http://www.cs.cornell.edu/courses/cs1110/2022sp

Lecture 6:
Specifications & Testing

(Sections 4.9, 9.5)

CS 1110

Introduction to Computing Using Python

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Lecture Afterthoughts

- We strongly encourage you to look at the `last_name_first` function in the Python tutor.
- Now try to fix the function implementation!

Welcome!

No Laptop Zone

Please, no cell phones during lecture

Announcements

- 1-on-1s are happening and they are awesome!
  - Sign up on CMS
- A1 goes out tonight! (many pages, but big figures)
- **Academic Integrity Policy:**
  - You can talk to each other
  - Do not show anyone (except staff) your code
    - Do not post your code to Ed Discussions
  - Do not look at anyone else's code
  - The Full Policy:

https://www.cs.cornell.edu/courses/cs1110/2022sp/policies/cs1110integrity.html

Asking Questions in Lecture

- Raise your hand for a notecard!
- Raise both hands for the catchBox!

Recall the Python API

https://docs.python.org/3/library/math.html

Function name

inputs

```
math.sqrt(x)
```

Return the square root of *x*.

What the function evaluates to

- This is a **specification**
  - How to **use** the function
  - **Not** how to implement it
- Write them as **docstrings**

math.**fabs**(*x*)

Return the absolute value of *x*.

math.**factorial**(*x*)

Return *x* factorial. Raises ValueError if *x* is not integral or is negative.

Anatomy of a Specification (1)

```
def greet(name):
    """Greets the person called name
    followed by conversation starter.

    <more details could go here>


    name: the person to greet
    Precondition: name is a string"""
    print('Hello '+name+'!')
    print('How are you?')
```

welcome.py

Short description, followed by blank line

As needed, more detail in 1 (or more) paragraphs

Parameter description

Precondition specifies assumptions we make about the arguments

Anatomy of a Specification (2)

```
def get_campus_num(phone_num):
    """Returns the on-campus version
    of a 10-digit phone number.


    Returns:  str of form "X-XXXX"


    phone_num: number w/area code
    Precondition: phone_num is a 10
    digit string of only numbers"""


    return phone_num[5]+"-"+phone_num[6:10]
```

campus.py

Short description, followed by blank line

Information about the return value

Parameter description

Precondition specifies assumptions we make about the arguments

A Precondition Is a Contract (1)

```python
def get_campus_num(phone_num):
    """Returns:  str of form "X-XXXX"
    phone_num: number w/area code
    Precondition: phone_num is a 10
    digit string of only numbers"""

    return phone_num[5]+ "-" + phone_num[6:10]
```

campus.py

If the precondition is met, **the function will work!**

```
>>> import campus
>>> campus.get_campus_num("6072554444")
'5-4444'
>>> campus.get_campus_num("6072531234")
'3-1234'
```

A Precondition Is a Contract (2)

```
def get_campus_num(phone_num):
   """Returns:  str of form "X-XXXX"
   phone_num: number w/area code
   Precondition: phone_num is a 10
   digit string of only numbers"""

   return phone_num[5]+ "-" + phone_num[6:10]
```

If the precondition is **not** met…

Sorry, no guarantees!

```
>>> import campus
>>> campus.get_campus_num(6072531234)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/Users/bracy/campus.py", line 7, in
get_campus_num
    return phone_num[5]+ "-" + phone_num[6:10]
TypeError: 'int' object is not subscriptable
```

Precondition violated: **error message!**

A Precondition Is a Contract (2)

```
def get_campus_num(phone_num):
    """Returns:  str of form "X-XXXX"
    phone_num: number w/area code
    Precondition: phone_num is a 10
    digit string of only numbers"""

    return phone_num[5]+ "-" + phone_num[6:10]
```

If the precondition is **not** met...

Sorry, no guarantees!

```
>>> import campus
>>> campus.get_campus_num("607-255-4444")
'5-5-44'
```

Precondition violated:
NO
error message!

Software Bugs occur if

- Precondition is not documented properly
  - Easy to be unaware of assumptions we make
- Function use violates the precondition
  - Easy to think we're using a function properly, even if we're not

NASA Mars Climate Orbiter

"NASA lost a $125 million Mars orbiter because a Lockheed Martin engineering team used English units of measurement while the agency's team used the more conventional metric system for a key spacecraft operation..."

Sources: Wikipedia & CNN

Preconditions Make Expectations Explicit

In American terms:

Preconditions help assign blame.

Something went wrong:

Engine breaks down.

Did you give the function a bad argument?

Did you put the wrong kind of fuel in the car?

OR

Was the function implemented/specified wrong?

Did the fuel tank ask for the wrong kind of fuel?

Was the engine simply poorly built?

Basic Terminology

- **Bug**: an error in a program. Expect them!
  - Conceptual & implementation
- **Debugging**: the process of finding bugs and removing them
- **Testing**: the process of *analyzing* and running a program, looking for bugs
- **Test case**: a set of input values, together with the expected output

Get in the habit of writing test cases for a function from its specification
– even *before* writing the function itself!

Test cases help you find errors

```
def vowel_count(word):
    """Returns: number of vowels in word.


    word: a string with at least one letter & only letters"""
    pass  # nothing here yet!
```

Some Test Cases

- `vowel_count('Bob')`
  Expect: 1
- `vowel_count('Aeiuo')`
  Expect: 5
- `vowel_count('Grrr')`
  Expect: 0

More Test Cases

- `vowel_count('y')`
  Expect: 0? 1?
- `vowel_count('Bobo')`
  Expect: 1? 2?

Test Cases can help you find errors in the **specification** as well as the implementation.

Representative Tests

- Cannot test all inputs
  - "Infinite" possibilities
- Limit ourselves to tests that are **representative**
  - Each test is a significantly different input
  - Every possible input is similar to one chosen
- An art, not a science
  - If easy, never have bugs
  - Learn with much practice

Representative Tests for
vowel_count(w)

- Word with just one vowel
  - For each possible vowel!
- Word with multiple vowels
  - Of the same vowel
  - Of different vowels
- Word with only vowels
- Word with no vowels

Representative Tests Example

name.py

```
def last_name_first(full_name):
    """Returns: copy of full_name
    in form <last-name>, <first-name>

    full_name: a string with the form <first-name> <last-name>
    with one or more blanks between the two names"""
    space_index = full_name.index(' ')
    first = full_name[:space_index]
    last  = full_name[space_index+1:]
    return last+', '+first
```

Look at precondition when choosing tests

Representative Tests:

```
>>> import name
>>> name.last_name_first(‘Katherine Jones’)
                              Expects: ‘Jones, Katherine'
>>> name.last_name_first(‘Katherine      Jones’)
                              Expects: ‘Jones, Katherine'
```

Motivating a Unit Test

- Right now to test a function, we:
  - Start the Python interactive shell
  - Import the module with the function
  - Call the function several times to see if it works right
- Super time consuming! ☹
  - Quit and re-enter python every time we change module
  - Type and retype…
- What if we wrote a script to do this ?!

`cornellasserts` module

- Contains useful testing functions
- To use:
  - Download from course website (one of today's lecture files)
  - Put in same folder as the files you wish to test

Unit Test: A Special Kind of Script

- A unit test is a script that tests another module. It:
  - **Imports the module to be tested** (so it can access it)
  - **Imports `cornellasserts` module** (supports testing)
  - **Defines one or more test cases** that each includes:
    - A representative input
    - The expected output
  - Test cases call a `cornellasserts` function:

```
def assert_equals(expected, received):
     """Quit program if `expected` and
 `received` differ"""
```

Testing last_name_first(full_name)

```
import name                    # The module we want to test
import cornellasserts          # Module that supports testing


# First test case
result = name.last_name_first('Katherine Jones')
cornellasserts.assert_equals('Jones, Katherine', result)


# Second test case
result = name.last_name_first('Katherine       Jones')
cornellasserts.assert_equals('Jones, Katherine', result)


print('All tests of the function last_name_first passed')
```

Actual output

Input

Expected output

Quits Python if actual and expected output not equal

Prints only if no errors

nametest.py

Organizing your Test Cases

- We often have a lot of test cases
  - Common at (good) companies
  - Need a way to cleanly organize them

Idea: Bundle all test cases into a single test!

- One **high level test** for each function you test
- High level test performs **all** test cases for function
- Also uses some print statements (for feedback)

One Test to Rule them All

name_campus_test.py

```
import cornellasserts
import name
import campus

def test_last_name_first():
    """Calls all the tests for last_name_first"""
    print('Testing function last_name_first’)
    # Test Case 1
    result = name.last_name_first('Katherine Jones')
    cornellasserts.assert_equals('Jones, Katherine', result)
    # Test Case 2
    result = name.last_name_first('Katherine       Jones')
    cornellasserts.assert_equals('Jones, Katherine', result)

# Execution of the testing code
test_last_name_first()
print(‘All tests of the module name passed’)
```

Put all test cases inside one function

No tests happen if you forget to call the function

Debugging with Test Cases (Question)

```
def last_name_first(full_name):
    """Returns: copy of full_name in the form <last-name>, <first-name>

    full_name: has the form <first-name> <last-name>
    with one or more blanks between the two names""“
    #get index of space after first name
1   space_index = full_name.index(' ')
    #get first name
2   first = full_name[:space_index]
    #get last name
3   last  = full_name[space_index+1:]
    #return “<last-name>, <first-name>”
4   return last+', '+first
```

Which line is “wrong”?

A: Line 1

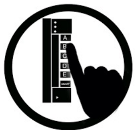
B: Line 2

C: Line 3

D: Line 4

E: I don't know

```
last_name_first('Katherine Jones’)        gives 'Jones, Katherine'
last_name_first('Katherine    Jones’)      gives '    Jones, Katherine'
```



How to debug

Do **not** ask:

"Why doesn't my code do what I want it to do?"

Instead, ask:

"What is my code doing?"

Two ways to inspect your code:

1. Step through your code, drawing pictures (or *use python tutor if possible*)
2. Use print statements to reveal intermediate program states—variable values

Take a look in the python tutor!

```
def last_name_first(full_name):
    # get index of space
    space_index = full_name.index(' ')
    # get first name
    first = full_name[:space_index]
    # get last name
    last  = full_name[space_index+1:]
    # return “<last-name>, <first-name>”
    return last+', '+first

last_name_first(“Katherine Johnson”)
```

Pay attention to:

- Code relevant to the failed test case
- Code you weren’t 100% sure of as you wrote it

Using `print` statement to debug

```
def last_name_first(full_name):
    # get index of space
    space_index = full_name.index(' ')
    print('space_index = '+ str(space_index))
    # get first name
    first = full_name[:space_index]
    print('first = '+ first)
    # get last name
    last  = full_name[space_index+1:]
    print('last = '+ last)
    # return “<last-name>, <first-name>”
    return last+', '+first
```

Sometimes this is your only option, but it does make a mess of your code, and introduces cut-n-paste errors.

How do I print this?