CSC 221: Introduction to Programming

Fall 2013

Python control statements

- operator precedence
- conditional execution: if, if-else, if-elif-else
- counter-driven repetition: for
- conditional repetition: while
- simulations & modeling

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Recall: Python functions

recall the general form of a Python function

```
def FUNCTION_NAME(PARAM1, …, PARAM2):
    """doc string that describes the function"""
    STATEMENTS
    return OUTPUT_VALUE                 # optional
```

$$\text{wind chill} = 35.74 + 0.6215*\text{temp} + (0.4275*\text{temp} - 35.75)*\text{wind}^{0.16}$$

```
def windChill(temp, speed):
    """Calculates the wind chill index given temperature and wind speed."""
    return 35.74 + 0.6215*temp + (0.4275*temp - 35.75)*(wind**0.16)
```

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Complex expressions

would it suffice to type this?

```
35.74 + 0.6215*temp + 0.4275*temp-35.75 * wind**0.16
```

Python has rules that dictate the order in which evaluation takes place

- ** has higher precedence, followed by * and /, then + and –
- meaning that you evaluate the part involving ** first, then * or /, then + or –

```
1 + 2 * 3 → 1 + (2 * 3) → 1 + 6 → 7
2 ** 10 - 1 → (2**10) - 1 → 1024 - 1 → 1023
```

- if more than one operator, ** evaluates right-to-left, all others evaluate left-to-right

```
8 / 4 / 2 → (8 / 4) / 2 → 2 / 2 → 1
2 ** 3 ** 2 → 2 ** (3 ** 2) → 2 ** 9 → 512
```

GOOD ADVICE: don't rely on these (sometimes tricky) rules

- place parentheses around sub-expressions to force the desired order

```
35.74 + 0.6215*temp + (0.4275*temp - 35.75)*(wind**0.16)
```

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Conditional execution

so far, all of the statements in methods have executed *unconditionally*

- when a method is called, the statements in the body are executed in sequence
- different parameter values may produce different results, but the steps are the same

many applications require *conditional execution*

- different parameter values may cause different statements to be executed

for example, consider the `windChill` formula

- the formula only applies when wind speed > 3 mph
- if wind speed is ≤ 3 mph, wind chill is the same as the temperature

$$\text{wind chill} = \begin{cases} \text{temp} & \text{if wind} <= 3 \\ 35.74 + 0.6215 * \text{temp} + (0.4275 * \text{temp} - 35.75) * \text{wind} ** 0.16 & \text{otherwise} \end{cases}$$

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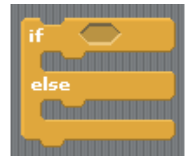
If statements

in Python, an *if statement* allows for conditional execution



- i.e., can choose between 2 alternatives to execute

```
if TEST_CONDITION:
    STATEMENTS_TO_EXECUTE_IF_TEST_IS_TRUE
else:
    STATEMENTS_TO_EXECUTE_IF_TEST_IS_FALSE
```

```
def windChill(temp, wind):
    if wind <= 3:
        return temp
    else:
        chill = 35.74 + 0.6215*temp + \
                (0.4275*temp - 35.75)*(wind**0.16)
        return chill
```

if the test is true (wind ≤ 3), then this statement is executed

otherwise (wind > 3), then these statements are executed

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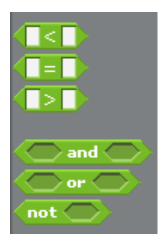
Boolean operators

standard relational operators are provided for the if test

`<`	less than	`>`	greater than
`<=`	less than or equal to	`>=`	greater than or equal to
`==`	equal to	`!=`	not equal to

`and` `or` `not`



a comparison using a relational operator is known as a *Boolean expression*, since it evaluates to a *Boolean* (`True` or `False`) value

EXERCISE:

```
import random

def flipCoin():
    """Simulates flipping a coin."""
    return random.choice(["heads", "tails"])
```

- reimplement using `randint` and an if-else statement
  1. generate a random integer in range [1, 2]
  2. if the number is 1, then return "heads
  3. else, return "tails"

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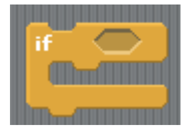
If statements (cont.)

you are not required to have an else case to an if statement

- if no else case exists and the test evaluates to false, nothing is done

```
def scale(grade, amount):
    newGrade = grade + amount
    if newGrade > 100:
        newGrade = 100
    return newGrade
```



an if statement (with no else case) is a 1-way conditional

- depending on the test condition, either execute the indented code or don't

an if-else statement (with else case) is a 2-way conditional

- depending on the test condition, execute one block of indented code or the other

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If examples

one more revision: wind chill is not intended for temperatures ≥ 50°

- could add a check for temp ≥ 50, then return what? temp?

```
def windChill(temp, wind):
    if temp >= 50 or wind <= 3:
        return temp
    else:
        chill = 35.74 + 0.6215*temp + \
                (0.4275*temp - 35.75)*(wind**0.16)
        return chill
```

really want to signify that the value is undefined

- the `float` function will convert a string into its corresponding number

  e.g., `float("12.5")` → `12.5`
- the expression `float("nan")` returns a special value, `nan`, that stands for 'not a number'
- whenever `nan` appears in an expression, the result is still `nan`

```
>>> x = float('nan')
>>> x
nan
>>> x + 1
nan
>>> y = 2 * x - 5
>>> y
nan
```

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Cascading if-else

now have 3 different cases, so need a 3-way conditional

- can accomplish this by nesting if-else statements
- known as a *cascading if-else* (control cascades down from one test to the next)

```
def windChill(temp, wind):
    if temp >= 50:
        return float('nan')
    else:
        if wind <= 3:
            return temp
        else:
            chill = 35.74 + 0.6215*temp + \
                    (0.4275*temp - 35.75)*(wind**0.16)
            return chill
```

reminder: Python uses indentation to determine code structure

- must make sure to align statements inside the appropriate if-else case

Cascading if-else: elif

because multi-way conditionals are fairly common, a variant exists to simplify the structure

- `elif` is shorthand for else-if
- introduces the next case without having to nest

```
def windChill(temp, wind):
    if temp >= 50:
        return float('nan')
    else:
        if wind <= 3:
            return temp
        else:
            chill = 35.74 + 0.6215*temp + \
                    (0.4275*temp - 35.75)*(wind**0.16)
            return chill
```

```
def windChill(temp, wind):
    if temp >= 50:
        return float('nan')
    elif wind <= 3:
        return temp
    else:
        chill = 35.74 + 0.6215*temp + \
                (0.4275*temp - 35.75)*(wind**0.16)
        return chill
```

Exercise: letter grades

define a Python function named `letterGrade`, that takes one input (a course average) and returns the corresponding letter grade

- assume grades of "A", "B", "C", "D", and "F" (no + or -)
- assume standard grade cutoffs

  e.g., `letterGrade(90)` should return "A"

  `letterGrade(89)` should return "B"

```
def letterGrade(average):
    ????
```


Repetition

an if statement provides for conditional execution

- can make a choice between alternatives, choose which (if any to execute)

if we want to repeatedly execute a block of code, need a loop

- loops can be counter-driven
  e.g., roll a die 10 times

- loops can be condition-driven
  e.g., roll dice until doubles

the simplest type of Python loop is a *counter-driven* for loop

```
for i in range(NUM_REPS):
  STATEMENTS_TO_BE_REPEATED
```

For loop examples

```
>>> for i in range(5):
        print(flipCoin())

heads
tails
tails
tails
heads
```

```
>>> for i in range(6):
        print(i, i**2, i**3)

0 0 0
1 1 1
2 4 8
3 9 27
4 16 64
5 25 125
```

```
def rollDie(numDieSides):
    """Simulates rolling a die with numDieSides."""
    return random.randint(1, numDieSides)
```

```
>>> for i in range(10):
        print(rollDie(8))

7
3
4
4
2
6
5
4
8
8
>>> for i in range(10):
        roll = rollDie(6) + rollDie(6)
        print(roll)

4
9
10
9
11
7
11
4
7
6
```

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Exercise: sum the dice rolls

suppose we wanted to define a function to sum up dice rolls

- need to initialize a variable to keep track of the sum (starting at 0)
- inside the loop, add each roll to the sum variable
- when done with the loop, display the sum

```
def sumRolls(numRolls):
    ???
```

similarly, suppose we wanted to average the dice rolls

- calculate the sum, as before
- return sum divided by the number of rolls

```
def avgRolls(numRolls):
    ???
```

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Loops & counters

for loops can be combined with if statements

- common pattern: perform multiple repetitions and count the number of times some event occurs
- e.g., flip a coin and count the number of heads
- e.g., roll dice and count the number of doubles
- e.g., traverse an employee database and find all employees making > $100K

```
def countHeads(numFlips):
    """Counts the number of heads obtained
       from numFlips coin flips."""
    numHeads = 0
    for i in range(numFlips):
        flip = flipCoin()
        if flip == "heads":
            numHeads = numHeads + 1
    return numHeads
```

```
def countDoubles(numRolls):
    """Counts the number of doubles obtained
       from numRolls dice rolls."""
    numDoubles = 0
    for i in range(numRolls):
        roll1 = rollDie(6)
        roll2 = rollDie(6)
        if roll1 == roll2:
            numDoubles = numDoubles + 1
    return numDoubles
```


Shorthand assignments

a variable that is used to keep track of how many times some event occurs is known as a *counter*

- a counter must be initialized to 0, then incremented each time the event occurs

```
def countDoubles(numRolls):
    """Counts the number of doubles obtained
       from numRolls dice rolls."""
    numDoubles = 0
    for i in range(numRolls):
        roll1 = rollDie(6)
        roll2 = rollDie(6)
        if roll1 == roll2:
            numDoubles += 1
    return numDoubles

def countHeads(numFlips):
    """Counts the number of heads obtained
       from numFlips coin flips."""
    numHeads = 0
    for i in range(numFlips):
        flip = flipCoin()
        if flip == "heads":
            numHeads += 1
    return numHeads
```

shorthand notation

`number += 1` ←→ `number = number + 1`

`number -= 1` ←→ `number = number - 1`

other shorthand assignments can be used for updating variables

`number += 5` ←→ `number = number + 5`

`number *= 2` ←→ `number = number * 2`

While loops

the other type of repetition in Python is the *condition-driven* while loop

- similar to an if statement, it is controlled by a Boolean test
- unlike an if, a while loop *repeatedly* executes its block of code as long as the test is true

```
while TEST_CONDITION:
  STATEMENTS_TO EXECUTE_AS_LONG_AS_TEST_IS_TRUE
```

```
>>> flip = ""
>>> while flip != "heads":
        flip = flipCoin()
        print(flip)
```

```
>>> roll1 = -1
>>> roll2 = -2
>>> while roll1 != roll2:
        roll1 = rollDie(6)
        roll2 = rollDie(6)
        print(roll1, roll2)
```


Example: hailstone sequence

interesting problem from mathematics

- start a sequence with some positive integer N
- if that number is even, the next number in the sequence is N/2;
  if that number is odd, the next number in the sequence is 3N+1

5 → 16 → 8 → 4 → 2 → 1 → 4 → 2 → 1 → …

15 → 46 → 23 → 70 → 35 → 106 → 53 → 160 → 80 → 40 → 20 → 10
↓
… ← 1 ← 2 ← 4 ← 8 ← 16 ← 5

it has been conjectured that no matter what number you start with, you will end up stuck in the 4-2-1 loop

- has been shown for all values <= $20 \times 2^{58} \approx 5.764 \times 10^{18}$
- but has not been proven to hold in general

Generating a hailstone sequence

need to be able to distinguish between even and odd numbers

- recall the remainder operator, %
- (x % y) evaluates to the remainder after dividing x by y
- thus, (x % 2) evaluates to 0 if x is even, 1 if x is odd

```
def hailstone(num):
    """Displays the hailstone sequence starting at num."""
    print(num)
    while num != 1:
        if num%2 == 0:
            num = num // 2
        else:
            num = 3*num + 1
        print(num)
```

EXERCISE: modify so that it also prints the length of the sequence

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Beware of "black holes"

since while loops repeatedly execute as long as the loop test is true, infinite loops are possible (a.k.a. *black hole* loops)

```
def flipUntilHeads():
    """Simulates repeatedly flipping
       a coin until get heads."""
    flip = flipCoin()
    numFlips = 1
    print(numFlips, ":", flip)
    while flip != "heads":
        numFlips += 1
        print(numFlips, ":", flip)
```

PROBLEM?

- a necessary condition for loop termination is that some value relevant to the loop test must change inside the loop

  in the above example, `flip` doesn't change inside the loop

  →if the test succeeds once, it succeeds forever!

- is it a sufficient condition? that is, does changing a variable from the loop test guarantee termination?

  NO – "With great power comes great responsibility."

  fix to above function?

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Example: Pig

Pig is a 2-player dice game in which the players take turns rolling a die.

On a given turn, a player rolls until either

1. he/she rolls a 1, in which case his/her turn is over and no points are awarded, or
2. he/she chooses to hold, in which case the sum of the rolls from that player's turn are added to his/her score.

The winner of the game is the first player to reach 100 points.

for example:

SCORE = 0 to start
TURN 1: rolls 5, 2, 4, 6, holds → SCORE = 0 + 17 = 17
TURN 2: rolls 4, 1, done → SCORE = 17 + 0 = 17
TURN 3: rolls 6, 2, 3, hold → SCORE = 17 + 11 = 28
…

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Pig simulation

we want to simulate Pig to determine the best strategy

- i.e., determine the optimal cutoff such that you should keep rolling until the score for a round reaches the cutoff, then hold
- i.e., what is the optimal cutoff that minimizes the expected number of turns

```
def pigTurn(cutoff):
    """Simulates a turn of the game Pig, with the player repeatedly
       rolling until they get a 1 or their score reaches the cutoff."""
    score = 0
    roll = 0
    while roll != 1 and score < cutoff:
        roll = rollDie(6)
        if roll == 1:
            score = 0
        else:
            score += roll
        print(roll, "-->", score)
```

why is roll set to 0 before the loop?
why not set it to rollDie(6)?

EXERCISE: modify the `pigTurn` function so that it returns the score for the round (as opposed to printing rolls/scores)

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Pig simulation (cont.)

EXERCISE: define a `pigGame` function that simulates a Pig game

- has 1 input, the cutoff value for each turn
- it repeatedly calls the `pigTurn` function, totaling up the score for each turn (and displaying the turn # and updated score)
- it stops when the score total reaches 100

```
>>> pigGame(15)
Turn 1 : 19
Turn 2 : 19
Turn 3 : 19
Turn 4 : 19
Turn 5 : 36
Turn 6 : 51
Turn 7 : 71
Turn 8 : 86
Turn 9 : 102
```

```
>>> pigGame(15)
Turn 1 : 16
Turn 2 : 33
Turn 3 : 33
Turn 4 : 33
Turn 5 : 33
Turn 6 : 48
Turn 7 : 68
Turn 8 : 86
Turn 9 : 86
Turn 10 : 86
Turn 11 : 101
```

```
>>> pigGame(15)
Turn 1 : 15
Turn 2 : 15
Turn 3 : 15
Turn 4 : 15
Turn 5 : 15
Turn 6 : 15
Turn 7 : 31
Turn 8 : 31
Turn 9 : 31
Turn 10 : 31
Turn 11 : 31
Turn 12 : 48
Turn 13 : 65
Turn 14 : 65
Turn 15 : 83
Turn 16 : 83
Turn 17 : 99
Turn 18 : 115
```


Pig simulation (cont.)

what can we conclude from running several experiments?

- Simulation 1: a cutoff of 15 yields a game of 12 turns
- Simulation 2: a cutoff of 20 yields a game of 14 turns
- can we conclude that a cutoff of 15 is *better* than a cutoff of 20?

note: because of the randomness of the die, there can be wide variability in the simulations

- note: a single roll of a die is unpredictable
- however: given a *large* number of die rolls, the distribution of the rolls can be predicted (since each die face is equally likely, each should appear ~ 1/6 of time)
- *Law of Large Numbers* states that as the number of repetitions increases to ∞, the percentages should get closer and closer to the expected values

Pig simulation (cont.)

in order to draw reasonable conclusions, will need to perform many experiments and average the results

EXERCISE: modify the `pigGame` function so that it returns the number of turns (as opposed to printing turns/scores)

EXERCISE: define a `pigStats` function that simulates numerous games

- has 2 inputs, the number of games and the cutoff value for each turn
- it repeatedly calls the `pigGame` function the specified number of times, totaling up the number of turns for each game
- it returns the average number of turns over all the games

QUESTION: what is the optimal cutoff that minimizes the number of turns

- how many games do you need to simulate in order to be confident in your answer?

Control summary

if statements provide for conditional execution

- use when you need to make choices in the code
- control is based on a Boolean (True/False) test
  1-way: if (with no else)
  2-way: if-else
  multi-way: cascading if-else, if-elif-elif-…-elif-else

for loops provide for counter-driven repetition

- use when you need to repeat a task a set number of times
- utilizes the range function (will learn more later)

while loops provide for conditional repetition

- use when you need to repeat a task but you don't know how many times
- control is based on a Boolean (True/False) test
- as long as test continues to be True, the indented code will be executed
- beware of infinite (black hole) loops