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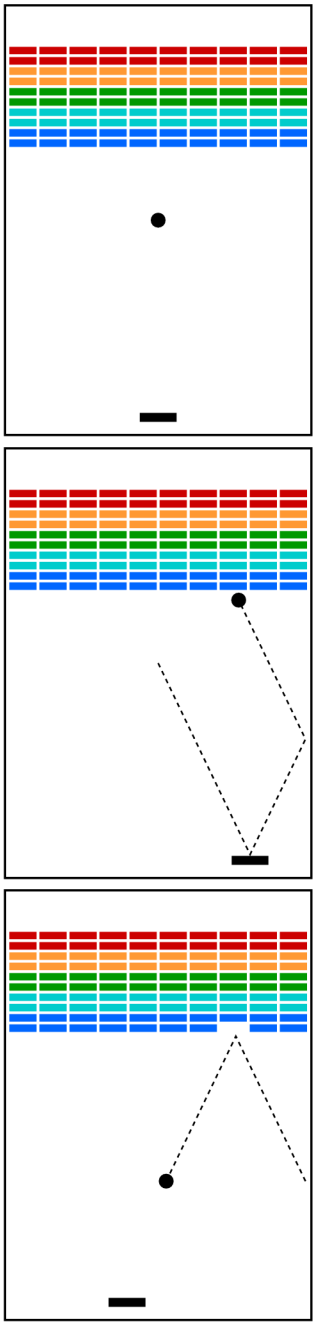
CSCI 121

Handout #10
February 11, 2019

Project #1—Breakout!

Due: Wednesday, February 20, 11:59 P.M.



Your job in this programming project is to write the classic arcade game of Breakout, which was invented by Steve Wozniak before he founded Apple with Steve Jobs. It is a large project, but well within your capabilities, as long as you break the problem up into manageable pieces. The decomposition is discussed in this handout, and there are several suggestions for staying on top of things in the "Strategy and tactics" section later in this handout.

The Breakout game

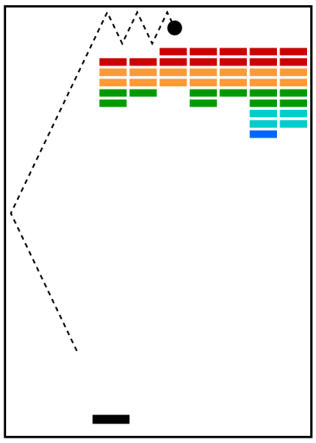
In Breakout, the initial configuration of the world appears in the top diagram on the right. The colored rectangles in the top part of the screen are bricks, and the slightly larger rectangle at the bottom is the paddle. The paddle is in a fixed position in the vertical dimension, but moves back and forth across the screen along with the mouse until it reaches the edges of the window.

A complete game consists of three turns. On each turn, a ball is launched from the center of the window toward the bottom of the screen at a random angle. That ball bounces off the paddle and the walls of the world, in accordance with the physical principle generally expressed as "the angle of incidence equals the angle of reflection" (which turns out to be very easy to implement as discussed later in this handout). Thus, after two bounces—one off the paddle and one off the right wall—the ball might have the trajectory shown in the second diagram. (Note that the dotted line is there only to show the ball's path and does not actually appear on the screen.)

As you can see from the second diagram, the ball is about to collide with one of the bricks on the bottom row. When that happens, the ball bounces just as it does on any other collision, but the brick disappears. The third diagram shows what the game looks like after that collision and after the player has moved the paddle to put it in line with the oncoming ball.

The play on a turn continues in this way until one of two conditions occurs:

1. The ball hits the lower wall, which means that the player must have missed it with the paddle. In this case, the turn ends and the next ball is served if the player has any turns left. If not, the game ends in a loss for the player.
2. The last brick is eliminated. In this case, the player wins, and the game ends immediately.



After all the bricks in a particular column have been cleared, a path will open to the top wall. When this delightful situation occurs, the ball will often bounce back and forth several times between the top wall and the upper line of bricks without the user ever having to worry about hitting the ball with the paddle. This condition is a reward for "breaking out" and gives meaning to the name of the game. The diagram on the right shows the situation shortly after the ball has broken through the wall. That ball will go on to clear several more bricks before it comes back down the open channel.

It is important to note that, even though breaking out is a very exciting part of the player's experience, you don't have to do anything special in your program to make it happen. The game is simply operating by the same rules it always applies: bouncing off walls, clearing bricks, and otherwise obeying the laws of physics.

The starter file

The starter file for this project contains the initial version of the **`Breakout.py`** file, as shown in Figure 1 on the next page. This file takes care of the following details:

- It includes the imports you will need in writing the game.
- It defines the constants that control the game parameters, such as the dimensions of the various objects. Your code should use these constants internally so that changing them in your file changes the behavior of your program accordingly. Note that some of these constants are specified directly but that others are derived from constants specified earlier.
- It includes a skeleton for the **`Breakout`** function that creates the graphics window. Your job is to add the code for the Breakout game along with the definition of any helper and callback functions, all of which are easiest to define as inner functions inside **`Breakout`** so that they can share its variables.
- It includes the startup code to invoke the **`Breakout`** function when the **`Breakout.py`** module is run from the command line.

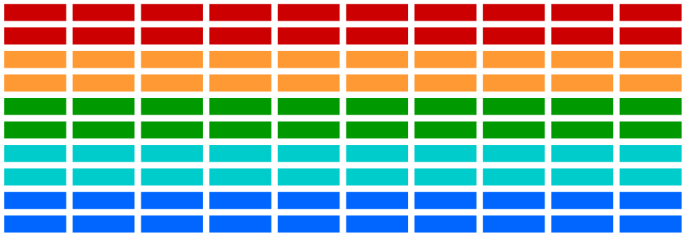
Success in this project will depend on decomposing the problem into manageable pieces and getting each one working before you move on to the next. The next few sections describe a reasonable staged approach to the problem.

Figure 1. The starter file for the Breakout game

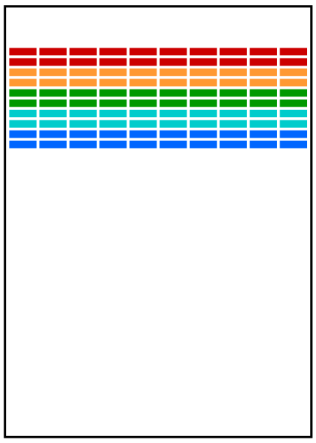
```
# File: Breakout.py

"""
This program (once you have finished it) implements the Breakout game.
"""

from pgl import GWindow, GOval, GRect
import random

# Constants

GWINDOW_WIDTH = 360               # Width of the graphics window
GWINDOW_HEIGHT = 600              # Height of the graphics window
N_ROWS = 10                       # Number of brick rows
N_COLS = 10                       # Number of brick columns
BRICK_ASPECT_RATIO = 4 / 1        # Width to height ratio of a brick
BRICK_TO_BALL_RATIO = 3 / 2       # Ratio of brick width to ball size
BRICK_TO_PADDLE_RATIO = 2 / 3     # Ratio of brick to paddle width
BRICK_SEP = 2                     # Separation between bricks
TOP_FRACTION = 0.1                # Fraction of window above bricks
BOTTOM_FRACTION = 0.05            # Fraction of window below paddle
N_BALLS = 3                       # Number of balls in a game
TIME_STEP = 10                    # Time step in milliseconds
INITIAL_Y_VELOCITY = 3.0          # Starting y velocity downward
MIN_X_VELOCITY = 1.0              # Minimum random x velocity
MAX_X_VELOCITY = 3.0              # Maximum random x velocity

# Derived constants

BRICK_WIDTH = (GWINDOW_WIDTH - (N_COLS + 1) * BRICK_SEP) / N_COLS
BRICK_HEIGHT = BRICK_WIDTH / BRICK_ASPECT_RATIO
PADDLE_WIDTH = BRICK_WIDTH / BRICK_TO_PADDLE_RATIO
PADDLE_HEIGHT = BRICK_HEIGHT / BRICK_TO_PADDLE_RATIO
PADDLE_Y = (1 - BOTTOM_FRACTION) * GWINDOW_HEIGHT - PADDLE_HEIGHT
BALL_SIZE = BRICK_WIDTH / BRICK_TO_BALL_RATIO

# Function: Breakout

def Breakout():
    """
    The main program for the Breakout game.
    """
    gw = GWindow(GWINDOW_WIDTH, GWINDOW_HEIGHT)

    # You fill in the rest of this function along with any additional
    # helper and callback functions you need.

# Startup code

if (__name__ == "__main__"):
    Breakout()
```

Stage 1—Set up the bricks

Before you start playing the game, you have to set up the various pieces. Thus, it makes sense to call a function to set up the game before you create the timer that starts the animation. An important part of the setup consists of creating the rows of bricks at the top of the game, which look like this:



The number, dimensions, and spacing of the bricks are specified using constants in the starter file, as is the distance from the top of the window to the first line of bricks. The only value you need to compute is the *x* coordinate of the first column, which should be chosen so that the bricks are centered in the window, with the leftover space divided equally on the left and right sides. The colors of the bricks remain constant for two rows and run in the following rainbow-like sequence: `"Red"`, `"Orange"`, `"Green"`, `"Cyan"` and `"Blue"`. If you change the definition of `N_ROWS` in the starter file, any additional rows should simply repeat this sequence, starting over from `"Red"`.



This part of the project is similar to the pyramid problem from Assignment #2. The parts that are only a touch more difficult are that you need to fill and color the bricks. This extra complexity is more than compensated by the fact that the number of bricks is the same in each row and you don't have to change the coordinate calculation as you move upward on the screen.

Here's a suggestion: Why don't you get this part of the program working by Wednesday the 13th, so that you can produce the diagram at the right? The display has most of what you see on the final screen and will give you considerable confidence that you can get the rest done. And you'll be well on your way before time gets short.

Stage 2—Create the paddle

The next step is to create the paddle. At one level, this is considerably easier than creating the bricks. There is only one paddle, which is a filled `GRect`. You even know its position relative to the bottom of the window.

The challenge in creating the paddle is to make it track the mouse. The technique is similar to that discussed in Chapter 5 for dragging an object around in the window. Here, however, you only have to pay attention to the *x* coordinate of the mouse because the *y* position of the paddle is fixed. The only additional wrinkle is that you should not let the paddle move off the edge of the window. Thus, you'll have to check to see whether the *x* coordinate of the mouse would make the paddle extend beyond the boundary and change that *x* coordinate if necessary to ensure that the entire paddle is visible in the window.

Here's another milestone suggestion: Why don't you get this part of the program working by Friday the 15th, so that you can follow the mouse with the paddle? This entire part of the program takes fewer than 10 lines of code, so it shouldn't take so long. The hard part lies in reading Chapter 5 ("Writing Interactive Programs") and understanding what you need to do.

Stage 3—Create a ball and get it to bounce off the walls

At one level, creating the ball is easy, given that it's just a filled `GOval`. The interesting part lies in getting it to move and bounce appropriately. You are now past the "setup" stage and into the "play" phase of the game. To start, create a ball and put it in the center of the window. As you do so, keep in mind that the coordinates of the `GOval` do not specify the location of the center of the ball but rather its upper left corner. The math is not any more difficult, but may be a bit less intuitive.

The program needs to keep track of the velocity of the ball, which consists of two separate components—`vx` and `vy` are the names used in this handout—which are local variables inside `Breakout`. The values of the `vx` and `vy` variables represent the change in position that occurs on each time step. Initially, the ball should be heading downward, and you might try a starting value of 3.0 for `vy`, which is included in the constants as `INITIAL_Y_VELOCITY`. The game would be boring if every ball took the same course, so you should choose the `vx` component randomly. Since I won't cover the `random` library until Friday, all you need to do is use the following code:

```
vx = random.uniform(MIN_X_VELOCITY, MAX_X_VELOCITY)
if random.uniform(0, 1) < 0.5:
    vx = -vx
```

This code sets `vx` to be a random real number in the range 1.0 to 3.0 (given the provided definitions of the constants) and then makes it negative half the time. This strategy gives better results than setting `vx = random.uniform(-MAX_X_VELOCITY, MAX_X_VELOCITY)`, which might generate a ball going more or less straight down. That would make life far too easy for the player.

You then need to get the ball moving by creating a timer that fires every `TIME_STEP` milliseconds and updates the position of the ball each time by moving it `vx` pixels in the *x* direction and `vy` pixels in the *y* direction. The model to use for this part of the program is the `AnimatedSquare.py` program in Chapter 5. But it wouldn't be sporting to have the ball start moving the moment the game started. To give the user a chance to get ready, what you want to have happen is that the ball starts moving when the user clicks the mouse. You therefore need to add a listener for the `"click"` event that starts the timer.

Once you've gotten the ball moving, your next challenge is to get it to bounce around the world, ignoring, at least for the moment, the paddle and the bricks entirely. To do so, you need to check to see if the coordinates of the ball have moved outside the window. Thus, to see if the ball has bounced off the right wall, you need to see whether the coordinate of the right edge of the ball has become greater than the width of the window; the other three directions are treated similarly. For now, have the ball bounce off the bottom wall so that you can watch it make its path around the world. You can change that test later so that hitting the bottom wall signifies the end of a turn.

Computing what happens after a bounce is extremely simple. If a ball bounces off the top or bottom wall, all you need to do is reverse the sign of **vy**. Symmetrically, bouncing off the side walls reverses the sign of **vx**.

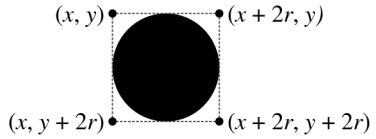
Stage 4—Checking for collisions

Now comes the interesting part. In order to make Breakout into a real game, you have to be able to tell whether the ball is colliding with another object in the window. As scientists often do, it helps to begin by making a simplifying assumption and then relaxing that assumption later. Suppose the ball were a single point rather than a circle. In that case, how could you tell whether it had collided with another object?

If you look in Chapter 5 at the methods that are defined for the **GWindow** class, you will discover that there is a method **getElementAt(***x***, *y***)** that takes a location in the window and returns the graphical object at that location, if any. If there are no graphical objects that cover that position, **getElementAt** returns the constant **None**. If there is more than one, **getElementAt** always chooses the one closest to the top of the stacking order, which is the one that appears to be in front on the display.

So far, so good. But, unfortunately, the ball is not a single point. It occupies physical area and therefore may collide with something on the screen even though its center does not. The easiest thing to do—which is in fact typical of the simplifying assumptions made in real computer games—is to check a few carefully chosen points on the outside of the ball and see whether any of those points has collided with anything. As soon as you find something at one of those points, you can declare that the ball has collided with that object.

In your implementation, the easiest thing to do is to check the four corner points on the square in which the ball is inscribed. Remember that a **GOval** is defined in terms of its bounding rectangle, so that if the upper left corner of the ball is at the point (*x*, *y*), the other corners will be at the locations shown in this diagram:



These points have the advantage of being outside the ball—which means that **getElementAt** can't return the ball itself—but nonetheless close enough to make it appear that collisions have occurred. Thus, for each of these four points, you need to:

1. Call **getElementAt** on that location to see whether anything is there.
2. If the value you get back is not **None**, then you need look no further and can take that value as the **GObject** with which the collision occurred.
3. If **getElementAt** returns **None** for a particular corner, go on and try the next corner.
4. If you get through all four corners without finding a collision, then no collision exists.

It would be very useful to decompose this part of the program into a separate function called **getCollidingObject** that returns the **GObject** colliding with the ball, if any, and **None** otherwise. You could then use it in a statement like

```
collider = getCollidingObject()
```

which assigns that value to a variable called **collider**.

From here, the only remaining thing you need to do is decide what to do when a collision occurs. There are only two possibilities. First, the object you get back might be the paddle, which you can test simply by checking whether **collider** is equal to the **GObject** for the paddle, which you've presumably stored in a local variable as part of Stage 2.

If the colliding object is the paddle, you need to bounce the ball so that it starts traveling up. If it isn't the paddle, the only other thing it might be is a brick, since those are the only other objects in the world. Once again, you need to cause a bounce in the vertical direction, but you also need to take the brick away. To do so, all you need to do is remove it from the screen by calling the **remove** method on the **GWindow** object.

Stage 5—Finishing up

If you've gotten to here, you've done all the hard parts. There are, however, a few more details you need to take into account:

- You have to take care of the case when the ball hits the bottom wall. In the prototype you've been building, the ball just bounces off this wall like all the others, but that makes the game impossible to lose. You've got to modify your program structure so that it tests for hitting the bottom wall and stops the interval timer.
- You have to give the user three chances to remove the bricks. When the ball falls through the bottom of the window, you should remove it from the window, create a new ball just as you did at the beginning, and then wait for a click to start things up. If the user has already had three chances, the game is over.
- You have to check for the other terminating condition, which is hitting the last brick. How do you know when you've done so? Although there are other ways to do it, one of the easiest is to have your program keep track of the number of bricks remaining. Every time you hit one, subtract one from that counter. When the count reaches zero, you must be done.
- You've got to test your program to see that it works. Play for a while and make sure that as many parts of it as you can check are working. If you think everything is working, here is something to try: Just before the ball is going to pass the paddle level, move the paddle quickly so that the paddle collides with the ball rather than vice-versa. Does everything still work, or does your ball seem to get "glued" to the paddle? If you get this error, try to understand why it occurs and how you might fix it.

Strategy and tactics

Here are some survival hints for this project assignment:

- *Start as soon as possible.* This assignment is due a week from Wednesday, which will be here before you know it. If you wait until the day before this project is due, you will have a very hard time getting it all together.
- *Implement the program in stages, as described in this handout.* Don't try to get everything working all at once. Implement the various pieces of the project one at a time and make sure that each one is working before you move on to the next phase.
- *Set up a milestone schedule.* In the handout, I've suggested that you get the brick display up and running by this Wednesday and the paddle moving by Friday. If you do, you'll have lots of time for the more interesting parts of the project and for implementing extensions.
- *Don't try to extend the program until you get the basic functionality working.* The following section describes several ways in which you could extend the implementation. Several of those are lots of fun. Don't start them, however, until the basic project is working. If you add extensions too early, you'll find that the debugging process gets really difficult.

Possible extensions

This project is perfect for those of you who are looking for + or (dare I say it) ++ scores, because there are so many possible extensions. Here are a few:

- *Add messages.* The sample application on the web site waits for the user to click the mouse before serving each ball and announces whether the player has won or lost at the end of the game. These are just `GLabel` objects that you can add and remove at the appropriate time.
- *Improve the user control over bounces.* The program gets rather boring if the only thing the player has to do is hit the ball. It is far more interesting if the player can control the ball by hitting it at different parts of the paddle. In the old arcade game, the ball would bounce in both the *x* and *y* directions if you hit it on the edge of the paddle from which the ball was coming.
- *Add in the "kicker."* The arcade version of Breakout lured you in by starting off slowly. But, as soon as you thought you were getting the hang of things, the program sped up, making life just a bit more exciting.
- *Keep score.* You could easily keep score, generating points for each brick. In the arcade game, bricks were more valuable higher up in the array, so that you got more points for red bricks than for blue ones.
- *Use your imagination.* What else have you always wanted a game like this to do?