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What's New in Python 2.2

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Overview

- Appetizers
  - Nested Scopes
  - Int/Long Unification
  - Integer Division
- First Course
  - Iterators
  - Generators
- Second Course
  - Type/Class Unification
- Dessert
  - Metaclass Programming

Nested Scopes

- Motivation:
  - functions inside functions need to access outer locals
- Optional in 2.1
  - from __future__ import nested_scopes
- Standard in 2.2
  - Can't turn it off (__future__ statement still allowed)
- Only issue to watch out for:
  - def f(*str*):
        def g(x): print *str*(x)
        ...
  - In 2.1, *str* argument independent from *str*() function
  - In 2.2, *str* inside g() references outer *str*

Int/Long Unification

- 2**1000 no longer raises OverflowError
  - but returns the appropriate long (no 'L' needed!)
- Ditto for:
  - 1000000*1000000
  - sys.maxint + 1
  - 1000000000000000000000000
- But:
  - 1<<100 is still zero
  - repr(2**1000) still ends in 'L'
  - hex(), oct(), %x, %o, %u differ for int vs. long
  - These will change in 2.3 or 3.0

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Integer Division

- Motivation:
  - x/y computes different thing for ints than for floats
    - This is **unique** among operators, and **confusing**
  - def velocity(dist, time): return dist/time
    - Lack of type declarations makes this hard to debug
- Solution:
  - x//y new, "floor division": always truncates (to -Inf)
  - x/y unchanged, "classic division"
  - from __future__ import division
    - x/y returns "true division": always a float value
- In Python 3.0, x/y will be true division
  - Use Tools/scripts/fixdiv.py tool for conversion help

Iterators

- Motivation:
  - Generalized for loop innards, doing away with index
- Iterator abstracts **state** of for loop
  - Sequence may be a *"real"* sequence (e.g. a list)
  - Or a *"virtual"* sequence (e.g. the nodes of a tree)
- Most iterator calls are implied by for loops
  - For loop gets items one at a time from *next()*
  - Exception *StopIteration* signals end of sequence
- You *can* also call next() explicitly

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Iterator API

- t = iter(obj) returns a (new) iterator for obj
  - Calls t = obj.__iter__(); obj must provide __iter__
- t.next() returns the next value
  - Raises StopIteration when there is no next value
    - Alternatives rejected (t.end(), if t, t.next() == None)
- The iterator should be a separate object
  - Allow for multiple iterations over the same object
    - e.g. nested loops, multiple threads, nested calls
- But when t is an iterator:
  - iter(t) is t
  - This is handy with "for x over <iterator>: ..."

The 'for' Loop

- for x in obj: f(x)
  is now translated (roughly) as follows:
- ```
  t = iter(obj)
  while 1:
      try:
          x = t.next()
      except StopIteration:
          break
      f(x)
  ```
  ```

Built-in Iterators

- for item in sequence: ... # nothing new :-)
- for line in file: ... # most efficient way!
- for key in dict: ... # must not modify dict!
  - for key, value in dict.iteritems(): ...
  - (unrelated but also new: if key in dict: ...)
- for val in iter(callable, endval): ...
  - while 1:
    ```
    while 1:
        val = callable()
        if val == endval: break
        ...
    ```
  - Example: iter(file.readline, "")

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Generators

- Motivation:
  - Function to produce a sequence, one item at a time
    - State represented by local variables and/or PC
    - Using an object is overkill or inconvenient
- Example:
  - from __future__ import generators
  - def fibonacci(a=1, b=1):
    ```
    def fibonacci(a=1, b=1):
        while 1:
            yield a
            a, b = b, a+b
    ```
  - t = fibonacci() # t is an iterator!
  - for i in range(10): print t.next()

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How Does It Work?

- Stack frame is created in **suspended** state
  - Arguments in place, but no byte code executed yet
- t is a wrapper pointing to the suspended frame
  - t supports the iterator interface
- Calling t.next() **resumes** the stack frame
  - Execution continues where it left off previously
- A yield statement **suspends** the stack frame
  - Yield "argument" is the returned from t.next()
- An exception **terminates** the stack frame
  - Propagates out normally
  - Return (or falling through) raises StopIteration

Examples: "Iterator Algebra"

- ```
  def alternating(a):
      ta = iter(a)
      while 1:
          ta.next(); yield ta.next()
  ```
- ```
  def zip(a, b):
      ta = iter(a); tb = iter(b)
      while 1:
          yield (ta.next(), tb.next())
  ```
- ```
  for x, y in zip("ABC", "XYZ"):
      print x+y
  ```
- For a real-life example, see tokenize.py

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  ```

Type/Class Unification

- Subclassing built-in types like dict or list
- "Cast" functions are now types, acting as factories
- Built-in objects have __class__, types have __dict__
- Overriding __getattr__()
- Descriptors and the __get__() operation
- property()
- classmethod(), staticmethod()
- super() and the new method resolution order (MRO)
- Subclassing immutable types: __new__()
- Performance hacks: __slots__
- Metaclasses

Subclassing Built-ins

- ```
  class mydict(dict):
      def keys(self):
          K = dict.keys(self)
          K.sort()
          return K
  ```
- ```
  class mylist(list):
      def __sub__(self, other):
          L = self[:]
          for x in other:
              if x in L: L.remove(x)
          return L
  ```
- These are "new-style" because of their base classes
- Note: **self is an instance of the base class**; the subclass is not a wrapper like UserDict or UserList

"Cast" Functions

- These built-ins are now types instead of factory functions (with the same signature):
  - int, long, float, complex
  - str, unicode
  - tuple, list
  - open (now an alias for file)
  - type
- These are new as built-in names:
  - dict, file
  - **object**: the universal base class (new-style)
- Useful new idiom: if isinstance(x, file) etc.

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Unified Introspection

- obj.__class__ == type(obj)
  - Exception for unconverted 3rd party extension types
- Types have __dict__, __bases__
- All methods and operators shown in __dict__
  - E.g. list.__dict__ contains 'append', '__add__' etc.
  - list.append is an "unbound method":
    - list.append(a, 12) same as a.append(12)
    - list.append.__doc__ yields the doc string
- list.__bases__ == (object,)
- list.__class__ is type

Overriding __getattribute__

-
```
class mylist(list):
    def __getattribute__(self, name):
        try:
            return list.__getattribute__(self, name)
        except AttributeError:
            return "Hello World"
```
- The __getattribute__ method is **always** called
  - Not just when the attribute isn't found
  - Classic __getattr__ also available on new-style classes
- Do not use self.__dict__[name]
  - Call the base class __getattribute__ or __setattr__

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Descriptors

- Generalization of unbound methods
  - Used by new-style object getattr, setattr
  - Also by classic instance getattr
- Descriptor protocol: __get__(), __set__(), __delete__()
- *descr*.__get__*(object)* is **binding** operation
  - invoked by getattr when descriptor found in class
  - e.g. function or unbound method -> bound method
- *descr*.__get__(None, *class*): *unbound* method
- *descr*.__set__*(object*, *value*)
  - invoked by setattr when descriptor found in class
- __get__() is also used by classic classes!

Properties

- class C(object):
```
    def get_x(self): return self.__x
    def set_x(self, value): self.__x = value
    x = property(get_x, set_x, doc="...")
```
- a = C()
- a.x # invokes C.get_x(a)
- a.x = 1 # invokes C.set_x(a, 1)
  - Descriptor overrides attribute assignment
- C.x.__doc__ == "..."
- You can leave out set_x, or add del_x

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Static Methods

- class C:
```
class C:
    def spawn():
        return C()
    spawn = staticmethod(spawn)
```
- c1 = C. spawn()
- c2 = c1.spawn()
- Use is just like in Java
- Syntax is ugly, provisional
  – Python 2.3 may bring new syntax

Class Methods

- *[Skip if running out of time]*

- Similar to static methods, but get class arg:
- class C:
```
class C:
    def spawn(cls):
        return cls()
    spawn = classmethod(spawn)
```
- class D(C): pass
- c1 = C.spawn(); c2 = c1.spawn()
- d1 = D.spawn()

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Superclass Method Calls

- class A(object):
```
class A(object):
    def save(self, f):
        "save state to file f"
        ...
```
- class B(A):
```
class B(A):
    def save(self, f):
        super(B, self).save(f)
        # instead of A.save(self, f)
        ...
```
- Motivation: see following slides
- Verbose syntax: may be fixed later

Cooperative Methods

- Now it gets interesting:
- class C(A):

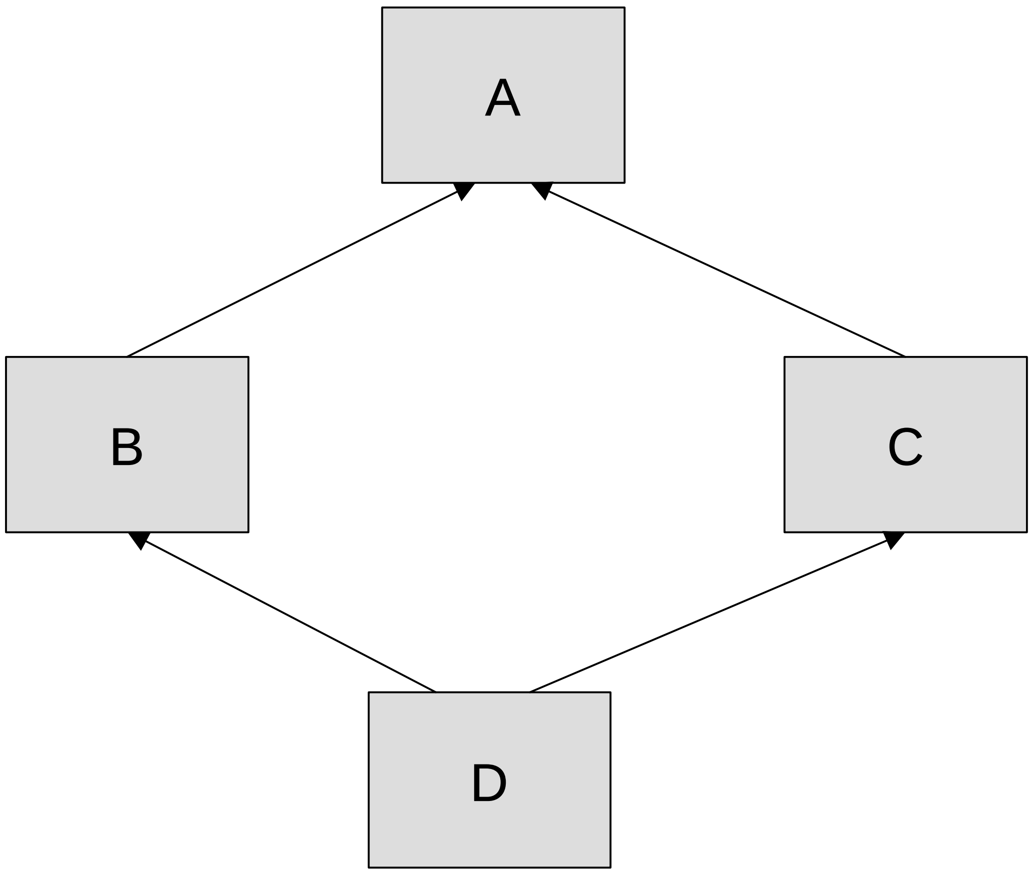
```
class C(A):
    def save(self, f):
        super(C, self).save(f)
        ...
```

- class D(B, C):

```
class D(B, C):
    def save(self, f):
        super(D, self).save(f)
```

- D().save(f)
  - D.save() -> B.save() -> C.save() -> A.save() !!!
  - This will be explained shortly :-)

Diamond Diagram



...But How...?!?!

- How does super(B, self).save(f) know to call C.save(f) when self is a D instance?!?!
- Answer: linearized MRO stored as D.__mro__
  - MRO = Method Resolution Order (see next slide)
- D.__mro__ == (D, B, C, A)
- super(B, self).save looks for B in self.__mro__ and looks for save in classes following it
  - It searches (C, A) for save
    - Specifically it looks for C.save and A.save in that order

Method Resolution Order

- Used for method lookup in new-style classes
- Compare to classic MRO:
  - classic MRO: left-to-right, depth-first (D, B, A, C, A)
  - new MRO removes duplicates **from the left**
- Motivation:
  - In diamond diagram, C.save should override A.save
    - If B and D don't define save, D.save should find C.save
  - This is more important because of 'object'
    - The universal base class for all new-style classes

Immutable Types

- Override __new__ instead of __init__
- __new__ is a static method with a class arg!
- tuple(arg) calls tuple.__new__(tuple, arg)
- class mytuple(tuple):

  ```
  class mytuple(tuple):
      def __new__(cls, *args):
          return tuple.__new__(cls, args)
  ```
- t = mytuple(1, 2, 3)

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__slots__

- Allocates instance variables in the object structure instead of using a pointer to a __dict__; saves a lot of space
- class C(object):
```
class C(object):
    __slots__ = ['foo', 'bar']
    def __init__(self, x, y):
        self.foo = x; self.bar = y
```
- c1 = C(1, 2)
- c1.spam = 12 **# error**

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Incompatibilities

- dir() behaves differently
  - shows instance variables **and** methods
  - shows methods from base classes as well
  - exceptions:
    - dir(*module*) returns only __dict__ contents
    - dir(*class_or_type*) doesn't look in the metaclass
- type("").__name__ == "str" # was "string"
- type(1L).__name__ == "long" # "long int"

Metaclass Programming

- class autosuper(type):
```
class autosuper(type):
    def __init__(cls, name, bases, dict):
        attrname = '_%s__super' % name
        setattr(cls, attrname, super(cls))
```
- class myclass(object):
```
class myclass(object):
    __metaclass__ = autosuper
    def foo(self):
        self.__super.foo()
        ...etc...
```
- myclass.__class__ is autosuper

Questions

- Now or never :-)