ENGG1003 - Monday Week 3

Loops and branching

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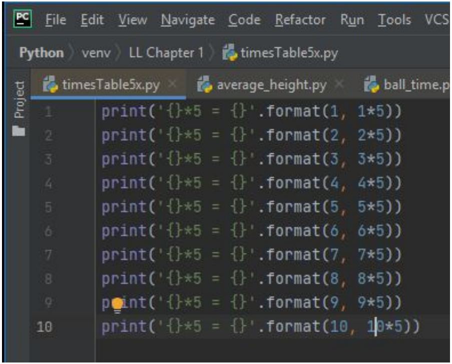
Lecture overview

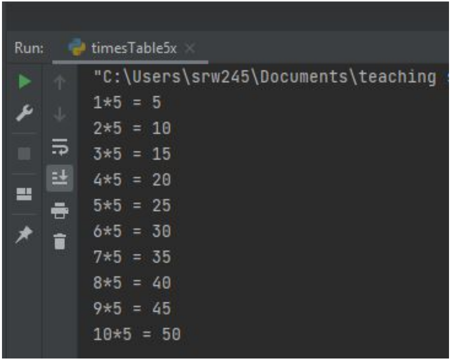
1. Iteration using **`for`** loop §3.1
   - fixed number of iterations
2. Iteration using **`while`** loop §3.2
   - keep iterating whenever a condition is satisfied
3. Branching: **`if`**, **`elif`** and **`else`** §3.3
   - check condition before executing code block

1) Iteration using `for` loop

- many computations for solving engineering problems are intrinsically repetitive
- all programming languages have certain *loop* structures to enable repetitive code execution
- Python provides two such structures:
  - `for` loop
  - `while` loop
- **Motivation:** print the 5 times table at the console

Live demo: 5 times table, brute force





Our first loop

- using `for` loop, can replace 10 lines of code with just 2 lines:

```
for i in [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]:      # Note... for, in and colon
    print('{:d}*5 = {:d}'.format(i, i*5))          # Note indent
```

- *loop variable* `i` takes on each of the values 1 to 10
- ...and for each value the `print` function is called

A typical `for` loop

```
for loop_variable in some_numbers:   # Loop header
    <code line 1>                         # 1st line in loop body
    <code line 2>                         # 2nd line in loop body
    ...
    ...                              # last line in loop body
# First line after the loop
```

- first line is *for loop header*
  - reserved word `for`, ends with colon, both necessary
- *indented* lines after header are a *block* of statements
  - called the *loop body*
- block of code inside a loop *must* be indented
  - indentation is 4 spaces by convention
- once indentation is reversed, loop body has ended

Nested loops

- for each iteration of a loop. . . execute *another* loop!
- one loop “inside” another, hence *nested*
- *two* levels of indentation are needed

```
for i in [1, 2, 3]:
    # First indentation level (4 spaces)
    print('i = {:d}'.format(i))
    for j in [4.0, 5.0, 6.0]:
        # Second indentation level (4+4 spaces)
        print('      j = {:.1f}'.format(j))
    # First line AFTER loop over j
# First line AFTER loop over i
```

```
i = 1
      j = 4.0
      j = 5.0
      j = 6.0
i = 2
      j = 4.0
      j = 5.0
      j = 6.0
i = 3
      j = 4.0
      j = 5.0
      j = 6.0
```

Combining `for` loop and `array`

- elements of each `array` are identified by an index
- `for` loop can use array index as a loop variable

Example: compute average of five numbers

$$\frac{h[0] + h[1] + h[2] + h[3] + h[4]}{5}$$

```
import numpy as np

N = 5
h = np.zeros(N)      # heights of family members (in meter)
h[0] = 1.60; h[1] = 1.85; h[2] = 1.75; h[3] = 1.80; h[4] = 0.50

sum = 0
for i in [0, 1, 2, 3, 4]:
    sum = sum + h[i]
average = sum/N

print('Average height: {:g} meter'.format(average))
```

Live demo: `for` loop

- Python code: `average_height.py`

Using the `range` function

- what about `for` loop with *really large* number of iterations?

  ✗ `for i in [0,1,2,3,4, ..., 9999]:`

- built-in function `range` solves this problem
- instead of `for i in [0, 1, 2, 3, 4]:`

  ... use this `for i in range(0, 5, 1):`

- general form of call to `range` as follows

```
for loop_variable in range(start, stop, step):
```

  - start at integer `start`

    ... increment by integer `step`

    ... stop before integer `stop`

2) Iteration using `while` loop

- `for` loop runs for a specified number of iterations
- second basic loop construction in Python is the `while` loop
  - runs as long as a *condition* is `True`
- how do we write "conditions" in Python?
- how do we decide a condition is `True` or `False`?

Boolean expressions

- in programming, often need to check whether something is true or not true
  - ...and take action accordingly
    eg: mass loading on bridge $< 30,000$ kg?
    eg: pH in a tank above 10?
- handled using *logical* or *Boolean expressions*
- these evaluate to *Boolean values* `True` and `False`
  - note capital letters T and F
- six *relational operators* to compare values in Python

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

Comparing values

Live demo

```
In [1]: x = 4

In [2]: # The following is a series of boolean expressions:

In [3]: x > 5        # x greater than 5
Out[3]: False

In [4]: x >= 5       # x greater than, or equal to, 5
Out[4]: False

In [5]: x < 5        # x smaller than 5
Out[5]: True

In [6]: x <= 5       # x smaller than, or equal to, 5
Out[6]: True

In [7]: x == 4       # x equal to 4
Out[7]: True

In [8]: x != 4       # x not equal to 4
Out[8]: False
```

Boolean operators: `and`, `or`, `not`

Live demo

```
In [9]: x < 5 and x > 3      # x less than 5 AND x larger than 3
Out[9]: True

In [10]: x == 5 or x == 4   # x equal to 5 OR x equal to 4
Out[10]: True

In [11]: not x == 4         # not x equal to 4
Out[11]: False
```

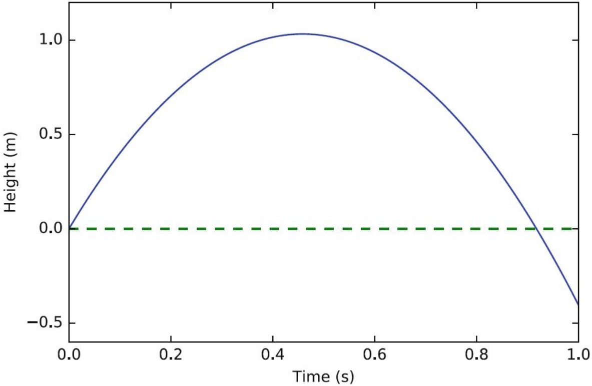
- Boolean variable type
  - int, float, str, **bool**
- Boolean values may be combined into longer expressions using `and`, `or` and `not`
- basics of Boolean operators: week 1 Thurs lecture
  - covered in *much* more depth in ELEC1710

Example: Finding the time of flight

- illustrate `while` loop by modifying earlier "soccer ball" example
- initial velocity of ball is slightly lower, only 4.5 m/s
  - was 5 m/s in last weeks lecture

Goal: compute how long ball is in the air

Ball height vs. time



- height is eventually *negative*, ie: for large enough t
- **Idea:** find smallest t where height $y(t) < 0$

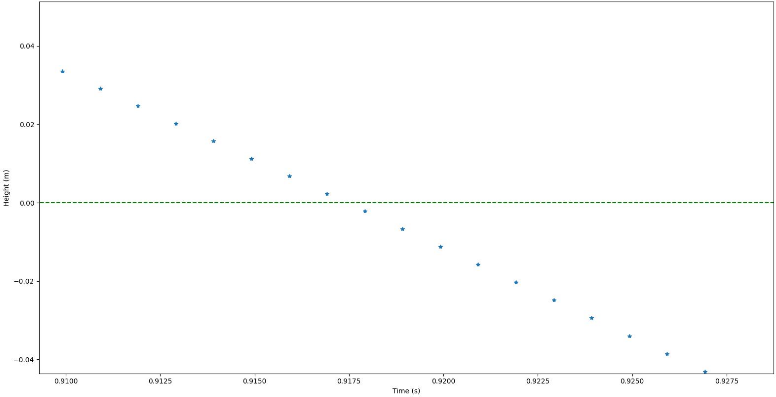
```python
import numpy as np

v0 = 4.5                        # 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

# Find index where ball approximately has reached y=0
i = 0
while y[i] >= 0:
    i = i + 1

# Since y[i] is the height at time t[i], we do know the
# time as well when we have the index i...
print('Time of flight (in seconds): {:g}'.format(t[i]))

# We plot the path again just for comparison
import matplotlib.pyplot as plt
plt.plot(t, y)
plt.plot(t, 0*t, 'g--')
plt.xlabel('Time (s)')
plt.ylabel('Height (m)')
plt.show()
```

Python code: `ball_time.py`

```
# Find index where ball approximately has reached y=0
i = 0
while y[i] >= 0:
    i = i + 1
```

- loop index `i` inialised at `0`
  - interested in heights `y[0], y[1], y[2], ...` at times `t[0], t[1], t[2], ...`
- loop runs as long as condition `y[i] >= 0` evaluates to `True`
  - . . . and index `i` is incremented by `1`
  - checks successive elements in array `y`
- when `y[i] >= 0` evaluates to `False`

  . . . we've found the first height that is negative!
- loop terminates and code *after* loop is executed
- `i` is smallest index for which height `y[i] < 0`



- `i` $= 917$
- `y[916]` $= 0.002312$
- `y[917]` $= -0.002190$

Structure of a typical `while` loop

```
while some_condition:   # Loop header
    <code line 1>           # 1st line in loop body
    <code line 2>           # 2nd line in loop body
    ...
    ...
# This is the first line after the loop
```

- first line is *while loop header*
  - reserved word `while`, ends with colon, both necessary
- indented lines after header are a *block* of statements
  - called the *loop body*
- indentation is 4 spaces by convention
- once indentation is reversed, loop body has ended

- `some_condition` is a Boolean expression
  - must evaluate to `True` or `False`

- if `some_condition` is initially `False`:
  - loop body statements are *never* executed

- if `some_condition` is initially `True`:
  - statements in loop body are evaluated once

    `some_condition` evaluated again

    ...and the process continues

Summary: `while` loop runs until the Boolean expression `some_condition` becomes `False`

Infinite loops

- Possible to have a `while` loop in which the condition *never* evaluates to `False`
  - program execution cannot escape the loop!

- Referred to as an *infinite loop*

- Might be deliberate . . .
  - program runs "forever", eg: surveillance camera system

- . . . but infinite loops are usually unintentional
  - result of a program *bug*
  - `Ctrl+c` to stop program

3) Branching: `if`, `elif` and `else`

Aim: write a program that helps us decide whether we should go swimming or not

- based on water temperature in degrees Celcius ($^\circ$C)

- will build up a program in stages
  - programming as a step-wise process

One `if`-test

```
T = float(input('What is the water temperature? '))
if T > 24:
    print('Great, jump in!')
# First line after if part
```

- `T = float(input(...`
  - reads string from console, and converts to float `T`
- if $T > 24$, then string is printed
- ...and if $T \leq 24$ then
  - print command is *not* executed
  - program continues to `# First line after if part`

Two `if`-tests

```
T = float(input('What is the water temperature? '))
if T > 24:                                  # testing condition 1
    print('Great, jump in!')
if T <= 24:                                 # testing condition 2
    print('Do not swim. Too cold!')
# First line after if-if construction
```

- precisely one of the following two strings is displayed:
  - "Great, jump in!"
  - "Do not swim. Too cold!"

An `if-else` construction

- since the conditions are *mutually exclusive*
  - $T > 24$
  - $T \leq 24$
- we can simplify code with `if-else`

```
T = float(input('What is the water temperature? '))
if T > 24:                              # testing condition 1
    print('Great, jump in!')
else:
    print('Do not swim. Too cold!')
# First line after if-else construction
```

An `if-elif-else` construction

```
T = float(input('What is the water temperature? '))
if T > 24:                                        # testing condition 1
    print('Great, jump in!')
elif 20 <= T <= 24:                               # testing condition 2
    print('Not bad. Put your toe in first!')
else:
    print('Do not swim. Too cold!')
# First line after if-elif-else construction
```

- final enhancement of program has advice for *three* temperature categories:
  - $T > 24$
  - $20 \leq T \leq 24$
  - $T < 20$
- $T < 20$ condition is captured by `else`

General form of an if-elif-else

```
if condition_1:            # testing condition 1
    <code line 1>
    <code line 2>
    ...
elif condition_2:          # testing condition 2
    <code line 1>
    <code line 2>
    ...
elif condition_3:          # testing condition 3
    <code line 1>
    <code line 2>
    ...
else:
    <code line 1>
    <code line 2>
    ...
# First line after if-elif-else construction
```

Lecture summary

- Iteration using **`for`** loop
  - fixed number of iterations
- Iteration using **`while`**
  - keep iterating whenever a Boolean condition is satisfied
- Branching: **`if`**, **`elif`** and **`else`**
  - conditional execution of code blocks
    - `if`
    - `if-else`
    - `if-elif-else`