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
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
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

- **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

![Pixel locations in Image](image.png)
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?

```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:
SimpleDisplay.py

- Access to PIL and Image module
  - What type is img?

```python
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if __name__ == '__main__':
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    img.show()
    print("type is:", type(img))
    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

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:
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
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”`
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"`

x is a list object from the `<class 'list'>`
b and c are string objects from the `<class 'str'>`
Types

```python
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

```python
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 insides.
  - `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 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, colormap, 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

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

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

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

PNG

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

JPEG
```
WOTO-2 Classes

Demo: Convert Color to Gray

Process each pixel
Convert to gray
```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))
```
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
12 def getGray(r, g, b):
13     gray = int(0.21*r + 0.71*g + 0.07*b)
14     return (gray, gray, gray)
```
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)
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    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)
Revisiting nested Loops

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

```python
>>> 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?

```python
>>> 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)`?
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.

```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)
```

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

Nested Loops

Tuple

Tuple

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

```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)
```
Processing all Pixels at Once

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

```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)
```

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

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

<table>
<thead>
<tr>
<th>Image function/method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>im.show()</code></td>
<td>Display image on screen</td>
</tr>
<tr>
<td><code>im.save(&quot;foo.jpg&quot;)</code></td>
<td>Save image with filename</td>
</tr>
<tr>
<td><code>im.copy()</code></td>
<td>Return copy of im</td>
</tr>
<tr>
<td><code>im.getdata()</code></td>
<td>Return iterable pixel sequence</td>
</tr>
<tr>
<td><code>im.load()</code></td>
<td>Return Pixel collection indexed by tuple (x,y)</td>
</tr>
</tbody>
</table>