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COMP1730/COMP6730
Programming for Scientists

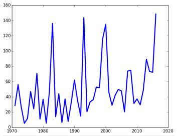
Data: Values, types and expressions.

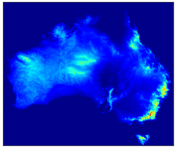
Lecture outline

- Data and data types.
- Expressions: computing values.
- Variables: remembering values.

What is "data"?

- The number of students currently enrolled in the course.
- The words typed into a web search engine.
- A time series of total rainfall in Canberra for the month of June since 1971.
- An elevation map of Australia.
- Most (scientific) applications of computing involve summarising or deriving information from data.





Example: Data analysis

- *In 2017, enrolment in COMP1730/6730, at its peak, was 485 students. In 2018, the enrolment (so far) is 523 students. How big an increase, in percent, is this?*

- The increase is: `523 - 485`
- as a fraction of the 2017 number: `(523 - 485) / 485`
- in percent: `((523 - 485) / 485) * 100`

Expressions

- `((523 - 485) / 485) * 100` is an *expression*;
- it *evaluates* to `7.835051546391752`;
- `523`, `485`, `100` and `7.835051546391752` are all *values*.
- In interactive mode, the python interpreter will print the result of evaluating an expression:

```
>>> ((523 - 485) / 485) * 100
7.835051546391752
```

(with one exception, which we'll see later).

python syntax (recap)

- A python program is a sequence of statements:
  - `import` a module;
  - function definition;
  - ~~function call~~ expression.
    - Every function call is an expression.
  - ...and more we'll see later.
- Comment: # to end-of-line.
- Whitespace:
  - end-of-line ends statement (except for function definition, which ends at the end of the suite);
  - indentation defines extent of (function) suite.

python expressions

- Expressions are built up of:
  - constants (“literals”);
  - variables;
  - operators; and
  - function calls.
- When an expression is executed, it *evaluates to* a *value* (a.k.a. the *return value*).
- Expressions can act as statements (the return value is ignored), but statements cannot act as expressions.

Continuation

- end-of-line marks the end of a statement.
- *Except* that,
  - adding a "\" at the end makes the statement continue onto the next line, e.g.,

    ```
    (2 ** 0) + (2 ** 1) + (2 ** 2) \
     + (2 ** 3) + (2 ** 4)
    ```

  - an expression enclosed in parentheses continues to the closing parenthesis, e.g.,

    ```
    math.sqrt((x2 - x1) ** 2 +
              (y2 - y1) ** 2)
    ```

Values and Types

Every value has a type

- Value (data) types in python:
  - Integers (type `int`)
  - Floating-point numbers (type `float`)
  - Strings (type `str`)
  - Truth values (type `bool`)
  - ...and many more we'll see later.
- Types determine what we can do with values (and sometimes what the result is).

* The `type` function tells us the type of a value:

```
>>> type(2)
<class 'int'>
>>> type(2 / 3)
<class 'float'>
>>> type("zero")
<class 'str'>
>>> type("1")
<class 'str'>
>>> type(1 < 0)
<class 'bool'>
```

Numeric types

- Integers (type `int`) represent positive and negative whole numbers (0, 1, 2, −1, −17, 4096, ...).
- Values of type `int` have no inherent size limit.

```
>>> 2 ** (2 ** 2)
16
>>> 2 ** (2 ** (2 ** 2))
65536
>>> 2 ** (2 ** (2 ** (2 ** 2)))
...
```

- Note: Can’t use commas to “format” integers (must write `1282736`, not `1,282,736`).

- Floating-point numbers (type `float`) represent decimal numbers.
- Values of type `float` have limited range and limited precision.
  - Min/max value: $\pm 1.79 \cdot 10^{308}$.
  - Smallest non-zero value: $2.22 \cdot 10^{-308}$.
  - Smallest value > 1: $1 + 2.22 \cdot 10^{-16}$.

  (These are typical limits; actual limits depend on the python implementation.)
- Type `float` also has special values $\pm$ `inf` (infinity) and `nan` (not a number).
- More about floating-point numbers and their limitations in a coming lecture.

- Every decimal number is a `float`:

```
>>> type(1.5 - 0.5)
<class 'float'>
>>> type(1.0)
<class 'float'>
```

- The result of division is always a `float`:

```
>>> type(4 / 2)
<class 'float'>
```

- `float`s can be written (and are sometimes printed) in “scientific notation”:
  - `2.99e8` means $2.99 \cdot 10^{8}$.
  - `6.626e-34` means $6.626 \cdot 10^{-34}$
  - `1e308` means $1 \cdot 10^{308}$.

Strings

- Strings (type `str`) represent text.
- A string literal is enclosed in single or double quote marks:

```
>>> "Hello world"
'Hello world'
>>> '4" long'
'4" long'
```

  - A string can contain other types of quote mark, but not the one used to delimit it.
- More about strings in a coming lecture.

Type conversion

- Explicit conversions use the type name like a function:

```
>>> int(2.0)
>>> float(" -1.05")
>>> str(0.75 * 1.75)
```

- Conversion from `str` to number only works if the string contains (only) a numeric literal.
- Conversion from `int` to `float` is automatic.
  – E.g., `int` times `float` becomes a `float`.

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Expressions: Operators and Functions

Numeric operators in python

`+`, `-`, `*`, `/`	standard arithmetic
`**`	power (`x ** n` means x^n)
`//`	floor division
`%`	remainder

- Some operators can be applied also to values of other (non-numeric) types, but with a different meaning (this is called “operator overloading”).
- We’ll see more operators later in the course.

Precedence

- There is an order of precedence on operators, that determines how an expression is read:
  - `2 * 3 - 1` means `(2 * 3) - 1`, not `2 * (3 - 1)`.
  - `-1 ** 5` means `-(1 ** 5)`, not `(-1) ** 5`.
- Operators with equal precedence associate left:
  - `d/2*pi` means `(d/2)*pi`, not `d/(2*pi)`
- ...except exponentiation, which associates right.
- Whenever it is not obvious, *use parentheses to make it clear*.

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Math functions

- The `math` module provides standard math functions, such as square root, logarithm, trigonometric functions, etc.

```
>>> import math
>>> help(math) # read documentation
...
>>> math.sqrt(3 ** 2 + 4 ** 2)
5.0
```

- Almost all math functions take and return values of type `float`.

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Comparison operators

$<, >, <=, >=$	ordering (strict and non-strict)
$==$	equality (note double '=' sign)
$!=$	not equal

- Can compare two values of the same type (for almost any type).
- Comparisons return a *truth value* (type `bool`), which is either `True` or `False`.
- *Caution:* Conversion from any type to type `bool` happens automatically, but the result may not be what you expect.

Variables

Variables

* A *variable* is a name that is associated with a value in the program.
  - The python interpreter stores name–value associations in a *namespace*.
    (More about namespaces later in the course.)
* A variable can be an expression: evaluating it returns the associated value.
* A name–value association is created by the first *assignment* to the name.

Valid names in python (reminder)

- A (function or variable) name in python may contain letters, numbers and underscores (_), but must begin with a letter or undescore.
- Reserved words cannot be used as names.
- Names are *case sensitive*: upper and lower case letters are not the same.
  - `Length_Of_Rope` and `length_of_rope` are different names.

Variable assignment

- A variable assignment is written

```
var_name = expression
```

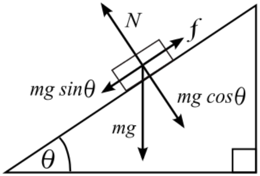
  - Reminder: Equality is written == (two ='s).
  - Assignment is a statement.

- When executing an assignment, the interpreter
  1. evaluates the right-hand side expression;
  2. associates the left-hand side name with the resulting value.

Programming problem

- *A block resting on an inclined surface will begin to move if the force pulling it down the slope is greater than the normal force times the static friction coefficient (μ_s).*

  Say m $= 1$, g $= 9.81$, $\theta = 23^\circ$ and $\mu_s = 0.62$: will the block move?
- Yes, if $mg\sin(\theta) > mg\cos(\theta)\mu_s$.



(Image from Wikipedia)

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The `print` function

* `print` prints text to the console:

```
>>> print("The answer is:", 42)
The answer is: 42
```

  – Non-text arguments are converted to type `str` before printing.
  – `print` takes a variable number of arguments, and prints them all followed by a newline.

* Print the result, and intermediate steps, when a program is run in script mode.