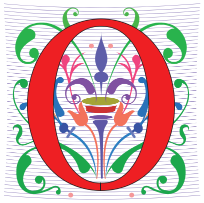
# Compsci 101

## Images, Tuples

Susan Rodger
October 25, 2022

## O is for …



- **Open Source**
  - Copyright meets the Creative Commons
- **Object Oriented**
  - Using classes and more in programming
- **Occam's Razor**
  - Not just compsci. Simple is good

## 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

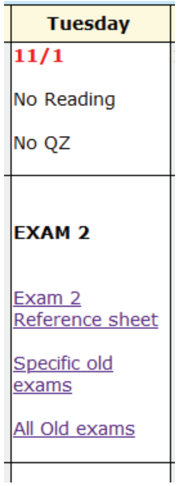
- **APT-4 due Thursday, Oct 27**
- **Assign 4 due Thursday, November 3**
- **Prelab 7 – do before lab this week**
  - Some of it is practice for the upcoming exam
- **Exam 2 in one week!**

# PFTD

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

# Exam 2 – in person – Tues, Nov 1

- **Exam is in class on paper – 10:15am**
  - Need pen or pencil
- **See materials under 11/1 date**
  - Exam 2 Reference sheet - part of exam
- **Covers**
  - topics /reading through today
  - APTs through APT4
  - Labs through Lab 7 (Parts 1 and 2)
  - Assignments through Assignment 3, parts of Assign 4 helpful



Tuesday

11/1

No Reading

No QZ

EXAM 2

Exam 2 Reference sheet

Specific old exams

All Old exams

# Exam 2 topics include …

- **List, tuples, list comprehensions**
- **Loops – for loop, while loop, indexing with a loop**
- **Reading from a file**
  - Converting data into a list of things
- **Parallel lists**
- **Sets – solving problems**
- **Dictionaries – only reading them and understanding output, no problem solving**
- **No turtles, no images - but note we are practicing other concepts with images**

# Exam 2

- **Exam 2 is your own work!**
- **No looking at other people's exam**
- **You cannot use any notes, books, computing devices, calculators, or any extra paper**
- **Bring only a pen or pencil**
- **The exam has extra white space and has the Exam 2 reference sheet as part of the exam.**

- **Do not discuss any problems on the exam with others until it is handed back**

# Exam 2 – How to Study

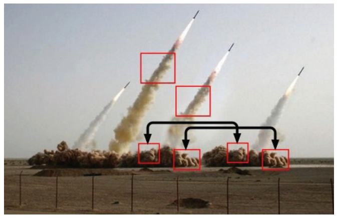
- **Practice writing code on paper!**
- **Rewrite an APT**
- **Try to write code from lecture from scratch**
- **Try to write code from lab from scratch**
- **Practice from old exams**
- **Put up old Sakai quizzes, but better to practice writing code**
- **Look at Exam 2 reference sheet when writing code!**

# 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

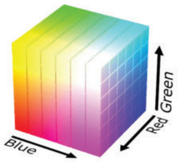


# Image Library

- **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

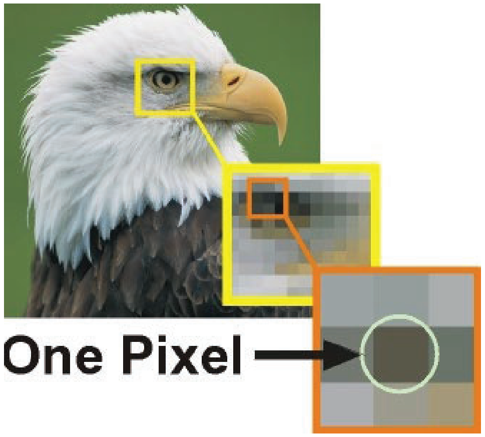
# Color Models

- **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

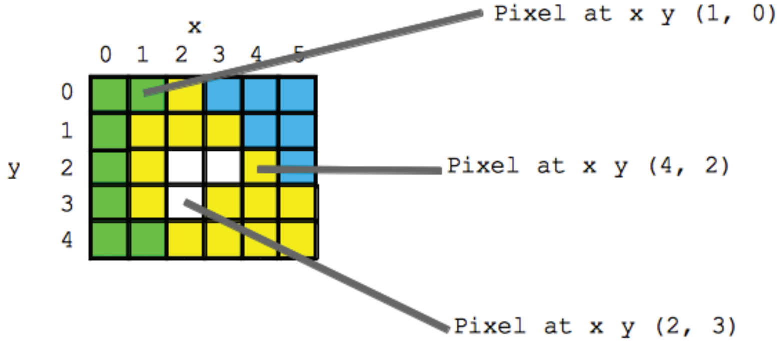
- **A pixel is a square of color**



# Images and Pixels

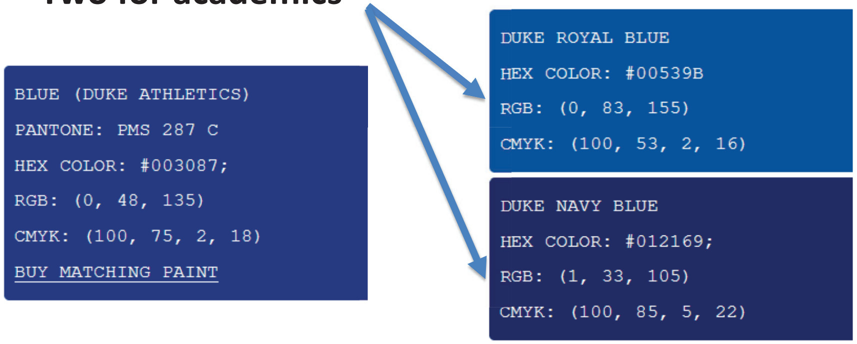
- **Image is a collection of pixels**
  - Organized in rows: # rows is image height
  - Each row has the same length: image width
- **Pixels addressed by (x, y) coordinates**
  - Upper-left (0,0), Lower-right (width-1,height-1)
  - Typically is a single (x, y) entity: tuple
- **Remember: Tuple is immutable,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



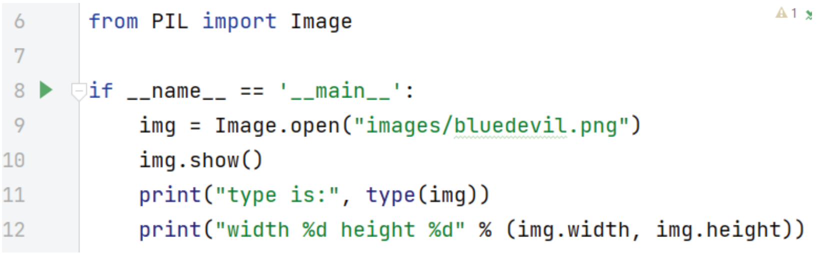
BLUE (DUKE ATHLETICS)
PANTONE: PMS 287 C
HEX COLOR: #003087;
RGB: (0, 48, 135)
CMYK: (100, 75, 2, 18)
BUY MATCHING PAINT

DUKE ROYAL BLUE
HEX COLOR: #00539B
RGB: (0, 83, 155)
CMYK: (100, 53, 2, 16)

DUKE NAVY BLUE
HEX COLOR: #012169;
RGB: (1, 33, 105)
CMYK: (100, 85, 5, 22)

# SimpleDisplay.py

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



```python
from PIL import Image

if __name__ == '__main__':
    img = Image.open("images/bluedevil.png")
    img.show()
    print("type is:", type(img))
    print("width %d height %d" % (img.width, img.height))
```

OUTPUT:

# 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

```python
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:**

# WOTO-1 Images
# http://bit.ly/101f22-1025-1

# 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”

# 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))
```

# 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

# 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

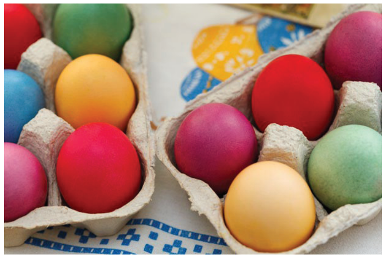
# Types

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

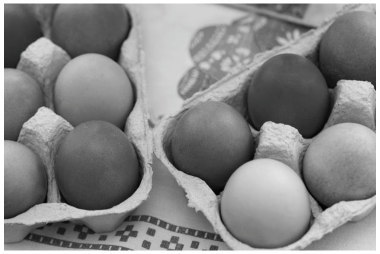
```
img = Image.open("images/eastereggs.jpg")
print(img.format)
```

# WOTO-2 Classes
http://bit.ly/101f22-1025-2

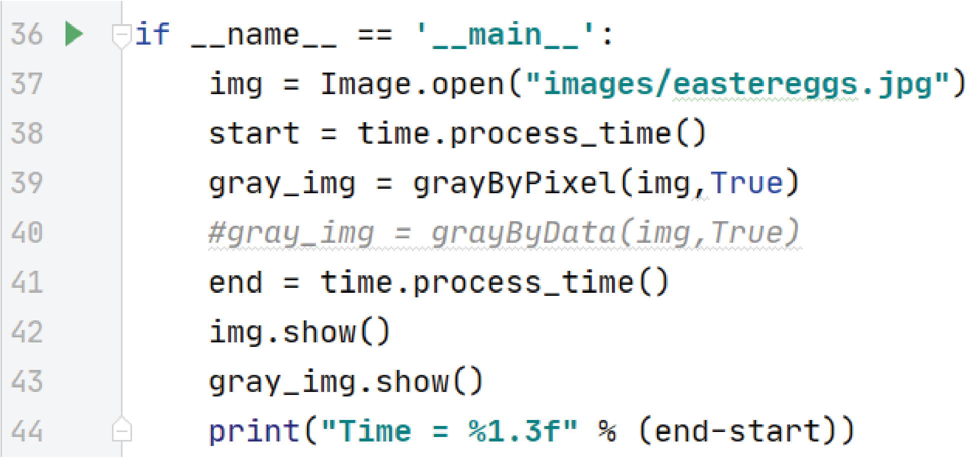
# Demo: Convert Color to Gray



*Process each pixel*
*Convert to gray*

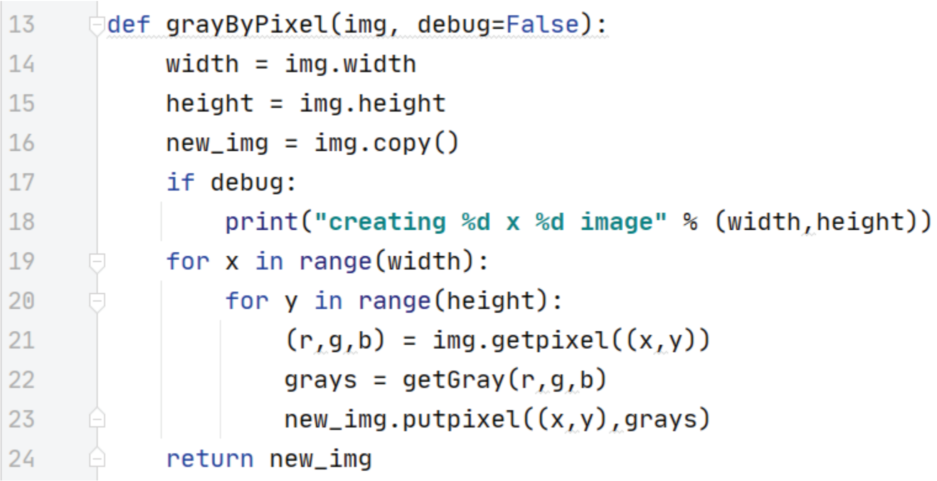


# main



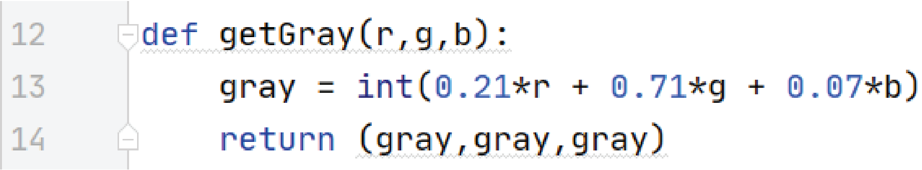
```python
if __name__ == '__main__':
    img = Image.open("images/eastereggs.jpg")
    start = time.process_time()
    gray_img = grayByPixel(img,True)
    #gray_img = grayByData(img,True)
    end = time.process_time()
    img.show()
    gray_img.show()
    print("Time = %1.3f" % (end-start))
```

# grayByPixel Function



```python
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
    return new_img
```

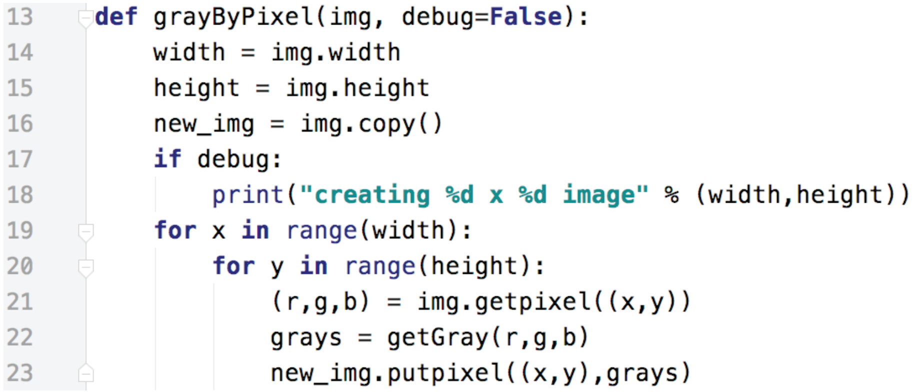
# getGray function



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

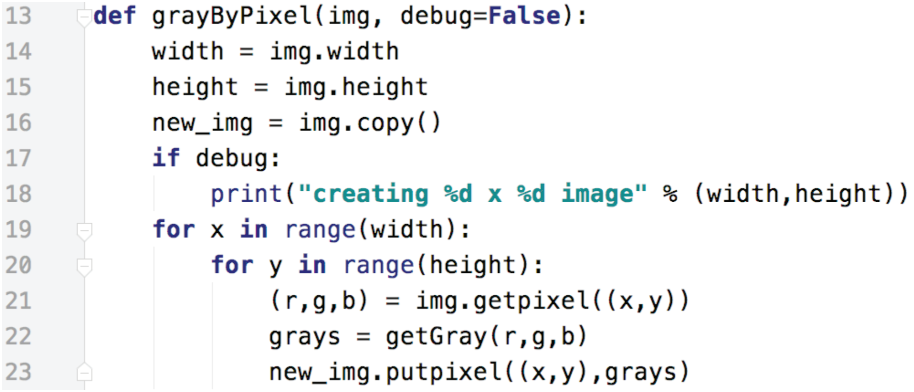
# WOTO-3 GrayScale
# http://bit.ly/101f22-1025-3

# Make Gray: Notice the Tuples!



```
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
```

# Make Gray cont.



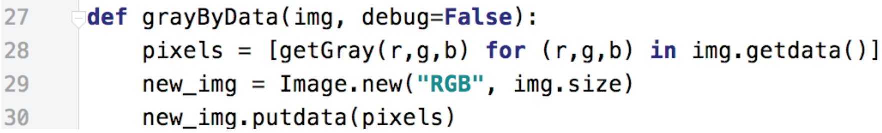
```
def grayByPixel(img, debug=False):
    width = img.width
    height = img.height
    new_img = img.copy()
    if debug:
        print("creating %d x %d image" % (width,height))
    for x in range(width):
        for y in range(height):
            (r,g,b) = img.getpixel((x,y))
            grays = getGray(r,g,b)
            new_img.putpixel((x,y),grays)
```

# 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)`**

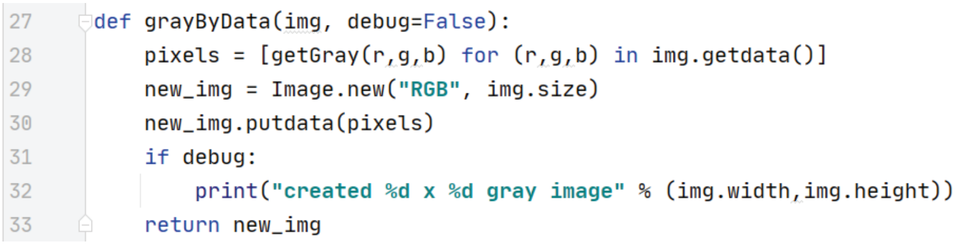
# Processing all Pixels at Once

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



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

# GrayByData



```python
def grayByData(img, debug=False):
    pixels = [getGray(r,g,b) for (r,g,b) in img.getdata()]
    new_img = Image.new("RGB", img.size)
    new_img.putdata(pixels)
    if debug:
        print("created %d x %d gray image" % (img.width,img.height))
    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/101f22-1025-4