Programming Principles in Python (CSCI 503/490)

Testing & OS Integration

Dr. David Koop

Exception Locality

- Generally, want try statement to be specific to a part of the code
-
```
try:
    fname = 'missing-file.dat'
    with open(fname) as f:
        lines = f.readlines()
except OSError:
    print(f"An error occurred reading {fname}")
try:
    out_fname = 'output-file.dat'
    with open('output-file.dat', 'w') as fout:
        fout.write("Testing")
except OSError:
    print(f"An error occurred writing {out_fname}")
```

Multiple Except Clauses

- Function like an if/elif sequence
- Checked in order so put more granular exceptions **earlier**!
-
```
try:
    fname = 'missing-file.dat'
    with open(fname) as f:
        lines = f.readlines()
    out_fname = 'output-file.dat'
    with open('output-file.dat', 'w') as fout:
        fout.write("Testing")
except OSError:
    print("An error occurred processing files")
except FileNotFoundError:
    print(f"File {fname} does not exist")
```

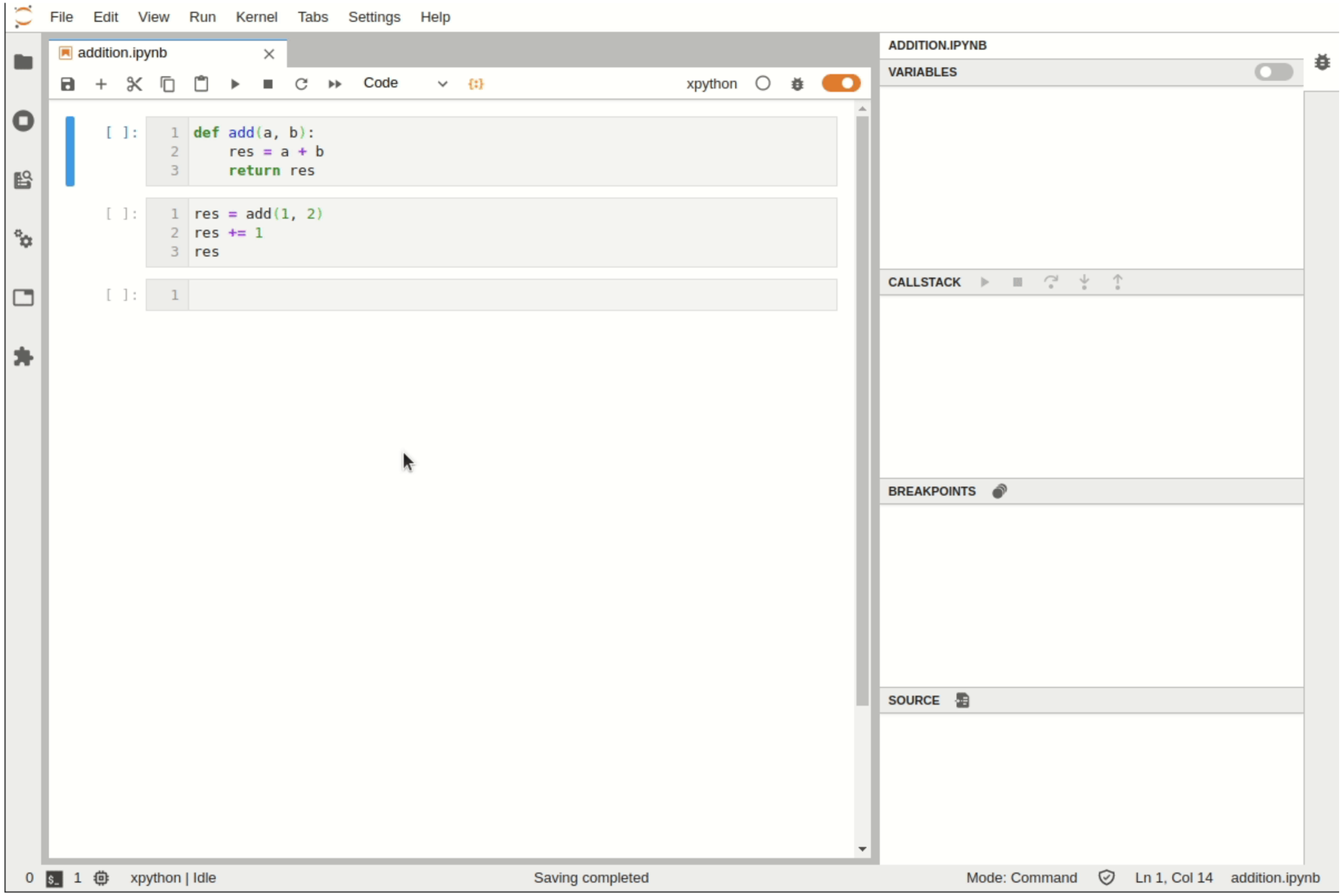
Multiple Except Clauses

- Function like an if/elif sequence
- Checked in order so put more granular exceptions **earlier**!
- ```
  try:
      fname = 'missing-file.dat'
      with open(fname) as f:
          lines = f.readlines()
      out_fname = 'output-file.dat'
      with open('output-file.dat', 'w') as fout:
          fout.write("Testing")
  except OSError:
      print("An error occurred processing files")
  except FileNotFoundError:
      print(f"File {fname} does not exist")
  ```
  ```

Try Block Clauses

- `try`: the block of code the handling applies to
- `except`: handle an exception
  - Can be multiple except clauses, only first matching clause is executed
- `else`: executed if there are no exceptions
- `finally`: executed no matter what, even if exception is not handled
- Nesting is allowed
  - E.g., can have a try-except inside a finally clause

Raising Exceptions

- Use `raise` keyword (not throw like other languages)
  - `raise ValueError('a must be between 3 and 10')`
- Can also reraise an exception in an except clause
  -
```
except FileNotFoundError as e:
    print("Missing file", e.filename)
    raise e
```

Debugging: Print Statements

- Just print the values or other information about identifiers:
- ```
  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
- ```
  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
- ```
  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)

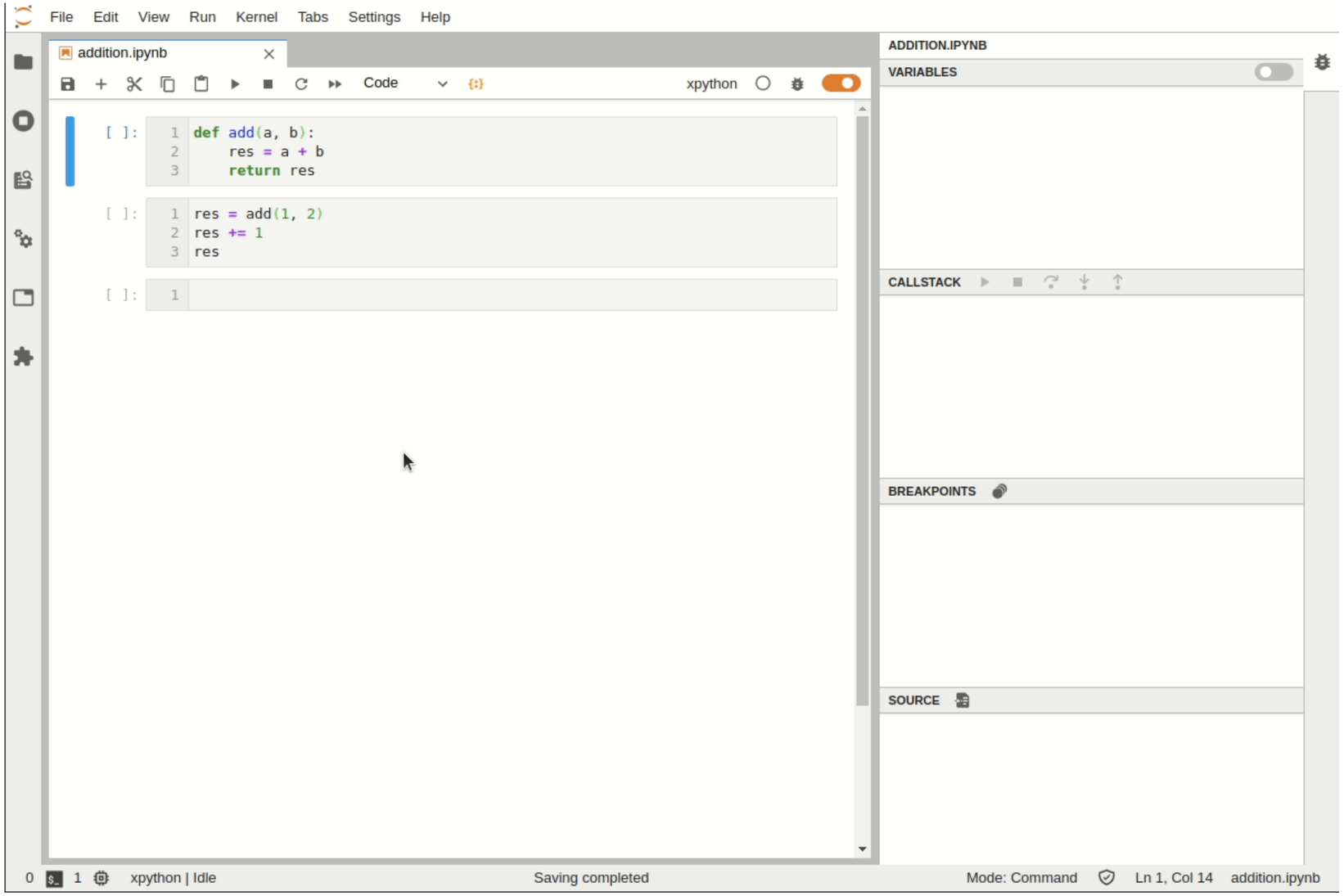
- Debuggers offer the ability to inspect and interact with code as it is running
  - Post-mortem inspection (`%debug`, `python -m pdb`)
  - Breakpoints (just call `breakpoint()`)
- pdb is standard Python, also an ipdb variant for IPython/notebooks
  - `p` [print expressions]: Print expressions, comma 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



[JupyterLab Docs]

Debugging: JupyterLab Debugger



[JupyterLab Docs]

Assignment 6

- Object-Oriented Programming
- Classes to create a library
  - Inheritance
  - Representations
  - Property
  - Exceptions
- Due next Friday, best to complete **before** the second test

Test 2

- Wednesday, November 5, in class from 9:30-10:45am
- 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

How do you test code?

Testing

- If statements
- Assert statements
- Unit Testing
- Integration Testing

Testing via Print/If Statements

- Can make sure that types or values satisfy expectations
- ```
  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

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
- ```
  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

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)
```

Running Unit Tests

- Command-Line:
  - File: `python -m unittest list`
  - Class: `python -m unittest list.TestLists`
  - Method: `python -m unittest list.TestLists.test_append`
- Notebook (basically specifying arguments via a function):
  - Notebook: `unittest.main(argv=[''], exit=False)`
  - Class: `unittest.main(argv=['', 'TestLists'], exit=False)`
  - Method: `unittest.main(argv=['', 'TestLists'], 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

```
- def setUp(self):
      self.widget = Widget(some_params)
  def tearDown(self):
      self.widget.dispose()
```

- Also functions for setting up classes and modules

[Python Documentation]

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
- ```
  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)
  ```

[Python Documentation]

OS Integration

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:
  - https://realpython.com/working-with-files-in-python/

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:
    for entry in entries:
        print(entry.name)
```
- Pathlib approach:
  -
```
from pathlib import Path
path = Path('my_directory/')
for entry in path.iterdir():
    print(entry.name)
```

[V. Ndlovu]

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)
```

[V. Ndlovu]

Listing Subdirectories

- Use `isdir`/`is_dir` instead
  - ```
    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:

```
- 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()`

[V. Ndlovu]

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()
  ```

[V. Ndlovu]
  ```

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)
  ```

[V. Ndlovu]
  ```

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('.'):
      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

[V. Ndlovu]
  ```

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

[V. Ndlovu]
  ```

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')`

[V. Ndlovu]
  ```

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')`

[V. Ndlovu]

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')
```

[V. Ndlovu]

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`

[V. Ndlovu]