CIS 1100

Objects (Making them and FFF)!

Python
Fall 2024
University of Pennsylvania

Reminder: Questions During Class

You can ask us about anything at all durinng class when we are walking around.
Even if it is not about the current activity, feel free to ask. Worst case we say "Ask us later/after class"

- Can ask about things covered 20 minutes earlier in the lecture
- Can ask questions about previous topics from previous lectures
- Homework questions are usually longer to answer,
  will probably tell you to talk about it after class

Review Data Class

If we wanted to make the `Point` object in the previous slide we would do:

```python
from dataclasses import dataclass

@dataclass      # mark the class as a data class
class Point:    # Declare a class
    x: int      # declare the field names and their types
    y: int
```

In Python, a `dataclass` is the simplest kind of class.

- Defined (in most basic case) just by what properties that members of this class should have.

More advanced type notations

If we want to have a data class with more advanced type notations, it would look something like this:

```
from dataclasses import dataclass

@dataclass
class Example:
    x: list[int]        # list of integers
    y: dict[str, int]  # dictionary, keys are strings, value are ints
    z: tuple[int, int, str]  # a tuple of two ints and a string
```

Practice:

(C12) Write a dataclass that represents a `Ball` with three fields:

- a float to represent the `radius`
- two more `float`s to represent the `center_x` and `center_y`
- a tuple containing three integers to represent the `color`

Classes

So far we have talked about data classes, which make
a simple (and convenient) way for us to define classes.
Dataclass mostly just creates the `__init__(self)` function (constructor).

```
# When we create an instance of a class like this, it is calling the __init__ function
my_ball = Ball(0.5, 0.25, 0.1, (10, 25, 216))
```

We can also define classes ourselves by defining our own `__init__(self)` function.

Writing our own `__init__`

We can write our class `Ball` again:

```
class Ball:
    def __init__(self, radius, center_x, center_y, color):
        self.radius = radius
        self.center_x = center_x
        self.center_y = center_y
        self.color = color
```

Here we just create attributes of the same name inside of `self` (self beinng the object that we are initializing).

Writing our own `__init__`

What if we slightly modify our class `Ball` to randomly generate the colors?

```
class Ball:
    def __init__(self, radius, center_x, center_y):
        self.radius = radius
        self.center_x = center_x
        self.center_y = center_y

        red = random.randint(0, 255)
        green = random.randint(0, 255)
        blue = random.randint(0, 255)
        self.color = (red, green, blue)
```

(L11) If we wanted to preserve the random number generation in the constructor, could this be written as a dataclass? Why or why not?

Review: Methods

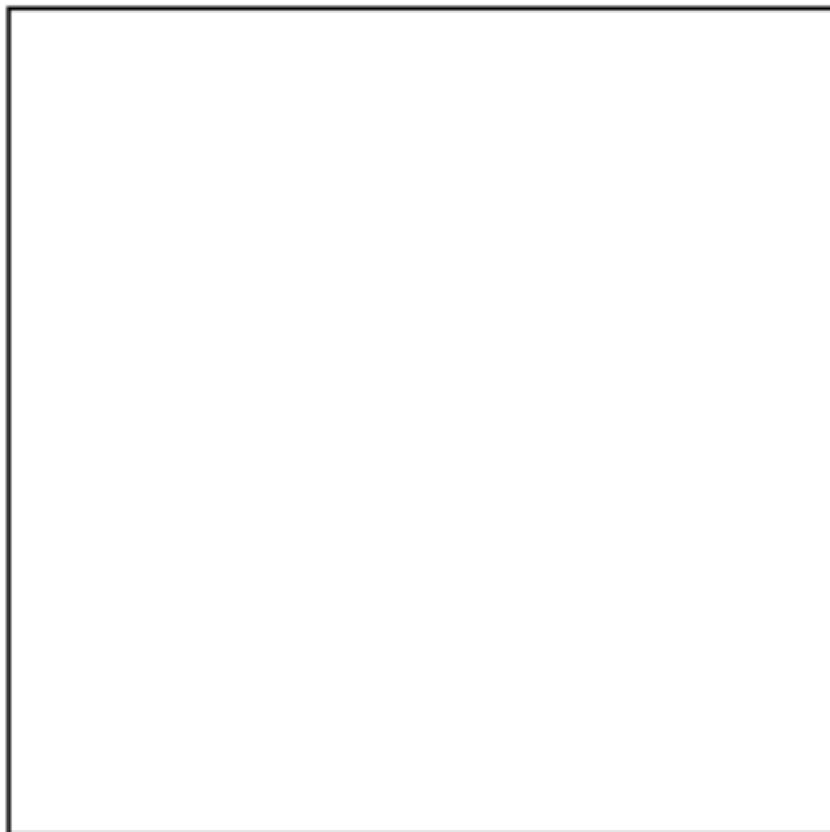
Classes can contain more than just attributes, they can also contain methods.

Here we have the `Square` class defined with the method `draw`

Each method is "called on" an instance of the class and takes in `self` as the first input

```
class Square:

    def __init__(self, half_length, center_x, center_y):
        self.half_length = radius
        self.center_x = center_x
        self.center_y = center_y

        red = random.randint(0, 255)
        green = random.randint(0, 255)
        blue = random.randint(0, 255)
        self.color = (red, green, blue)

    def draw(self):
        penndraw.set_pen_color(self.color) # note how we use self to refer to attributes
        penndraw.filled_square(self.center_x, self.center_y, self.half_length)
```

square.py

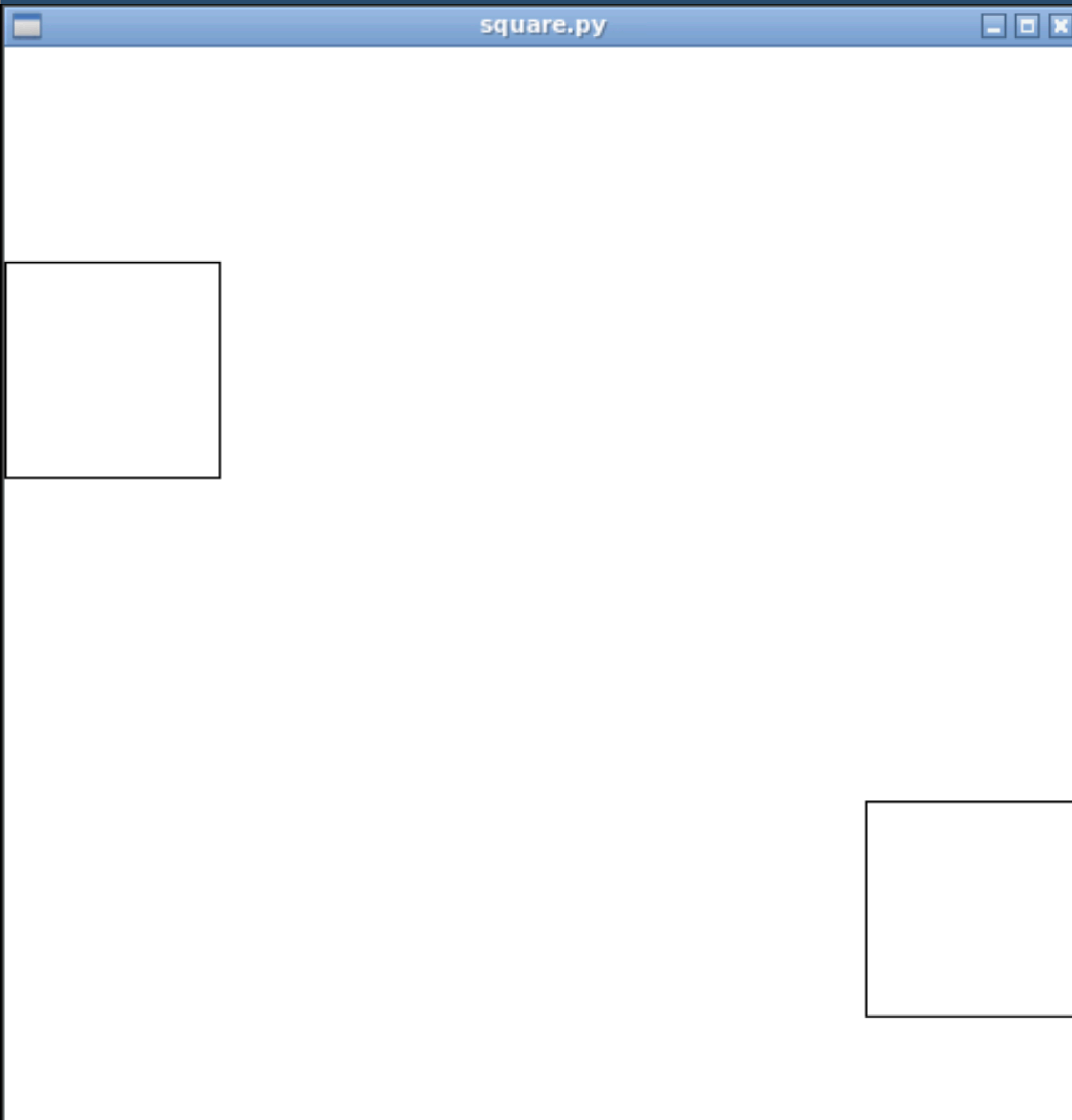


Review: Using Methods

Methods are functions that belong to an object, so they are called (mostly) like any function

- Call by name and pass in arguments within parentheses
- Make sure to call the method *on the object* that you want to perform that behavior!

```
my_square = Square(0.5, 0.5, 0.2)
my_square.draw()
```



Review: Methods

You might have several instances of a class in your program.

- A method called on an object should *modify/use just that object.*
- Other objects will be unchanged by another object's method call.

```
left_square = Square(0.1, 0.2, 0.1)
right_square = Square(0.9, 0.2, 0.1)
left_square.move_by(0, 0.5)
left_square.draw()
right_square.draw()
```

Practice: Contains Point

Write the method `contains_point` for the `Square` class that checks to see if a point is contained within the square.

Returns `True` if the point is in the square, or `False` if it is not in the square.

(C14)

```
def contains_point(self, other_x, other_y):
    # TODO: probably use half_length, center_x and center_y
```

Demo: Furious Flying Fish

Note:

- Target health does not change till after fish resets
- Fish does not reset when going above the frame
- Can drag the window for better targeting
- Note the direction of the velocity line

Bouncing Ball Simulation

Ingredients:

- `ball.py`, a class that defines how a 2D ball moves & bounces on a screen
- `bouncing_balls.py`:
    - contains a main method so that the simulation is runnable
    - creates an `list[Ball]` in which to store the objects to be simulated
    - defines a "physics" (animation) loop

A Bit of Physics

To simulate an object's motion in 2D space over time, we need to keep track of its:

- position (p_x, p_y)
  - where the object is **right now**
- velocity/speed (v_x, v_y)
  - how much the object should move from where it is right now to where it will be next time we look
- acceleration (a_x, a_y)
  - how much the object's velocity should change from what it is right now to what it will be next time we look
  - we'll hold acceleration constant

A Bit of Physics

Since our simulation is run using a loop, we do our calculations in *discrete steps*.

- We denote the step number using superscripts, so p_x^t means "x position at step t"
- We'll assume a constant unit timestep, meaning that we don't have to account for the length of the timestep in our equations
  - *(ignore this point if the details of physical simulations are not interesting to you)*

A Bit of Physics

Equation	Meaning	Code
$p_x^{t+1} = p_x^t + v_x^t$	x position in the next iteration is equal to the x position now plus the x speed now	`px = px + vx`
$p_y^{t+1} = p_y^t + v_x^t$	y position in the next iteration is equal to the y position now plus the y speed now	`py = py + vy`
$v_x^{t+1} = v_x^t + a_x^t$	x speed in the next iteration is equal to the x speed now plus the x acceleration	`vx = vx + ax`
$v_y^{t+1} = v_y^t + a_y^t$	y speed in the next iteration is equal to the y speed now plus the y acceleration	`vy = vy + ay`

Implementing `ball.py`

What behaviors does a `Ball` object need to exhibit as part of a simple physics simulation?

- Needs to be drawable so that we can see the simulation
- Needs to move & bounce pursuant to the previous equations

Methods:

`def draw(self)`, `def update(self)`

Implementing `ball.py`

What properties does a `Ball` object need to store in order to perform these operations?

- position, x and y
- velocity, x and y
- acceleration, x and y
  - we'll ignore x acceleration, and y acceleration is just gravity
- radius
  - used for drawing
  - used for deciding when to bounce

The Simulator

The simulator will be responsible for initializing and keeping track of all of the balls in the simulation.

- How will we store all of the objects being simulated?
  - Create an `list[Ball]`
- How will we draw each of the objects being simulated?
  - Iterate through the list and call the `draw()` method on each of the `Ball` objects.
- How will we get each of the objects to move and bounce?
  - Iterate through the list and call the `update()` method on each of the `Ball` objects

The Simulator

```python
import penndraw
import ball

def main():
    N = 40
    all_balls = []

    for _ in range(N):
        all_balls.append(ball.Ball())

    penndraw.set_canvas_size(600, 600)

    while True:
        penndraw.clear()
        for current_ball in all_balls:
            current_ball.draw()
            current_ball.update()
        penndraw.advance()

    penndraw.run()
```

A First Pass at the "Bouncing" Ball

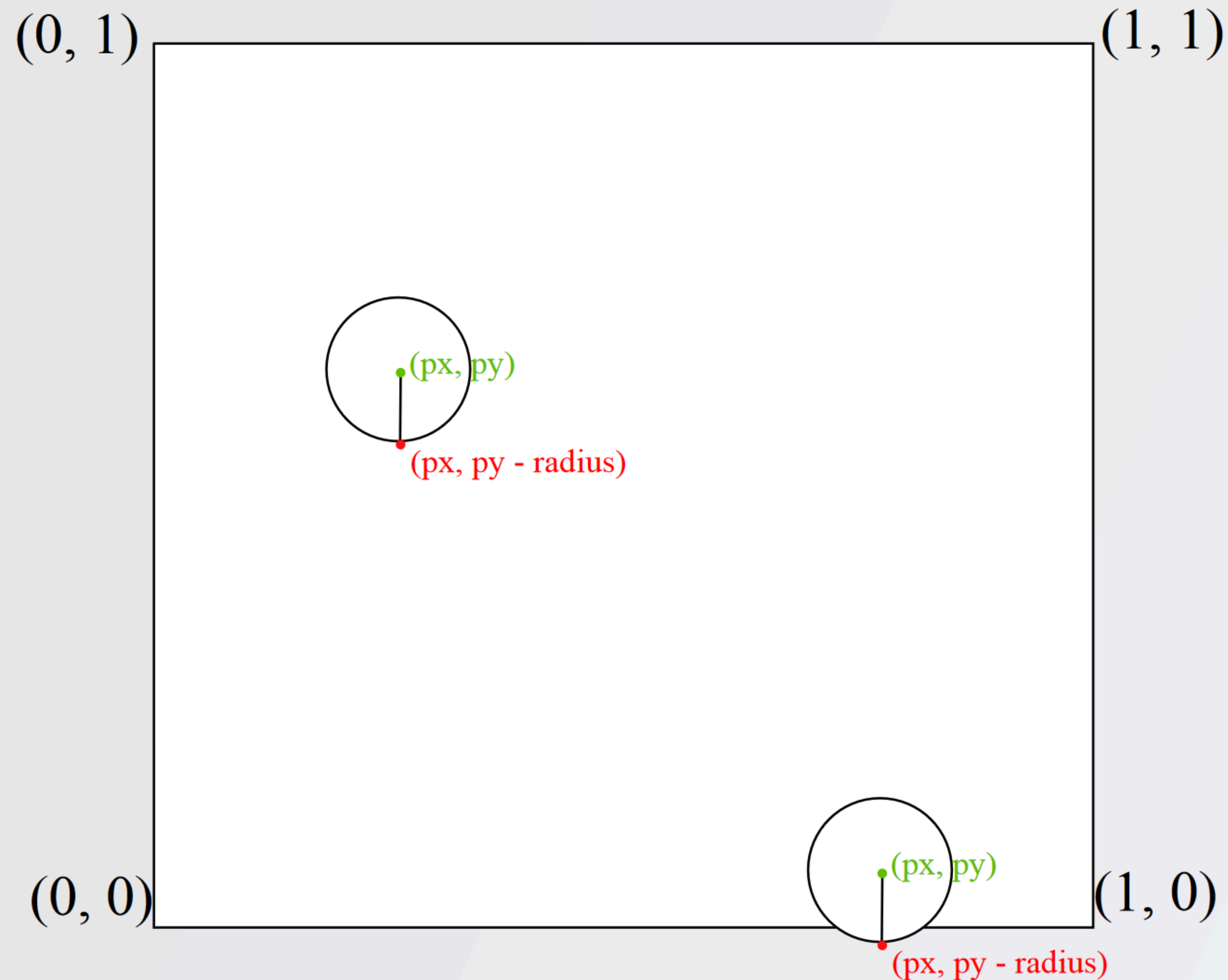
```python
import random
import penndraw

class Ball:
    def __init__(self):
        self.px = random.random()
        self.py = random.random()
        self.vx = -0.005 + (random.random() * 0.01) # [-0.005, 0.005]
        self.vy = -0.005 + (random.random() * 0.01)
        self.gravity = -0.0001
        self.radius = 0.02 + random.random() * 0.04 # [0.02, 0.06]

    def draw(self):
        penndraw.filled_circle(self.px, self.py, self.radius)

    def update(self):
        self.px = self.px + self.vx
        self.py = self.py + self.vy
        self.vy = self.vy + self.gravity
```

Problem: No Bouncing!

Currently, the balls just drop off the sides or bottom of the screen. How can we get them to bounce?

- Check if the ball has gone past the left, right, or bottom of the screen
- Simulate a bounce by inverting the velocity for the next update step

A Bounce



On the left, we have a sketch of the canvas with two balls.

- Which one should "bounce"?
- How can you formalize what it means for a ball to bounce off of the bottom of the screen?

(L13)

Checking a Bounce

A ball should bounce off the bottom of the screen when, at time step t:

- The ball is traveling downwards ($v_y^t < 0$)
- The bottom of the ball is at or below the bottom of the screen ($p_y^t - \text{radius} \leq 0$)

Modeling a Bounce

What happens when an object bounces off of a surface?

- The object should change direction
- The object should lose a bit of momentum

The Bounce:

$$v_y = -0.9 * v_y$$

A Better `update()`

```
def update(self):
    self.px = self.px + self.vx
    self.py = self.py + self.vy
    self.vy = self.vy + self.gravity

    if (self.vy < 0 and self.py - self.radius <= 0):
        self.vy = -0.9 * self.vy
```

Collision Practice:

What if we want to make the balls bounce off of the walls?

A ball should bounce off the side of the screen when, at time step t:

- The ball is traveling in the direction of the wall
  - $v_x^t < 0$ for the left wall
  - $v_x^t > 0$ for the right wall
- The bottom of the ball is at or past the wall
  - $p_x^t - \text{radius} \leq 0$ for the left wall
  - $p_x^t - \text{radius} \geq 1$ for the right wall

What can we add to the update method to support bouncing off of the walls? (C16)

The Bounce:

$$v_x = -0.9 * v_x$$

A Best `update()`

```
def update(self):
    self.px = self.px + self.vx
    self.py = self.py + self.vy
    self.vy = self.vy + self.gravity

    if (self.vy < 0 and self.py - self.radius <= 0):
        self.vy = -0.9 * self.vy

    if ((self.vx < 0 and self.px - self.radius <= 0) or
            (self.vx > 0 and self.px + self.radius >= 1)):
        self.vx = -0.9 * self.vx
```

Next time

- Searching with Harry :)