introduction (week 1)

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Introduction

Administrative trivia

- Instructor: Ben Bolker
  - `bolker@mcmaster.ca`: please include `1mp3` in Subject:
  - `http://www.math.mcmaster.ca/bolker`
  - HH 314 (sometimes LSB 336); office hours TBA
- TA: Jake Szamosi
- Grading:
  - midterm 20%
  - final (take-home?) 30%
  - weekly assignments 30%
  - project 20%
- Laptop policy
- Course material on Github and Avenue
- Expectations of professor and students
- Textbook (none); see resources
- Course content: reasonable balance among
  - nitty-gritty practical programming instruction:

> … I just sat down in front of a text editor, with nothing but thoughts, and ended up with a program that did exactly what I wanted it to a few hours later … (ankit panda)

- – conceptual foundations of computing/computer science
  - context/culture of mathematical/scientific computing
  - interesting applications

More interesting stuff

Using computers in math and science

- math users vs. understanders vs. developers
- develop conjectures; draw pictures; write manuscripts

- mathematical proof (e.g. four-colo(u)r theorem and other examples); computer algebra
- applied math: cryptography, tomography, logistics, finance, fluid dynamics, ...
- applied statistics: bioinformatics, Big Data/analytics, ...
- discrete vs. continuous

Fun!

Hello, world

```
print('hello, python world!')
```

```
## hello, python world!
```

Python as a fancy calculator:

```
print(62**2*27/5+3)
```

```
## 20760
```

- *reference*: Python intro section 3.1.1

Interlude: about Python

- scripting; high-level; glue; general-purpose; flexible
  - contrast: *domain-specific* scripting languages (MATLAB, R, Mathematica, Maple)
  - contrast: *general-purpose* scripting languages (Perl, PHP)
  - contrast: general-purpose *compiled* languages (Java, C, C++) ("close to the metal")
- relatively modern (1990s; Python 3, 2008)
- currently the 8th most popular computer language overall; most popular for teaching
- well suited to mathematical and scientific programming (NumPy; SciPy)
- ex.: Sage; BioPython

the Mandelbrot set

Suppose we iterate $z_{n+1} = z_n^2 + c$, for some complex number c, starting with $z_0 = 0$. The Mandelbrot set is the set for which the iterations do *not* go off to infinity. (*What happens for* $c = 0$*?* $c = -1$*?* $c = i$*?* $c = 1$*?*)

We can iterate by hand ...

```
print(complex(0,0.65)**2+complex(0,0.65))
print((complex(0,0.65)**2+complex(0,0.65))**2+complex(0,0.65))
print(((complex(0,0.65)**2+complex(0,0.65))**2+complex(0,0.65))**2)+complex(0,0.65)
```

```
## (-0.4225+0.65j)
## (-0.24399375+0.10075j)
## (0.0493823875391+0.600835259375j)
```

Use **assignments** to simplify ...

```
z0=0
c=complex(0,0.65)
z1=z0**2+c
z2=z1**2+c
z3=z2**2+c
print(abs(z3)<2)
```

```
## True
```

The basic method for generating pretty pictures is:

- for lots of different values of c
  - set $z_0 = 0$
  - keep calculating $z_{n+1} = z_n^2 + c$ until $\mathrm{mod}(z_{n+1})$ is greater than 2
  - record the final value of n
- translate values of n into some colour scale and plot the results

Complex arithmetic is built into Python
(*What is* $(2 + 3i)^2$=`(complex(2,3))**2`?)

Mandelbrot set program

Note:

- easier to understand/modify than write from scratch
- build on existing components (*modules*)

Interfaces

- command line/console (PyCharm: `View/Tool Windows/Python Console`)
- programming editor
- integrated development environment (IDE)
- **not** MS Word! 

Features

- syntax highlighting
- bracket-matching
- hot-pasting
- integrated help
- integrated debugging tools
- integrated project management tools
- **most important**: maintain reproducibility; well-defined **workflows**

Assignment

- superficially simple
  - `=` is the **assignment operator**
  - `<variable>=<value>`
  - variable names
    * what is legal? (letters, numbers, underscores, start with a letter)
    * what is customary? convention is `variables_like_this`
    * what works well? `v` vs. `temporary_variable_for_loop`
- variables can be of different **types**
  - built-in: integer (`int`), floating-point (`float`), complex, **Boolean** (`bool`: `True` or `False`),
  - *dynamic* typing
  - (relatively) *strong* typing
    * try `print(type(x))` for different possibilities (`x=3`; `x=3.0`; `x="a"`)

- * *what happens if you try* `x=a`*?*
- * **don't be afraid to experiment!**

```
x=3
y=3.0
z="a"
q=complex(1,2)
type(x+y)  ## mixed arithmetic
type(int(x+y))  ## int(), float() convert explicitly
type(x+z)
type(q)
type(x+q)
type(True)
type(True+1) ## WAT
```

Comparisons and logical expressions

- comparison: (`==`, `!=`)
- inequalities: `>`, `<`, `>=`, `<=`,
- basic logic: (`and`, `or`, `not`)
- remember your truth tables, e.g. `not(a and b)` equals `(not a) or (not b)`

```
a = True; b = False; c=1; d=0
a and b
not(a and not b)
a and not(b>c)
a==c  ## careful!
not(d)
not(c)
```

- **operator precedence**: same issue as order of operations in arithmetic; `not` has higher precedence than `and`, `or`. When in doubt use parentheses ...

String operations

reference: Python intro section 3.1.2

- Less generally important, but fun
- `+` concatenates
- `*` replicates and concatenates

- `in` searches for a substring

```
a = "xyz"
b = "abc"
a+1  ## error
a+b
b*3
(a+" ")*5
b in a
```

Regular expressions

Large topic – somewhat more advanced than 'basic programming', but worth a digression.

What if we are looking for some number, but we don't know what number?

```
import re
bool(re.search('[0-9]', 'Plan 9'))
```

Pattern	Description
`^`	Beginning of line
`$`	End of line
`.`	Any single character except newline
`[...]`	Any single character in brackets
`[^...]`	Any single character **not** in brackets
`re*`	0 or more occurrences of preceding expression
`re+`	1 or more occurrence of preceding expression
`re?`	0 or 1 occurrence of preceding expression
`re1|re2`	match `re1` or `re2`
`()`	grouping

- How would you test whether a string contains a numeric value at the end (e.g. "Plan 99")?
- What if the string might contain a comma (e.g. "Plan 99,478")?
- What if you're looking for the abbreviations of rooms in Hamilton Hall (my office is HH314)?
- … rooms in LSB *or* HH?

Lists and indexing

reference: Python intro section 3.1.3

Lists

- Use square brackets `[]` to set up a **list**
- Lists can contain anything but usually homogeneous
- Put other variables into lists
- Put lists into lists!
- `range()` makes a **range** but you can turn it into a list with `list()`
- *Make a list that runs from 101 to 200*
- *Make a list that . . .*

Indexing and slicing

Indexing

- Extracting elements is called **indexing** a list
- Indexing starts from zero
- Negative indices count backward from the end of the string
  (-1 is the last element)
- Indexing a non-existent element gives an error

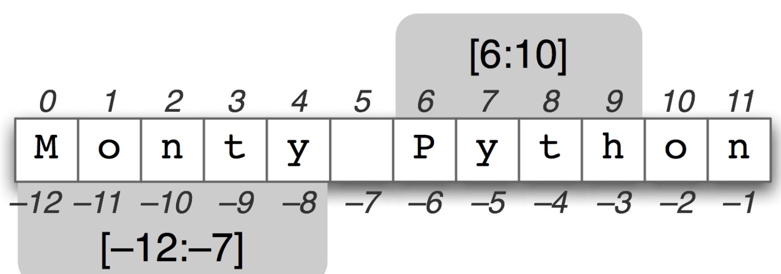

Figure 1: slicing

Slicing

- Extracting sets of elements is called **slicing**
- Slicing non-existent element(s) gives a truncated result
- Slicing specifies *start*, *end*, *step* (or “stride”)

- Leaving out a bit goes from the beginning/to the end
- Slicing works on strings too!

```
x[:]        # everything
x[a:b]      # element a (zero-indexed) to b-1
x[a:]       # a to end
x[:b]       # beginning to b
x[a:b:n]    # from a to b-1 in steps of n
```

- generate list of odd numbers from 3 to 15
- reverse a string?

Other list operations

- Lots of things you can do with lists!
- Distinguish between *copying* lists and modifying them in-place
- Distinguish between *functions* and *methods* `foo(x)` vs. `x.foo()`
  - appending:
  - list *methods*
  - appending and extending:

```
x = [1,2,3]
y = [4,5]
x.append(y)
print(x)
```

```
## [1, 2, 3, [4, 5]]
```

```
x = [1,2,3] # reset x
y = [4,5]
x.extend(y)
print(x)
```

```
## [1, 2, 3, 4, 5]
```

Can use `+` as a shortcut for extending:

```
x = [1,2,3]
y = [4,5]
z = x+y
print(z)
```

```
## [1, 2, 3, 4, 5]
```

- `x.insert(position,value)`: inserts
- `x.remove(value)`:
- `x.pop(position)` (or `del x[position]` or `x[position]=[]`)
- `x.reverse()` (or `x[::-1]`)
- `x.sort()`: what it says
- `x.count(value)`: number of occurrences of `value`
- `x.index(value)`: first occurrence of `value`
- `value in x`: does `value` occur in `x`? (or `logical(x.count(value)==0)`)
- `len(x)`: length

Note: pythonicity vs. TMTOWTDI