Programming Principles in Python (CSCI 503/490)

OS Integration

Dr. David Koop
Debugging: Print Statements

• Just print the values or other information about identifiers:
  ```python
def my_function(a, b):
    print(a, b)
    print(b - a == 0)
    return a + b
  ```

• Note that we need to remember what is being printed

• Can add this to print call, or use f-strings with trailing = which causes the name and value of the variable to be printed
  ```python
def my_function(a, b):
    print(f"{a=} {b=} {b - a == 0}")
    return a + b
  ```
Debugging: Logging Library

- Allows different levels of output (e.g. DEBUG, INFO, WARNING, ERROR CRITICAL)
- Can output to a file as well as stdout/stderr
- Can configure to suppress certain levels or filter messages

```python
import logging
logger = logging.Logger('my-logger')
logger.setLevel(logging.DEBUG)
def my_function(a, b):
    logger.debug(f"{a=} {b=} {b-a == 0}")
    return a + b
my_function(3, 5)
```
Debugging: Python Debugger (pdb)

- Debuggers offer the ability to inspect and interact with code as it is running
  - Post-mortem inspection (`%debug, python -m pdb`)
  - Breakpoints (just call `breakpoint()`)

- `pdb` is standard Python, also an `ipdb` variant for IPython/notebooks
  - `p` [print expressions]: Print expressions, comma separated
  - `n` [step over]: continue until next line in current function
  - `s` [step into]: stop at next line of code (same function or one being called)
  - `c` [continue]: continue execution until next breakpoint
Debugging: JupyterLab Debugger
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Testing via Print/If Statements

- Can make sure that types or values satisfy expectations
  
  ```python
  if not isinstance(a, str):
      raise Exception("a is not a string")
  
  if 3 < a <= 7:
      raise Exception("a should not be in (3,7]\")
  ```

- These may not be something we need to always check during runtime
Testing via Assertions

- Shortcut for the manual if statements
- Have python throw an exception if a particular condition is not met
- `assert` is a keyword, part of a statement, not a function
- `assert a == 1, "a is not 1"
- Raises `AssertionError` if the condition is not met, otherwise continues
- Can be caught in an except clause or made to crash the code
- Problem: first failure ends error checks
Unit Tests

• "Testing shows the presence, not the absence of bugs", E. Dijkstra

• Want to test many parts of the code

• Try to cover different functions that may or may not be called

• Write functions that test code

  ```python
  def add(a, b):
      return a + b + 1
  
def test_add():
      assert add(3, 4) == 7, "add not working"
  
def test_operator():
      assert operator.add(3, 4) == 7, "__add__ not working"
  
  ```

• If we just call these in a program, first error stops all testing
Unit Testing Framework

- unittest: built in to Python Standard Library
- nose2: nose tests, was nose, now nose2 (some nicer filtering options)
- pytest: extra features like restarting tests from last failed test
- doctest: built-in, allows test specification in docstrings

With the exception of doctest, the frameworks allow the same specification of tests
unittest

- Subclass from `unittest.TestCase`, write `test_*` functions
- Use `assert*` instance functions
- `import unittest`

```python
class TestOperators(unittest.TestCase):
    def test_add(self):
        self.assertEqual(add(3, 4), 7)

    def test_add_op(self):
        self.assertEqual(operator.add(3, 4), 7)

unittest.main(argv=[''], exit=False)
```
Lots of Assertions

- `assertEqual/assertNotEqual`: smart about lists/tuples/etc.
- `assertLess/assertGreater/assertLessEqual/assertGreaterEqual`
- `assertAlmostEqual`: allows for floating-point arithmetic errors
- `assertTrue/assertFalse`: check boolean assertions
- `assertIsNone`: check for `None` values
- `assertIn`: check containment
- `assertIsInstance`
- `assertRegex`: check that a regex matches
- `assertRaises`: check that a particular exception is raised
Test Options

• Run only certain tests
  - argv=[''] # run default set of tests
  - argv=['', 'TestLists'] # run all test* methods in TestLists
  - argv=['', 'TestAdd.test_add'] # run test_add in TestAdd

• Show more detailed output
  - By default, one character per test plus listing at end
    • F.
    • . indicates success, F indicates failed, E indicates error
  - verbosity=2
    • test_add (__main__.TestAdd) ... FAIL
    • test_add_op (__main__.TestAdd) ... ok
Startup and Cleanup for Tests

- **setUp**: instantiate particular objects, read data, etc.
- **tearDown**: get rid of unnecessary objects
- **Example**: set up a GUI widget that will be tested
  ```python
  def setUp(self):
      self.widget = Widget(some_params)
  def tearDown(self):
      self.widget.dispose()
  ```
- Also functions for setting up classes and modules
Mock Testing

- Sometimes we don't want to actually execute all of the code that may be triggered by a particular test.
- Examples: code that posts to Twitter, code that deletes files.
- We can mock this behavior by substituting the actual methods with mockers.
- Can even simulate side effects like having the function being mocked raise an exception signifying the network is done.
Mock Examples

- Can check whether/how many times the mocked function was called

```python
from unittest.mock import MagicMock
thing = ProductionClass()
thing.method = MagicMock(return_value=3)
thing.method(3, 4, 5, key='value')
thing.method.assert_called_with(3, 4, 5, key='value')
```

- from unittest.mock import patch
  with patch.object(ProductionClass, 'method',
      return_value=None) as mock_method:
      thing = ProductionClass()
      thing.method(1, 2, 3)
      mock_method.assert_called_once_with(1, 2, 3)
```
Assignment 6

- Object-Oriented Programming
- Due after the test, but very helpful for Test 2
- Build an online shopping store
- Design classes, use inheritance
Test 2

- Wednesday, April 3, 2024 in class from 12:30-1:45pm
- Similar Format to Test 1
- Emphasizes topics covered since Test 1, but still need to know core concepts from the first third of the course
Integration with the Operating System

• For now, focus on the filesystem
  - Listing & Traversing Directories
  - Creating Directories
  - Matching Files
  - Copying, Moving, Removing Files/Directories

• Using Material by Vuyisile Ndlovu:
Modules

• In general, cross-platform! (Linux, Mac, Windows)
• os: translations of operating system commands
• shutil: better support for file and directory management
• fnmatch, glob: match filenames, paths
• os.path: path manipulations
• pathlib: object-oriented approach to path manipulations, also includes some support for matching paths
Directory Listing

- Old approach: `os.listdir`
- New approach: `os.scandir`
  - Uses iterators, object-based, faster (fewer stat calls), returns `DirEntry`
  - with `os.scandir('my_directory/')` as `entries`:
    ```python
    for entry in entries:
        print(entry.name)
    ```
- Pathlib approach:
  - from `pathlib` import `Path`
    ```python
    path = Path('my_directory/)
    for entry in path.iterdir():
        print(entry.name)
    ```
Listing Files in a Directory

- Difference between file and directory
- `isfile/is_file` methods:
  - `os.path.isfile`
  - `DirEntry.is_file`
  - `Path.is_file`
- Test while iterating through
  - `from pathlib import Path
    basepath = Path('my_directory/')
    files_in_basepath = basepath.iterdir()
    for item in files_in_basepath:
      if item.is_file():
        print(item.name)"
Listing Subdirectories

- Use `isdir/is_dir` instead

```python
from pathlib import Path
basepath = Path('my_directory/')
files_in_basepath = basepath.iterdir()
for item in files_in_basepath:
    if item.is_dir():
        print(item.name)
```
File Attributes

• Getting information about a file is "stat"-ing it (from the system call name)
• Names are similarly a bit esoteric, use documentation
• `os.stat` or use `.stat` methods on `DirEntry/Path`
• Modification time:

```python
from pathlib import Path

current_dir = Path('my_directory')
for path in current_dir.iterdir():
    info = path.stat()
    print(info.st_mtime)
```
• Also can check existence: `path.exists()`
Making Directories

• Modify the filesystem
• Know where you **currently are** first
  - `os.getcwd()` or `Path.cwd()`: current working directory
• `os.mkdir`: single subdirectory
• `os.makedirs`: multiple subdirs
• `pathlib.Path.mkdir`: single or multiple directories (with `parents=True`)
• Can raise exceptions (e.g. file already exists)
• `from pathlib import Path
  p = Path('example_directory/')
  p.mkdir()`
Filename Pattern Matching

- **string.endswith/startswith**: no wildcards
- **fnmatch**: adds * and ? wildcards to use when matching (**not** just like regex!)
- **glob.glob**: treats filenames starting with . as special
  - can do recursive matchings (e.g. in subdirectories) using **
- **pathlib.Path.glob**: object-oriented version of glob
- **from pathlib import Path**
  - p = Path('.')
  - for name in p.glob('*.p*'):
    - print(name)
Pathname Manipulation

- **os.path.split** returns tuple (dirname, basename)
  - can use **os.path.dirname/basename** to get these only
  - `os.path.split('/path/to/file.txt')` # ('/path/to', 'file.txt')

- **os.path.join**: inverse of split

- **os.path.splitext**: split filename and extension

- **pathlib.Path** has OOP versions:
  - `.parent/.name == dirname/basename`
  - `.stem/.suffix ~ splitext, also suffixes`
  - `/ operator (also joinpath ~ join)`
Traversing Directories and Processing Files

• `os.walk`
  
  `for dirpath, dirnames, files in os.walk('.'):`
  
    ```python
    print(f'Found directory: {dirpath}')
    for file_name in files:
        print(file_name)
    ```

  Returns three values on loop iteration:
  1. The name of the current directory
  2. A list of subdirectories in the current directory
  3. A list of files in the current directory

• `topdown` and `followlinks` arguments

• `pathlib algorithms exist but DIY`
Temporary Files and Directories

• tempfile knows system directories for storing temporary files
• deletes the file when it is closed
• from tempfile import TemporaryFile
  with TemporaryFile('w+t') as fp:
    fp.write('Hello universe!')
    fp.seek(0)
    fp.read()
  # File is now closed and removed
• Can also use in with statement (context manager)
• Can also create temporary directories
Deleting Files and Directories

- **Files:** `os.remove` or `os.unlink`, or `pathlib.Path.unlink`

- `from pathlib import Path
  Path('home/data.txt').unlink()`

- **Directories:** `rmdir` or `shutil.rmtree`
  - `rmdir` only works if the directory is **empty**
  - **Careful:** this deletes the entire directory (and everything inside it)
    - `shutil.rmtree('my_documents/bad_dir')`
Copying Files & Directories

- **shutil.copy**: copy file to specified directory
  - `shutil.copy('path/to/file.txt', 'path/to/dest_dir')`
- **shutil.copy2**: preserves metadata, same syntax
- **Copy entire tree**: `shutil.copytree('data_1', 'data1_backup')`
Moving and Renaming Files/Directories

• Moving files or directories:
  - `shutil.move('dir_1/', 'backup/')`

• Renaming files or directories:
  - `os.rename`
  - `pathlib.Path.rename`
  - `data_file = Path('data_01.txt')`
    `data_file.rename('data.txt')`
Archives

- **zipfile**: module to deal with zip files
- **tarfile**: module to deal with tar files, can compress (tar.gz)
- **Easier**: `shutil.make_archive`
  - Specify base name, format, and root directory to archive
  - `shutil.make_archive('data/backup', 'tar', 'data/')`
- **To extract, use** `shutil.unpack_archive`