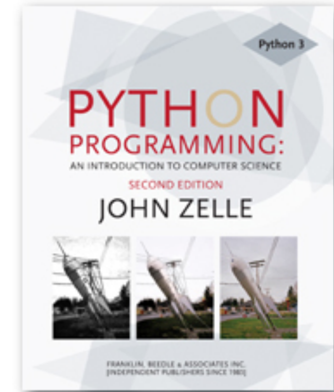
Python Programing: An Introduction to Computer Science



Chapter 11
Data Collections

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

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 = eval(xStr)
        sum = sum + x
        count = count + 1
        xStr = input("Enter a number (<Enter> to quit) >> ")
    print("\nThe average of the numbers is", sum / count)

main()
```

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.

- 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 the data is.

Sample Problem: Simple Statistics

- The standard deviation is

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

- Here $\bar{x}$ is the mean, x_i represents the *i*th data value and *n* is the number of data values.
- The expression $\left(\bar{x} - x_i\right)^2$ 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

$$(6.8-2)^2+(6.8-4)^2+(6.8-6)^2+(6.8-9)^2+(6.8-13)^2=149.6$$

$$s=\sqrt{\frac{149.6}{5-1}}=\sqrt{37.4}=6.11$$

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.

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 = eval(input('Enter a number: '))
while x >= 0:
    nums.append(x)
    x = eval(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 ith 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

- One way we can solve our statistics problem is to store the data in lists.
- 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 = eval(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 Objects

- 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.

- 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
```

- 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.
  ```

Lists of Objects

- 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((s.getName(),s.getHours(),s.getQPoints(),
                sep="\t", 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=<somefunc>)
- 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.
- Can 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()

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()
```

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, `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)
```

- 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

- ```
  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)
  ```
- 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

```
# dieview2.py
#     A widget for displaying the value of a die.
#     This version uses lists to simplify keeping track of
      pips.

class DieView:
    """ DieView is a widget that displays a graphical
      representation
    of a standard six-sided die."""

    def __init__(self, win, center, size):
        """Create a view of a die, e.g.:
           d1 = GDie(myWin, Point(40,50), 20)
        creates a die centered at (40,50) having sides
        of length 20."""

        # first define some standard values
        self.win = win
        self.background = "white" # color of die face
        self.foreground = "black" # color of the pips
        self.psize = 0.1 * size   # radius of each pip
        hsize = size / 2.0        # half of size
        offset = 0.6 * hsize      # distance from center to
      outer pips

        # create a square for the face
        cx, cy = center.getX(), center.getY()
        p1 = Point(cx-hsize, cy-hsize)
        p2 = Point(cx+hsize, cy+hsize)
        rect = Rectangle(p1,p2)
        rect.draw(win)
        rect.setFill(self.background)
```

```
# Create 7 circles for standard pip locations
       self.pips = [ self.__makePip(cx-offset, cy-offset),
                     self.__makePip(cx-offset, cy),
                     self.__makePip(cx-offset, cy+offset),
                     self.__makePip(cx, cy),
                     self.__makePip(cx+offset, cy-offset),
                     self.__makePip(cx+offset, cy),
                     self.__makePip(cx+offset, cy+offset) ]

       # Create a table for which pips are on for each
     value
       self.onTable = [ [], [3], [2,4], [2,3,4],
           [0,2,4,6], [0,2,3,4,6], [0,1,2,4,5,6] ]

       self.setValue(1)

   def __makePip(self, x, y):
       """Internal helper method to draw a pip at (x,y)"""
       pip = Circle(Point(x,y), self.psize)
       pip.setFill(self.background)
       pip.setOutline(self.background)
       pip.draw(self.win)
       return pip

   def setValue(self, value):
       """ Set this die to display value."""
       # Turn all the pips off
       for pip in self.pips:
           pip.setFill(self.background)

       # Turn the appropriate pips back on
       for i in self.onTable[value]:
           self.pips[i].setFill(self.foreground)
```

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."

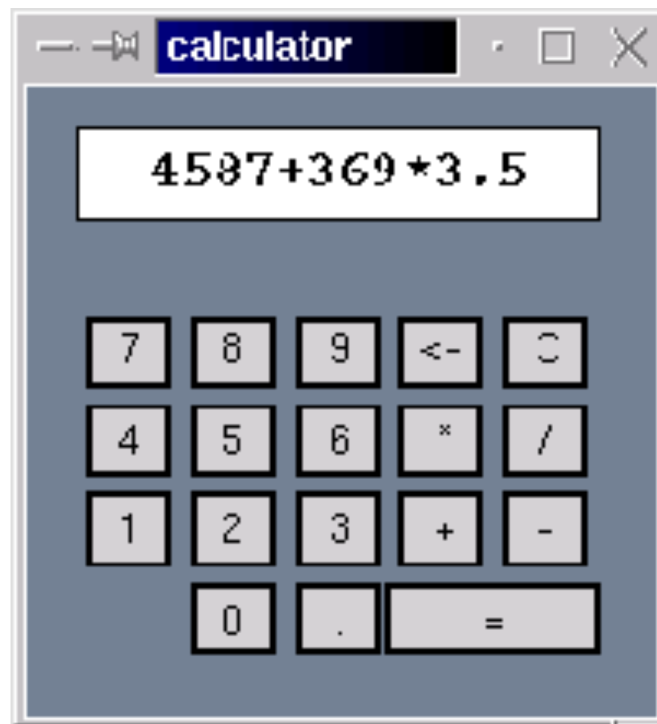
Case Study: Python Calculator

- 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 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()
```

- `bspecs` contains a list of button specifications, including the center point of the button and its label.

Constructing the Interface

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

- 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.

```
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.