CS 1
Introduction to Computer Programming

Lecture 6: October 12, 2015

Loops and decisions...

Last time

- Docstrings
- Lists

Today

- Loops
  - the `for` statement
- Making decisions
  - the `if` statement
  - the `else` and `elif` statements

Loops

- So far, have seen multiple kinds of data
  - `int`s, `float`s, strings, lists
- Have seen how to write functions with `def` and `return`
- Now we introduce another fundamental concept: a loop

Loops

- A loop is a chunk of code that executes repeatedly
  - though something must change each time the chunk is repeated (or else the program will never terminate)
- Python has two kinds of loop statements:
  - `for` loops (this lecture)
  - `while` loops (next lecture)

Loops

- Loops are often associated with lists
- Basic idea:
  - for each element of this list
  - do the following ... [chunk of code] ...
- Example:
  - for each element of a list
  - print the element

Loops

```
title_words = ['Monty', 'Python',
               'and', 'the',
               'Holy', 'Grail']
for word in title_words:
    print word
```

for loop

Loops

- Result:

```
Monty
Python
and
the
Holy
Grail
```

Loops

- Structure of a `for` loop:

```
for <name> in <list>:
    <chunk of code>
```

- `for` and `in` are keywords (reserved words)
- Chunk of code is executed once for each element of the list
- Each time through, the next element of `<list>` is assigned to the variable `<name>` and `<chunk of code>` is executed

Loops

```
title_words = ['Monty', 'Python', ...]
for word in title_words:
    print word
```

- First time through:
  - `word` is `'Monty'`
  - `print` prints `Monty`
- Second time through:
  - `word` is `'Python'`
  - `print` prints `Python`
- *etc.* until no more elements in list

Loops

- Another way to look at this:

```
for word in title_words:
    print word
```

- This is equivalent to:

```
word = 'Monty'
print word
word = 'Python'
print word
word = 'and'
print word  # etc.
```

Loops

- The variable name isn't important:

```
for frobnitz in title_words:
    print frobnitz
```

- This does the same thing as:

```
for word in title_words:
    print word
```

- But we like to use meaningful names for variable names, so 2nd version is greatly preferred

Loops

- Chunk of code in a `for` loop is called a *block*
- Blocks can consist of multiple lines:

```
for word in title_words:
    print word
    print '---'
```

- This puts a line of `'---'` between words:

```
Monty
---
Python
---    (etc.)
```

Loops

- Syntax:
  1. Must have a colon (`:`) at the end of the `for` line
  2. Every line in block must be indented the same amount (or else it's a syntax error)
  3. End of block indicated when indent goes back to value before `for` loop began

Loop syntax errors

- No colon at end of `for` line:

```
for word in title_word
                       ^
SyntaxError: invalid syntax
```

Loop syntax errors

- Irregular indentation:

```
for word in title_word:
    print word
      print '---'
      ^
IndentationError: unexpected indent
for word in title_word:
    print word
  print '---'
  ^
IndentationError: unindent does not match any
  outer indentation level
```

Application: summing

- Want to sum elements of a list of numbers

```
nums = [-32, 0, 45, -101, 334]
sum_nums = 0
for n in nums:
    sum_nums = sum_nums + n
print sum_nums
```

- Result: `246`

The += operator and friends

- When you see a line of the form

```
x = x + 10
```

you can write

```
x += 10
```

(meaning is the same)

- Similarly, can write

```
x *= 10
```

for

```
x = x * 10
```

The += operator and friends

- In general, many operators `op` have `op=` counterparts:
  - `+=  -=  *=  /=  %=`
- You should use them where applicable
  - makes code more concise, readable

Application: summing

- Another way to do this:

```
nums = [-32, 0, 45, -101, 334]
sum_nums = 0
for n in nums:
    sum_nums += n
print sum_nums
```

- Result: `246`

Application: summing

- Yet another way to do this:

```
nums = [-32, 0, 45, -101, 334]
sum_nums = sum(nums)  # !!!
```

- Result: `246`
- `sum` is a built-in function on lists
- *Moral*: there is usually more than one way to accomplish any task!

Loops and strings

- Can use a `for` loop to loop through the characters of a string:

```
>>> for c in 'Python':
...     print c
P
y
t
h
o
n
```

Loops and strings

- Lists and strings are both *sequences*, so a `for` loop works similarly for both of them
  - much like the `len` function works for both lists and strings in a similar way

Loops and strings

- However, strings are immutable, so can't do this:

```
>>> s = 'Python'
>>> s[0] = 'J'
TypeError: 'str' object does not
  support item assignment
```

Nested loops

- Can nest one `for` loop inside another:

```
title = ['Monty', 'Python']
for word in title:
    for char in word:
        print char
```

```
M
o
n
t
...
```

Nested loops

- Can nest one `for` loop inside another:

```
title = ['Monty', 'Python']
for word in title:
    for char in word:
        print char
```

- First time through outer loop: `word` is `'Monty'`
- Inner loop: `char` is `'M'`, then `'o'`, then `'n'`, then `'t'`, then `'y'`
- Second time through outer loop: `word` is `'Python'`
- Inner loop: `char` is `'P'`, then `'y'`, etc.

Continued...

- We'll talk more about loops next lecture
- We'll show you a different kind of loop
  - `while` loop

Interlude

- TV clip!

So far...

- Our programs have been "straight-line" programs
  - always do the same thing no matter what
  - We lacked the ability to make *decisions* based on the data
- Now we'll fix that
- Introduce the `if` statement

Problem

- Given a list of temperatures
  - say, temperature at noon every day this week
  - How many temps are above 72 degrees?
- Can't solve this with what we know so far

Two subproblems

1. How do we *test* to see whether or not a particular temperature is greater than 72 degrees?
2. How do we *use* that information to control our program?

Testing a number

- To test a number against some other number, we need a *relational operator*
- Examples: `<` `<=` `>` `>=` `==` `!=`
- Relational operators return a boolean value (`True` or `False`)

Relational operators

- `x == y` (is `x` equal to `y`?)
- `x != y` (is `x` not equal to `y`?)
- `x < y` (is `x` less than `y`?)
- `x <= y` (is `x` less than or equal to `y`?)
- `x > y` (is `x` greater than `y`?)
- `x >= y` (is `x` greater than or equal to `y`?)
- All of these operators return boolean (`True`/`False`) values

== vs. =

- Note: the == operator is completely different from the = (assignment) operator
  - really easy to make mistakes with this!

```
>>> a = 10    # assign a the value 10
>>> a == 10   # is a equal to 10?
```

- Completely different!

Testing the temperature

- Want to test if a temperature is greater than 72 degrees

```
>>> temp = 85
>>> temp > 72
True
```

The `if` statement

- Let's use this to do something:

```
>>> temp = 85
>>> if temp > 72:
...     print "Hot!"
Hot!
```

`if` statement

The `if` statement

- Structure of an `if` statement:

```
if <boolean expression>:
    <block of code>
```

The `if` statement

- Structure of an `if` statement:

```
if <boolean expression>:
    <block of code>
```

- Note that, like `for` statement, colon (`:`) has to come at the end of the `if` line

The `if` statement

- Structure of an `if` statement:

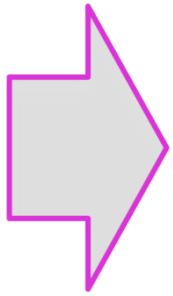
```
if <boolean expression>:
    <line of code>
    <line of code>
    ...
```

- Note that, like `for` statement, block of code can consist of multiple lines

The `if` statement

- Structure of an `if` statement:

```
if <boolean expression>:
    <line of code>
    <line of code>
    ...
```



- Note that, like `for` statement, block of code must be indented relative to `if` line

The `if` statement

- Interpretation of an **`if`** statement:

```
if <boolean expression>:
    <block of code>
```

- If the **`<boolean expression>`** evaluates to **`True`**, then execute the **`<block of code>`**
- Otherwise, don't!
- In either case, continue by executing the code after the **`if`** statement

Back to our problem

- We have a list of temperatures, one for each day this week

```
temps = [67, 75, 59, 73, 81, 80, 71]
```

- We want to compute how many of these temperatures are above 72
- How do we go about doing this?

Back to our problem

- For any given temperature, we know how to compare it with 72 and do something based on the result
  - need a relational operator (`>`) and an `if` statement
- But we have a whole list of temperatures
  - so will need a `for` loop as well
- This pattern (`if` inside a `for` loop) is a *very* common programming pattern!

Back to our problem

- Also need to keep track of the number of temperatures seen so far which are above 72
  - so need a variable to store the current count of temperatures above 72

Back to our problem

- Given all that, let's write our code
- To start with, haven't examined any temps
  - so count of temps > 72 is 0

```
temps_above_72 = 0
```

Back to our problem

- Now we have to examine each temp to see if it's above 72
  - use a `for` loop

```
temps_above_72 = 0
for t in temps:
    ???
```

Back to our problem

- For any given temp `t`, use an `if` statement and the `>` operator to test it:

```
temps_above_72 = 0
for t in temps:
    if t > 72:
        ???
```

Back to our problem

- If temperature t is > 72, add it to the count
  - otherwise do nothing

```
temps_above_72 = 0
for t in temps:
    if t > 72:
        temps_above_72 += 1
```

- And we're done!

Back to our problem

- All the code:

```
temps = [67, 75, 59, 73, 81, 80, 71]
temps_above_72 = 0
for t in temps:
    if t > 72:
        temps_above_72 += 1
print '%d days above 72' % temps_above_72
```

- Prints:

```
4 days above 72
```

Note

- This is a trivial example
  - Can easily do it in your head
- Would become less trivial if list contained 1,000,000 or 1,000,000,000 elements
- *Moral*: Computers aren't just about doing difficult computations
  - also about doing large numbers of *simple* calculations

More decisions

- An `if` statement allows you to either
  - do something (execute a block of code) when some condition is true
  - otherwise do nothing
- More generally, we might want to
  - do something when some condition is true
  - otherwise, do something `else` ...

`if` and `else`

- An `if` statement can *optionally* include a second part called the `else` clause
  - executed only if the `<boolean expression>` in the `if` statement was false

```
if <boolean expression>:
    <block of code>
else:
    <different block of code>
```

Example of `if` and `else`

```
temp = 69
if temp > 72:
    print "greater than 72!"
else:
    print "less than or equal to 72!"
```

- This will print:

```
less than or equal to 72!
```

But wait! There's more!

- Temperature can be compared more precisely than we did
- Might want to keep records of
  - days where temp is < 72
  - days where temp is == 72
  - days where temp is > 72
- Assume we have three variables, all initialized to `0`:
  - `temps_below_72`
  - `temps_at_72`
  - `temps_above_72`

Multi-way tests (the bad way)

- We could write this (for a temperature `t`):

```
if t < 72:
    temps_below_72 += 1
if t == 72:
    temps_at_72 += 1
if t > 72:
    temps_above_72 += 1
```

- This is bad code – why?

Multi-way tests (the bad way)

- Let's say that `t` is `69`
- Let's follow the execution of the code...

```
if t < 72:
    temps_below_72 += 1
if t == 72:
    temps_at_72 += 1
if t > 72:
    temps_above_72 += 1
```

Multi-way tests (the bad way)

- First, execute the first `if` statement
- Causes `temps_below_72` to be incremented by 1

```
if t < 72:
    temps_below_72 += 1
if t == 72:
    temps_at_72 += 1
if t > 72:
    temps_above_72 += 1
```

Multi-way tests (the bad way)

- Then, execute the second `if` statement
- Nothing happens, because `t` isn't `72`

```
if t < 72:
    temps_below_72 += 1
if t == 72:
    temps_at_72 += 1
if t > 72:
    temps_above_72 += 1
```

Multi-way tests (the bad way)

- Then, execute the third `if` statement
- Nothing happens, because `t` isn't `> 72`

```
if t < 72:
    temps_below_72 += 1
if t == 72:
    temps_at_72 += 1
if t > 72:
    temps_above_72 += 1
```

Multi-way tests (the bad way)

- The problem:
  - For many values of `t`, some of the three `if` statements may be executed unnecessarily
  - Can we figure out a better way to do this?
    - maybe using `else`?

Second try

- Use `else`:

```
if t < 72:
    temps_below_72 += 1
else:
    if t == 72:
        temps_at_72 += 1
    else:
        temps_above_72 += 1
```

Second try

- The good news: this works and is efficient

```
if t < 72:
    temps_below_72 += 1
else:
    if t == 72:
        temps_at_72 += 1
    else:
        temps_above_72 += 1
```

Second try

- The bad news: nested `if`s are ugly!

```
if t < 72:
    temps_below_72 += 1
else:
    if t == 72:
        temps_at_72 += 1
    else:
        temps_above_72 += 1
```

Second try

- The bad news: nested `if`s are ugly!

```
if t < 72:
    temps_below_72 += 1
else:
    if t == 72:
        temps_at_72 += 1
    else:
        temps_above_72 += 1
```

outer `if`

Second try

- The bad news: nested `if`s are ugly!

```
if t < 72:
    temps_below_72 += 1
else:
    if t == 72:
        temps_at_72 += 1
    else:
        temps_above_72 += 1
```

inner `if`

Second try

- Is there a better way?

```
if t < 72:
    temps_below_72 += 1
else:
    if t == 72:
        temps_at_72 += 1
    else:
        temps_above_72 += 1
```

Third try

- How would we say this in English?
- "*If* the temperature is less than 72, do <thing1>, *else if* the temperature is 72, do <thing 2>, *else* do <thing 3>."
- We can express this in Python using an **`elif`** statement inside an **`if`** statement
- **`elif`** is short for *"else if"*

Third try's the charm

- This leads to:

```
if t < 72:
    temps_below_72 += 1
elif t == 72:
    temps_at_72 += 1
else:
    temps_above_72 += 1
```

Third try's the charm

- This is both efficient and readable:

```
if t < 72:
    temps_below_72 += 1
elif t == 72:
    temps_at_72 += 1
else:
    temps_above_72 += 1
```

Next time

- **`while`** loops
- the **`break`** statement
- Files and file input/output