# ENGG1003 - Monday Week 4

## Iteration again: `for` vs. `while` loops, debugging strategies & random numbers

Steve Weller

University of Newcastle

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# Lecture overview

1. Iteration again (again): `for` vs. `while` loops §3.3.3
2. Debugging strategies
3. Random numbers in Python §2.4

# 1) iteration again: `for` vs. `while` loops

Two Python programs to count from 1 to 10

```
for i in range(1,11,1):
    print(i)
```

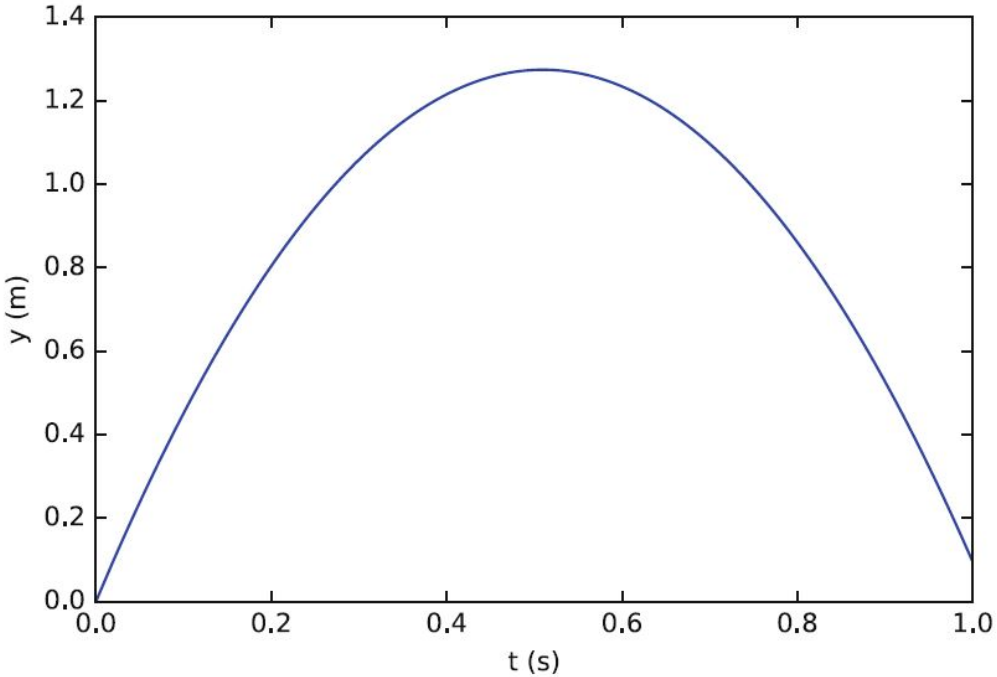
```
i = 1
while i <= 10:
    print(i)
    i = i + 1
```

- recall: `range(1,11,1)` generates list `[1,2,3,4,5,6,7,8,9,10]`

# `for` vs. `while`

- in `while` loop, counter `i` needs to be:
  - *initialised* before loop header
  - *incremented* in loop body
- `for` loop does these two tasks automatically
- shorter `for` loop code here, but that does *not* mean it's preferred in general
  - `while` often more efficient
- which of `for` or `while` is "best" usually determined by problem at hand—both are useful!

# Example: Finding the maximum height




- previously calculated height vs. time, and time of flight
- now calculate **maximum height** of ball
- will solve using `for` and `while` loops

```
import numpy as np
import matplotlib.pyplot as plt

v0 = 5                          # Initial velocity
g = 9.81                        # Acceleration of gravity
t = np.linspace(0, 1, 1000)     # 1000 points in time interval
y = v0*t - 0.5*g*t**2           # Generate all heights

# At this point, the array y with all the heights is ready,
# and we need to find the largest value within y.

largest_height = y[0]           # Starting value for search
for i in range(1, len(y), 1):
    if y[i] > largest_height:
        largest_height = y[i]

print('The largest height achieved was {:g} m'.format(largest_height))

# We might also like to plot the path again just to compare
plt.plot(t,y)
plt.xlabel('Time (s)')
plt.ylabel('Height (m)')
plt.show()
```

# Python code: `ball_max_height.py`

# Focus: `for` loop to find max height

Strategy:

- compute array of ball heights, `y`
  - values stored as `y[0], y[1], y[2], ...`
- largest height initialised to `y[0]`
- work through remaining indices `i = 1,2,3,...`
- each time `y[i]` is bigger than largest, it becomes the new largest

```
largest_height = y[0]          # Starting value for search
for i in range(1, len(y), 1):
    if y[i] > largest_height:
        largest_height = y[i]
```

```
The largest height achieved was 1.27421 m
```

- live demo

# Focus: `while` loop to find max height

Strategy is to examine successive pairs of heights:

- `y[0]` and `y[1]`
- `y[1]` and `y[2]`
- `y[2]` and `y[3]`
- `...`

- ball still rising when `y[i]` $<$ `y[i+1]`
- ball has reached maximum height when `y[i+1]` $\leq$ `y[i]`

  ie: when `y[i+1]` $>$ `y[i]` is `False`
- report `y[i]` as maximum height

```
i = 0
while y[i+1] > y[i]:
    i = i + 1
```

# 2) Debugging strategies

1. running code by hand
   - know what you expect your code to do
   - use pen and paper to "think like a computer"
   - very easy to fool yourself with "looks about right. . . "
   - use "toy problems": use tiny arrays, and values calculated at console
   - near enough isn't good enough when debugging
2. don't guess, print!
   - use temporary debug `print()` statements to check values and types of variables during loop iterations
3. take baby steps
   - change one line at a time, then re-run code
   - if interpreter generates an error, must have been the most recent change

# 3) Random numbers in Python

- Python provides ability to produce (apparently) random numbers
- referred to as *pseudo-random numbers*
- these numbers are not *truly* random
  - produced in a complicated (but "deterministic" or predictable) way once a *seed* has been set
- seed is a number which depends on the current time

# Drawing **one** random number at a time

```
import random

a = 1; b = 6
r1 = random.randint(a, b)   # first die
r2 = random.randint(a, b)   # second die

print('The dice gave:  {:d} and {:d}'.format(r1, r2))
```

Python code: `throw_2_dice.py`

- function `randint(a,b)`
  - available from imported module `random`
  - returns a pseudo-random *integer* in the range $[a, b]$ where $a \leq b$

# Fixing the seed

- when debugging programs that involve pseudo-random numbers, often helps to *fix the seed*
- ensures that *identical sequence of numbers will be generated* each time code is run
  - hence results are *repeatable*
- tell Python what seed should be using `random.seed` function
- **Example:** `random.seed(10)` and run Python code: `throw_2_dice.py`

# Two functions: `random` and `uniform`

- both `random` and `uniform` return a floating point number from an interval where each number has *equal probability* of being drawn
  - random number drawn from *uniform* probability distribution
  - Note: `random` function in `random` module

- `random`
  - draw from interval $[0, 1)$

- `uniform`
  - draw from interval $[a, b]$

# Live demo: `random` and `uniform`

```
In [1]: import random

In [2]: x = random.random()          # draw float from [0, 1), assign to x

In [3]: y = random.uniform(10, 20) # ...float from [10, 20], assign to y

In [4]: print('x = {:g}, y = {:g}'.format(x, y))
Out[5]: x = 0.714621 , y = 13.1233
```

# Drawing **many** random numbers at a time

- three random number generators seen so far
  - each generates just *one* random number at a time
- to generate an *array* of random numbers. . .

  . . . could use a loop & generate one random number in each iteration
- better (faster) solution: use `random` module in `numpy` library

# Live demo: random numbers from `numpy` library

**Example:** `np.random.randint`

- `numpy` library / `random` module / `randint` function
- `randint(a,b,n)` generates $n$ integers from $[a, b)$

```
In [1]: import numpy as np

In [2]: np.random.randint(1, 6, 4)      # ...4 integers from [1, 6)
Out[2]: array([1, 3, 5, 3])

In [3]: np.random.random(4)          # ...4 floats from [0, 1)
Out[3]: array([ 0.79183276,  0.01398365,  0.04982849,  0.11630963])

In [4]: np.random.uniform(10, 20, 4)    # ...4 floats from [10, 20)
Out[4]: array([ 10.95846078,  17.3971301 ,  19.73964488,  18.14332234])
```

- live demo, also fix seed: `np.random.seed(10)`

# Lecture summary

- Iteration again
  - `for` vs. `while`
- Debugging strategies
  - running code by hand
  - don't guess, print!
  - take baby steps
- Random numbers
  - random module—random numbers one at a time
  - random module in `numpy` library—arrays of random numbers