Lecture 17: Mutable Linked Lists

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July 20, 2016
Announcements

• Homework 6 is due today at 11:59pm
• Project 3 is due 7/26 at 11:59pm
  • Earn 1 EC point for completing it by 7/25
• Quiz 5 tomorrow at the beginning of lecture
  • May cover mutability, OOP I (Monday)
• Project 1 revisions due 7/27 at 11:59pm
This week (Objects), the goals are:

- To learn the paradigm of object-oriented programming
- To study applications of, and problems that be solved using, OOP
Practical OOP
Checking Types (and Accounts)  (demo)

- We often check the type of an object to determine what operations it permits.
- The `type` built-in function returns the class that its argument is an instance of.
- The `isinstance` built-in function returns whether its first argument (object) is an instance of the second argument (class) or a subclass.
- `isinstance(obj, cls)` is usually preferred over `type(obj) == cls`.

```python
>>> a = Account('Brian')
>>> ch = CheckingAccount('Brian')

>>> type(a) == Account
True

>>> type(ch) == Account
False

>>> type(ch) == CheckingAccount
True

>>> isinstance(a, Account)
True

>>> isinstance(ch, Account)
True

>>> isinstance(a, CheckingAccount)
False

>>> isinstance(ch, CheckingAccount)
True
```
Python's Magic Methods

- How does the Python interpreter display values?
  - First, it evaluates the expression to some value
  - Then, it calls repr on that value and prints that string
- How do magic methods work?
- Are integers objects too? (Yep!)
- Are ___ objects too? (Yep!)

```python
>>> x = Rational(3, 5)
>>> y = Rational(1, 3)
>>> y
Rational(1, 3)
>>> repr(y)
'Rational(1, 3)'
>>> print(repr(y))
Rational(1, 3)
>>> x * y
Rational(1, 5)
>>> x.__mul__(y)
Rational(1, 5)
```
Linked Lists
The Link Class

```python
class Link:
    empty = ()

    def __init__(self, first, rest=empty):
        self.first = first
        self.rest = rest

def link(first, rest=empty):
    return [first, rest]

def first(lnk):
    return lnk[0]

def rest(lnk):
    return lnk[1]

>>> link_adt = link(1, link(2, link(3)))

>>> first(rest(link_adt))
2

>>> link_cls = Link(1, Link(2, Link(3)))

>>> link_cls.rest.first
2
```
Mutable Linked Lists

• Instances of user-defined classes are mutable by default

```python
class Link:
    empty = ()

    def __init__(self, first, rest=empty):
        self.first = first
        self.rest = rest

    def __repr__(self):
        if self.rest is Link.empty:
            return 'Link({0})'.format(self.first)
        else:
            return 'Link({0}, {1})'.format(self.first, repr(self.rest))
```
Linked Lists are Sequences (demo)

class Link:
    empty = ()
    ...

def __getitem__(self, i):
    if i == 0:
        return self.first
    elif self.rest is Link.empty:
        raise IndexError('...')
    else:
        return self.rest[i - 1]

def __len__(self):
    return 1 + len(self.rest)

Sneaky recursive call: equivalent to self.rest.__getitem__(i-1)

Another sneaky recursive call: equivalent to self.rest.__len__()?

Where's the base case??
The \_setitem\_ Magic Method (demo)

```python
>>> s = Link(1, Link(2, Link(3)))
>>> s[1] = 3
>>> s
Link(1, Link(3, Link(3)))
```

```python
class Link:
...

def \_setitem\_(self, i, val):
    if i == 0:
        self.first = val
    elif self.rest is Link.empty:
        raise IndexError('...')
    else:
        self.rest[i - 1] = val
```
Mutating Map  (demo)

```python
class Link:
    ...

def map(self, f):
    for i in range(len(self)):
        self[i] = f(self[i])
```

```python
>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
>>> s
Link(1, Link(4, Link(9)))
```

Runtime?
Mutating Map

>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
>>> s
Link(1, Link(4, Link(9)))

class Link:
    ...
    def __getitem__(self, i):
        if i == 0:
            return self.first
        else:
            return self.rest[i - 1]

def map(self, f):
    for i in range(len(self)):
        self[i] = f(self[i])

θ(n²)
Mutating Map (Improved)

```python
class Link:
    ...

    def map(self, f):
        self.first = f(self.first)
        if self.rest is not Link.empty:
            self.rest.map(f)

>>> s = Link(1, Link(2, Link(3)))
>>> s.map(lambda x: x * x)
>>> s
Link(1, Link(4, Link(9)))
```

Runtime? \(\theta(n)\)
contains and in (demo)

class Link:
    ...
    def __contains__(self, e):
        return self.first == e or e in self.rest

>>> s = Link(1, Link(2, Link(3)))
>>> 2 in s
True
>>> 4 in s
False
Break!
Environments
Environment Frames

• An environment is a sequence of frames
  • Each frame has some data (bindings) and a parent, which points to another frame
• A linked list is a sequence of values
  • Each link has some data (first) and a rest, which points to another link
• An environment is just a special case of a linked list!
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• An environment is just a special case of a linked list!
The Call Stack

• A stack is a data structure that permits two operations
  • Add to the top of a stack ("push")
  • Remove from the top of a stack ("pop")

• Two new Link operations required: insert_front and remove_front

• A call stack keeps track of frames that are currently open
  • Calling a function adds a new frame to the stack
  • Returning from a function removes that frame from the stack
  • The current frame is always on the top of the stack
Python
What if we could have Python functions use the environment frames and the call stack that we just defined?

Two important parts:

- What should happen when defining a Brython function?
- What should happen when calling a Brython function?

A different Brython: [http://brython.info/](http://brython.info/)
Function Definitions

• What happens in a function definition?
  • Determine the current frame of execution: this is the function's parent frame
  • Bind the function name to the function value
Function Calls

What happens in a function call?

- Create a brand new call frame (using the function parent as the parent of that frame) and insert it into the stack
- Bind function's parameters to arguments
- Execute the function in the environment of the call frame
  - Remember: the current frame is at the top of the stack
- After executing the function, remove the frame from the stack
Summary

• Linked lists are one way to store sequential data

• An object–based implementation of the linked list abstraction allows for easy mutability
  
  • No more crazy nonlocal stuff!

• Implementing magic methods lets us hook into convenient Python syntax and built–in functions

• Linked lists can be used to implement some of the core ideas of this course!