

ENGG1003 - Thursday Week 2

Data types, and introduction to arrays

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Lecture overview

1 variables and data types §2.2

- ▶ principles
- ▶ live demo

2 arrays in Python §2.3

- ▶ principles
- ▶ live demo

1) variables and data types

- variable names—make them descriptive but short(-ish), not always easy!
 - ✓ waterLevel, altitudeUAV, tunnelDepth
 - ✗ w, a, t
 - ✗ averageAnnualBatteryVoltage
- camelCase
 - ▶ lower camel case eg: iPhone, macOS
 - ▶ upper camel case eg: PlayStation, YouTube
- snake_case
 - ▶ also known as lower_case_with_underscores
 - ▶ LL textbook uses this convention
- matter of preference/style/taste/context
 - ▶ experiment, find what works best for you!

Assignment

- $x = 2$
 - ▶ “variable x is *assigned* the value of 2”
- $x = x + 4$
 - ▶ value of x is increased by 4
 - ▶ new value of x over-writes old value
- abbreviations
 - ▶ $x += 4$ is short for $x = x + 4$
 - ▶ $x -= 4 \iff x = x - 4$
 - ▶ $x *= 4 \iff x = x * 4$
 - ▶ $x /= 4 \iff x = x / 4$

Data types in Python

Python data types of variables seen so far:

- **int**
- **float**
- **str**
- one more data type will be introduced next week
dramatic music plays
 - ▶ **int**—integers, eg: 0, 1, 9, -10, 452617
 - ▶ **float**—real numbers, eg: 3.14159, -5.5, 2.0
 - will explain “floating point number” terminology later
 - ▶ **str**—strings, eg: 'Hello ENGG1003'

Type function

- built-in function `type` returns type of a variable
 - ▶ technically: returns type of an *object*
 - ▶ we won't emphasise objects in this course
 - ▶ see elsewhere, eg: SENG1100 Object Oriented Programming

```
In [1]: x = 2
```

```
In [2]: y = 4.0
```

```
In [3]: s = 'hello'
```

```
In [4]: type(x)           # ...object named x is an integer
Out[4]: int
```

```
In [5]: type(y)           # ...object named y is a float
Out[5]: float
```

```
In [6]: type(s)           # ...object named s is a string
Out[6]: str
```

Type function (ctd.)

- *type conversion*—variables may be converted from one type to another (if it makes sense)

```
In [1]: x = 1  
  
In [2]: y = float(x)  
  
In [3]: y  
Out[3]: 1.0  
  
In [1]: x = 1.0  
  
In [2]: y = int(x)  
  
In [3]: y  
Out[3]: 1
```

- *automatic type conversion*

```
In [1]: x = 2  
  
In [2]: x = x + 4.0  
  
In [3]: x  
Out[3]: 6.0
```

Live demo of variables and data types

2) Arrays in Python

- simple arrays appeared in Monday's lecture
 - ▶ height of a ball was computed for each millisecond
 - ▶ time stored in array `t`
 - ▶ height stored in array `y`
- arrays we use in this course are imported from `numpy` library
- for each array, all array *elements* must be of the same type
 - ▶ eg: all `int`, or all `float`

Array creation and array elements



- array *index* used to identify array elements
 - ▶ Python uses *zero-based indexing*
 - ▶ indices start at zero: 0, 1, 2, ...
- four common ways of creating arrays:
 - ▶ `linspace`
 - ▶ `zeros`
 - ▶ `array`
 - ▶ `copy`

#1 Linspace

- have seen `linspace` function already
- `t = np.linspace(0, 1, 1001)` creates 1001 coordinates between 0 and 1, inclusive at both ends

0	1	2				1000
0	0.001	0.002	...			0.998 0.999 1

- `t` is the name of the array
- array indices are `0, 1, 2, ...`
- array elements: `t[0], t[1], t[2], ..., t[1000]`

```
In [1]: from numpy import linspace
```

```
In [2]: x = linspace(0, 2, 3)
```

```
In [3]: x
```

```
Out[3]: array([ 0.,  1.,  2.])
```

```
In [4]: type(x)           # check type of array as a whole
```

```
Out[4]: numpy.ndarray
```

```
In [5]: type(x[0])        # check type of array element
```

```
Out[5]: numpy.float64
```

- array has 3 elements: $x[0]$, $x[1]$, $x[2]$
- individual array elements have type `numpy.float64`
 - ▶ `float64` is a particular float data type in NumPy
- array `x` itself has type `numpy.ndarray`

#2 Zeros function

```
In [1]: from numpy import zeros
```

```
In [2]: x = zeros(3, int)           # get array with integer zeros
```

```
In [3]: x
```

```
Out[3]: array([ 0,  0,  0])
```

```
In [4]: y = zeros(3)               # get array with floating point zeros
```

```
In [5]: y
```

```
Out[5]: array([ 0.,  0.,  0.])
```

```
In [6]: y[0] = 0.0;   y[1] = 1.0;   y[2] = 2.0       # overwrite
```

```
In [7]: y
```

```
Out[7]: array([ 0.,  1.,  2.])
```

```
In [8]: len(y)
```

```
Out[8]: 3
```

- can define an array of `int`, or an array of `float`
 - ▶ but cannot mix `int` and `float` type in a single array!
- `zeros(3, int)`
 - ▶ creates an array of 3 integer zeros
- `zeros(3)`
 - ▶ creates an array of 3 floating point (`float`) zeros
- how to tell if array of `int` or `float`?
 - ▶ look carefully ...
 - ▶ `[0, 0, 0]` for `int`
 - ▶ `[0., 0., 0.]` for `float`
- `len(y)` is *length* of array `y`

#3 Array function

```
In [1]: from numpy import array
```

```
In [2]: x = array([0, 1, 2])           # get array with integers
```

```
In [3]: x
```

```
Out[3]: array([0, 1, 2])
```

```
In [4]: x = array([0., 1., 2.])       # get array with real numbers
```

```
In [5]: x
```

```
Out[5]: array([ 0.,  1.,  2.])
```

- ▶ `array([0, 1, 2])` creates array of integers
- ▶ `array([0., 1., 2.])` creates array of real numbers

Index out of bounds

```
In[3]: from numpy import array
In[3]: x = array([11, 12, 13])
In[4]: x
Out[4]: array([11, 12, 13])
In[5]: print(x)
[11 12 13]
In[6]: x[0]
Out[6]: 11
In[7]: x[1]
Out[7]: 12
In[8]: x[2]
Out[8]: 13
In[9]: x[3]
Traceback (most recent call last):
  File "C:\Users\srw245\Documents\teaching software\Python\venv\lib\site-packa
    exec(code_obj, self.user_global_ns, self.user_ns)
  File "<ipython-input-9-dc2cd44e899d>", line 1, in <module>
    x[3]
IndexError: index 3 is out of bounds for axis 0 with size 3

In[10]: |
```

- for array with 3 elements $x[0]$, $x[1]$, $x[2]$, only legal indices are 0, 1 and 2
- ✗ “out of bounds” error if we try and access $x[3]$

#4 Copying an array—*take care!*

```
In [10]: y = x
In [11]: y
Out[11]: array([ 0.,  1.,  2.])    # ...as expected

In [12]: y[0] = 10.0
In [13]: y
Out[13]: array([ 10.,  1.,  2.])    # ...as expected

In [14]: x
Out[14]: array([ 10.,  1.,  2.])    # ...x has changed too!
```

- changed value of an element in array y ...
...but it caused the same change in array x !
- why? Because assignment $y = x$ creates another reference *to the same array that x refers to*
- **be very careful** with “obvious” array copy method

#4 Copying an array—doing it right

```
In [15]: from numpy import copy

In [16]: x = linspace(0, 2, 3)           # x becomes array([ 0.,  1.,  2.])

In [17]: y = copy(x)

In [18]: y
Out[18]: array([ 0.,  1.,  2.])

In [19]: y[0] = 10.0

In [20]: y
Out[20]: array([ 10.,  1.,  2.]) # ...changed

In [21]: x
Out[21]: array([ 0.,  1.,  2.]) # ...unchanged
```

- `copy` function—actually *creates* a new array ...
... then fills with values copied from another array

Slicing an array

- needs a figure showing boxes
- ppt figure
- colon $x[i:j]$ address all elements from index i (inclusive) to j (exclusive)
 - ▶ well that's confusing ...
- x length 6, $x[0], \dots, x[5]$, write $x[0:5]$, entries 11...16
- y length 5, subset $x[1:5]$ from y
- WARNING: When copying a slice, the same logic applies as when naively *copying* the whole array
- no screenshot needed, but illustrate live (maybe)

Slicing an array (ctd)

```
In [1]: from numpy import linspace
```

```
In [2]: x = linspace(11, 16, 6)
```

```
In [3]: x
```

```
Out[3]: array([ 11.,  12.,  13.,  14.,  15.,  16.])
```

```
In [4]: y = x[1:5]
```

```
In [5]: y
```

```
Out[5]: array([ 12.,  13.,  14.,  15.])
```

Live demo of Python arrays