Lecture #6: Abstraction and Objects

Pig Contest Rules

- The score for an entry is the sum of win rates against every other entry.
- All strategies must be deterministic functions of the current score! Non-deterministic strategies will be disqualified.
- Winner: 3 points extra credit on Project 1
- Second place: 2 points
- Third place: 1 point
- The real prize: honor and glory
- To enter: submit a file pig.py that contains a function called `final_strategy` via the command `submit proj1-contest` by Monday, 2/13.

Decorators: Pythonic Use of Higher-Order Functions

- The syntax

```
@expr
def func(expr):
    body
```

is equivalent to

```
def func(expr):
    body
func = expr(func)
```

- For example, our `ucb` module defines decorator `trace`. After

```
from ucb import trace
@trace
def mysum(x, y):
    return x + y
```

`mysum` will print its arguments and return value each time it is called.

- Usually, *expr* is a simple name, but it can be any expression that takes and returns a function.

Functional Abstraction

Consider two implementations of polynomial evaluation:

```
def quadratic_val(a, b, c, x):
    """The value of A*X**2+B*X+C."""
    return a*x**2 + b*x + c
```

```
def quadratic_val(a, b, c, x):
    """The value of A*X**2+B*X+C."""
    return c + x*(b + x*a)
```

- Both have the same name, signature, and (for integers) values.
- To use them, that's all we need—the implementations are irrelevant.
- There is a *separation of concerns* here:
  - The caller (client) is concerned with providing values of x, a, b, and c and using the result, but *not* how the result is computed.
  - The implementor is concerned with how the result is computed, but not where x, a, b, and c come from or how the value is used.
  - From the client's point of view, `quadratic_val` is an *abstraction* from the set of possible ways to compute this result.
  - We call this particular kind *functional abstraction.*
- Programming is largely about choosing abstractions that lead to clear, fast, and maintainable programs.

Guidelines for Defining Functions (I)

- Each function should have exactly one, logically coherent and well defined job.
  - Intellectual manageability.
  - Ease of testing.
- Functions should be properly documented, either by having names (and parameter names) that are unambiguously understandable, or by having comments (docstrings in Python) that accurately describe them.
  - Should be able to understand code that calls a function without reading the body of the function.
- Don't Repeat Yourself (*DRY*).
  - Simplifies revisions.
  - Isolates problems.

Guidelines for Defining Functions (II)

- Corollary of DRY: Make functions general
  - copy-paste leads to maintenance headaches
- Keep names of functions and parameters meaningful:

Instead of	Use
boolean	turn_is_over
d	dice
helper	take_turn

(Bowling example From Kernighan&Plauger):

Instead of	Use
y	score
L	ball
f	frame

Data Abstraction

- Functions are abstractions that represents computations and actions.
- In the old days, one described programs as hierarchies of actions: *procedural decomposition*.
- Starting in the 1970's, emphasis moved to the data that the functions operate on.
- An *abstract data type* represents some kind of thing and the operations upon it.
- We can usefully organize our programs around the abstract data types in them.
- We could just organize our documentation into sections describing the abstract data types we conceptually use,
- But modern programming languages tend to have specific features and syntax for this purpose: *object-oriented programming*.

Objects in Python

- In Python 3, every value is an object.
- Varieties of object correspond (roughly) to *classes* (*types*).
- Each object has some set of *attributes*, accessible using dot notation, which are values:
  - E.Attr, where E is a simple expression and Attr is a name, means "the current value of the Attr attribute of the value of E."
- Among these attributes are those whose values are a kind of function known as a *method*.
- For historical reasons or convenience, there are often alternative ways to access attributes than dot notation:

x.__add__(y)	add(x, y) or x+y
L.__getitem__(k)	L[k]
x.__len__()	len(x)
x.__eq__(y)	x == y

Primitive Types: Numbers

- A *primitive type* is one that is built into a language, possibly with characteristics or syntax that cannot be written into user-defined types.
- In Python, numbers are such types: have their own literals and internal attributes that are not accessible to the programmer.
- Python distinguishes four types:
  - int: Integers.
  - bool: Limited integers restricted to values that denote true and false.
  - float: A subset of the rational numbers used to approximate real-valued quantities.
  - complex: A subset of the rational complex numbers used to approximate complex-valued quantities.
- Let's look briefly at one of them: float.

Floating-point

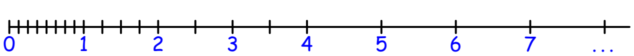
- It would be nice if we could represent general real arithmetic efficiently, but we can't.
- Even if we restrict ourselves to the rationals, simple computations can become quite slow (denominators can grow exponentially).
- Since we don't usually need absolute accuracy, floating-point was devised as a compromise.
- Typically, (i.e., according to the IEEE Floating-point standard, to which Berkeley faculty (Prof. Kahan) made major contributions), the floating-point numbers are the set

  $$\{\pm s \cdot 2^e \mid 0 \leq s < 2^{53}, \ -1023 \leq e + 53 \leq 1024\} \cup \{\pm\infty, -0, \ldots\}$$

  allowing us to represent numbers with maximum magnitude up to 2^{1024} and non-zero magnitudes as small as 2^{-1074}.
- s is the *significand*, e is the *exponent*.

Floating-point Approximation Visualized

- To make things manageable, suppose we restrict s to the range 0–3, and e to the range -3 to 1
- Then the set of positive floating-point numbers would look like this on a number line:



- Numbers get farther apart for larger magnitudes.
- Arithmetic results on these numbers that fall between the represented numbers are *rounded* to a represented number. (Therein lies much confusion.)
- Although this means that the approximation error increases for larger numbers, the *relative error*—ratio of the error in an approximated number to the magnitude of the number—does not, which is the reason for choosing the floating-point representation.
- Also means that the number of *significant digits* (more precisely, significant bits) remains about the same.