quite a list**
  - Iterable: object use in "`for … in …`" loop

```
27  def grayByData(img, debug=False):
28      pixels = [getGray(r,g,b) for (r,g,b) in img.getdata()]
29      new_img = Image.new("RGB", img.size)
30      new_img.putdata(pixels)
```


Processing all Pixels at Once

- **Treat `img.getdata()` as list, it's not quite a list**
  - Iterable: object use in "`for … in …`" loop

```
27  def grayByData(img, debug=False):
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29      new_img = Image.new("RGB", img.size)
30      new_img.putdata(pixels)
```

Think: An image is 2D and putdata(seq) takes a 1D sequence. How did we get an image?

Hint: What type are the elements in the list comprehension?

Hint: What do we know about the length of that sequence and the sequence putdata(…) needs?

GrayByData

```
27  def grayByData(img, debug=False):
28      pixels = [getGray(r,g,b) for (r,g,b) in img.getdata()]
29      new_img = Image.new("RGB", img.size)
30      new_img.putdata(pixels)
31      if debug:
32          print("created %d x %d gray image" % (img.width,img.height))
33      return new_img
```

Summary of Image functions

- **Many, many more**
  - http://bit.ly/pillow-image

Image function/method	Purpose
`im.show()`	Display image on screen
`im.save("foo.jpg")`	Save image with filename
`im.copy()`	Return copy of im
`im.getdata()`	Return iterable pixel sequence
`im.load()`	Return Pixel collection indexed by tuple (x,y)

WOTO-4 More on Images
http://bit.ly/101s23-0321-4