


UC Berkeley EECS
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Computational Structures in Data Science

Lecture #11: More on Object-Oriented Programming and Exceptions

Nov 18, 2019 <http://inst.eecs.berkeley.edu/~cs88>

1




Computational Concepts Toolbox

- Data type: values, literals, operations,
- Expressions, Call expression
- Variables
- Assignment Statement
- Sequences: tuple, list
- Dictionaries
- Data structures
- Tuple assignment
- Function Definition Statement
- Conditional Statement
- Iteration: list comp, for, while
- Lambda function expr.
- Higher Order Functions
 - Functions as Values
 - Functions with functions as argument
 - Assignment of function values
- Higher order function patterns
 - Map, Filter, Reduce
- Function factories – create and return functions
- Recursion
- Abstract Data Types
- Mutation
- **Class**
 - Object Oriented Programming
 - Inheritance
- **Exceptions**

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2




Administrative Issues

- Project 2 “Wheel” goes out soon
 - Discussion in lab
- Reading: (2.5-7), 2.9 , exceptions: 3.3

Notebooks from L09+L10: <http://bit.ly/cs88-fa18-l09>

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3




Today:

- Review Class concept
- Using class to create and manipulate objects
- Inheritance to specialize a class
 - Create subtypes of the object type
- Exceptions
 - Unprogrammed control transfers to catch unusual situations or errors
 - How they arise
 - How to handle exception
 - How to raise your own

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4



Review: Python class


```
class <ClassName>:
    def <method-1>(self, ..)
        self.<instance_attr> = ...
    .
    .
    .
    def <method-N>
```

<https://docs.python.org/3/tutorial/classes.html>

Class names should normally use the **CapWords** convention.
<https://www.python.org/dev/peps/pep-0008/>

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5



Creating an object, invoking a method

The Class Constructor

```
my_acct = Account ("David Culler", 93)
my_acct.withdraw(42)
```

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6

Review: class example

```
class Account:
    # Class attributes outside and class defs
    _account_number_seed = 1000  # class attributes
    # Constructor
    def __init__(self, name, initial_deposit):
        # Initialize the instance attributes
        self.name = name  # The object
        self.acct_no = Account._account_number_seed  # private instance attributes, dot notation
        Account._account_number_seed += 1
        self.balance = initial_deposit
        # Return None
    # Selectors
    def account_name(self):
        return self.name
    def account_number(self):
        return self.acct_no
```

object namespace

Methods

class attributes, dot notation

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7

7

Inheritance

- Define a class as a specialization of an existing class
- Inherent its attributes, methods (behaviors)
- Add additional ones
- Redefine (specialize) existing ones
 - Ones in superclass still accessible in its namespace

```
class ClassName ( <inherits> ):
    <statement-1>
    .
    .
    <statement-N>
```

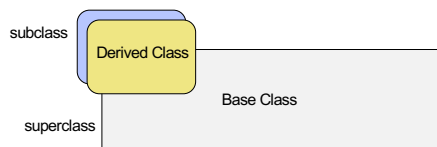
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8

8

Inheritance



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9

9

Example

```
class CheckingAccount(Account):
    def __init__(self, name, initial_deposit):
        # Use superclass initializer
        Account.__init__(self, name, initial_deposit)
        # Additional initialization
        self._type = "Checking"
    def account_type(self):
        return self._type
    # Display representation
    def __repr__(self):
        return '<' + str(self.account_type()) + 'Account:...'
```

Attribute in subclass, not in superclass

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10

10

Another Example

```
class SavingsAccount(Account):
    interest_rate = 0.02
    def __init__(self, name, initial_deposit):
        # Use superclass initializer
        Account.__init__(self, name, initial_deposit)
        # Additional initialization
        self._type = "Savings"
    def account_type(self):
        return self._type
    def accrue_interest(self):
        self.balance = self.balance *
            (1 + SavingsAccount.interest_rate)
```

Methods in subclass, not in superclass

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11

11

Classes using classes

```
class Bank:
    _accounts = []
    def add_account(self, name, account_type, initial_deposit):
        if account_type == 'Savings':
            new_account = SavingsAccount(name, initial_deposit)
        elif account_type == 'Checking':
            new_account = CheckingAccount(name, initial_deposit)
        else:
            assert True, "Bad Account type: " + account_type
            assert initial_deposit > 0, "Bad deposit"
        Bank._accounts.append(new_account)
        return new_account
    def accounts(self):
        return self._accounts[:]
    def show_accounts(self):
        for acct in self.accounts():
            print(acct.account_number(), acct.account_type(),
                  acct.account_name(), acct.account_balance())
```

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12

12

Key concepts to take forward

- Classes embody and allow enforcement of ADT methodology
- Class definition
- Class namespace
- Methods
- Instance attributes (fields)
- Class attributes
- Inheritance
- Superclass reference

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13

13

Additional examples

- Redesign our KV as a class
- How should “new KV” vs mutation be handled
- Inheritance and “new object” in superclass

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14

14

KV as a true object

```
class KV:
    """Key-Value container abstraction: a collection of key-value pairs"""
    def __init__(self, kv_pairs=[]):
        self._kv = []
        for (key, val) in kv_pairs: # Verify and initialize
            assert (type(key) == str) # the key should be a string
            self._kv.append((key, val))

    def items(self):
        """Return a list of the (key, value) pairs in kv."""
        return self._kv

    def get(self, key):
        """Return the value bound to key in kv, or None if not present."""
        for k, v in self.items():
            if k == key:
                return v
        return None

    def keys(self):
        """Return a list of the keys in kv"""
        return [key for (key, val) in self.items()]

    def values(self):
        """Return a list of the values in kv"""
        return [val for (key, val) in self.items()]

    def add(self, key, value):
        """Return a new KV adding binding (key, value)"""
        return KV([(key, value)] + self.items())

    def delete(self, key):
        """Return a new KV having removed any binding for key"""
        return KV([(k, v) for (k, v) in self.items() if k != key])
```

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15

15

Class methods

- Defined on the class
 - rather than objects of the class
 - Like class attributes
- Indicated by @classmethod
 - Take a class argument, rather than self

```
class KV:
    """Key-Value container abstraction: a collection of key-value pairs such that kv_get(kv, key) returns the value"""
    def __init__(self, kv_pairs=[]):
        self._kv = []
        for (key, val) in kv_pairs: # Verify and initialize
            assert (type(key) == str) # the key should be a string
            self._kv.append((key, val))

    @classmethod
    def create(cls, kv_pairs=[]):
        return cls(kv_pairs)
```

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16

16

Inheritance Example

```
class KVnodup(KV):
    def __init__(self, kv_pairs=[]):
        self._kv = []
        for (key, val) in kv_pairs: # Verify that initialization is valid
            assert type(key) == str # the key should be a string
            if not key in self:
                self._kv.append((key, val))
```

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17

17

Subclass type

Explicit use of class constructor – interferes with inheritance

```
def add(self, key, value):
    """Return a new KV adding binding (key, value)"""
    return KV([(key, value)] + self.items())
```

Use type(self) as constructor to maintain inherited type

```
def add(self, key, value):
    """Return a new KV adding binding (key, value)"""
    return type(self)([(key, value)] + self.items())
```

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18

18

Exception (read 3.3)

- Mechanism in a programming language to declare and respond to “exceptional conditions”
 - enable non-local continuations of control
- Often used to handle error conditions
 - Unhandled exceptions will cause python to halt and print a stack trace
 - You already saw a non-error exception – end of iterator
- Exceptions can be handled by the program instead
 - assert, try, except, raise statements
- Exceptions are objects!
 - They have classes with constructors

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19

19

Handling Errors

- Function receives arguments of improper type?
- Resource, e.g., file, is not available
- Network connection is lost or times out?



Grace Hopper's Notebook, 1947, Moth found in a Mark II Computer

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20

20

Example exceptions

```
>>> 3/0
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ZeroDivisionError: division by zero
>>> str.lower(1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: descriptor 'lower' requires a 'str' object
but received a 'int'
>>> "[2]"
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
>>>
```

notebook

- Unhandled, “thrown” back to the top level interpreter
- Or halt the Python program

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21

21

Functions

- Q: What is a function supposed to do?
- A: One thing well
- Q: What should it do when it is passed arguments that don't make sense?

```
>>> def divides(x, y):
...     return y%x == 0
...
>>> divides(0, 5)
???

>>> def get(data, selector):
...     return data[selector]
...
>>> get({'a': 34, 'cat': '9 lives'}, 'dog')

???
```

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22

22

Exceptional exit from functions

```
>>> def divides(x, y):
...     return y%x == 0
...
>>> divides(0, 5)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in divides
ZeroDivisionError: integer division or modulo by zero
>>> def get(data, selector):
...     return data[selector]
...
>>> get({'a': 34, 'cat': '9 lives'}, 'dog')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in get
KeyError: 'dog'
>>>
```

- Function doesn't “return” but instead execution is thrown out of the function

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23

23

Continue out of multiple calls deep

```
def divides(x, y):
    return y%x == 0
def divides24(x):
    return divides(x, 24)
divides24(0)

ZeroDivisionError: integer division or modulo by zero
Traceback (most recent call last):
  <ipython-input-14-ad26ce8ae76a> in <module>()
    3 def divides24(x):
    4     return divides(x, 24)
----> 5 divides24(0)

<ipython-input-14-ad26ce8ae76a> in divides24(x)
    2     return y%x == 0
    3 def divides24(x):
----> 4     return divides(x, 24)
    5 divides24(0)

<ipython-input-14-ad26ce8ae76a> in divides(x, y)
    1 def divides(x, y):
----> 2     return y%x == 0
    3 def divides24(x):
    4     return divides(x, 24)
    5 divides24(0)

ZeroDivisionError: integer division or modulo by zero
```

- Stack unwinds until exception is handled or top

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24

24

Types of exceptions

- **TypeError** -- A function was passed the wrong number/type of argument
- **NameError** -- A name wasn't found
- **KeyError** -- A key wasn't found in a dictionary
- **RuntimeError** -- Catch-all for troubles during interpretation
- ...

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25

25

Demo

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26

26

Flow of control stops at the exception

- And is 'thrown back' to wherever it is caught

```
def divides24(x):
    return noisy_divides(x, 24)

divides24(0)

-----
ZeroDivisionError                                Traceback (most recent)
<ipython-input-24-0a94e81be222> in <module>()
----> 1 divides24(0)

<ipython-input-23-c56bc11b3032> in divides24(x)
----> 1 def divides24(x):
      2     return noisy_divides(x, 24)

<ipython-input-20-df96adb0c18a> in noisy_divides(x, y)
----> 1 def noisy_divides(x, y):
      2     result = (y % x == 0)
      3     if result:
      4         print("{0} divides {1}".format(x, y))
      5     else:

ZeroDivisionError: integer division or modulo by zero
```

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27

27

Assert Statements

- Allow you to make assertions about assumptions that your code relies on
 - Use them liberally!
 - Incoming data is dirty till you've washed it

assert <assertion expression>, <string for failed>

- Raise an exception of type **AssertionError**
- Ignored in optimize flag: **python3 -O ...**
 - Governed by bool `__debug__`

```
def divides(x, y):
    assert x != 0, "Denominator must be non-zero"
    return y%x == 0
```

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28

28

Handling Errors – try / except

- Wrap your code in **try – except** statements

```
try:
    <try suite>
except <exception class> as <name>:
    <except suite>
... # continue here if <try suite> succeeds w/o exception
```

- **Execution rule**
 - <try suite> is executed first
 - If during this an exception is raised and not handled otherwise
 - And if the exception inherits from <exception class>
 - Then <except suite> is executed with <name> bound to the exception
- Control jumps to the except suite of the most recent **try** that handles the exception

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29

29

Demo

```
def safe_apply_fun(f, x):
    try:
        return f(x)           # normal execution, return the result
    except Exception as e:    # exceptions are objects of class deri
        return e              # value returned on exception
```

```
def divides(x, y):
    assert x != 0, "Bad argument to divides - denominator should be non-zero"
    if (type(x) != int or type(y) != int):
        raise TypeError("divides only takes integers")
    return y%x == 0
```

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30

30

Raise statement

- Exception are raised with a **raise** statement\


```
raise <exception>
```
- **<expression>** must evaluate to a subclass of **BaseException** or an instance of one
- Exceptions are constructed like any other object


```
TypeError('Bad argument')
```

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31

31

Exceptions are Classes

```
class NoisyException(Exception):
    def __init__(self, stuff):
        print("Bad stuff happened", stuff)
```

```
try:
    return fun(x)
except:
    raise NoisyException((fun, x))
```

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32

32

Demo

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33

33

Summary

- **Approach creation of a class as a design problem**
 - Meaningful behavior => methods [& attributes]
 - ADT methodology
 - What's private and hidden? vs What's public?
- **Design for inheritance**
 - Clean general case as foundation for specialized subclasses
- **Use it to streamline development**
- **Anticipate exceptional cases and unforeseen problems**
 - try ... catch
 - raise / assert

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34

34