Python Programming Essentials

Unit 3: Object-Oriented Python

CHAPTER 11: DATA COLLECTIONS

DR. ERIC CHOU

IEEE SENIOR MEMBER

Objectives

LECTURE 1

Objectives

- To understand the use of lists (arrays) to represent a collection of related data.
- To be familiar with the functions and methods available for manipulating Python lists.
- To be able to write programs that use lists to manage a collection of information.

Objectives

- To be able to write programs that use lists and classes to structure complex data.
- To understand the use of Python dictionaries for storing nonsequential collections.

Example Problem: Simple Statistics

- Many programs deal with large collections of similar information.
  - Words in a document
  - Students in a course
  - Data from an experiment
  - Customers of a business
  - Graphics objects drawn on the screen
  - Cards in a deck

Simple Statistics

LECTURE 2

Sample Problem: Simple Statistics

- Let's review some code we wrote in chapter 8:

```
# average4.py
#    A program to average a set of numbers
#    Illustrates sentinel loop using empty string as sentinel

def main():
    sum = 0.0
    count = 0
    xStr = input("Enter a number (<Enter> to quit) >> ")
    while xStr != "":
        x = float(xStr)
        sum = sum + x
        count = count + 1
        xStr = input("Enter a number (<Enter> to quit) >> ")
    print("\nThe average of the numbers is", sum / count)
```

Sample Problem: Simple Statistics

- This program allows the user to enter a sequence of numbers, but the program itself doesn't keep track of the numbers that were entered – it only keeps a running total.
- Suppose we want to extend the program to compute not only the mean, but also the median and standard deviation.

Sample Problem: Simple Statistics

- The *median* is the data value that splits the data into equal-sized parts.
- For the data 2, 4, 6, 9, 13, the median is 6, since there are two values greater than 6 and two values that are smaller.
- One way to determine the median is to store all the numbers, sort them, and identify the middle value.

Sample Problem: Simple Statistics

- The *standard deviation* is a measure of how spread out the data is relative to the mean.
- If the data is tightly clustered around the mean, then the standard deviation is small. If the data is more spread out, the standard deviation is larger.
- The standard deviation is a yardstick to measure/express how exceptional a value is.

Sample Problem: Simple Statistics

The standard deviation is

$$s = \sqrt{\frac{\sum(\bar{x} - x_i)^2}{n-1}}$$

Here $\bar{x}$ is the mean, x_i represents the i^{th} data value and n is the number of data values.

The expression $(\bar{x} - x_i)^2$ is the square of the "deviation" of an individual item from the mean.

Sample Problem: Simple Statistics

- The numerator is the sum of these squared "deviations" across all the data.
- Suppose our data was 2, 4, 6, 9, and 13.
  - The mean is 6.8
  - The numerator of the standard deviation is

$$(6.8-2)^2+(6.8-4)^2+(6.8-6)^2+(6.8-9)^2+(6.8-13)^2=74.8$$

$$s=\sqrt{\frac{74.8}{5-1}}=\sqrt{18.7}=4.32$$

Sample Problem: Simple Statistics

- As you can see, calculating the standard deviation not only requires the mean (which can't be calculated until all the data is entered), but also each individual data element!
- We need some way to remember these values as they are entered.

Application of Lists (Arrays)

LECTURE 3

Applying Lists

- We need a way to store and manipulate an entire collection of numbers.
- We can’t just use a bunch of variables, because we don’t know many numbers there will be.
- What do we need? Some way of combining an entire collection of values into one object.

Lists and Arrays

- Python lists are ordered sequences of items. For instance, a sequence of *n* numbers might be called *S*:
  $S = s_0, s_1, s_2, s_3, \ldots, s_{n-1}$
- Specific values in the sequence can be referenced using *subscripts*.
- By using numbers as subscripts, mathematicians can succinctly summarize computations over items in a sequence using subscript variables.

$$\sum_{i=0}^{n-1} s_i$$

Lists and Arrays

- Suppose the sequence is stored in a variable `s`. We could write a loop to calculate the sum of the items in the sequence like this:

```
sum = 0
for i in range(n):
    sum = sum + s[i]
```

- Almost all computer languages have a sequence structure like this, sometimes called an *array*.

Lists and Arrays

- A list or array is a sequence of items where the entire sequence is referred to by a single name (i.e. `s`) and individual items can be selected by indexing (i.e. `s[i]`).
- In other programming languages, arrays are generally a fixed size, meaning that when you create the array, you have to specify how many items it can hold.
- Arrays are generally also *homogeneous*, meaning they can hold only one data type.

Lists and Arrays

- Python lists are dynamic. They can grow and shrink on demand.
- Python lists are also *heterogeneous*, a single list can hold arbitrary data types.
- Python lists are mutable sequences of arbitrary objects.

List Operations

Operator	Meaning
<seq> + <seq>	Concatenation
<seq> * <int-expr>	Repetition
<seq>[]	Indexing
len(<seq>)	Length
<seq>[:]	Slicing
for <var> in <seq>:	Iteration
<expr> in <seq>	Membership (Boolean)

List Operations

- Except for the membership check, we've used these operations before on strings.
- The membership operation can be used to see if a certain value appears anywhere in a sequence.

```
>>> lst = [1,2,3,4]
>>> 3 in lst
True
```

List Operations

- The summing example from earlier can be written like this:

```
sum = 0
for x in s:
    sum = sum + x
```

- Unlike strings, lists are mutable:

```
>>> lst = [1,2,3,4]
>>> lst[3]
4
>>> lst[3] = "Hello“
>>> lst
[1, 2, 3, 'Hello']
>>> lst[2] = 7
>>> lst
[1, 2, 7, 'Hello']
```

List Operations

- A list of identical items can be created using the repetition operator. This command produces a list containing 50 zeroes:

```
zeroes = [0] * 50
```

List Operations

- Lists are often built up one piece at a time using append.

```
nums = []
x = float(input('Enter a number: '))
while x >= 0:
    nums.append(x)
    x = float(input('Enter a number: '))
```

- Here, `nums` is being used as an accumulator, starting out empty, and each time through the loop a new value is tacked on.

List Operations

Method	Meaning
<list>.append(x)	Add element x to end of list.
<list>.sort()	Sort (order) the list. A comparison function may be passed as a parameter.
<list>.reverse()	Reverse the list.
<list>.index(x)	Returns index of first occurrence of x.
<list>.insert(i, x)	Insert x into list at index i.
<list>.count(x)	Returns the number of occurrences of x in list.
<list>.remove(x)	Deletes the first occurrence of x in list.
<list>.pop(i)	Deletes the i^{th} element of the list and returns its value.

List Operations

```
>>> lst = [3, 1, 4, 1, 5, 9]
>>> lst.append(2)
>>> lst
[3, 1, 4, 1, 5, 9, 2]
>>> lst.sort()
>>> lst
[1, 1, 2, 3, 4, 5, 9]
>>> lst.reverse()
>>> lst
[9, 5, 4, 3, 2, 1, 1]
>>> lst.index(4)
2
```

```
>>> lst.insert(4, "Hello")
>>> lst
[9, 5, 4, 3, 'Hello', 2, 1, 1]
>>> lst.count(1)s
2
>>> lst.remove(1)
>>> lst
[9, 5, 4, 3, 'Hello', 2, 1]
>>> lst.pop(3)
3
>>> lst
[9, 5, 4, 'Hello', 2, 1]
```

List Operations

- Most of these methods don't return a value – they change the contents of the list in some way.
- Lists can grow by appending new items, and shrink when items are deleted. Individual items or entire slices can be removed from a list using the `del` operator.

List Operations

```
 >>> myList=[34, 26, 0, 10]
>>> del myList[1]
>>> myList
[34, 0, 10]
>>> del myList[1:3]
>>> myList
[34]
```

- `del` isn't a list method, but a built-in operation that can be used on list items.

List Operations

- Basic list principles
  - A list is a sequence of items stored as a single object.
  - Items in a list can be accessed by indexing, and sublists can be accessed by slicing.
  - Lists are mutable; individual items or entire slices can be replaced through assignment statements.

List Operations

- Lists support a number of convenient and frequently used methods.
- Lists will grow and shrink as needed.

Statistics with Lists

LECTURE 4

Statistics with Lists

- One way we can solve our statistics problem is to store the data in a list.
- We could then write a series of functions that take a list of numbers and calculates the mean, standard deviation, and median.
- Let's rewrite our earlier program to use lists to find the mean.

Statistics with Lists

- Let's write a function called `getNumbers` that gets numbers from the user.
  - We'll implement the sentinel loop to get the numbers.
  - An initially empty list is used as an accumulator to collect the numbers.
  - The list is returned once all values have been entered.

Statistics with Lists

```
def getNumbers():
    nums = []      # start with an empty list
    # sentinel loop to get numbers
    xStr = input("Enter a number (<Enter> to quit) >> ")
    while xStr != "":
        x = float(xStr)
        nums.append(x)   # add this value to the list
        xStr = input("Enter a number (<Enter> to quit) >> ")
    return nums
```

- Using this code, we can get a list of numbers from the user with a single line of code:

```
data = getNumbers()
```

Statistics with Lists

- Now we need a function that will calculate the mean of the numbers in a list.
  - Input: a list of numbers
  - Output: the mean of the input list

```
def mean(nums):
    sum = 0.0
    for num in nums:
        sum = sum + num
    return sum / len(nums)
```

Statistics with Lists

- The next function to tackle is the standard deviation.
- In order to determine the standard deviation, we need to know the mean.
  - Should we recalculate the mean inside of `stdDev`?
  - Should the mean be passed as a parameter to `stdDev`?

Statistics with Lists

- Recalculating the mean inside of `stdDev` is inefficient if the data set is large.
- Since our program is outputting both the mean and the standard deviation, let's compute the mean and pass it to `stdDev` as a parameter.

Statistics with Lists

```
def stdDev(nums, xbar):
    sumDevSq = 0.0
    for num in nums:
        dev = xbar - num
        sumDevSq = sumDevSq + dev * dev
    return sqrt(sumDevSq/(len(nums)-1))
```

- The summation from the formula is accomplished with a loop and accumulator.
- `sumDevSq` stores the running sum of the squares of the deviations.

Statistics with Lists

- We don’t have a formula to calculate the median. We’ll need to come up with an algorithm to pick out the middle value.
- First, we need to arrange the numbers in ascending order.
- Second, the middle value in the list is the median.
- If the list has an even length, the median is the average of the middle two values.

Statistics with Lists

Pseudocode -

```
sort the numbers into ascending order
if the size of the data is odd:
 median = the middle value
else:
 median = the average of the two middle
  values
return median
```

Statistics with Lists

```
def median(nums):
    nums.sort()
    size = len(nums)
    midPos = size // 2
    if size % 2 == 0:
        median = (nums[midPos]+nums[midPos-1])/2
    else:
        median = nums[midPos]
    return median
```

Statistics with Lists

- With these functions, the main program is pretty simple!

```
def main():
    print("This program computes mean, median and standard deviation.")

    data = getNumbers()
    xbar = mean(data)
    std = stdDev(data, xbar)
    med = median(data)

    print("\nThe mean is", xbar)
    print("The standard deviation is", std)
    print("The median is", med)
```

Statistics with Lists

- Statistical analysis routines might come in handy some time, so let's add the capability to use this code as a module by adding:

```
if __name__ == '__main__': main()
```

Lists of Records

LECTURE 5

Lists of Records

- All of the list examples we've looked at so far have involved simple data types like numbers and strings.
- We can also use lists to store more complex data types, like our student information from chapter ten.

Lists of Objects

- Our grade processing program read through a file of student grade information and then printed out information about the student with the highest GPA.
- A common operation on data like this is to sort it, perhaps alphabetically, perhaps by credit-hours, or even by GPA.

Lists of Objects

- Let's write a program that sorts students according to GPA using our `Sutdent` class from the last chapter.

```
Get the name of the input file from the user
Read student information into a list
Sort the list by GPA
Get the name of the output file from the user
Write the student information from the list
into a file
```

Lists of Records

- Let's begin with the file processing. The following code reads through the data file and creates a list of students.

```
def readStudents(filename):
    infile = open(filename, 'r')
    students = []
    for line in infile:
        students.append(makeStudent(line))
    infile.close()
    return students
```

- We're using the `makeStudent` from the `gpa` program, so we'll need to remember to import it and the `Student` class.

Lists of Records

- Let's also write a function to write the list of students back to a file.
- Each line should contain three pieces of information, separated by tabs: name, credit hours, and quality points.

```
def writeStudents(students, filename):
    # students is a list of Student objects
    outfile = open(filename, 'w')
    for s in students:
        print("{0}\t{1}\t{2}".format(s.getName(),\
            s.getHours(),s.getQPoints(), file=outfile)
    outfile.close()
```

Lists of Objects

- Using the functions `readStudents` and `writeStudents`, we can convert our data file into a list of students and then write them back to a file. All we need to do now is sort the records by GPA.
- In the statistics program, we used the `sort` method to sort a list of numbers. How does Python sort lists of objects?

Lists of Objects

- To make sorting work with our objects, we need to tell `sort` how the objects should be compared.
- Can supply a function to produce the key for an object using `<list>.sort(key=<key-function>)`
- To sort by GPA, we need a function that takes a Student as parameter and returns the student's GPA.

Lists of Objects

```
def use_gpa(aStudent):
    return aStudent.gpa()
```

- We can now sort the data by calling sort with the key function as a keyword parameter.

```
data.sort(key=use_gpa)
```

Lists of Objects

```
data.sort(key=use_gpa)
```

- Notice that we didn't put `()`'s after the function name.
- This is because we don't want to *call* `use_gpa`, but rather, we want to send `use_gpa` to the sort method.

Lists of Objects

- Actually, defining `use_gpa` was unnecessary.
- The gpa method in the Student class is a function that takes a student as a parameter (formally, self) and returns GPA.
- To use it: `data.sort(key=Student.gpa)`

Lists of Objects

```
# gpasort.py
#    A program to sort student information
#    into GPA order.
from gpa import Student, makeStudent
def readStudents(filename):
    infile = open(filename, 'r')
    students = []
    for line in infile:
        students.append(makeStudent(line))
    infile.close()
    return students

def writeStudents(students, filename):
    outfile = open(filename, 'w')
    for s in students:
        print(s.getName(), s.getHours(),  s.getQPoints(),sep="\t", file=outfile)
    outfile.close()
```

Lists of Objects

```
def main():
    print ("This program sorts student grade information by GPA")
    filename = input("Enter the name of the data file: ")
    data = readStudents(filename)
    data.sort(Student.gpa)
    filename = input("Enter a name for the output file: ")
    writeStudents(data, filename)
    print("The data has been written to", filename)

if __name__ == '__main__':
    main()
```

Classes

LECTURE 6

Designing with Lists and Classes

- In the `dieView` class from chapter ten, each object keeps track of seven circles representing the position of pips on the face of the die.
- Previously, we used specific instance variables to keep track of each pip: `pip1`, `pip2`, `pip3`, …

Designing with Lists and Classes

- What happens if we try to store the circle objects using a list?
- In the previous program, the pips were created like this:
  `self.pip1 = self.__makePip(cx, cy)`
- `__makePip` is a local method of the `DieView` class that creates a circle centered at the position given by its parameters.

Designing with Lists and Classes

- One approach is to start with an empty list of pips and build up the list one pip at a time.

```
pips = []
pips.append(self.__makePip(cx-offset,cy-offset)
pips.append(self.__makePip(cx-offset,cy)
…
self.pips = pips
```

Designing with Lists and Classes

- An even more straightforward approach is to create the list directly.

```
self.pips = [self.__makePip(cx-offset,cy-offset),
             self.__makePip(cx-offset,cy),
             …
             self.__makePip(cx+offset,cy+offset)
             ]
```

- Python is smart enough to know that this object is continued over a number of lines, and waits for the ‘]’.
- Listing objects like this, one per line, makes it much easier to read.

Designing with Lists and Classes

- Putting our pips into a list makes many actions simpler to perform.
- To blank out the die by setting all the pips to the background color:

```
for pip in self.pips:
    pip.setFill(self.background)
```

- This cut our previous code from seven lines to two!

Designing with Lists and Classes

- We can turn the pips back on using the pips list. Our original code looked like this:

```
self.pip1.setFill(self.foreground)
self.pip4.setFill(self.foreground)
self.pip7.setFill(self.foreground)
```

- Into this:

```
self.pips[0].setFill(self.foreground)
self.pips[3].setFill(self.foreground)
self.pips[6].setFill(self.foreground)
```

Designing with Lists and Classes

- Here's an even easier way to access the same methods:

```
for i in [0,3,6]:
    self.pips[i].setFill(self.foreground)
```

- We can take advantage of this approach by keeping a list of which pips to activate!

```
Loop through pips and turn them all off
Determine the list of pip indexes to turn on
Loop through the list of indexes - turn on
those pips
```

Designing with Lists and Classes

```
for pip in self.pips:
 self.pip.setFill(self.background)
if value == 1:
 on = [3]
elif value == 2:
 on = [0,6]
elif value == 3:
 on = [0,3,6]
elif value == 4:
 on = [0,2,4,6]
elif value == 5:
 on = [0,2,3,4,6]
else:
 on = [0,1,2,3,4,5,6]
for i in on:
 self.pips[i].setFill(self.foreground)
```

Designing with Lists and Classes

- We can do even better!
- The correct set of pips is determined by `value`. We can make this process *table-driven* instead.
- We can use a list where each item on the list is itself a list of pip indexes.
- For example, the item in position 3 should be the list `[0,3,6]` since these are the pips that must be turned on to show a value of 3.

Designing with Lists and Classes

- Here's the table-driven code:

```
onTable = [ [], [3], [2,4], [2,3,4], [0,2,4,6],
            [0,2,3,4,6], [0,1,2,4,5,6] ]

for pip in self.pips:
   self.pip.setFill(self.background)

on = onTable[value]
for i in on:
   self.pips[i].setFill(self.foreground)
```

Designing with Lists and Classes

- The table is padded with '[]' in the 0 position, since it shouldn't ever be used.
- The `onTable` will remain unchanged through the life of a `dieView`, so it would make sense to store this table in the constructor and save it in an instance variable.

Designing with Lists and Classes

- Lastly, this example showcases the advantages of encapsulation.
  - We have improved the implementation of the `dieView` class, but we have not changed the set of methods it supports.
  - We can substitute this **new** version of the class without having to modify any other code!
  - Encapsulation allows us to build complex software systems as a set of "pluggable modules."

Python Calculator

LECTURE 7

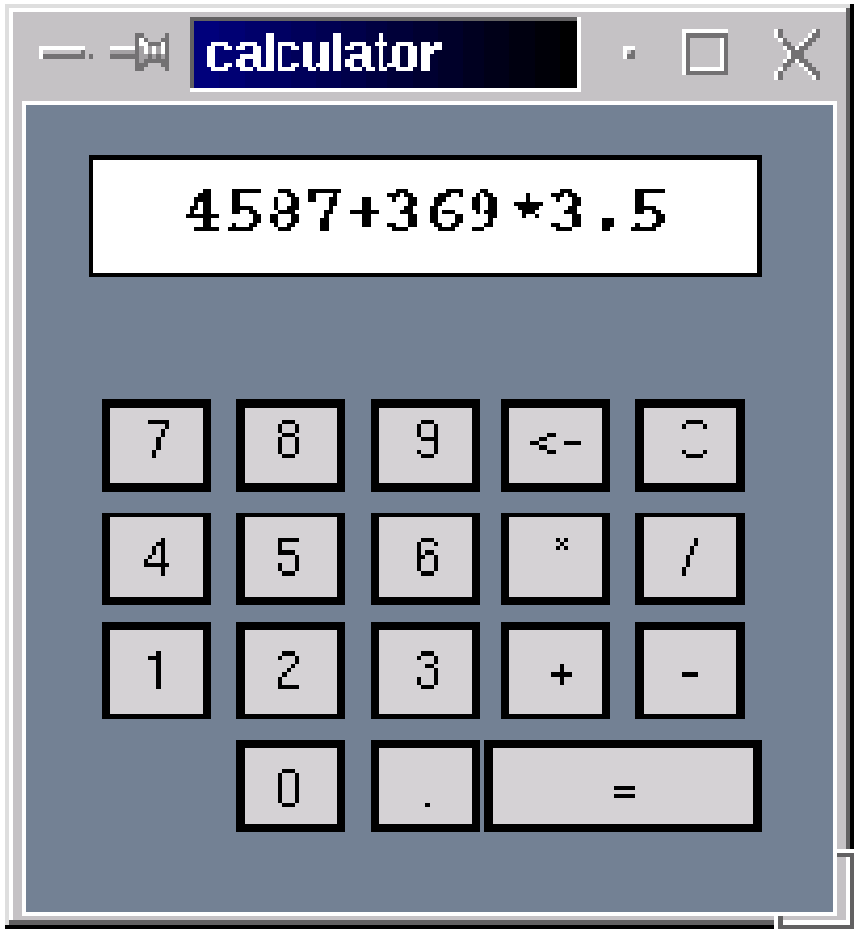
Case Study: Python Calculator

- The new `dieView` class shows how lists can be used effectively as instance variables of objects.
- Our pips list and `onTable` contain circles and lists, respectively, which are themselves objects.
- We can view a program itself as a collection of data structures (collections and objects) and a set of algorithms that operate on those data structures.

A Calculator as an Object

- Let’s develop a program that implements a Python calculator.
- Our calculator will have buttons for
  - The ten digits (0-9)
  - A decimal point (.)
  - Four operations (+,-,*,/)
  - A few special keys
    - ‘C’ to clear the display
    - ‘<-’ to backspace in the display
    - ‘=’ to do the calculation

A Calculator as an Object



A Calculator as an Object

- We can take a simple approach to performing the calculations. As buttons are pressed, they show up in the display, and are evaluated and the value displayed when the = is pressed.
- We can divide the functioning of the calculator into two parts: creating the interface and interacting with the user.

Constructing the Interface

- First, we create a graphics window.
- The coordinates were chosen to simplify the layout of the buttons.
- In the last line, the window object is stored in an instance variable so that other methods can refer to it.

```
def __init__(self):
    # create the window for the calculator
    win = GraphWin("calculator")
    win.setCoords(0,0,6,7)
    win.setBackground("slategray")
    self.win = win
```

Constructing the Interface

- Our next step is to create the buttons, reusing the button class.

```
        # create list of buttons
        # start with all the standard sized buttons
        # bSpecs gives center coords and label of buttons
        bSpecs = [(2,1,'0'), (3,1,'.'),
                  (1,2,'1'), (2,2,'2'), (3,2,'3'), (4,2,'+'), (5,2,'-'),
                  (1,3,'4'), (2,3,'5'), (3,3,'6'), (4,3,'*'), (5,3,'/'),
                  (1,4,'7'), (2,4,'8'), (3,4,'9'), (4,4,'<-'),(5,4,'C')]
        self.buttons = []
        for cx,cy,label in bSpecs:

self.buttons.append(Button(self.win,Point(cx,cy),.75,.75,label))
        # create the larger = button
        self.buttons.append(Button(self.win, Point(4.5,1), 1.75, .75, "="))
        # activate all buttons
        for b in self.buttons:
            b.activate()
```

Constructing the Interface

- `bspecs` contains a list of button specifications, including the center point of the button and its label.
- Each specification is a *tuple*.
- A *tuple* looks like a list but uses '()' rather than '[]'.
- Tuples are sequences that are immutable.

Constructing the Interface

- Conceptually, each iteration of the loop starts with an assignment:
  `(cx,cy,label)=<next item from bSpecs>`
- Each item in `bSpecs` is also a tuple.
- When a tuple of variables is used on the left side of an assignment, the corresponding components of the tuple on the right side are *unpacked* into the variables on the left side.
- The first time through it's as if we had:

```
cx,cy,label = 2,1,"0"
```

Constructing the Interface

- Each time through the loop, another tuple from `bSpecs` is unpacked into the variables in the loop heading.
- These values are then used to create a `Button` that is appended to the list of buttons.
- Creating the display is simple – it's just a rectangle with some text centered on it. We need to save the text object as an instance variable so its contents can be accessed and changed.

Constructing the Interface

- Here's the code to create the display

```
bg = Rectangle(Point(.5,5.5), Point(5.5,6.5))
bg.setFill('white')
bg.draw(self.win)
text = Text(Point(3,6), "")
text.draw(self.win)
text.setFace("courier")
text.setStyle("bold")
text.setSize(16)
self.display = text
```

Processing Buttons

- Now that the interface is drawn, we need a method to get it running.
- We'll use an event loop that waits for a button to be clicked and then processes that button.

```
def run(self):
    # Infinite 'event loop' to process button clicks.
    while True:
        key = self.getKeyPress()
        self.processKey(key)
```

Processing Buttons

- We continue getting mouse clicks until a button is clicked.
- To determine whether a button has been clicked, we loop through the list of buttons and check each one.

```
def getKeyPress(self):
    # Waits for a button to be clicked and
    #    returns the label of
    #    the button that was clicked.
    while True:
        p = self.win.getMouse()
        for b in self.buttons:
            if b.clicked(p):
                return b.getLabel() # method exit
```

Processing Buttons

Having the buttons in a list like this is a big win. A `for` loop is used to look at each button in turn.

If the clicked point `p` turns out to be in one of the buttons, the label of the button is returned, providing an exit from the otherwise infinite loop.

Processing Buttons

- The last step is to update the display of the calculator according to which button was clicked.
- A digit or operator is appended to the display. If `key` contains the label of the button, and `text` contains the current contents of the display, the code is:

```
self.display.setText(text+key)
```

Processing Buttons

- The clear key blanks the display:
  `self.display.setText("")`
- The backspace key strips off one character:
  `self.display.setText(text[:-1])`
- The equal key causes the expression to be evaluated and the result displayed.

Processing Buttons

```
try:
    result = eval(text)
except:
    result = 'ERROR'
    self.display.setText(str(result))
```

- Exception handling is necessary here to catch run-time errors if the expression being evaluated isn't a legal Python expression. If there's an error, the program will display `ERROR` rather than crash.

Animation

LECTURE 8

Case Study: Better Cannon Ball Animation

- The calculator example used a list of `Button` objects to simplify the code.
- Maintaining a collection of similar objects as a list was strictly a programming convenience, because the contents of the button list never changed.
- Lists become essential when the collection changes dynamically.

Case Study: Better Cannon Ball Animation

- In last chapter's cannon ball animation, the proram could show only a single shot at a time.
- Here we will extend the program to allow multiple shots.
  - Doing this requires keeping track of all the cannon balls currently in flight.
  - This is a constantly varying collection, and we can use a list to manage it.

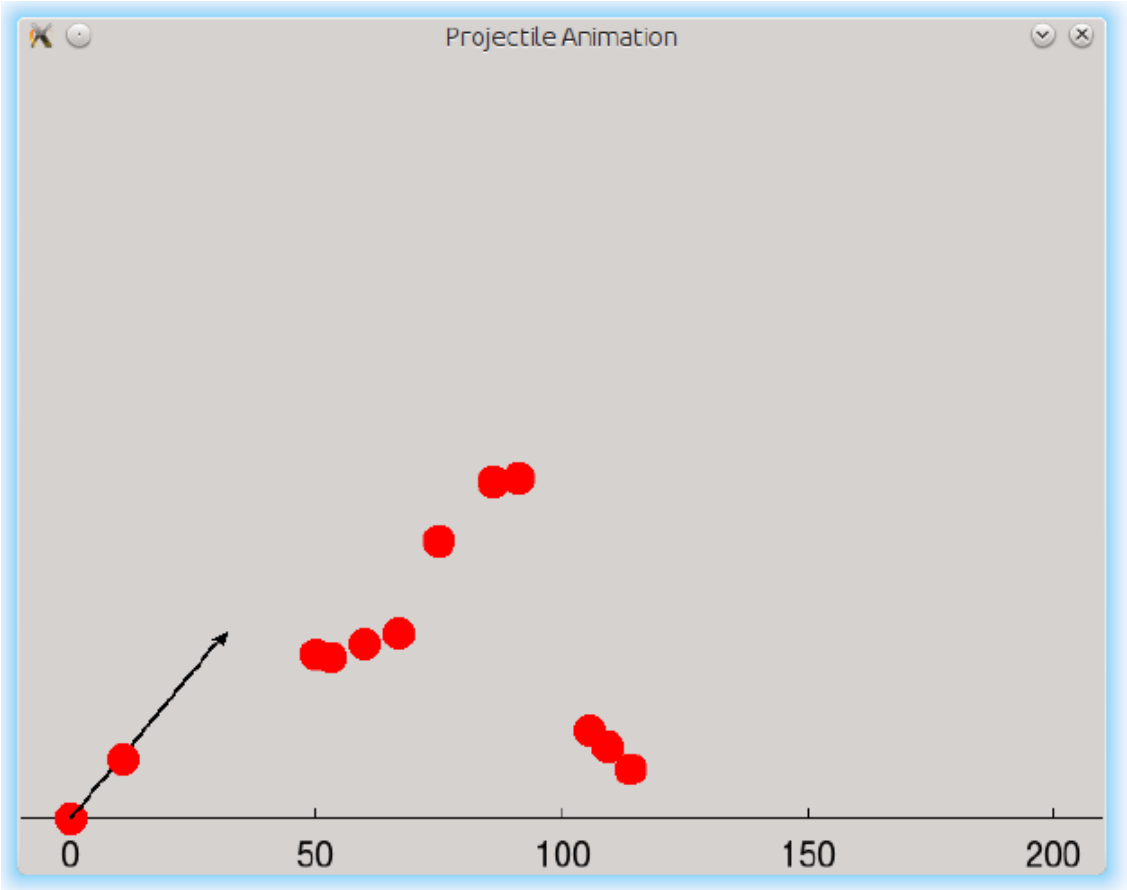
Creating a Launcher

- We need to update the program's user interface so that firing multiple shots is feasible.
- In the previous version, we got information from the user via a simple dialog window.
- For this version we want to add a new widget that allows the user to rapidly fire shots with various starting angles and velocities, like in a video game.

Creating a Launcher

- The launcher widget will show a cannon ball ready to be launched along with an arrow representing the current settings for the angle and velocity of launch.
- The angle of the arrow indicates the direction of the launch, and the length of the arrow represents the initial speed.
  - Mathematically inclined readers might recognize this as the standard vector representation of the initial velocity.

Creating a Launcher



Creating a Launcher

- The entire simulation will be under keyboard control, with keys to increase/decrease the launch angle, increase/decrease the speed, and fire the shot.
- We start by defining a `Launcher`.
- The `Launcher` will need to keep track of a current angle (`self.angle`) and velocity (`self.vel`).

Creating a Launcher

- We need to first decide on units.
  - The obvious choice for velocity is meters per second, since that's what `Projectile` uses.
  - For the angle, it's most efficient to work with radians since that's what the Python library uses. For passing values in, degrees are useful as they are more intuitive for more programmers.
- The constructor will be the hardest method to write, so let's write some others first to gain insight into what the constructor will have to do.

Creating a Launcher

- We need mutator methods to change the angle and velocity.
- When we press a certain key, we want the angle to increase or decrease a fixed amount. The exact amount is up to the interface, so we will pass that as a parameter to the method.
- When the angle changes, we also need to redraw the `Launcher` to reflect the new value.

Creating a Launcher

```
class Launcher:
    def adjAngle(self, amt):
        """ change angle by amt degrees """
         self.angle = self.angle+radians(amt)
        self.redraw()
```

- Redrawing will be done by an as-yet unwritten method (since adjusting the velocity will also need to redraw).
- Positive values of `amt` will raise the launch angle, negative will decrease it.

Creating a Launcher

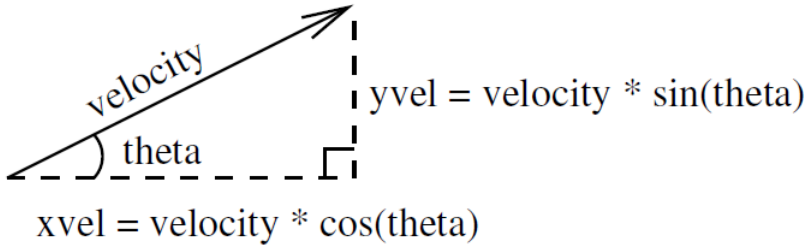
```
def adjVel(self, amt):
    """ change velocity by amt"""
    self.vel = self.vel + amt
    self.redraw()
```

- Similarly, we can use positive or negative values of `amt` to increase or decrease the velocity, respectively.

Creating a Launcher

- What should `redraw` do?
  - Undraw the current arrow
  - Use the values of `self.angle` and `self.vel` to draw a new one
  - We can use the `setArrow` method of our graphics library to put an arrowhead at either or both ends of a line.
  - To undraw the arrow, we'll need an instance variable to store it – let's call it `self.arrow`.

Creating a Launcher




```
def redraw(self):
    """undraw the arrow and draw a new one for the
    current values of angle and velocity.
    """
    self.arrow.undraw()
    pt2 = Point(self.vel*cos(self.angle),
                self.vel*sin(self.angle)) # p. 321
    self.arrow = Line(Point(0,0), pt2).draw(self.win)
    self.arrow.setArrow("last")
    self.arrow.setWidth(3)
```

Creating a Launcher

- We need a method to “fire” a shot from the Launcher.
  - Didn’t we just design a `ShotTracker` class that we could reuse?
  - `ShotTracker` requires window, angle, velocity, and height as parameters.
  - The initial height will be 0, angle and velocity are instance variables.
  - But what about the window? Do we want a new window, or use the existing one? We need a `self.win`

Creating a Launcher

```
def fire(self):
    return ShotTracker(self.win, degrees(self.angle), self.vel, 0.0)
```

- This method simply returns an appropriate `ShotTracker` object.
- It will be up to the interface to actually animate the shot.
  - Is the `fire` method the right place?
  - Hint: Should launcher interaction be modal?

Creating a Launcher

```
def __init__(self, win):
    # draw the base shot of the launcher
    base = Circle(Point(0,0), 3)
    base.setFill("red")
    base.setOutline("red")
    base.draw(win)

    # save the window and create initial angle and velocity
    self.win = win
    self.angle = radians(45.0)
    self.vel = 40.0

    # create inital "dummy" arrow
    self.arrow = Line(Point(0,0), Point(0,0)).draw(win)
    # replace it with the correct arrow
    self.redraw()
```

Shots

LECTURE 9

Tracking Multiple Shots

- The more interesting problem is how to have multiple things happening at one time.
- We want to be able to adjust the launcher and fire more shots while some shots are still in the air.
- To do this, the event loop that monitors keyboard input has to run (to keep interaction active) while the cannon balls are flying.

Tracking Multiple Shots

- Our event loop needs to also serve as the animation loop for all the shots that are “alive.”
- The basic idea:
- The event loop iterates at 30 iterations per second (for smooth animation)
  - Each time through the loop:
    - Move all the shots that are in flight
    - Perform any requested action

Tracking Multiple Shots

- Let's proceed like the calculator, and create an application object called `ProjectileApp`.
- The class will contain a constructor that draws the interface and initializes all the necessary variables, as well as a `run` method to implement the combined event/animation loop.

Tracking Multiple Shots

```
class ProjectileApp:

    def __init__(self):
        self.win = GraphWin("Projectile Animation", 640, 480)
        self.win.setCoords(-10, -10, 210, 155)
        Line(Point(-10,0), Point(210,0)).draw(self.win)
        for x in range(0, 210, 50):
            Text(Point(x,-7), str(x)).draw(self.win)
            Line(Point(x,0), Point(x,2)).draw(self.win)

        self.launcher = Launcher(self.win)
        self.shots = []
```

Tracking Multiple Shots

```
def run(self):
    launcher = self.launcher
    win = self.win
    while True:
        self.updateShots(1/30)

        key = win.checkKey()
        if key in ["q", "Q"]:
            break
```

Tracking Multiple Shots

```
        if key == "Up":
            launcher.adjAngle(5)
        elif key == "Down":
            launcher.adjAngle(-5)
        elif key == "Right":
            launcher.adjVel(5)
        elif key == "Left":
            launcher.adjVel(-5)
        elif key == "f":
          self.shots.append(launcher.fire())
        update(30)
    win.close()
```

Tracking Multiple Shots

- The first line in the loop invokes a helper method that moves all of the live shots. (This is the animation portion of the loop.)
- We use `checkKey` to ensure that the loop keeps going around to keep the shots moving even when no key has been pressed.
- When the user presses “f”, we get a `ShotTracker` object from the launcher and simply add this to the list of live shots.

Creating a Launcher

- The `ShotTracker` created by the launcher's `fire` method is automatically drawn in the window, and adding it to the list of shots (via `self.shots.append`) ensures that its position changes each time through the loop, due to the `updateShots` call at the top of the loop.
- The last line of the loop ensures that all of the graphics updates are drawn and serves to throttle the loop to a maximum of 30 iterations per second, matching the time interval (1/30 second).

Creating a Launcher

- `updateShots` has two jobs
  - Move all the live shots
  - Update the list to remove any that have “died” (either landed or flown horizontally out of the window).
- The second task keeps the list trimmed to just the shots that need animating.
- The first task is easy – loop through the list of `ShotTracker` objects and ask each to `update`.

Creating a Launcher

```
def updateShots(self, dt):
    for shot in self.shots:
        shot.update(dt)
```

- `dt` tells the amount of time into the future to move the shot.
- The second task is to remove dead shots.
  - Test that its y position is above 0 and x is between -10 and 210.

Creating a Launcher

- Would something like this work?

```
If shot.getY() < 0 or shot.getX() < -10 or shot.getX() > 210:
   self.shots.remove(shot)
```

- The loop is iterating over `self.shots`, and modifying the list while looping through it can produce strange anomalies.
- A better approach? Create another list to keep track of shots that are still alive, and swap it for self.shots at the end of the method.

Creating a Launcher

```
def updateShots(self, dt):
    alive = []
    for shot in self.shots:
        shot.update(dt)
        if shot.getY() >= 0 and shot.getX() < 210:
            alive.append(shot)
        else:
            shot.undraw()
    self.shots = alive
```

Creating a Launcher

- Two differences from a moment ago
  - We accumulate the shots that are “alive” (which reverses the logic)
  - We undraw the shots that are “dead”

Collections - Dictionary

LECTURE 10

Non-sequential Collections

- After lists, a *dictionary* is probably the most widely used collection data type.
- Dictionaries are not as common in other languages as lists (arrays).

Dictionary Basics

- Lists allow us to store and retrieve items from sequential collections.
- When we want to access an item, we look it up by index – its position in the collection.
- What if we wanted to look students up by student id number? In programming, this is called a *key-value pair*
- We access the value (the student information) associated with a particular key (student id)

Dictionary Basics

- Three are lots of examples!
  - Names and phone numbers
  - Usernames and passwords
  - State names and capitals
- A collection that allows us to look up information associated with arbitrary keys is called a *mapping*.
- Python dictionaries are *mapping*s. Other languages call them *hashes* or *associative arrays*.

Dictionary Basics

- Dictionaries can be created in Python by listing key-value pairs inside of curly braces.
- Keys and values are joined by ":" and are separated with commas.

```
>>>passwd = {"guido":"superprogrammer",
"turing":"genius", "bill":"monopoly"}
```

- We use an indexing notation to do lookups

```
>>> passwd["guido"]

'superprogrammer'
```

Dictionary Basics

`<dictionary>[<key>]` returns the object with the associated key.

- Dictionaries are mutable.

```
>>> passwd["bill"] = "bluescreen"
>>> passwd
{'guido': 'superprogrammer', 'bill': 'bluescreen',
'turing': 'genius'}
```

- Did you notice the dictionary printed out in a different order than it was created?

Dictionary Basics

- Mappings are inherently unordered.
- Internally, Python stores dictionaries in a way that makes key lookup very efficient.
- When a dictionary is printed out, the order of keys will look essentially random.
- If you want to keep a collection in a certain order, you need a sequence, not a mapping!
- Keys can be any immutable type, values can be any type, including programmer-defined.

Dictionary Operations

- Like lists, Python dictionaries support a number of handy built-in operations.
- A common method for building dictionaries is to start with an empty collection and add the key-value pairs one at a time.

```
passwd = {}
for line in open('passwords', 'r'):
    user, pass = line.split()
    passwd[user] = pass
```

Dictionary Operations

Method	Meaning
<key> in <dict>	Returns true if dictionary contains the specified key, false if it doesn't.
<dict>.keys()	Returns a sequence of keys.
<dict>.values()	Returns a sequence of values.
<dict>.items()	Returns a sequence of tuples (key, value) representing the key-value pairs.
del <dict>[<key>]	Deletes the specified entry.
<dict>.clear()	Deletes all entries.
for <var> in <dict>:	Loop over the keys.
<dict>.get(<key>, <default>)	If dictionary has key returns its value; otherwise returns default.

Dictionary Operations

```
>>> list(passwd.keys())
['guido', 'turing', 'bill']
>>> list(passwd.values())
['superprogrammer', 'genius', 'bluescreen']
>>> list(passwd.items())
[('guido', 'superprogrammer'), ('turing',
'genius'), ('bill', 'bluescreen')]
>>> "bill" in passwd
True
>>> "fred" in passwd
False
```

Dictionary Operations

```
>>> passwd.get('bill','unknown')
'bluescreen'
>>> passwd.get('fred','unknown')
'unknown'
>>> passwd.clear()
>>> passwd
{}
```

Dictionary as Histogram

LECTURE 11

Example Program: Word Frequency

- Let's write a program that analyzes text documents and counts how many times each word appears in the document.
- This kind of document is sometimes used as a crude measure of the style similarity between two documents and is used by automatic indexing and archiving programs (like Internet search engines).

Example Program: Word Frequency

- This is a multi-accumulator problem!
- We need a count for each word that appears in the document.
- We can use a loop that iterates over each word in the document, incrementing the appropriate accumulator.
- The catch: we may possibly need hundreds or thousands of these accumulators!

Example Program: Word Frequency

- Let's use a dictionary where strings representing the words are the keys and the values are ints that count up how many times each word appears.
- To update the count for a particular word, `w`, we need something like:

```
counts[w] = counts[w] + 1
```

- One problem – the first time we encounter a word it will not yet be in `counts`.

Example Program: Word Frequency

- Attempting to access a nonexistent key produces a run-time `KeyError`.

```
if w is already in counts:
    add one to the count for w
else:
    set count for w to 1
```

- How could this be implemented?

Example Program: Word Frequency

```
if w in counts:
    counts[w] = counts[w] + 1
else:
    counts[w] = 1
```

- A more elegant approach:

```
counts[w] = counts.get(w, 0) + 1
```

- If `w` is not already in the dictionary, this `get` will return 0, and the result is that the entry for `w` is set to 1.

Example Program: Word Frequency

- The other tasks include
  - Convert the text to lowercase (so occurrences of “Python” match “python”)
  - Eliminate punctuation (so “python!” matches “python”)
  - Split the text document into a sequence of words

Example Program: Word Frequency

```
# get the sequence of words from the file
    fname = input("File to analyze: ")
    text = open(fname,'r').read()
    text = text.lower()
    for ch in '!"#$%&()*+,-./:;<=>?@[\\]^_`{|}~':
        text = text.replace(ch, ' ')
    words = text.split()
```

- Loop through the words to build the counts dictionary

```
counts = {}
    for w in words:
        counts[w] = counts.get(w,0) + 1
```

Example Program: Word Frequency

- How could we print a list of words in alphabetical order with their associated counts?

```
# get list of words that appear in document
uniqueWords = list(counts.keys())

# put list of words in alphabetical order
uniqueWords.sort()

# print words and associated counts
for w in uniqueWords:
    print(w, counts[w])
```

Example Program: Word Frequency

- This will probably not be very useful for large documents with many words that appear only a few times.
- A more interesting analysis is to print out the counts for the *n* most frequent words in the document.
- To do this, we'll need to create a list that is sorted by counts (most to fewest), and then select the first *n* items.

Example Program: Word Frequency

- We can start by getting a list of key-value pairs using the `items` method for dictionaries.

```
items = list(count.items())
```

- `items` will be a list of tuples like

```
[('foo', 5), ('bar', 7), ('spam', 376)]
```

- If we try to sort them with items.sort(), they will be ordered by components, from left to right (the left components here are words).

```
[('bar', 7), ('foo', 5), ('spam', 376)]
```

Example Program: Word Frequency

- This will put the list into alphabetical order – not what we wanted.
- To sort the items by frequency, we need a function that will take a pair and return the frequency.

```
def byFreq(pair):
    return pair[1]
```

- To sort he list by frequency:

```
items.sort(key=byFreq)
```

Example Program: Word Frequency

- We're getting there!
- What if have multiple words with the same number of occurrences? We'd like them to print in alphabetical order.
- That is, we want the list of pairs primarily sorted by frequency, but sorted alphabetically within each level.

Example Program: Word Frequency

- Looking at the documentation for sort (via help([].sort), it says this method performs a "*stable* sort **in place**".
  - "In place" means the method modifies the list that it is applied to, rather than producing a new list.
  - Stable means equivalent items (equal keys) stay in the same relative position to each other as they were in the original.

Example Program: Word Frequency

- If all the words were in alphabetical order before sorting them by frequency, words with the same frequency will be in alphabetical order!
- We just need to sort the list twice – first by words, then by frequency.

```
items.sort()                                    # orders pairs
alphabetically
items.sort(key=byFreq, reverse = True) # orders by frequency
```

- Setting `reverse` to `True` tells Python to sort the list in reverse order.

Example Program: Word Frequency

- Now we are ready to print a report of the *n* most frequent words.
- Here, the loop index `i` is used to get the next pair from the list of items.
- That pair is unpacked into its `word` and `count` components.
- The word is then printed left-justified in fifteen spaces, followed by the count right-justified in five spaces.

Example Program: Word Frequency

```
for i in range(n):
    word, count = items[i]
    print("{0:<15}{1:>5}".format(word, count))
```

Homework

LECTURE 12

Homework 11

- Read Chapter Summary
- Work on True/False Questions, Multiple Choice Questions, Discussion.
- Work on Programming Exercises: 1, 5 and 7