Table Of Contents

Previous topic

Fortran Best Practices

Next topic

FAQ

This Page

Show Source

Quick search

Go

Enter search terms or a module, class or function name.

Python Fortran Rosetta Stone

Python with NumPy and Fortran are very similar in terms of expressiveness and features. This rosetta stone shows how to implement many common idioms in both languages side by side.

How to Execute Code Snippets

Consider for example the following code snippets:

NumPy

```
from numpy import array, size, shape, min, max, sum
a = array([1, 2, 3])
print shape(a)
print size(a)
print max(a)
print min(a)
print sum(a)
```

Fortran

```
integer :: a(3)
a = [1, 2, 3]
print *, shape(a)
print *, size(a)
print *, maxval(a)
print *, minval(a)
print *, sum(a)
```

In Python, just save the code to a file `a.py` and execute using `python a.py`. In Fortran, save it to a file `a.f90` and append the line `end` at the end of the file (see the section *Modules* for more info how this works). Compile using `gfortran a.f90` and execute using `./a.out` (you can of course add compilation options to gfortran, for example to produce the executable with a different name).

Arrays

Arrays are builtin in Fortran, and available in the NumPy module in Python. The usage is identical, except for the following differences:

- Fortran counts (by default) from 1, NumPy always from 0
- Fortran array sections (slices) include both ends, in NumPy the initial point is included, the final is excluded
- In C the array is stored row wise in the memory (by default NumPy uses C storage), while in Fortran it is stored column wise (this only matters in the next two points)
- By default `reshape` uses Fortran ordering in Fortran, and C ordering in NumPy (in both cases an optional argument `order` allows to use the other ordering). This also matters when `reshape` is used implicitly in other operations like flattening.
- The first index is the fastest in Fortran, while in NumPy, the last index is the fastest
- By default NumPy prints the 2d array nicely, while in Fortran one has to specify a format to print it (also Fortran prints column wise, so one has to transpose the array for row wise printing)

Everything else is the same, in particular:

- There is one-to-one correspondence between NumPy and Fortran array operations and things can be expressed the same easily/naturally in both languages
- For 2D arrays, the first index is a row index, the second is the column index (just like in mathematics)

- NumPy and Fortran arrays are equivalent if they have the same shape and same elements corresponding to the same index (it doesn't matter what the internal memory storage is)
- Any array expression involving mathematical functions is allowed, for example `a**2 + 2*a + exp(a)`, `sin(a)`, `a * b` and `a + b` (it operates element wise)
- You need to use a function to multiply two matrices using matrix multiplication
- Advanced indexing/slicing
- Arrays can be of any integer, real or complex type
- ...

NumPy

Fortran

```python
from numpy import array, size, shape, min, max, sum
a = array([1, 2, 3])
print shape(a)
print size(a)
print max(a)
print min(a)
print sum(a)
```

```fortran
integer :: a(3)
a = [1, 2, 3]
print *, shape(a)
print *, size(a)
print *, maxval(a)
print *, minval(a)
print *, sum(a)
```

```python
from numpy import reshape
a = reshape([1, 2, 3, 4, 5, 6], (2, 3))
b = reshape([1, 2, 3, 4, 5, 6], (2, 3), order="F")
print a[0, :]
print a[1, :]
print
print b[0, :]
print b[1, :]
```

```fortran
integer :: a(2, 3), b(2, 3)
a = reshape([1, 2, 3, 4, 5, 6], [2, 3], order=[2, 1])
b = reshape([1, 2, 3, 4, 5, 6], [2, 3])
print *, a(1, :)
print *, a(2, :)
print *
print *, b(1, :)
print *, b(2, :)
```

Output:

```
[1 2 3]
[4 5 6]

[1 3 5]
[2 4 6]
```

Output:

```
1           2           3
4           5           6

1           3           5
2           4           6
```

```python
from numpy import array, size, shape, max, min
a = array([[1, 2, 3], [4, 5, 6]])
print shape(a)
print size(a, 0)
print size(a, 1)
print max(a)
print min(a)
print a[0, 0], a[0, 1], a[0, 2]
print a[1, 0], a[1, 1], a[1, 2]
print a
```

```fortran
integer :: a(2, 3)
a = reshape([1, 2, 3, 4, 5, 6], [2, 3], order=[2, 1])
print *, shape(a)
print *, size(a, 1)
print *, size(a, 2)
print *, maxval(a)
print *, minval(a)
print *, a(1, 1), a(1, 2), a(1, 3)
print *, a(2, 1), a(2, 2), a(2, 3)
print "(3i5)", transpose(a)
```

Output:

```
(2, 3)
2
```

Output (whitespace trimmed):

```
2 3
2
```

```
3
6
1
1 2 3
4 5 6
[[1 2 3]
 [4 5 6]]
```

```
3
6
1
1 2 3
4 5 6
1 2 3
4 5 6
```

```python
from numpy import array, all, any
i = array([1, 2, 3])
all(i == [1, 2, 3])
any(i == [2, 2, 3])
```

```fortran
integer :: i(3)
i = [1, 2, 3]
all(i == [1, 2, 3])
any(i == [2, 2, 3])
```

```python
from numpy import array, empty
a = array([1, 2, 3, 4, 5, 6, 7, 8, 9, 10])
b = empty(10)
b[:] = 0
b[a > 2] = 1
b[a > 5] = a[a > 5] - 3
```

```fortran
integer :: a(10), b(10)
a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
where (a > 5)
    b = a - 3
elsewhere (a > 2)
    b = 1
elsewhere
    b = 0
end where
```

```python
from numpy import array, empty
a = array([1, 2, 3, 4, 5, 6, 7, 8, 9, 10])
b = empty(10)
for i in range(len(a)):
    if a[i] > 5:
        b[i] = a[i] - 3
    elif a[i] > 2:
        b[i] = 1
    else:
        b[i] = 0
```

```fortran
integer :: a(10), b(10)
a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
where (a > 5)
    b = a - 3
elsewhere (a > 2)
    b = 1
elsewhere
    b = 0
end where
```

```python
from numpy import array, sum, ones, size
a = array([1, 2, 3, 4, 5, 6, 7, 8, 9, 10])
print sum(a)
print sum(a[(a > 2) & (a < 6)])
o = ones(size(a), dtype="int")
print sum(o[(a > 2) & (a < 6)])
```

```fortran
integer :: a(10)
a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
print *, sum(a)
print *, sum(a, mask=a > 2 .and. a < 6)
print *, count(a > 2 .and. a < 6)
```

```python
from numpy import array, dot
a = array([[1, 2], [3, 4]])
b = array([[2, 3], [4, 5]])
print a * b
print dot(a, b)
```

Output:

```
[[ 2  6]
 [12 20]]
```

```fortran
integer :: a(2, 2), b(2, 2)
a = reshape([1, 2, 3, 4], [2, 2], order=[2, 1])
b = reshape([2, 3, 4, 5], [2, 2], order=[2, 1])
print *, a * b
print *, matmul(a, b)
```

Output:

```
 2          12           6          20
10          22          13          29
```

```
[[10 13]
 [22 29]]
```

```
from numpy import array, pi
a = array([i for i in range(1, 7)])
b = array([(2*i*pi+1)/2 for i in range(1, 7)])
c = array([i for i in range(1, 7) \
    for j in range(1, 4)])
```

```
use types, only: dp
use constants, only: pi
integer :: a(6), c(18)
real(dp) :: b(6)
integer :: i, j
a = [ (i, i = 1, 6) ]
b = [ ((2*i*pi+1)/2, i = 1, 6) ]
c = [ ((i, j = 1, 3), i = 1, 6) ]
```

Some indexing examples

NumPy

```
from numpy import array
a = array([1, 2, 3])
b = a
print a[:]
print b[:]
print a[:2]
print b[:2]
```

Output:

```
[1 2 3]
[1 2 3]
[1 2]
[1 2]
```

Fortran

```
integer :: a(3), b(-1:1)
a = [1, 2, 3]
b = a
print *, a(:)
print *, b(:)
print *, a(:2)
print *, b(:0)
```

Output:

```
1     2     3
1     2     3
1     2
1     2
```

First *n* elements:

NumPy

```
a[:n]
```

Fortran

```
a(:n)     ! assuming starting index 1 (default)
a(:n+m-1) ! assuming starting index m
```

Last *n* elements:

NumPy

```
a[-n:] # equivalent to a[size(a)-n:]
```

Fortran

```
a(size(a)-n+1:)
```

Select elements between *i* and *j* (inclusive):

NumPy Fortran

`a[i:j+1]`	`a(i:j)`

Select *n* elements starting with index *i*:

NumPy	Fortran
`a[i:i+n]`	`a(i:i+n-1)`

Select elements between *-n*, ..., *n* (inclusive):

NumPy	Fortran
`# Not possible (arrays start at 0 index)`	`a(-n:n)`

Loop over the whole array:

NumPy	Fortran

`r = 1`
`for i in range(len(a)):`
`    r *= a[i]`
	`r = 1`
	`do i = 1, size(a)`
	`    r = r*a(i)`
	`end do`

Loop between index *3* and *7* (inclusive):

NumPy	Fortran

`r = 1`
`for i in range(3, 8):`
`    r *= a[i]`
	`r = 1`
	`do i = 3, 7`
	`    r = r*a(i)`
	`end do`

Loop between *3*-th and *7*-th elements (inclusive):

NumPy	Fortran

`r = 1`
`for i in range(2, 7):`
`    r *= a[i]`
	`r = 1`
	`do i = 3, 7`
	`    r = r*a(i)`
	`end do`

Split a string into three parts at indices *i* and *j*, the parts are:

NumPy	Fortran

`a[ :i]`
`a[i:j]`
`a[j: ]`
	`a( :i-1)`
	`a(i:j-1)`
	`a(j:   )`

Laplace update:

NumPy	Fortran

`u[1:-1,1:-1] = ((u[2:,1:-1]+u[:-2,1:-1])*dy2 +`
`    (u[1:-1,2:] + u[1:-1,:-2])*dx2) / (2*(dx2+dy2))`
	`nx = size(u, 1)`
	`ny = size(u, 2)`
	`u(2:nx-1,2:ny-1) = ((u(3:,2:ny-1)+u(:ny-2,2:ny-1))*dy2 + &`
	`    (u(2:nx-1,3:) + u(2:nx-1,:ny-2))*dx2) / (2*(dx2+dy2))`

Modules

Comparison of Fortran and Python import statements:

Python	Fortran

`from A import foo`
`from A import foo as Afoo`
`from A import *`
	`use A, only: foo`
	`use A, only: Afoo => foo`
	`use A`

The following Python statements have no equivalent in Fortran:

Python	Fortran

`import A`
`import ALongName as A`	

Fortran modules work just like Python modules. Differences:

- Fortran modules cannot be nested (i.e. they are all top level, while in Python one can nest the module arbitrarily using the `__init__.py` files)
- There is no Fortran equivalent of Python's `import A`
- One can specify private module symbols in Fortran

Identical features:

- A module contains variables, types and functions/subroutines
- By default all variables/types/functions can be accessed from other modules, but one can change this by explicitly specifying which symbols are private or public (in Python this only works for implicit imports)
- Symbols that are public don't pollute the global namespace, but need to be explicitly imported from the module in order to use them
- Importing a symbol into a module becomes part of that module and can then be imported from other modules
- One can use explicit or implicit imports (explicit imports are recommended)

One creates the module:

Python

File `a.py`:

```python
i = 5

def f(x):
    return x + 5

def g(x):
    return x - 5
```

Fortran

File `a.f90`:

```fortran
module a
implicit none

integer :: i = 5

contains

integer function f(x) result(r)
integer, intent(in) :: x
r = x + 5
end function

integer function g(x) result(r)
integer, intent(in) :: x
r = x - 5
end function

end module
```

And uses it from the main program as follows:

Python

File `main.py`:

```python
from a import f, i

print f(3)
print i
```

Output:

```
8
5
```

Fortran

File `main.f90`:

```fortran
program main
use a, only: f, i
implicit none
print *, f(3)
print *, i
end program
```

Output:

```
8
5
```

In Fortran, one can ommit the line `program main`, also one can just end the file with `end` instead of `end program`. That way one can test any code snippet just by appending `end` at the end.

In order to specify which symbols are public and private, one would use:

Python

File `a.py`:

Fortran

File `a.f90`:

```python
__all__ = ["i", "f"]

i = 5

def f(x):
    return x + 5

def g(x):
    return x - 5
```

```fortran
module a
implicit none
private
public i, f

integer :: i = 5

contains

integer function f(x) result(r)
integer, intent(in) :: x
r = x + 5
end function

integer function g(x) result(r)
integer, intent(in) :: x
r = x - 5
end function

end module
```

There is a difference though. In Fortran, the symbol `g` will be private (not possible to import from other modules no matter if we use explicit or implicit import), `f` and `i` public. In Python, when implicit import is used, the symbol `g` will not be imported, but when explicit import is used, the symbols `g` can still be imported.

Floating Point Numbers

Both NumPy and Fortran can work with any specified precision and if no precision is specified, then the default platform precision is used.

In Python, the default precision is typically double precision, while in Fortran it is single precision. See also the relevant Python and NumPy documentation.

Python 2.x

Single precision:

```python
from numpy import float32
f = float32(1.1)
```

Fortran

Single precision:

```fortran
real :: f
f = 1.1
```

Python 2.x

Double precision:

```python
f = 1.1            # 1.1
f = 1e8            # 100000000.0
f = float(1) / 2   # 0.5
f = float(1 / 2)   # 0.0
f = float(5)       # 5.0
```

Fortran

Double precision:

```fortran
integer, parameter :: dp=kind(0.d0)
real(dp) :: f
f = 1.1_dp             ! 1.1
f = 1e8_dp             ! 100000000.0
f = real(1, dp) / 2    ! 0.5
f = 1 / 2              ! 0.0
f = 5                  ! 5.0
```

In Fortran the habit is to always specify the precision using the `_dp` suffix, where `dp` is defined in the `types.f90` module below as `integer, parameter :: dp=kind(0.d0)` (so that one can change the precision at one place if needed). If no precision is specified, then single precision is used (and as such, this leads to single/double corruption), so one *always* needs to specify the precision.

In all Fortran code snippets below, it is assumed, that you did `use types, only: dp`. The `types.f90` module is:

```
module types
implicit none
private
public dp, hp
integer, parameter :: dp=kind(0.d0), &          ! double precision
                      hp=selected_real_kind(15) ! high precision
end module
```

Math and Complex Numbers

Fortran has builtin mathematical functions, in Python one has to import them from the `math` module or (for the more advanced functions) from the SciPy package. Fortran doesn’t include constants, so one has to use the `constants.f90` module (included below).

Otherwise the usage is identical.

Python

```
from math import cos, pi, e
I = 1j
print e**(I*pi) + 1
print cos(pi)
print 4 + 5j
print 4 + 5*I
```

Output:

```
1.22460635382e-16j
-1.0
(4+5j)
(4+5j)
```

Fortran

```
use constants, only: pi, e
complex(dp) :: I = (0, 1)
print *, e**(I*pi) + 1
print *, cos(pi)
print *, (4, 5)
print *, 4 + 5*I
```

Output:

```
(  0.0000000000000000     , 1.22460635382237726E-016)
 -1.0000000000000000
(  4.0000000     ,  5.0000000    )
(  4.0000000000000000     ,  5.0000000000000000     )
```

Fortran module `constants.f90`:

```
module constants
use types, only: dp
implicit none
private
public pi, e, I
! Constants contain more digits than double precision, so that
! they are rounded correctly:
real(dp), parameter :: pi   = 3.1415926535897932384626433832795_dp
real(dp), parameter :: e    = 2.7182818284590452353602874713527_dp
complex(dp), parameter :: I = (0, 1)
end module
```

Strings and Formatting

The functionality of both Python and Fortran is pretty much equivalent, only the syntax is a litte different.

In both Python and Fortran, strings can be delimited by either `"` or `'`.

There are three general ways to print formatted strings:

Python

```
print "Integer", 5, "and float", 5.5, "works fine."
print "Integer " + str(5) + " and float " + str(5.5) + "."
print "Integer %d and float %f." % (5, 5.5)
```

Output:

```
Integer 5 and float 5.5 works fine.
Integer 5 and float 5.5.
Integer 5 and float 5.500000.
```

Fortran

```
use utils, only: str
print *, "Integer", 5, "and float", 5.5, "works fine."
print *, "Integer " // str(5) // " and float " // str(5.5_dp) // "."
print '("Integer ", i0, " and float ", f0.6, ".")', 5, 5.5
```

Output:

```
 Integer           5 and float   5.5000000     works fine.
 Integer 5 and float 5.500000.
Integer 5 and float 5.500000.
```

And here are some of the frequently used formats:

Python

```
print "%3d" % 5
print "%03d" % 5
print "%s" % "text"
print "%15.7f" % 5.5
print "%23.16e" % -5.5
```

Output:

```
  5
005
text
      5.5000000
-5.5000000000000000e+00
```

Fortran

```
print '(i3)', 5
print '(i3.3)', 5
print '(a)', "text"
print '(f15.7)', 5.5_dp
print '(es23.16)', -5.5_dp
```

Output:

```
  5
005
text
      5.5000000
-5.5000000000000000E+00
```

Nested Functions

Both Python and Fortran allow nested functions that can access the outer function’s namespace:

Python

```
def foo(a, b, c):
    def f(x):
        return a*x**2 + b*x + c
    print f(1), f(2), f(3)
```

Fortran

```
subroutine foo(a, b, c)
real(dp) :: a, b, c
print *, f(1._dp), f(2._dp), f(3._dp)

contains
```

```
real(dp) function f(x) result(y)
real(dp), intent(in) :: x
y = a*x**2 + b*x + c
end function f

end subroutine foo
```

Use it like:

Python

```
foo(1, 2, 1)
foo(2, 2, 1)
```

Output:

```
4 9 16
5 13 25
```

Fortran

```
call foo(1._dp, 2._dp, 1._dp)
call foo(2._dp, 2._dp, 1._dp)
```

Output:

```
4.0000000000000000        9.0000000000000000        16.000000000000000
5.0000000000000000        13.000000000000000        25.000000000000000
```

You can use the nested functions in callbacks to pass context:

Python

```
def simpson(f, a, b):
    return (b-a) / 6 * (f(a) + 4*f((a+b)/2) + f(b))

def foo(a, k):
    def f(x):
        return a*sin(k*x)
    print simpson(f, 0., pi)
    print simpson(f, 0., 2*pi)
```

Fortran

```
real(dp) function simpson(f, a, b) result(s)
real(dp), intent(in) :: a, b
interface
    real(dp) function f(x)
    use types, only: dp
    implicit none
    real(dp), intent(in) :: x
    end function
end interface
s = (b-a) / 6 * (f(a) + 4*f((a+b)/2) + f(b))
end function


subroutine foo(a, k)
real(dp) :: a, k
print *, simpson(f, 0._dp, pi)
print *, simpson(f, 0._dp, 2*pi)

contains

real(dp) function f(x) result(y)
real(dp), intent(in) :: x
y = a*sin(k*x)
end function f

end subroutine foo
```

And use it like:

Python

```
foo(0.5, 1.)
foo(0.5, 2.)
```

Output:

```
1.0471975512
1.28244712915e-16
6.41223564574e-17
-7.69468277489e-16
```

Fortran

```
call foo(0.5_dp, 1._dp)
call foo(0.5_dp, 2._dp)
```

Output:

```
   1.0471975511965976
  1.28244712914785977E-016
  6.41223564573929883E-017
 -7.69468277488715811E-016
```

Control flow in loops

The common loop types in Python and Fortran are the `for` and `do` loops respectively. It is possible to skip a single loop or to stop the execution of a loop in both languages but the statements to do so differ.

break and exit statements

In Python, `break` is used to stop the execution of the innermost loop. In Fortran, this is accomplished by the `exit` statement. For named loops, it is possible to speficy which loop is affected by appending its name to the `exit` statement. Else, the innermost loop is interrupted.

Python's `exit()` interrupts the execution of program or of an interactive session.

NumPy

```
for i in range(1, 9):
    if i>2:
        break
    print i
```

Fortran

```
loop_name: do i = 1, 8
    if (i>2) exit loop_name
    print *, i
end do loop_name
```

continue and cycle statements

Python's `continue` statement is used to skip the rest of a loop body. The loop then continues at its next iteration cycle. Fortran's `continue` statement does not do anything and one should use `cycle` instead. For named loops, it is possible to speficy which loop is affected by appending its name to the `cycle` statement.

NumPy

```
for i in range(1, 9):
    if i%2 == 0:
        continue
    print i
```

Fortran

```
loop_name: do i = 1, 8
    if (modulo(i, 2) == 0) cycle loop_name
    print *, i
end do loop_name
```

Examples

Mandelbrot Set

Here is a real world program written in NumPy and translated to Fortran.

Python

```python
import numpy as np

ITERATIONS = 100
DENSITY = 1000
x_min, x_max = -2.68, 1.32
y_min, y_max = -1.5, 1.5

x, y = np.meshgrid(np.linspace(x_min, x_max, DENSITY),
                   np.linspace(y_min, y_max, DENSITY))
c = x + 1j*y
z = c.copy()
fractal = np.zeros(z.shape, dtype=np.uint8) + 255

for n in range(ITERATIONS):
    print "Iteration %d" % n
    mask = abs(z) <= 10
    z[mask] *= z[mask]
    z[mask] += c[mask]
    fractal[(fractal == 255) & (-mask)] = 254. * n / ITERATIONS

print "Saving..."
np.savetxt("fractal.dat", np.log(fractal))
np.savetxt("coord.dat", [x_min, x_max, y_min, y_max])
```

Fortran

```fortran
program Mandelbrot
use types, only: dp
use constants, only: I
use utils, only: savetxt, linspace, meshgrid
implicit none

integer, parameter :: ITERATIONS = 100
integer, parameter :: DENSITY = 1000
real(dp) :: x_min, x_max, y_min, y_max
real(dp), dimension(DENSITY, DENSITY) :: x, y
complex(dp), dimension(DENSITY, DENSITY) :: c, z
integer, dimension(DENSITY, DENSITY) :: fractal
integer :: n
x_min = -2.68_dp
x_max = 1.32_dp
y_min = -1.5_dp
y_max = 1.5_dp

call meshgrid(linspace(x_min, x_max, DENSITY), &
    linspace(y_min, y_max, DENSITY), x, y)
c = x + I*y
z = c
fractal = 255

do n = 1, ITERATIONS
    print "('Iteration ', i0)", n
    where (abs(z) <= 10) z = z**2 + c
    where (fractal == 255 .and. abs(z) > 10) fractal = 254 * (n-1) / ITERATIONS
end do

print *, "Saving..."
call savetxt("fractal.dat", log(real(fractal, dp)))
call savetxt("coord.dat", reshape([x_min, x_max, y_min, y_max], [4, 1]))
end program
```

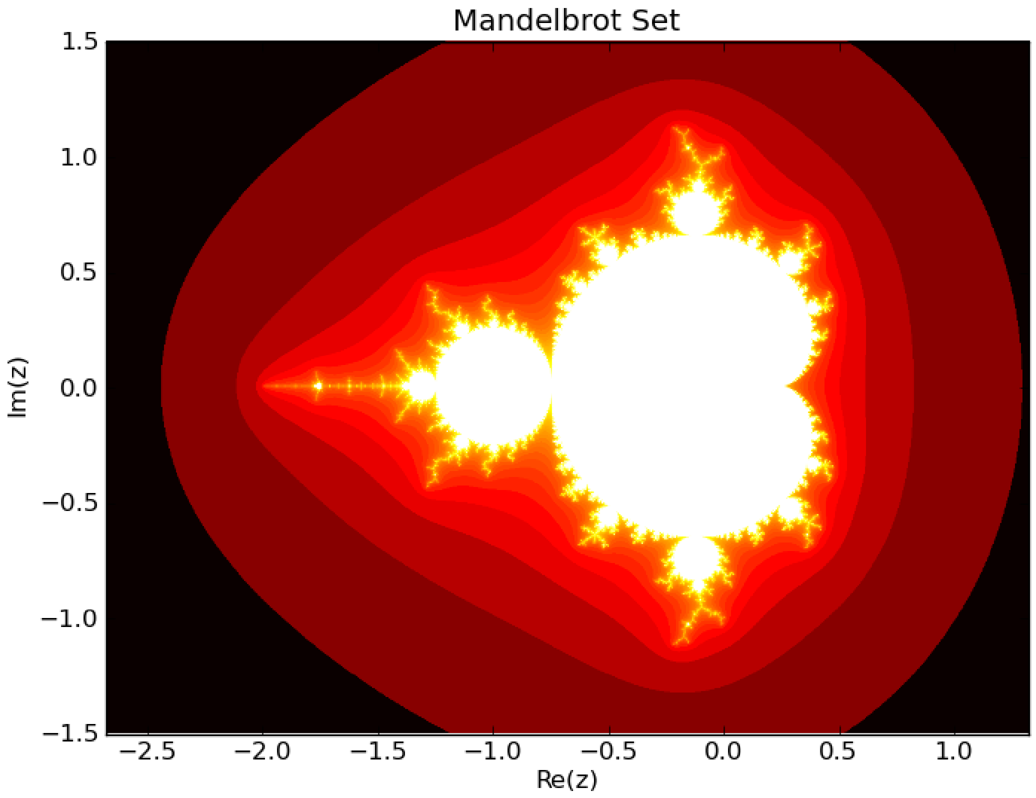
To run the Python version, you need Python and NumPy. To run the Fortran version, you need `types.f90`, `constants.f90` and `utils.f90` from the fortran-utils package. Both versions generate equivalent `fractal.dat` and `coord.dat` files.

The generated fractal can be viewed by (you need matplotlib):

```python
from numpy import loadtxt
import matplotlib.pyplot as plt

fractal = loadtxt("fractal.dat")
x_min, x_max, y_min, y_max = loadtxt("coord.dat")
```

```
plt.imshow(fractal, cmap=plt.cm.hot,
           extent=(x_min, x_max, y_min, y_max))
plt.title('Mandelbrot Set')
plt.xlabel('Re(z)')
plt.ylabel('Im(z)')
plt.savefig("mandelbrot.png")
```



Timings on Acer 1830T with gfortran 4.6.1 are:

	Python	Fortran	Speedup
Calculation	12.749	00.784	16.3x
Saving	01.904	01.456	1.3x
Total	14.653	02.240	6.5x

Least Squares Fitting

In Python we use Minpack via SciPy, in Fortran we use Minpack directly. We first create a module `find_fit_module` with a function `find_fit`:

Python

```python
from numpy import array
from scipy.optimize import leastsq

def find_fit(data_x, data_y, expr, pars):
    data_x = array(data_x)
    data_y = array(data_y)
    def fcn(x):
        return data_y - expr(data_x, x)
    x, ier = leastsq(fcn, pars)
    if (ier != 1):
        raise Exception("Failed to converge.")
    return x
```

Fortran

```fortran
module find_fit_module
use minpack, only: lmdif1
use types, only: dp
implicit none
private
public find_fit

contains

subroutine find_fit(data_x, data_y, expr, pars)
real(dp), intent(in) :: data_x(:), data_y(:)
interface
    function expr(x, pars) result(y)
    use types, only: dp
    implicit none
    real(dp), intent(in) :: x(:), pars(:)
    real(dp) :: y(size(x))
    end function
end interface
real(dp), intent(inout) :: pars(:)

real(dp) :: tol, fvec(size(data_x))
integer :: iwa(size(pars)), info, m, n
real(dp), allocatable :: wa(:)

tol = sqrt(epsilon(1._dp))
m = size(fvec)
n = size(pars)
allocate(wa(m*n + 5*n + m))
call lmdif1(fcn, m, n, pars, fvec, tol, info, iwa, wa, size(wa))
if (info /= 1) stop "failed to converge"

contains

subroutine fcn(m, n, x, fvec, iflag)
integer, intent(in) :: m, n, iflag
real(dp), intent(in) :: x(n)
real(dp), intent(out) :: fvec(m)
! Suppress compiler warning:
fvec(1) = iflag
fvec = data_y - expr(data_x, x)
end subroutine

end subroutine

end module
```

Then we use it to find a nonlinear fit of the form `a*x*log(b + c*x)` to a list of primes:

Python

```python
from numpy import size, log
from find_fit_module import find_fit
```

Fortran

```fortran
program example_primes
use find_fit_module, only: find_fit
```

```python
def expression(x, pars):
    a, b, c = pars
    return a*x*log(b + c*x)

y = [2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31,
    37, 41, 43, 47, 53, 59, 61, 67, 71]
pars = [1., 1., 1.]
pars = find_fit(range(1, size(y)+1), y, expression, pars)
print pars
```

```fortran
use types, only: dp
implicit none

real(dp) :: pars(3)
real(dp), parameter :: y(*) = [2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, &
    37, 41, 43, 47, 53, 59, 61, 67, 71]
integer :: i
pars = [1._dp, 1._dp, 1._dp]
call find_fit([(real(i, dp), i=1,size(y))], y, expression, pars)
print *, pars

contains

function expression(x, pars) result(y)
real(dp), intent(in) :: x(:), pars(:)
real(dp) :: y(size(x))
real(dp) :: a, b, c
a = pars(1)
b = pars(2)
c = pars(3)
y = a*x*log(b + c*x)
end function

end program
```

This prints:

```
1.4207732655565537        1.6556111085593115       0.53462502018670921
```