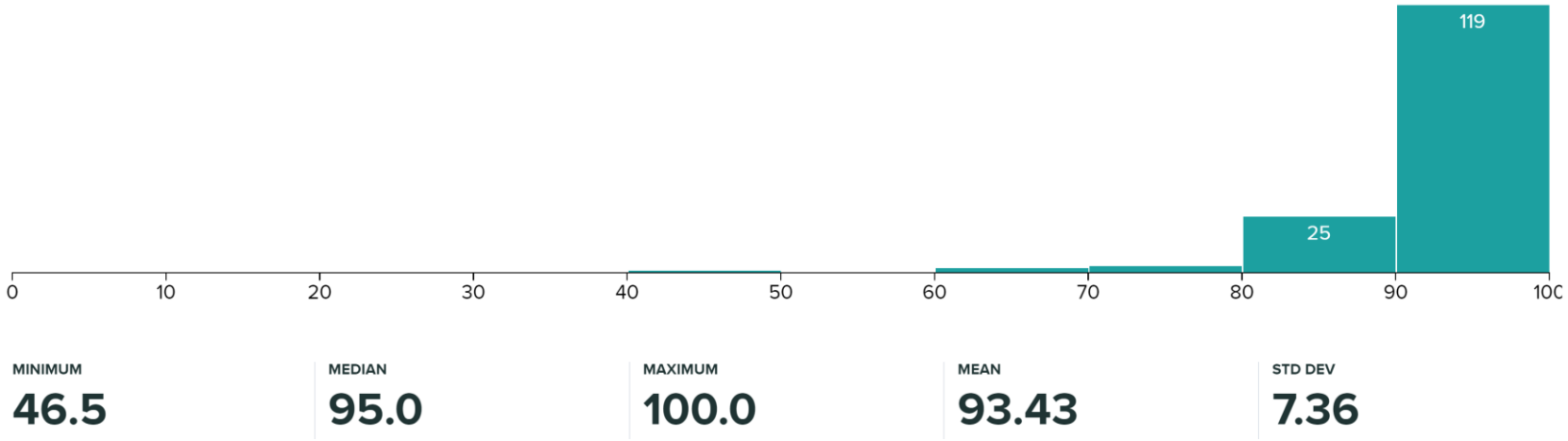
Managing Large Code Projects

15-110 – Friday 04/09

Announcements

- **Quiz4** grades released
  - Median of 95 – excellent work!



- **Hw5** due on **Monday**

Learning Goals

- Use the **input** command and **try/except** structures to handle direct user input in code
- Implement and use **helper functions** in code to break up large problems into solvable subtasks
- Install **external modules** with the **pip** command
- Read **documentation** to learn how to use a new module

New Unit: CS as a Tool

Our next unit focuses on how computer science can be used to benefit other domains.

We'll investigate three different applications of computer science: **data analysis**, **simulation**, and **machine learning**.

These three applications share a core idea in common: all three **organize data** to **help people answer questions**.

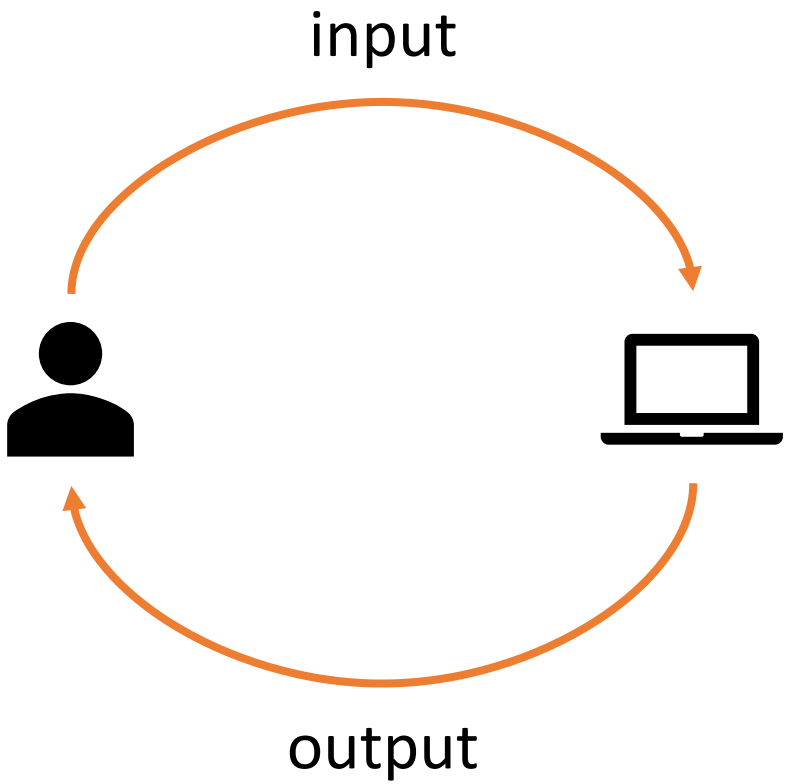
Before we get into these topics, we need to learn a bit about how to approach coding **large projects** instead of individual functions.

User Input

Input-Output Cycle

When you use a program (like your internet browser, or Pyzo), you're communicating with the computer. You give the computer **input** on what you want to do, and it produces **output** based on your requests.

When we write programs, we can capture input directly from the user. When combined with output (printed strings), we can make programs that a interact with a user!



Getting Input from the User

Up until now, we've written programs that get their input solely from the function arguments we provide. Alternatively, we can write programs that ask the user to enter information while the program is running.

The built-in function `input(msg)` displays a message in the interpreter, lets the user type a response in the interpreter, then **returns the response** as a string when the user presses enter.

```
name = input("Enter your name: ")
print("Hello, " + name + "!")
```

`input()` Returns a String

`input()` will **always** return a string. If we want to use a user's response as a number, we need to use type-casting to change it.

```
age = int(input("Enter your age: "))
print("You'll be", age + 1, "next year")
```

Note: users sometimes enter unexpected whitespace at the beginning or end of a response. The built-in function `s.strip()` may prove useful! It removes extra whitespace from the beginning/end of a string.

Handle User Errors with Try-Except Statements

What happens if we ask the user to enter a number and try to convert their text to a number, but they enter a non-number instead?

The code will throw a `ValueError` when it tries to convert the text to an int. This is not great, because users get frustrated if the program crashes each time they make a mistake.

In order to make a program robust against human errors, we can use a **try-except** control structure to recover from such errors.

Try-Except Statements

A **Try-Except** statement looks like this:

```
try:
    <try-block>
except:
    <what to do if the try code throws an error>
```

This works a bit like an if-else statement. Go to the `try` block first. If the code in the `try` block runs correctly, the `except` block is skipped. Alternatively, if Python encounters a runtime error in the `try` block, it immediately exits that block and jumps to the beginning of the `except` block.

Example: Inputting a Number

Let's try our age-entering program again, this time with error handling.

```
try:
    age = int(input("Enter your age:"))
    print("You'll be", age + 1, "next year")
except:
    print("That's not a real age!")
```

Note that the first print statement does not run if the user enters a non-number into the input.

Activity: Write error-catching code

You do: write a short snippet of code that asks the user to enter two numbers (with two separate `input()` calls), then prints the result of multiplying those two numbers. If at least one of the inputs isn't a number, print an error message using an `except` block.

Test your code by trying good inputs (two inputs) and bad inputs of different kinds.

User Input Loops Ensure Correct Inputs

Sometimes you might need to try several times to get the user to input a valid option into the program.

When you need to get a real input from a user, use a **loop** to continue asking them for input until they get it right.

What's the loop control variable? You could use the variable you're setting based on the user's entry. You could also use `while True`, then `break` when you get the right input.

Example: Entering y/n

For example, let's write a simple program that requires the user to respond with either y (yes) or n (no).

```
answer = ""
while True:
    answer = input("Do you like ice cream? [y/n]:")
    if answer == "y" or answer == "n":
        break
    else:
        print("Seriously, answer the question.")
if answer == "y":
    print("Me too!")
else:
    print("Lactose intolerance sucks :(")
```

Helper Functions

Helper Functions

In Hw5 and Hw6 (and in projects you might work on outside of 15-110), the code you write will be bigger than a single function. You'll often need to write many functions that work together to solve a larger problem.

We call a function that solves part of a larger problem this way a **helper function.** By breaking up a large problem into multiple smaller problems and solving those problems with helper functions, we can make complicated tasks more approachable.

We've used helper functions in class before- to calculate how much to pay for a meal (helper function calculated tip), in selection sort (to swap two items in a list), and in merge sort (to merge two lists).

Designing Helper Functions

In Hw5 and Hw6 we've broken a problem down into helper functions for you. But if you work on a separate project, you'll need to do this process on your own.

Try to identify **subtasks** that are repeated or are separate from the main goal; break down the problem into smaller parts. Have **one subtask per function** to keep things simple.

Example: Tic-Tac-Toe

Consider the game tic-tac-toe. It seems simple, but it involves multiple parts to play through a whole game.

Discuss: what are the subtasks of tic-tac-toe?

Breaking down Tic-Tac-Toe

Let's organize our tic-tac-toe game based on four core subtasks:

`makeNewBoard()`, which constructs and returns the starter board

`showBoard(board)`, which displays a given board

`takeTurn(board, player)`, which lets the given player make a move on the board

`isGameOver(board)`, which returns `True` or `False` based on whether or not the game is over

We'll only go over how each function works briefly. The most important thing right now is how we **use the helper functions** in the main code.

makeNewBoard and showBoard

makeNewBoard and showBoard are simple; we can program these just using concepts we've already learned.

The board will be a 3x3 2D list with "." for empty spaces, "X" for player X, and "O" for player O.

We'll **call** these functions in a main function that will actually run the game.

```
# Construct the tic-tac-toe board
def makeNewBoard():
    board = []
    for row in range(3):
        # Add a new row to board
        board.append([".", ".", "."])
    return board

# Print the board as a 3x3 grid
def showBoard(board):
    for row in range(3):
        line = ""
        for col in range(3):
            line += board[row][col]
        print(line)
```

takeTurn

takeTurn uses the concepts we just went over in the User Input section!

Have the user input the row and col they want to fill in. Check to make sure the row and col are numbers with try/except and ensure that they show a valid and unfilled space with if statements.

Keep looping until a valid location is chosen. Update the board at that spot, then return the updated board.

```
# Ask the user to input where they want
# to go next with row,col position
def takeTurn(board, player):
  while True:
    try:
      row = int(input("Enter a row for " + \
                      player + ":"))
      col = int(input("Enter a col for " + \
                      player + ":"))
      # Make sure its in the grid!
      if 0 <= row < 3 and 0 <= col < 3:
        if board[row][col] == ".":
          board[row][col] = player
          # stop looping when move is made
          break
        else:
          print("That space isn't open!")
      else:
        print("Not a valid space!")
    except:
      print("That's not a number!")
  return board
```

`isGameOver` needs more helper functions

`isGameOver` is a bit more complicated. There are multiple scenarios where the game can end- if a player gets three in a row horizontally, or vertically, or diagonally. The game can also end if the board is filled.

Use more helper functions to break up the work into parts! Generate strings holding all rows/columns/diagonals with `horizLines`, `vertLines`, and `diagLines`.

```
# Generate all horizontal lines
def horizLines(board):
  lines = []
  for row in range(3):
    lines.append(board[row][0] + board[row][1] + \
                 board[row][2])
  return lines

# Generate all vertical lines
def vertLines(board):
  lines = []
  for col in range(3):
    lines.append(board[0][col] + board[1][col] + \
                 board[2][col])
  return lines

# Generate both diagonal lines
def diagLines(board):
  leftDown = board[0][0] + board[1][1] + \
             board[2][2]
  rightDown = board[0][2] + board[1][1] + \
              board[2][0]
  return [ leftDown, rightDown ]
```

`isGameOver` and `isFull`

We can also make a separate function to check whether the board is full.

Now all we need to do in `isGameOver` is call our functions. First, check whether the board is full. If it isn't, generate all the lines and check whether any hold `"XXX"` or `"OOO"`. Much easier!

Note that when we call the helper functions, we have to **pass in the needed data** as arguments to the call. For now, that's just the board.

```
# Check if the board has no empty spots
def isFull(board):
    for row in range(3):
        for col in range(3):
            if board[row][col] == ".":
                return False
    return True

# True if game is over, False is not
def isGameOver(board):
    if isFull(board):
        return True
    allLines = horizLines(board) + \
               vertLines(board) + \
               diagLines(board)
    for line in allLines:
        if line == "XXX" or line == "OOO":
            return True
    return False
```

Put it All Together

Now we can finally write the main function!

Start by calling `makeNewBoard` to generate the board. Display the starting state by calling `showBoard`.

Use a loop to iterate over every turn in the game. Alternate a Boolean variable to decide whether it's X's or O's turn, and call `takeTurn` on the board *and the appropriate player* to decide which move to make. Call `showBoard` again each time to show the updated board.

Keep looping until the game is over by checking `isGameOver` in the loop condition.

```
def playGame():
    print("Let's play tic-tac-toe!")
    board = makeNewBoard()
    showBoard()
    player1Turn = True
    while not isGameOver(board):
        if player1Turn:
            board = takeTurn(board, "X")
        else:
            board = takeTurn(board, "O")
        showBoard()
        player1Turn = not player1Turn
    print("Goodbye!")
```

Python Modules

Python Modules

The Python programming language comes with a large set of built-in functions that cover a range of different purposes. However, it would take too long to load all these functions every time we want to run a program.

Python organizes its different functions into **modules**. When you run Python, it loads only a small set of functions from the built-in module. To use any other functions, you must **import** them.

Built-in Modules

We've already used a few core modules for homework assignments - mainly `math` and `tkinter`.

For a full list of python libraries, look here:
https://docs.python.org/3/library/index.html

External Modules

There are many other libraries that have been built by developers outside of the core Python team to add additional functionality to the language. These modules don't come as part of the Python language, but can be added in. We call these **external modules**.

In order to use an external module, you must first **install** it on your machine. To install, you'll need to download the files from the internet to your computer, then integrate them with the main Python library so that the language knows where the module is located.

Finding Useful Modules

One of the main strengths of Python as a language is that there are thousands of external modules available, which means that you can start many projects based on work others have done instead of starting from scratch.

You can find a list of popular modules here: wiki.python.org/moin/UsefulModules

And a more complete list of pip-installable modules here: pypi.org

There are bonus slides on the course website that introduce Python modules that are popular among CMU students

`pip`

It is usually possible to install modules manually, but this process can be a major pain. Luckily, Python also gives us a streamlined approach for installing modules – the **`pip` module**! This feature can locate modules that are indexed in the Python Package Index (a list of commonly-used modules), download them, and attempt to install them.

Traditionally, programmers run `pip` from the **terminal**. This is a command interface that lets you make changes directly to your computer. But in this class, we'll just run `pip` in Pyzo.

Running `pip`

To run `pip` in Pyzo, use this command in the interpreter

```
pip install module-name
```

This will identify the module and your version of Python and start the download and installation process. It may run into a **dependency error** if the module needs a second module to already be installed – in general, installing that module and then running `pip` again will fix the problem.

Note: you will not be able to run `pip` on CMU cluster machines, as these have restricted permissions. You may need to log into your main account on personal machines to run it.

Using an Installed Module

Once you've successfully installed a module, you should be able to put

```
import module-name
```

at the top of a Python file, and it will load the module the same way it would load a built-in library.

Note: this may fail if you have multiple versions of Python installed on your machine and you install in the terminal. Make sure to use the `pip` associated with the version of Python you're using in your editor. You can check your editor's version in Pyzo with Shell > Edit Shell Configurations (check the value in exe), then call `pip` using

```
pythonversion-number -m pip install module-name
```

Documentation

Learning how a Module Works

Once a new module is installed, you're still left with a major question: how do you use it?

This varies by module, but the best answer is to **read the documentation**. Most external modules have official documentation or APIs that describe which functions exist and how to use the module.

For example: how can we run a T-test on two datasets using scipy?

T-test Documentation

Searching "python scipy t-test" gets us this link from scipy's official documentation.

The page describes what the function does. It also outlines the required arguments and what it returns.

It's common for functions to also have **optional keyword parameters,** like tkinter's `fill` parameter; we can choose to include these or leave them to the default value.

scipy.stats.ttest_ind

scipy.stats.ttest_ind(*a*, *b*, *axis=0*, *equal_var=True*, *nan_policy='propagate'*, *alternative='two-sided'*) [source]

Calculate the T-test for the means of *two independent* samples of scores.

This is a two-sided test for the null hypothesis that 2 independent samples have identical average (expected) values. This test assumes that the populations have identical variances by default.

Parameters:

a, b : *array_like*

The arrays must have the same shape, except in the dimension corresponding to *axis* (the first, by default).

axis : *int or None, optional*

Axis along which to compute test. If None, compute over the whole arrays, *a*, and *b*.

equal_var : *bool, optional*

If True (default), perform a standard independent 2 sample test that assumes equal population variances [1]. If False, perform Welch's t-test, which does not assume equal population variance [2].

New in version 0.11.0.

Returns:

statistic : *float or array*

The calculated t-statistic.

pvalue : *float or array*

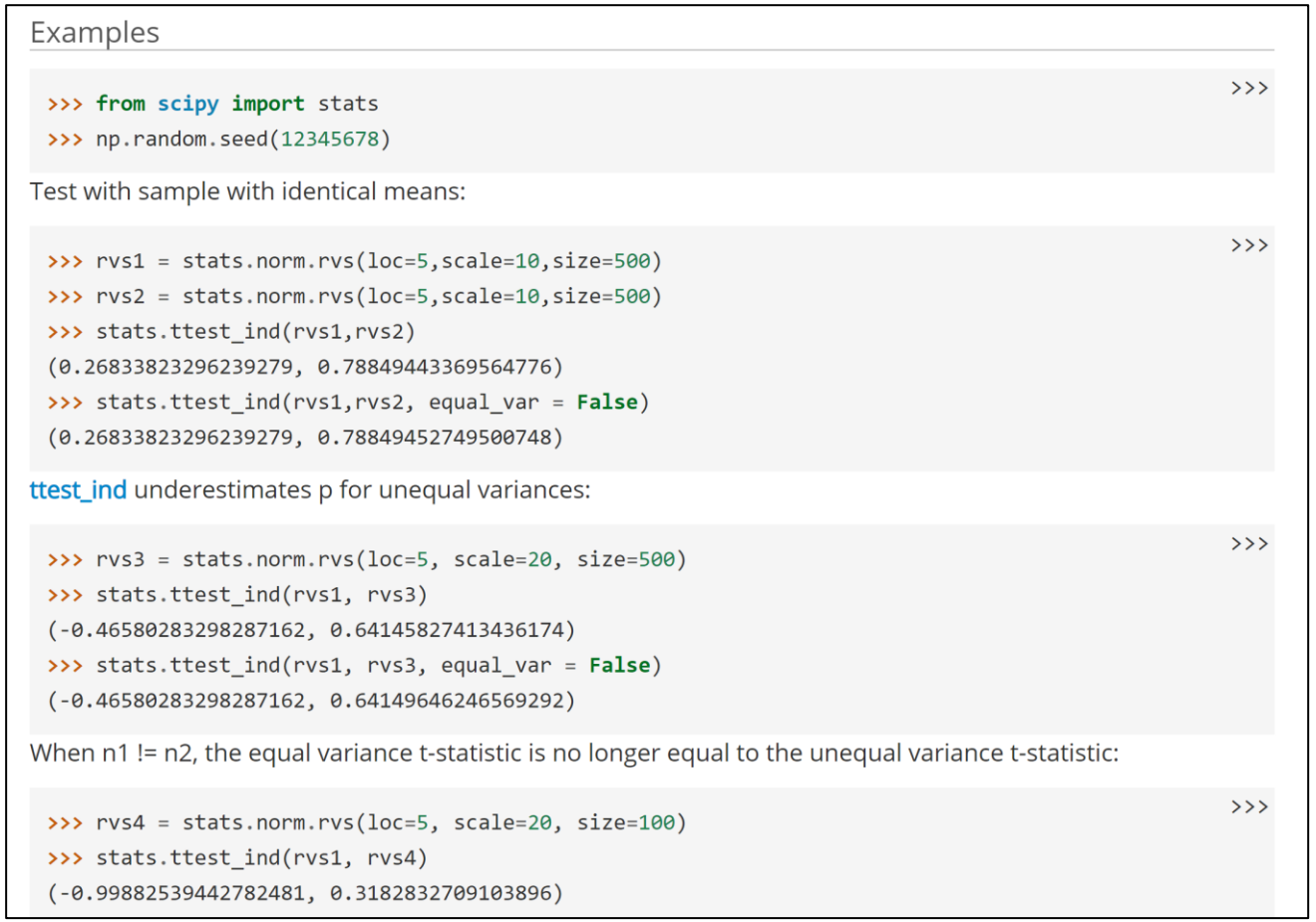
The two-tailed p-value.

Documentation with Examples

Really good documentation may also contain **examples** showing how to use the function!

If you want to learn how to use a function, try copying the example code into your editor and running it. Then try changing some things to see how the results are affected.

If you find that you're completely lost, it's likely that the module organizes things differently from what we've learned in class. Search the documentation site for a Getting Started / Introduction page to learn the basics.



Examples

```
>>> from scipy import stats
>>> np.random.seed(12345678)
```

Test with sample with identical means:

```
>>> rvs1 = stats.norm.rvs(loc=5,scale=10,size=500)
>>> rvs2 = stats.norm.rvs(loc=5,scale=10,size=500)
>>> stats.ttest_ind(rvs1,rvs2)
(0.26833823296239279, 0.78849443369564776)
>>> stats.ttest_ind(rvs1,rvs2, equal_var = False)
(0.26833823296239279, 0.78849452749500748)
```

ttest_ind underestimates p for unequal variances:

```
>>> rvs3 = stats.norm.rvs(loc=5, scale=20, size=500)
>>> stats.ttest_ind(rvs1, rvs3)
(-0.46580283298287162, 0.64145827413436174)
>>> stats.ttest_ind(rvs1, rvs3, equal_var = False)
(-0.46580283298287162, 0.64149646246569292)
```

When n1 != n2, the equal variance t-statistic is no longer equal to the unequal variance t-statistic:

```
>>> rvs4 = stats.norm.rvs(loc=5, scale=20, size=100)
>>> stats.ttest_ind(rvs1, rvs4)
(-0.99882539442782481, 0.3182832709103896)
```

Other Resources

It can also be helpful to search online for other projects that have used the same module, to find examples of how to set it up. Many people have written helpful tutorials for this exact purpose.

Two standard resources for finding help are **StackOverflow**, a site where people can ask questions about code and get answers from other developers, and **GitHub**, a site where people post open-source projects for others to use and contribute to.

IMPORTANT: whenever you copy code from online, make sure to **cite it** the same way you would cite a paragraph of text in an essay. You can do this by putting a comment above the copied code that includes a link to the URL you got the code from.

Learning Goals

- Use the **input** command and **try/except** structures to handle direct user input in code
- Implement and use **helper functions** in code to break up large problems into solvable subtasks
- Install **external modules** with the **pip** command
- Read **documentation** to learn how to use a new module
- **Feedback: http://bit.ly/110-s21-feedback**