Generators and Iterators

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Lecture 11
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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
Administrative Issues

• Project 2 “Wheel” is out
  – Part I due 11/10
• There will be no Project 3
• No lecture 11/12 due to holiday
  – There will be lab Friday 11/16
Today:

- Review Exceptions
- Sequences vs Iterables
- Using iterators without generating all the data
- Generator concept
  - Generating an iterator from iteration with `yield`
- Magic methods
  - `next`
  - `Iter`
- Iterators – the `iter` protocol
- `GetItem` protocol
- Is an object iterable?
- Lazy evaluation with iterators
Summary of last week

• 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
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
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
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
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

```python
def safe_apply_fun(f,x):
    try:
        return f(x)  # normal execution, return the result
    except Exception as e:  # exceptions are objects of class derived
        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
```
class NoiseyException(Exception):
    def __init__(self, stuff):
        print("Bad stuff happened", stuff)

try:
    return fun(x)
except:
    raise NoiseyException((fun, x))
Iterators - Notebook

Iterable - an object you can iterate over

• *iterable*: An object capable of yielding its members one at a time.
• *iterator*: An object representing a stream of data.
• We have worked with many iterables as if they were sequences
Functions that return iterables

- map
- range
- zip

- These objects are not sequences.
- If we want to see all of the elements at once, we need to explicitly call list() or tuple() on them.
Define objects that behave like sequences
Generators: turning iteration into an iterable

- *Generator* functions use iteration (for loops, while loops) and the yield keyword
- Generator functions have no return statement, but they don’t return None
- They implicitly return a generator object
- Generator objects are just iterators

```python
def squares(n):
    for i in range(n):
        yield i*i
```
def all_pairs(x):
    for item1 in x:
        for item2 in x:
            yield(item1, item2)
Next element in generator iterable

- Iterables work because they have some "magic methods" on them. We saw magic methods when we learned about classes,
- e.g., __init__, __repr__ and __str__.
- The first one we see for iterables is __next__

- iter( ) – transforms a sequence into an iterator
Iterators – iter protocol

• In order to be *iterable*, a class must implement the *iter protocol*

• The iterator objects themselves are required to support the following two methods, which together form the iterator protocol:

  – __iter__() : Return the iterator object itself. This is required to allow both containers and iterators to be used with the for and in statements.

  – __next__() : Return the next item from the container. If there are no further items, raise the StopIteration exception.

• Classes get to define how they are iterated over by defining these methods
Getitem protocol

- Another way an object can behave like a sequence is *indexing*: Using square brackets “[ ]” to access specific items in an object.
- Defined by special method: `__getitem__(self, i)`
  - Method returns the item at a given index

```python
class myrange2:
    def __init__(self, n):
        self.n = n

    def __getitem__(self, i):
        if i >= 0 and i < self.n:
            return i
        else:
            raise IndexError

    def __len__(self):
        return self.n
```
Determining if an object is iterable

- from collections.abc import Iterable
- isinstance([1,2,3], Iterable)

- This is more general than checking for any list of particular type, e.g., list, tuple, string...
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