Defining Your Own Types

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Programming for Scientists

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User-Defined Types

Built-in Types

1. lists
2. dictionaries
3. strings
4. ...

Type

What's a Type

1. A domain of values
2. A set of methods (functions)

Examples of Types

List

1. Domain: lists
2. Functions: L.append(e),L.insert(idx,e), ...
3. Operators: L[0], 'Rita' in L

Examples of Types

List

1. Domain: lists
2. Functions: L.append(e),L.insert(idx,e), ...
3. Operators: L[0], 'Rita' in L

Integer

1. Domain: $\ldots, -2, 1, 0, 1, 2, \ldots$
2. Operators: A + B,...

User-defined Types

Object-oriented programming languages allow us to define new types.

Motivating Example

Simple Population Simulation

1. We want to simulate a bacterial population.
2. Our environment is a single float e.
3. Each bacterium has two characteristics: adaptation α and mutation rate σ.
4. The smaller the difference $|\alpha - \mathrm{e}|$, the better an bacterium is adapted to the world.
5. When an bacterium reproduces, its offspring has adaptation $\alpha + \mathcal{N}(0, \sigma)$
6. At each iteration:
    1. Bacteria die with a probability given by $\lambda \exp(-\lambda|\alpha - \mathrm{e}|)$
    2. Bacteria that survive, sometimes reproduce.

Bacteria World

Bacterium Class

We define a bacterium class, with two values:

1. adaptation: its current adaptation value
2. sigma: its variability parameter

and two methods:

1. P_dead(environ): make a stochastic decision on whether the bacteriumdies
2. reproduce(): make a new bacterium, derived from current one

Using our Bacteria

```
population = [Bacterium(random(),random())
        for i in xrange(nr_inital_bacteria)]
for i in xrange(max_iters):
    bi = 0
    while bi < len(population):
        if population[bi].P_dead(environ) < random():
            del population[bi]
        else:
            bi += 1
    N = len(population)
    for bi in xrange(N):
        if random() < p_reprod:
            population.append(population[bi].reproduce())
    if N >= max_population:
        shuffle(population)
        while len(population) >= max_population:
            population.pop()
```

Using our Bacteria

```
...
DeltaAdaptation = [math.abs(environ-b.adaptation)
                    for b in population]
Sigmas = [b.sigma for b in population]
hist(Sigmas)
```

Classes As Logical Units

Class

A class aggregates data and functions that belong together.

Bacterium Interface

Interface

Functions:

1. Constructor: Takes the initial adaptation value and sigma.
2. P_dead(environ): Probability of dying in this environment.
3. reproduce(): Return a new Bacterium.

Data elements:

1. adaptation: Current adaptation.
2. sigma: Current sigma.

```python
class Bacterium(object):
    '''
    Bacterium

    ...
    '''
    def __init__(self,adaptation,sigma):
        self.adaptation = adaptation
        self.sigma = sigma

    def P_dead(self,environ):
        '''
        prob = bact.P_dead(environ)

        ...
        '''
        return L*math.exp(-abs(self.adaptation-environ)*L)
    def reproduce(self):
        '''...'''
        return Bacterium(self.adaptation +
                            normalvariate(0,self.sigma),
                            self.sigma)
    ...
```

Calling Methods

Defining a method

```
class Bacterium(object):
    ...
    def method(self,arg1,arg2):
        '''...'''
        ...
```

Calling a Method

```
anim = Bacterium(random(),random())

anim.method(arg1,arg2)
```

Object Oriented Programming

OOP

Aggregation organise functions & data into classes.

Encapsulation hide information inside methods.

Polymorphism re-use code for multiple types.

Inheritance re-use code from one class to build another.

Simulation of Changing Bacteria

Why should only adaptation change? Why not sigma too?

Evolving Bacterium

```
class EvolveSigmaBacterium(object):
    '''...'''
    def __init__(self,adapt,sigma,sigmafact):
        self.adaptation = adapt
        self.sigma = sigma
        self.sigmafact = sigmafact

    def P_dead(self,environ):
        '''...'''
        return L*math.exp(-
                math.abs(self.adaptation-environ)*L)

    def reproduce(self):
        '''...'''
        return EvolveBacterium(
            self.adaptation + normalvariate(0,self.sigma),
            self.sigma + normalvariate(0,self.sigma*self.sig
            self.sigmafact)
```

```python
population = [EvolveSigmaBacterium(random(),random(),0.5)
        for i in xrange(nr_inital_bacteria)]
for i in xrange(max_iters):
    bi = 0
    while bi < len(population):
        if population[bi].P_dead(environ) < random():
            del population[bi]
        else:
            bi += 1
    N = len(population)
    for bi in xrange(N):
        if random() < p_reprod:
            population.append(population[bi].reproduce())
    if N >= max_population:
        shuffle(population)
        while len(population) >= max_population:
            population.pop()
```

Mixing populations

We can have a mixed population of σ-fixed and σ-changing bacteria!

```
population = [EvolveSigmaBacterium(random(),random(),0.5)
        for i in xrange(nr_inital_bacteria//2)] + \
        [Bacterium(random(),random())
        for i in xrange(nr_inital_bacteria//2)]

for i in xrange(max_iters):
    bi = 0
    while bi < len(population):
        if population[bi].P_dead(environ) < random():
            del population[bi]
        else:
            bi += 1
    N = len(population)
    for bi in xrange(N):
        if random() < p_reprod:
            population.append(population[bi].reproduce())
    if N >= max_population:
        shuffle(population)
        while len(population) >= max_population:
            population.pop()
```

Polymorphism

Type Polymorphism

Code is polymorphic if it can use different types without change

Duck Typing

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Typical Polymorphism

Typical examples

- Actors in a simulation.
- File-like objects.
- Widgets.
- ...

Inheritance

The code for EvolveSigmaBacterium is very similar to the code for Bacterium.

```
class EvolveSigmaBacterium(Bacterium):
    '''
    A type of Bacterium, where $\sigma$ (which controls
    the rate of adaptative mutation) is itself subject
    to mutation (subject to sigma*sigmafact).

    Methods
    -------
        * Constructor:
        * P_dead(environ): inherited from Bacterium
        * reproduce():
    '''
    def __init__(self,adaptation,sigma,sigmafact):
        Bacterium.__init__(self,adaptation,sigma)
        self.sigmafact = sigmafact
    def reproduce(self):
        '''...'''
        return EvolveSigmaBacterium(
            self.adaptation + normalvariate(0,self.sigma),
            self.sigma + normalvariate(0,self.sigma*self.sig
            self.sigmafact)
```

Lyskov Substitution Principle

If D inherits from C, then
you should be able to use D anywhere you previously used C.

Behaves-Like

If D inherits from C, then
D should behave-like C.

New-Style vs. Old-Style Classes

```python
class Bacterium(object):
    ...
```

Are we inheriting from object?

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