Imperative programming with Python

Class #1

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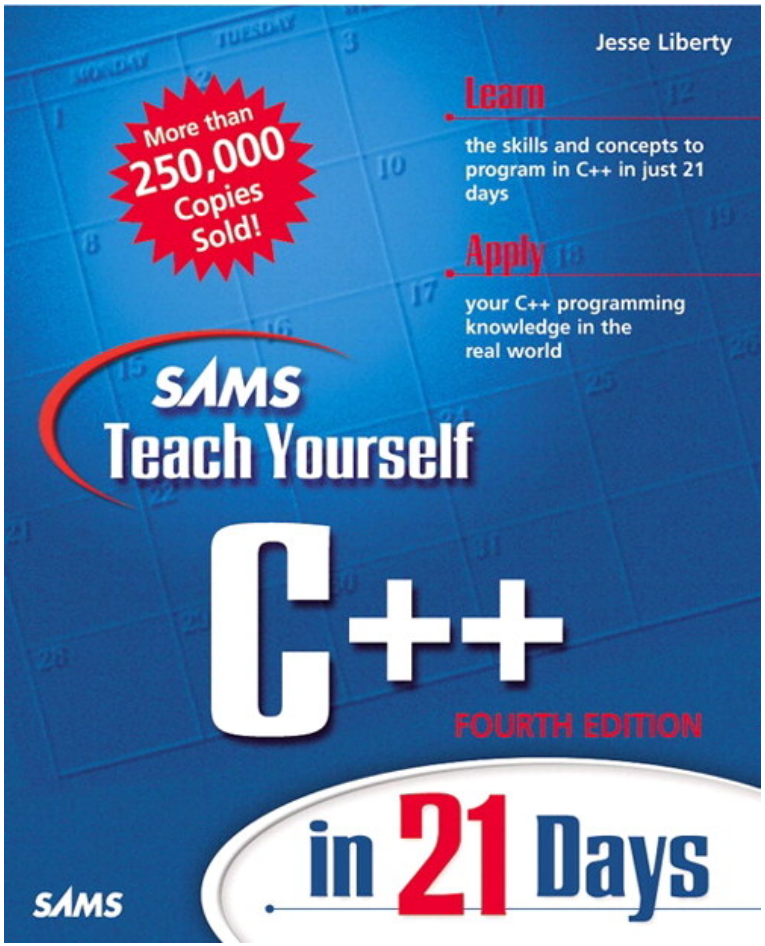
Organizational & administrative stuff

- Instructor: Facundo Carreiro (http://glyc.dc.uba.ar/facu/).
- Teaching Assistant: (Aaron) Li Feng Han.
- 6 ECs.
- From 05/01/2015 to 30/01/2015.
- 4x2h sessions per week (3 classes and 1 tutorial).
- Schedule in `https://datanose.nl/#course[24621]`.
- Evaluation
  1. 3 homework sets (one per week in the first 3 weeks).
  2. A final project during the last week (negotiate topic with me).
  3. Everything to be done in groups of around 3–4 people.

Contents (roughly)

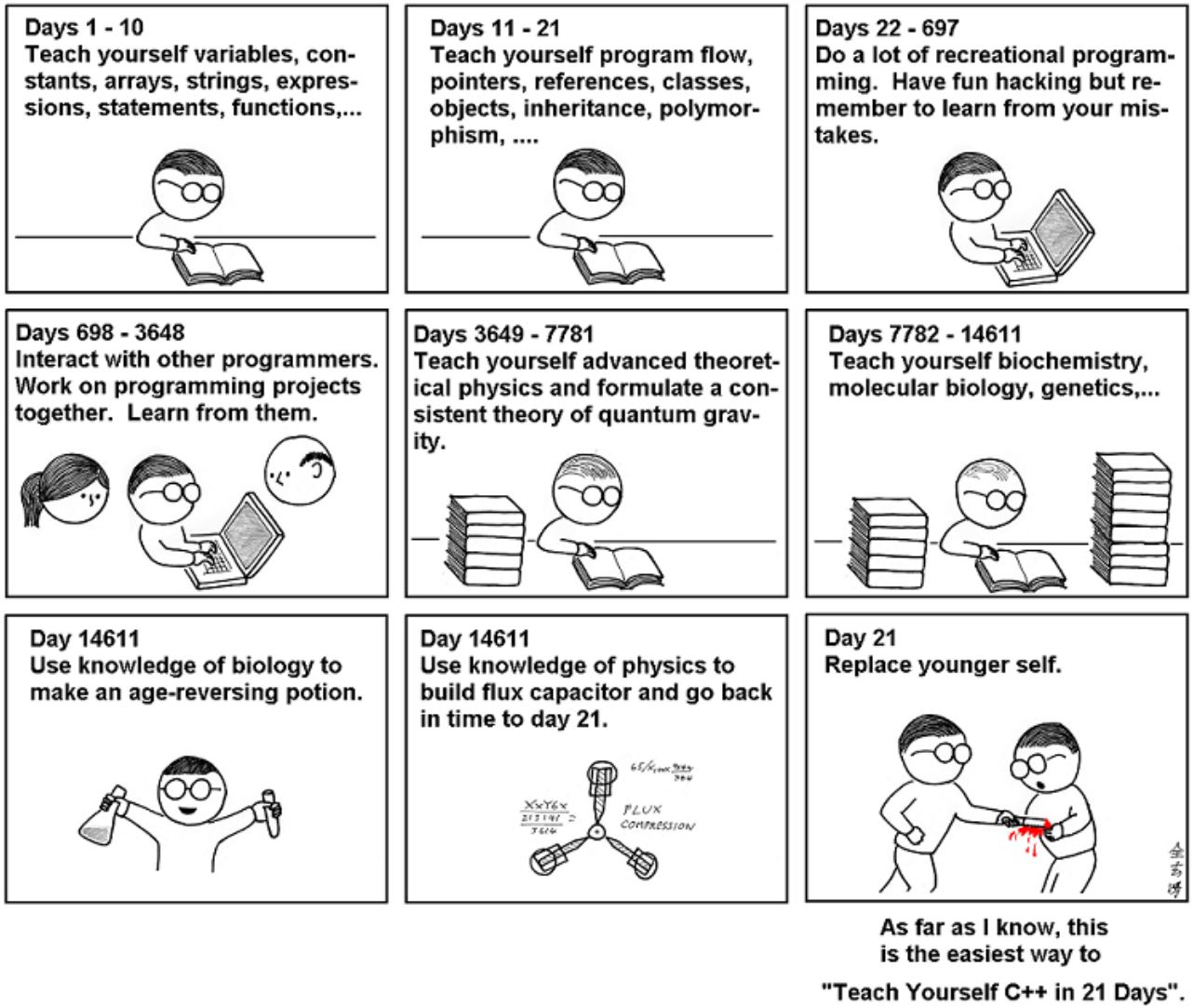
1. Basic object-oriented programming
   - Variables, expressions and statements.
   - Functions.
   - Execution flow control.
   - Iteration and repetition.
   - Data structures: Lists, dictionaries, tuples.
   - File Input/Output.
   - Classes, objects and inheritance.
2. Python specifics
   - Python modules.
   - A glimpse of the *huge* Python standard library.
3. A bit of 'theoretical' computer science.
4. A bit of software engineering
   - Group work, time estimation, testing, debugging.

About the contents: one month is just the beginning



About the contents

By the Abstruse Goose webcomic



What is programming all about?

- *"Computer science is no more about computers than astronomy is about telescopes, biology is about microscopes or chemistry is about beakers and test tubes. Science is not about tools, it is about how we use them and what we find out when we do." – Fellows, M.R., and Parberry, I.*
- Computer science is about *problem solving*.
- The most important skill is knowing how to analyze a problem, break it into pieces and solve it efficiently.
- Examples of problems:
  1. I want to get to Amsterdam Central Station as fast as possible.
  2. I want to sort a deck of cards.
  3. I want to solve the world's hunger problem.
- We will focus on problems that **can** be solved with a computer.

Algorithms

- An *algorithm* is a finite sequence of steps to solve a particular problem.

Input: Flour, eggs, sugar, butter, milk
Output: Cake

1. Heat the oven.
2. Mix ingredients in a bowl.
3. Put mixture in a baking pan.
4. Bake for 50 minutes.
5. Keep baking until top springs back when touched.

Input: A list of numbers $L = n_1, \ldots, n_k$
Output: L ordered by $<$

1. For `current_pos` := 1 to k do
   - Look for the smallest $n_{current\_pos}, \ldots, n_k$.
   - Switch it with $n_{current\_pos}$

Input: Money
Output: Cake

1. Go to Albert Heijn.
2. Look for cake.
3. Buy cake.

Programming languages

- Formal, unambiguous languages to write algorithms.
- Can be classified in *low-level* (aka. "machine code") and *high-level*.

Low-level programming languages

- Use a *tiny* set of instructions that the computer's CPU understands.
- Mess directly with the computer's memory cells.
- Are *architecture-specific* (only work for one specific CPU).

```
; Author: Paul Hsieh
gcd:    neg     eax
        je      L3
L1:     neg     eax
        xchg    eax,edx
L2:     sub     eax,edx
        jg      L2
        jne     L1
L3:     add     eax,edx
        jne     L4
        inc     eax
L4:     ret
```

Figure : GCD for Intel x86

High-level programming languages

- Complex set of instructions and constructions.
- More similar to natural language.
- Easier to read and write. Shorter (in general). *Portable*.

```
int GCD(int a, int b)
{
    while(1)
    {
        a = a % b;
        if(a == 0)
            return b;

        b = b % a;
        if(b == 0)
            return a;
    }
}
```

Figure : GCD in C

How does the computer execute a program?

- Strictly speaking, the CPU only understands 'bytecode' (binary encoded instructions).
- Low-level languages get compiled to bytecode quite easily.

  LL source code → Compiler → Bytecode → CPU → Output
- High-level languages can also be compiled

  HL source code → Compiler → Bytecode → CPU → Output
- and some of them can be *interpreted*! (e.g., Python!)

  HL source code → Interpreter → Output

  An interpreter is a program that translates and executes the code live.

Time for some Python!

- Python is an *interpreted* high-level language.
- It is an *imperative* language but also has some functional features.
- Let's take a look at our first Python program

```
# greetings!
print "Hello World!"

# assign some variables
a = 2
b = 4
c = 3

# print the average
print (a + b + c)/3
```

- How do we run this code? Do it with me...

The Terminal

- In Linux/Mac you can open a *Terminal* to execute commands.
- When you open it, you get something like this:

```
Last login: Sun Nov 18 14:03:53 on ttys002
hostname:folder user$
```

- The '`hostname:folder user$`' part is called the *command prompt*.
- You can use commands to go around your computer.
- These commands are NOT python.

```
hostname:folder user$ ls
subfolder    catvideos    pythonstuff
hw1          hw2
hostname:folder user$ cd subfolder
hostname:subfolder user$ cd ..
hostname:folder user$
```

PS: On Windows you can execute 'cmd' to get a terminal.
Instead of 'ls' you have to use 'dir'.

Executing python code: options

(1) Run the Python interpreter and write this program.

```
hostname:folder user$ python
Python 2.7.8 | (default, Aug 21 2014, 15:21:46)
[GCC 4.2.1 (Apple Inc. build 5577)] on darwin
Type "help", "copyright", "credits" or "license" for more infor
>>>
```

Observe the change of the prompt to >>>!

```
>>> print "Hello World!"
Hello World!
>>> a = 2
>>> b = 4
>>> c = 3
>>> print (a + b + c)/3
3
```

Finally exit the interpreter.

```
>>> exit()
hostname:folder user$
```

Executing python code: options

(2) Write this code in a file and run it in *interactive* mode.

```
hostname:folder user$ ls
subfolder    code.py
hostname:folder user$ python -i code.py
Hello World!
3
>>>
```

You are still inside the interpreter and can check the variables, etc.

(3) Run the code with '`python code.py`'.

```
hostname:folder user$ ls
subfolder    code.py
hostname:folder user$ python code.py
Hello World!
3
hostname:folder user$
```

Values and types

- A program works by manipulating *value*s.
- Values are classified in *types*.

Value	**Type**
$3, 4, 1000$	Integer
`'a', "Hello World", '"Freedom"'`	String
3.141592654	Float
`True, False`	Boolean
$\vdots$	$\vdots$

Figure : Some built-in data types

The `type(·)` function tells you the type of an expression

```
>>> type(3 + 8)
<type 'int'>
```

```
>>> type('stupid example')
<type 'str'>
```

Variables

- *Variables* are names that we assign to values.
- The `=` sign links a value to a variable.
- In Python, variables are created when first assigned a value.

```
n = 3
welcome_message = "Welcome␣aboard!"
```

should be read as $n \mapsto 3$ and `welcome_message` $\mapsto$ `Welcome aboard`.

- Variables can later be used in other expressions

```
>>> print n + 7
10
>>> n = n + 1
>>> print n
4
```

- *Good practice tip*: use meaningful names for variables!
- Watch out: Some names are reserved and can not be used as variable names (aka. reserved keywords).

Numeric types: Integers, floating point and friends

- *Integers* are (relatively) small numbers without a decimal part.
- It is the default type when you write a number without a point.

```
>>> type(2000)
<type 'int'>
```

```
>>> type(-15)
<type 'int'>
```

- They are bounded

```
>>> type(1234567890123)
<type 'long'>
```

```
>>> type(-1234567890123)
<type 'long'>
```

Numeric types: Integers, floating point and friends

- *Long* numbers have "unlimited" precision.
- You specify them by using an `L` suffix.

```
>>> type(2000L)
<type 'long'>
```

- If a number is too big to be an Integer it is interpreted a as Long.

```
>>> type(12345678901)
<type 'long'>
```

- Note: In Python 3.x Integers and Longs have been unified.

Numeric types: Integers, floating point and friends

- *Floats* are an approximation to real numbers.
- You specify them using a dot in the number.

```
>>> type(15.0)
<type 'float'>
```

```
>>> type(-3.141592654)
<type 'float'>
```

- They are also bounded

```
>>> print 0.1234567890123456
0.123456789012
```

Numeric types: operations

- Operations between numeric types include, among others: addition (`+`), subtraction (`-`), multiplication (`*`), division (`/`), exponentiation (`**`), remainder (`%`).
- They are used in *infix* notation: `arg` $\odot$ `arg` .

```
>>> 3 + 2 ** 5 * 4 / 2
```

- Watch out for the precedence in the operations! The expression above is equivalent to...
  1. $3 + 2^{\frac{5 \times 4}{2}}$
  2. $(3 + 2)^{\frac{5 \times 4}{2}}$
  3. $3 + 2^5 \times \frac{4}{2}$
- We use *parenthesis* to group the expressions

```
>>> 3 + (2 ** (5 * 4 / 2))
1027
```

```
>>> (3 + 2) ** (5 * 4 / 2)
9765625
```

Numeric types: operations

- The same symbol may refer to different functions, i.e:

```
>>> 5/2
2
```

in this case $/ : \text{Integer} \times \text{Integer} \rightarrow \text{Integer}$ therefore the answer gets rounded to an integer.

- If we use floats we get what we expected

```
>>> 5.0/2.0
2.5
```

- Which division do we use in the following line? does this work?

```
>>> 5/2.0
```

Yes, in these cases the most general function is used, i.e.:
$/ : \text{Float} \times \text{Float} \rightarrow \text{Float}$

Boolean expressions

- *Booleans* are expressions that can be either true or false.
- The boolean type has two values: `True` and `False`.

```
>>> type(True)
<type 'bool'>
```

```
>>> type(False)
<type 'bool'>
```

- We use comparison operators to form basic expression, e.g.

```
>>> 5 == 5
True
```

```
>>> 'Hello' == 'hello'
False
```

- We have many other operators and we can use them with variables

```
x != y                # x is different to y
x > y                 # x is greater than y
x < y                 # x is less than y
x >= y                # x is greater than or equal to y
x <= y                # x is less than or equal to y
x in y                # x belongs to y (in 'some' sense)
```

Boolean expressions

- We have *logical operators* to form complex expressions

```
not x                    # true iff x is false
x and y                  # true iff x is true and y is true
x or y                   # true iff x is true or y is true
```

- Some examples

```
not x or y
(not x) or y                      # true iff x implies y
```

```
(x or y) and not (x and y)        # exclusive or
```

```
>>> ('lala' in 'shalala') and len('two') == 3
True
```

Debugging

- It is the process of finding and fixing errors in a computer program.

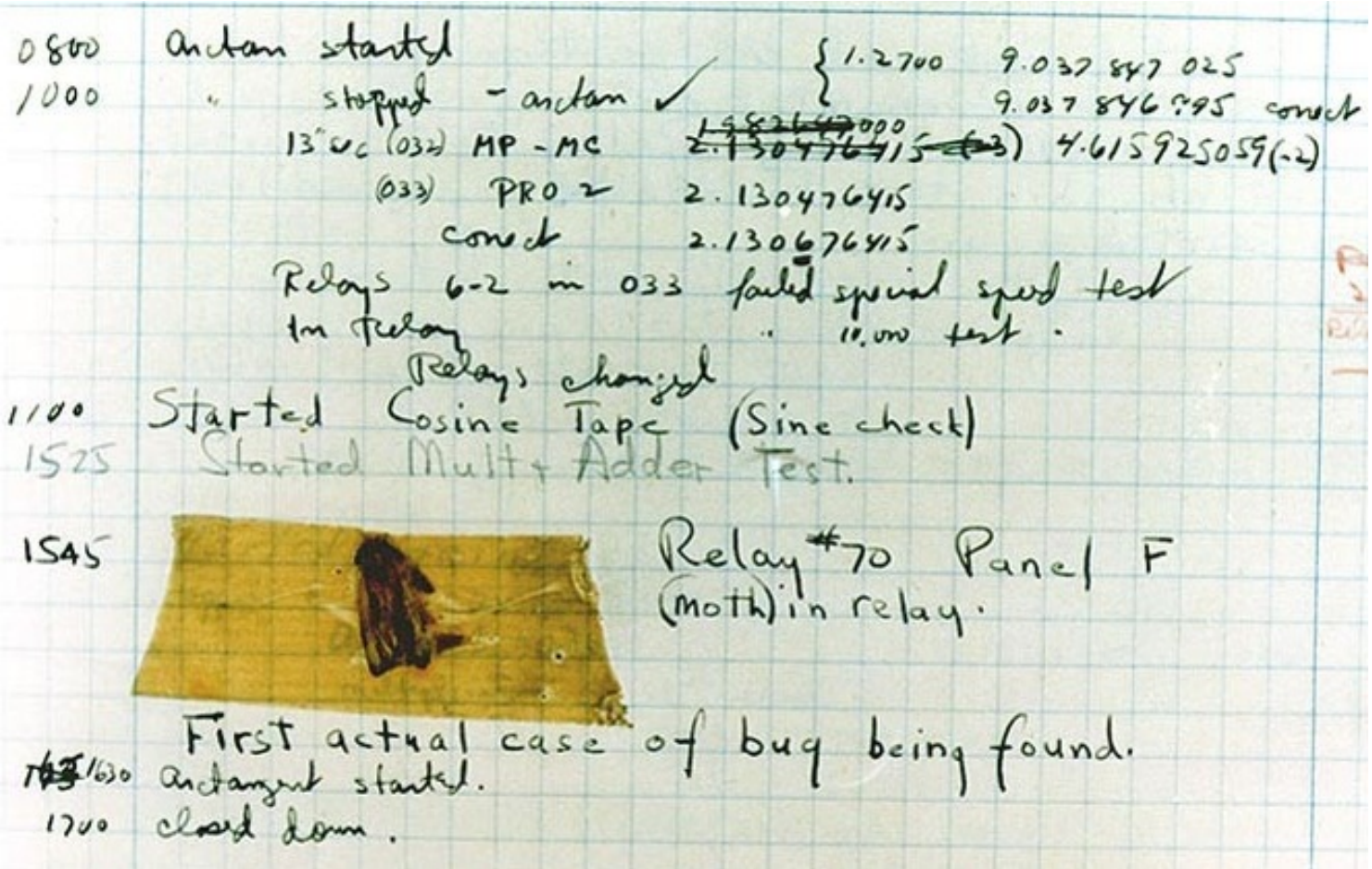


Figure : First computer bug (1947)

Debugging

- *Syntax errors*: Your text is not a valid Python program.

```
>>> n * 5 = 20
  File "<stdin>", line 1
SyntaxError: can't assign to operator
```

- *Runtime errors*: Found during the execution of a program.

```
>>> principal = 327.68
>>> interest = principle * rate
NameError: name 'principle' is not defined
```

```
>>> n = 0
>>> 5555/n
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ZeroDivisionError: integer division or modulo by zero
```

- *Semantic error*: No apparent error yet the program does not do what you want. May be cause, for instance, by
  - Order of operations
  - Wrong assumptions about an operation (e.g. integer division)

References

- Chapters 1 and 2 of the book
  http://greenteapress.com/thinkpython/thinkpython.html
- Python documentation (extremely useful)
  http://docs.python.org/
- Numeric types
  http://docs.python.org/library/stdtypes.html#typesnumeric
- Floating point
  http://docs.python.org/tutorial/floatingpoint.html
- First computer bug
  http://www.history.navy.mil/photos/images/h96000/h96566kc.htm