F21SC Industrial Programming:
Python Introduction & Control Flow

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[0] No proprietary software has been used in producing these slides

Contents

1. Python Overview
2. Getting started with Python
3. Control structures
4. Functions

Online Resources

- `www.python.org`: official website
- Course mostly based on *Guido van Rossum*'s tutorial.
- For textbooks in Python introductions see the end of this slideset.
- Stable version: 3.7 (June 2018)
- Implemented in C (CPython)

Python

- Python is named after *Monty Python's Flying Circus*
- Python is an object-oriented language focussing on rapid prototyping
- Python is a scripting language
- Python features an elegant language design, is easy to learn and comprehend
- Open source
- Highly portable
- First version was made available 1990
- Current stable version is 3.7 (June 2018)

Python 3 vs Python 2

We will use Python 3, which offers several important new concepts over Python 2.
If you find Python 2 code samples, they might not run with python3.
There is a tool `python3-2to3` which tells you what to change (and it works in most cases). The most common issues are

- In Python 3, `print` is treated as any other function, especially you need to use parentheses as in write `print(x)` NOT `print x`
- Focus on iterators: pattern-like functions (e.g. `map`) now return iterators, i.e. a handle used to perform iteration, rather than a data structure.

For details check:
https://www.python.org/downloads/release/python-363/

Runtime behaviour

- Python source code is compiled to byte-code, which is then interpreted
- Compilation is performed transparently
- Automatic memory management using *reference counting* based garbage collection
- No uncontrolled crash *(as in seg faults)*

Language features

- Everything is an object (pure object-oriented design)
- Features classes and multiple inheritance
- Higher-order functions (similar to Scheme)
- Dynamic typing and polymorphism
- Exceptions as in Java
- Static scoping and modules
- Operator overloading
- Block structure with semantic-bearing indentation ("off-side rule" as in Haskell)

Data types

- Numbers: `int`, `long`, `float`, `complex`
- Strings (similar to Java)
- Tuples, Lists, Dictionaries
- Add-on modules can define new data-types
- Can model arbitrary data-structures using classes

Why Python?

- Code $2 - 10\times$ shorter than C#, C++, Java
- Code is easy to comprehend
- Encourages *rapid prototyping*
- Good for *web scripting*
- Scientific applications (numerical computation, natural language processing, data visualisation, etc)
- Python is increasingly used at US universities as a *starting language*
- Rich libraries for XML, Databases, Graphics, etc.
- *Web content management* (Zope/Plone)
- GNU Mailman
- JPython

Python vs. other languages

- Very active community
- A lot of good libraries
- Increasingly used in teaching (MIT, Berkeley, etc)
- Good online teaching material, e.g. Online Python Tutor
- Picks up many advanced language features from other languages (e.g. Haskell)

Python Textbooks (Advanced)

x[Mark Lutz, *"Programming Python."* O'Reilly Media; 4 edition (10 Jan 2011). ISBN-10: 0596158106. Good texbook for more

experienced programmers. Detailed coverage of libraries.David M. Beazley, *"Python Essential Reference."* Addison Wesley; 4 edition (9 July 2009). ISBN-10: 0672329786. Detailed reference guide to

Python and libraries.Alex Martelli, *"Python in a Nutshell."* O'Reilly Media; 2nd edition (July 2006). Concise summary of Python language and libraries. Fairly dated.

Python Textbooks (Beginner)

- Mark Lutz, *"Learning Python."*, 5th edition, O'Reilly, 2013. ISBN-10: 1449355730
  Introduction to Python, assuming little programming experience.
- John Guttag. *"Introduction to Computation and Programming Using Python."*, MIT Press, 2013. ISBN: 9780262519632.
  Doesn't assume any programming background.
- Timothy Budd. *"Exploring Python."*, McGraw-Hill Science, 2009. ISBN: 9780073523378.
  Exploring Python provides an accessible and reliable introduction into programming with the Python language.

Python Textbooks (Beginner)

- Zed A. Shaw. *“Learn Python the Hard Way.”*,
  Heavily exercise-based introduction to programming. Good on-line material.
- Michael Dawson, *“Python Programming for the Absolute Beginner.”*,
  3rd edition, Cengage Learning PTR, 2010. ISBN-10: 1435455002
  Good introduction for beginners. Slightly dated. Teaches the principles of programming through simple game creation.
- Tony Gaddis, *“Starting Out with Python.”*,
  Pearson New International Edition, 2013. ISBN-10: 1292025913
  Good introduction for beginners..

Python Textbooks (Beginner)

Online resources:

- How to Think Like a Computer Scientist.
- An Introduction to Python.
- Dive into Python 3.
- Google’s Python Class.
- Main Python web page.

For this course:

- Main course information page:
  http://www.macs.hw.ac.uk/ hwloidl/Courses/F21SC/index_new.html.
- Python sample code:
  http://www.macs.hw.ac.uk/ hwloidl/Courses/F21SC/Samples/python_samples.html
- FAQs:
  http://www.macs.hw.ac.uk/ hwloidl/Courses/F21SC/faq.html#python

Launching Python

- Interactive Python shell: `python`
- Exit with *eof* (Unix: Ctrl-D, Windows: Ctrl-Z)
- Or: `import sys; sys.exit()`
- Execute a script: `python myfile.py`

```
python3 ..python-args.. script.py ..script-args..
```

- Evaluate a Python expression

```
python3 -c "print (5*6*7)"
python3 -c "import sys; print (sys.maxint)"
python3 -c "import sys; print (sys.argv)" 1 2 3 4
```

- Executable Python script

```
#!/usr/bin/env python3
# -*- coding: iso-8859-15 -*-
```


Integer Arithmetic

- `>>>` is the Python prompt, asking for input

```
>>> 2+2  # A comment on the same line as code.
4
>>> # A comment; Python asks for a continuation ...
... 2+2
4
>>> (50-5*6)/4
5
>>> # Integer division returns the floor:
... 7/3
2
>>> 7/-3
-3
```

Arbitrary precision integers

- `int` represents signed integers (32/64 Bit).

```
>>> import sys; sys.maxint
2147483647
```

- `long` represents arbitrary precision integers.

```
>>> sys.maxint + 1
2147483648L
>>> 2 ** 100
1267650600228229401496703205376L
```

- Conversion: [“_” is a place-holder for an *absent* value.]

```
>>> - 2 ** 31
-2147483648L
>>> int(_)
-2147483648
```


Assignment

- Variables don’t have to be declared (scripting language).

```
>>> width = 20
>>> height = 5*9
>>> width * height
900
```

- Parallel assignments:

```
>>> width, height = height, width + height
```

- Short-hand notation for parallel assignments:

```
>>> x = y = z = 0  # Zero x, y and z
>>> x
0
>>> z
0
```


Floating-point numbers

- Arithmetic operations are overloaded.
- Integers will be converted on demand:

```
>>> 3 * 3.75 / .5
22.5
>>> 7. / 2
3.5
>>> float(7) / 2
3.5
```

- Exponent notation: `1e0 1.0e+1  1e-1 .1e-2`
- Typically with 53 bit precision (as `double` in C).

```
>>> 1e-323
9.8813129168249309e-324
>>> 1e-324
0.0
```


Further arithmetic operations

- Remainder:

```
>>> 4 % 3
1
>>> -4 % 3
2
>>> 4 % -3
-2
>>> -4 % -3
-1
>>> 3.9 % 1.3
1.2999999999999998
```

- Division and Floor:

```
>>> 7.0 // 4.4
1.0
```

Complex Numbers

- Imaginary numbers have the suffix `j`.

```
>>> 1j * complex(0,1)
(-1+0j)
>>> complex(-1,0) ** 0.5
(6.1230317691118863e-17+1j)
```

- Real- and imaginary components:

```
>>> a=1.5+0.5j
>>> a.real + a.imag
2.0
```

- Absolute value is also defined on `complex`.

```
>>> abs(3 + 4j)
5.0
```


Bit-operations

- Left- (`<<`) and right-shift (`>>`)

```
>>> 1 << 16
65536
```

- Bitwise and (`&`), or (`|`), xor (`^`) and negation (`~`).

```
>>> 1000 & 0377
232
>>> 0x7531 | 0x8ace
65535
>>> ~0
-1
>>> 0123 ^ 0123
0
```


Strings

- Type: `str`.
- Single- and double-quotes can be used

```
Input                    Output
-------                  ---------
'Python tutorial'        'Python tutorial'
'doesn\'t'               "doesn't"
"doesn't"                "doesn't"
'"Yes," he said.'        '"Yes," he said.'
"\"Yes,\" he said."      '"Yes," he said.'
'"Isn\'t," she said.'    '"Isn\'t," she said.'
```


Escape-Sequences

```
\\          backslash
\'          single quote
\"          double quote
\t          tab
\n          newline
\r          carriage return
\b          backspace
```

Multi-line string constants

- The expression

```
print ("This is a rather long string containing\n\
several lines of text as you would do in C.\n\
    Whitespace at the beginning of the line is\
 significant.")
```

- displays this text

```
This is a rather long string containing
several lines of text as you would do in C.
    Whitespace at the beginning of the line is significant.
```


Triple-quote

- Multi-line string including line-breaks:

```
print ("""
Usage: thingy [OPTIONS]
     -h                        Display this usage message
     -H hostname               Hostname to connect to
""")
```

- gives

```
Usage: thingy [OPTIONS]
     -h                        Display this usage message
     -H hostname               Hostname to connect to
```


Raw strings

- An `r` as prefix preserves all escape-sequences.

```
>>> print ("Hello! \n\"How are you?\"")
Hello!
"How are you?"
>>> print (r"Hello! \n\"How are you?\"")
Hello! \n\"How are you?\"
```

- Raw strings also have type `str`.

```
>>> type ("\n")
<type 'str'>
>>> type (r"\n")
<type 'str'>
```


Unicode

- Unicode-strings (own type) start with `u`.

```
>>> print ("a\u0020b")
a b
>>> "\xf6"
"ö"
>>> type (_)
<type 'unicode'>
```

- Standard strings are converted to unicode-strings on demand:

```
>>> "this " + "\u00f6" + " umlaut"
'this ö umlaut'
>>> print _
this ö umlaut
```

String operations

```
"hello"+"world"     "helloworld"       # concat.
"hello"*3           "hellohellohello"  # repetition
"hello"[0]          "h"                # indexing
"hello"[-1]         "o"                # (from end)
"hello"[1:4]        "ell"              # slicing
len("hello")        5                  # size
"hello" < "jello"   True               # comparison
"e" in "hello"      True               # search
```


Lists

- Lists are *mutable arrays.*

```
a = [99, "bottles of beer", ["on", "the", "wall"]]
```

- String operations also work on lists.

```
a+b, a*3, a[0], a[-1], a[1:], len(a)
```

- Elements and segments can be modified.

```
a[0] = 98
a[1:2] = ["bottles", "of", "beer"]
            # -> [98, "bottles", "of", "beer",
                      ["on", "the", "wall"]]
del a[-1] # -> [98, "bottles", "of", "beer"]
```


More list operations

```
>>> a = range(5)          # [0,1,2,3,4]
>>> a.append(5)           # [0,1,2,3,4,5]
>>> a.pop()               # [0,1,2,3,4]
5
>>> a.insert(0, 42)       # [42,0,1,2,3,4]
>>> a.pop(0)              # [0,1,2,3,4]
42
>>> a.reverse()           # [4,3,2,1,0]
>>> a.sort()              # [0,1,2,3,4]
```

N.B.: Use `append` for push.

While

- Print all Fibonacci numbers up to 100 (interactive):

```
>>> a, b = 0, 1
>>> while b <= 100:
...       print (b)
...       a, b = b, a+b
...
```

- Comparison operators: `== < > <= >= !=`
- **NB:** Indentation carries semantics in Python:
  - Indentation starts a block
  - De-indentation ends a block
- Or:

```
>>> a, b = 0, 1
>>> while b <= 100: print (b); a,b = b, a+b
...
```

If

Example

```
x = int(input("Please enter an integer: "))
if x < 0:
     x = -1
     print('Sign is Minus')
elif x == 0:
     print('Sign is Zero')
elif x > 0:
     print('Sign is Plus')
else:
     print('Should never see that')
```

- **NB:** `elif` instead od `else if` to avoid further indentations.

For

- `for` iterates over a sequence (e.g. list, string)

Example

```
a = ['cat', 'window', 'defenestrate']
for x in a:
    print(x, len(x))
```

- **NB:** The iterated sequence must not be modified in the body of the loop! However, it's possible to create a copy, e.g. using segment notation.

```
for x in a[:]:
    if len(x) > 6: a.insert(0,x)
print (a)
```

- Results in

```
['defenestrate', 'cat', 'window', 'defenestrate']
```


Range function

- Iteration over a sequence of numbers can be simplified using the `range()` function:

```
>>> range(10)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> range(5, 10)
[5, 6, 7, 8, 9]
>>> range(0, 10, 3)
[0, 3, 6, 9]
>>> range(-10, -100, -30)
[-10, -40, -70]
```

- Iteration over the indices of an array can be done like this:

```
a = ['Mary', 'had', 'a', 'little', 'lamb']
for i in range(len(a)):
    print (i, a[i])
```


For-/While-loops: `break`, `continue`, `else`

- `break` (as in C), terminates the enclosing loop immediately.
- `continue` (as in C), jumps to the next iteration of the enclosing loop.
- The `else`-part of a loop will only be executed, if the loop hasn't been terminated using `break` construct.

Example

```
for n in range(2, 10):
    for x in range(2, n):
        if n % x == 0:
            print (n, 'equals', x, '*', n//x)
            break
    else: # loop completed, no factor
        print (n, 'is a prime number')
```

The empty expression

- The expression `pass` does nothing.

```
while True:
    pass # Busy-wait for keyboard interrupt
```

- This construct can be used, if an expression is syntactically required, but doesn't have to perform any work.

Procedures

- Procedures are defined using the key word `def`.

```
def fib(n):    # write Fibonacci series up to n
    """Print a Fibonacci series up to n."""
    a, b = 0, 1
    while b < n:
        print (b)
        a, b = b, a+b
```

- Variables `n`, `a`, `b` are local.
- The return value is `None` (hence, it is a procedure rather than a function).

```
print (fib(10))
```


A procedure as an object

- Procedures are values in-themselves.

```
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
1 1 2 3 5 8 13 21 34 55 89
```


Call-by-value

- When passing arguments to functions, a **Call-by-value** discipline is used (as in C, C++, or C#).
- Assignment to parameters of a function are local.

```
def bla(l):
    l = []

l = ['not', 'empty']
bla(l)
print(l)
```

- `l` is a reference to an object.
- The referenced object can be modified:

```
def exclamate(l):
    l.append('!')

exclamate(l)
print(l)
```

Global Variables

- The access to a global variable has to be explicitly declared.

```
def clear_l():
    global l
    l = []

l = ['not', 'empty']
clear_l()
print(l)
```

- ...prints the *empty* list.

Return values

- The `return` construct immediately terminates the procedure.
- The `return ...value...` construct also returns a concrete result value.

```
def fib2(n):
    """Return the Fibonacci series up to n."""
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)     # see below
        a, b = b, a+b
    return result

f100 = fib2(100)     # call it
f100                 # write the result
```


Default values for function parameters

- In a function definition, default values can be specified for parameters:

```
def ask(prompt, retries=4, complaint='Yes/no?'):
  while True:
    ok = raw_input(prompt)
    if ok in ('y', 'ye', 'yes'): return True
    if ok in ('n', 'no'): return False
    retries -= 1
    if retries < 0: raise IOError, 'refused'
    print (complaint)
```

- When calling the function, some arguments can be omitted.

```
ask ("Continue (y/n)?", 3, "Yes or no, please!")
ask ("Continue (y/n)?", 3)
ask ("Continue (y/n)?")
```


Default values for function parameters (cont'd)

- Wrong:

```
ask ("Continue (y/n)?", "Yes or no, please!")
ask ()
```

- Named arguments (*keyword arg*) are useful when using arguments with and without default values:

```
ask ("Continue (y/n)?", complaint="Yes or no?")
ask (prompt="Continue (y/n)?")
```

- Wrong:

```
ask (prompt="Continue (y/n)?", 5)
ask ("Yes/no?", prompt="Continue (y/n)?")
```

Evaluation of default values:

- Default values will be evaluated *only once*, when the function is *defined:*

```
i = 5

def f(arg=i):
    print (arg)

i = 6
f()
```

- Which number will be printed?
- . . . prints 5.

Evaluation of default values

- Beware of mutable objects!

```
def f(a, L=[]):
    L.append(a)
    return L

print (f(1))
print (f(2))
```

- ... prints `[1]` and `[1, 2]`. However:

```
def f(a, L=None):
    if L is None:
        L = []
    L.append(a)
    return L
```

- ... prints `[1]` and `[2]`.

Argument lists

- Prefixing a paramter with `*` declares a paramter that can take an arbitrary number of values.

```
def fprintf(file, format, *args):
    file.write(format % args)
```

- A list can be passed as individual arguments using `*` notation:

```
>>> args = [3, 6]
>>> range(*args)
[3, 4, 5]
```


Doc-strings

- The first expression in a function can be a string (as in elisp).

```
def my_function():
    """Do nothing, but document it.

    No, really, it doesn't do anything.
    """
    pass
```

- The first line typically contains usage information (starting with an upper-case letter, and terminated with a full stop).
- After that several more paragraphs can be added, explaining details of the usage information.
- This information can be accessed using `.__doc__` or `help` constructs.

```
my_function.__doc__    # return doc string
help(my_function)      # print  doc string
```

Anonymous Functions

- A function can be passed as an expression to another function:

```
>>> lambda x, y: x
<function <lambda> at 0xb77900d4>
```

- This is a factory-pattern for a function incrementing a value:

```
def make_incrementor(n):
    return lambda x: x + n

f = make_incrementor(42)
f(0)
f(1)
```

- Functions are compared using the address of their representation in memory:

```
>>> (lambda x: x) == (lambda x: x)
False
```


Exercises

- Implement Euclid's greatest common divisor algorithm as a function over 2 int parameters.
- Implement matrix multiplication as a function taking 2 2-dimensional arrays as arguments.

More list operations

- Modifiers:
  - `l.extend(l2)` means `l[len(l):] = l2`, i.e. add `l2` to the end of the list `l`.
  - `l.remove(x)` removes the first instance of `x` in `l`. Error, if `x not in l`.
- Read-only:
  - `l.index(x)` returns the position of `x` in `l`. Error, if `x not in l`.
  - `l.count(x)` returns the number of occurrences of `x` in `l`.
  - `sorted(l)` returns a new list, which is the sorted version of `l`.
  - `reversed(l)` returns an iterator, which lists the elements in `l` in reverse order.

Usage of lists

- Lists can be used to model a *stack*: `append` and `pop()`.
- Lists can be used to model a *queue*: `append` und `pop(0)`.

Higher-order functions on lists

- `filter(test, sequence)` returns a sequence, whose elements are those of `sequence` that fulfill the predicate `test`. E.g.
  `filter(lambda x: x % 2 == 0, range(10))`
- `map(f, sequence)` applies the function `f` to every element of `sequence` and returns it as a new sequence.
  ```
  map(lambda x: x*x*x, range(10))
  map(lambda x,y: x+y, range(1,51), range(100,50,-1))
  ```
- `reduce(f, [a1,a2,a3,...,an])` computes `f(...f(f(a1,a2),a3),...,an)`
  `reduce(lambda x,y:x*y, range(1,11))`
- `reduce(f, [a1,a2,...,an], e)` computes `f(...f(f(e,a1),a2),...,an)`

List comprehensions

- More readable notation for combinations of `map` and `filter`.
- Motivated by *set comprehensions* in mathematical notation.
- `[ e(x,y) for x in seq1 if p(x) for y in seq2 ]`
  ```
  >>> vec = [2, 4, 6]
  >>> [3*x for x in vec]
  [6, 12, 18]
  >>> [3*x for x in vec if x > 3]
  [12, 18]
  >>> [(x, x**2) for x in vec]
  [(2, 4), (4, 16), (6, 36)]
  >>> vec1 = [2, 4, 6]
  >>> vec2 = [4, 3, -9]
  >>> [x*y for x in vec1 for y in vec2]
  [8, 6, -18, 16, 12, -36, 24, 18, -54]
  ```


Deletion

- Deletion of (parts of) a list:
  ```
  >>> a = [-1, 1, 66.25, 333, 333, 1234.5]
  >>> del a[0]
  >>> a
  [1, 66.25, 333, 333, 1234.5]
  >>> del a[2:4]
  >>> a
  [1, 66.25, 1234.5]
  >>> del a[:]
  >>> a
  []
  ```
- Deletion of variables:
  ```
  >>> del a
  ```


Tuples

- ```
  >>> t = 12345, 54321, 'hello!'
  >>> t[0]
  12345
  >>> t
  (12345, 54321, 'hello!')
  >>> # Tuples may be nested:
  ... u = t, (1, 2, 3, 4, 5)
  >>> u
  ((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))
  >>> x, y, z = t
  >>> empty = ()
  >>> singleton = 'hello',    # trailing comma
  ```
  ```

Sets

- `set(l)` generates a set, formed out of the elements in the list `l`.
- `list(s)` generates a list, formed out of the elements in the set `s`.
- `x in s` tests for set membership
- Operations: `-` (difference), `|` (union), `&` (intersection), `^` (xor).
- `for v in s` iterates over the set (sorted!).

Dictionaries

- Dictionaries are finite maps, *hash maps*, *associative arrays*.
- The represent unordered sets of (key, value) pairs.
- Every key may only occur once.
- Generated using the notation:
  `{ key1 : value1, ..., keyn : valuen }` or

```
>>> tel = dict([('guido', 4127), ('jack', 4098)])
{'jack': 4098, 'guido': 4127}
```

- Access to elements is always through the key: `tel['jack']`.
- Insertion and substitution is done using assignment notation:
  `tel['me'] = 1234`.
- Deletion: `del tel['me']`.
- `tel.keys()` returns all key values. `tel.has_key('guido')` returns a boolean, indicating whether the key exists.

Dictionaries

- The Python implementation uses dictionaries internally, e.g. to list all names exported by a module, or for the symbol table of the interpreter.
- Iteration over a dictionary:

```
for k, v in tel.items():
  print (k, v)
```

- Named arguments:

```
def fun(arg, *args, **keyArgs): ...

fun (1, 2, 3, opt1=4, opt2=5)
```

- This binds `arg = 1` and `args = [2,3]` and `keyArgs = {opt1:4, opt2:5}`.

Loop techniques

- Here are some useful patterns involving loops over dictionaries.
- Simultaneous iteration over both keys and elements of a dictionary:

```
l = ['tic', 'tac', 'toe']
for i, v  in enumerate(l):
    print (i, v)
```

- Simultaneous iteration over two or more sequences:

```
for i, v in zip(range(len(l)), l):
    print (i, v)
```

- Iteration in sorted and reversed order:

```
for v in reversed(sorted(l)):
  print (v)
```

Booleans

- `0, '', [], None`, etc. are interpreted as `False`.
- All other values are interpreted as `True` (also functions!).
- `is` checks for object identity: `[] == []` is true, but `[] is []` isn't. `5 is 5` is true.
- Comparisons can be chained like this: `a < b == c > d`.
- The boolean operators `not`, `and`, `or` are *short-cutting*.

```
def noisy(x): print (x); return x

a = noisy(True) or noisy(False)
```

- This technique can also be used with non-Boolean values:

```
>>> '' or 'you' or 'me'
'you'
```


Comparison of sequences and other types

- Sequences are compared lexicographically, and in a nested way:

```
() < ('\x00',)
('a', (5, 3), 'c') < ('a', (6,) , 'a')
```

- **NB**: The comparison of values of *different* types doesn't produce an error but returns an arbitrary value!

```
>>> "1" < 2
False
>>> () < ('\x00')
False
>>> [0] < (0,)
True
```


Modules

- Every Python file is a module.
- `import myMod` imports module `myMod`.
- The system searches in the current directory and in the `PYTHONPATH` environment variable.
- Access to the module-identifier `x` is done with `myMod.x` (both read and write access!).
- The code in the module is evaluated, when the module is imported the first time.
- Import into the main name-space can be done by

Example

```
from myMod import myFun
from yourMod import yourValue as myValue

myFun(myValue) # qualification not necessary
```

- **NB:** In general it is not advisable to do `from myMod import *`.

Executing modules as scripts

- Using `__name__` the name of the module can be accessed.
- The name is `'__main__'` for main program:

Example

```
def fib(n): ...

if __name__ == '__main__':
  import sys
  fib(int(sys.argv[1]))
```

- Typical application: unittests.

Modules as values

- A module is an object.

```
>>> fib = __import__('fibonacci')
>>> fib
<module 'fibonacci' from 'fibonacci.py'>
>>> fib.fib(10)
1 1 2 3 5 8
```

- `fib.__name__` is the name of the module.
- `fib.__dict__` contains the defined names in the module.
- `dir(fib)` is the same as `fib.__dict__.keys()`.

Standard- und built-in modules

- See *Python Library Reference*, e.g. module `sys`.
- `sys.ps1` and `sys.ps2` contain the prompts.
- `sys.path` contains the module search-path.
- With `import __builtin__` it's possible to obtain the list of all built-in identifiers.

```
>>> import __builtin__
>>> dir(__builtin__)
```


Packages

- A directory, that contains a (possibly empty) file `__init__.py`, is a package.
- Packages form a tree structure. Access is performed using the notation `packet1.packet2.modul`.

Example

```
import packet.subpacket.module
print (packet.subpacket.module.__name__)

from packet.subpacket import module
print (module.__name__)
```

- If a package `packet/subpacket/__init__.py` contains the expression `__all__ = ["module1", "module2"]`, then it's possible to import both modules using `from packet.subpacket import *`

Output formatting

- `str(v)` generates a "machine-readable" string representation of `v`
- `repr(v)` generates a representation that is readable to the interpreter. Strings are escaped where necessary.
- `s.rjust(n)` fills the string, from the left hand side, with space characters to the total size of `n`.
- `s.ljust(n)` and `s.center(n)`, analogously.
- `s.zfill(n)` inserts zeros to the number `s` in its string representation.
- `'-3.14'.zfill(8)` yields `'%08.2f' % -3.14`.
- Dictionary-Formating:

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098 }
>>> print ('Jack: %(Jack)d; Sjoerd: %(Sjoerd)d' % table
Jack: 4098; Sjoerd: 4127
```

File I/O

- Standard-output is `sys.stdout`.
- `f = open(filename,mode)` creates a file-object `f`, referring to `filename`.
- Access modi are: `'r'`, `'w'`, `'a'`, `'r+'` (read, write, append, read-write) plus suffix `b` (binary).
- `f.read()` returns the entire contents of the file as a string. `f.read(n)` reads the next `n` bytes.
- `f.readline()` reads the next line, terminated with `'\n'`. Empty string if at the end of the file.
- `f.readlines()` returns a list of all lines.
- Iteration over all lines:

```
for line in f: print (l)
```


Writing and moving

- `f.write(s)` writes the string `s`.
- `f.seek(offset,0)` moves to position `seek` (counting from the start of the file).
- `f.seek(offset,1)` moves to position `seek` (counting from the current position).
- `f.seek(offset,2)` moves to position `seek` (counting from the end of the file).
- `f.close()` closes the file.

Pickling

- Arbitrary objects can be written to a file.
- This involves serialisation, or “pickling”, of the data in memory.
- Module `pickle` provides this functionality.
- `pickle.dump(x,f)` turns `x` into a string and writes it to file `f`.
- `x = pickle.load(f)` reads `x` from the file `f`.

Saving structured data with JSON

- JSON (JavaScript Object Notation) is a popular, light-weight data exchange format.
- Many languages support this format, thus it’s useful for data exchange across systems.
- It is much ligher weight than XML, and thus easier to use.
- `json.dump(x, f)` turns `x` into a string in JSON format and writes it to file `f`.
- `x = json.load(f)` reads `x` from the file `f`, assuming JSON format.
- For detail on the JSON format see: `http://json.org/`

JSON Example

Example

```
tel = dict([('guido', 4127), ('jack', 4098)])
ppTelDict(tel)

# write dictionary to a file in JSON format
json.dump(tel, fp=open(jfile,'w'), indent=2)
print("Data has been written to file ", jfile);

# read file in JSON format and turn it into a dictionary
tel_new = json.loads(open(jfile,'r').read())
ppTelDict(tel_new)

# test a lookup
the_name = "Billy"
printNoOf(the_name,tel_new);
```


Numerical Computation using the `numpy` library

- `numpy` provides a powerful library of mathematical/scientific operations
- Specifically it provides
  - a powerful N-dimensional array object
  - sophisticated (broadcasting) functions
  - tools for integrating C/C++ and Fortran code
  - useful linear algebra, Fourier transform, and random number capabilities
- For details see: http://www.numpy.org/

Numerical Computation Example: `numpy`

Example

```
import numpy as np
m1 = np.array([ [1,2,3],
                [7,3,4] ]); # fixed test input
# m1 = np.zeros((4,3),int); # initialise a matrix
r1 = np.ndim(m1);         # get the number of dimensions for matrix 1
m, p = np.shape(m1);      # no. of rows in m1 and no. of cols in m1
# use range(0,4) to generate all indices
# use m1[i][j] to lookup a matrix element

print("Matrix m1 is an ", r1, "-dimensional matrix, of shape ", m, "x", p)
```