BABEŞ-BOLYAI UNIVERSITY
Faculty of Mathematics and Computer Science

# Algorithms and Programming

*Lecture 7 – Testing, GRASP patterns*

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# Course content

- Introduction in the software development process
- Procedural programming
- Modular programming
- Abstract data types
- Software development principles
- **Testing and debugging**
- Recursion
- Complexity of algorithms
- Search and sorting algorithms
- Backtracking
- Recap

# Last time

- Classes
    - Data abstraction
    - Instance attributes vs Class attributes

- UML

# Today

- Testing
  - Concept
  - Testing data
  - Examples

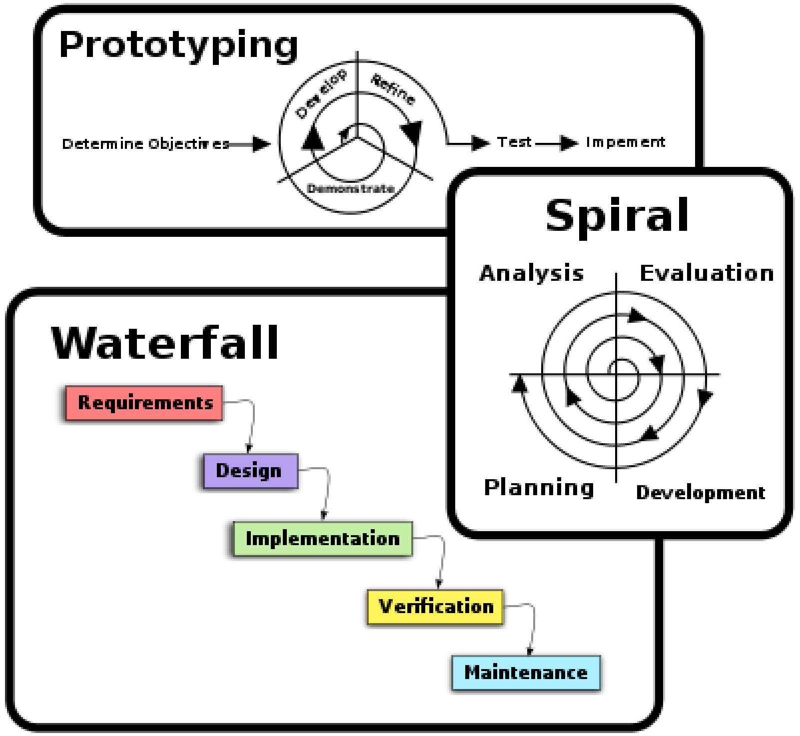
- GRASP - General Responsibility Assignment Software Patterns

# Recap: Testing and debugging

- Separate the code in modules – test and debug them separately
- Document modules and functions
- Debugging the code
  - Identify why a program is not working as expected
  - Study the events that generate an error
  - Use print!
- Testing the code
  - No syntax errors
  - No semantic errors
  - Use assertions
  - Unit testing: validate each unit, test each function separately

# Stages in the life of a program (software)

- **Requirements definition**
- **Analysis** (decompose the problem in subproblems)
- **Design** (specification of ADT, structure / layers of the application)
- **Implementation**
- **Testing**



# Testing

- Testing
  - Observing the behavior of an application for different test data
  - Program verification
  - Continuous activity

- Determine the data for testing (how to choose test data)
  - Exhaustive testing – incomplete testing
  - Black box testing
  - White box testing (or glass box testing)

# Why testing

- **"UNTESTED == BROKEN",** Schlomo Shapiro, EuroPython 2014
- **"... we have as many testers as we have developers. And testers spend all their time testing, and developers spend half their time testing. We're more of a testing, a quality software organization than we're a software organization.",** Bill Gates (Information Week, May 2002)
- **"Everyone knows that debugging is twice as hard as writing a program in the first place. So if you're as clever as you can be when you write it, how will you ever debug it?",** Brian Kernighan, "The Elements of Programming Style", 2nd edition, chapter 2
- **"Pay attention to zeros. If there is a zero, someone will divide by it.",** Cem Kaner

https://github.com/krother/python_testing_tutorial

# Testing methods: Exhaustive testing

- Exhaustive testing
  - Verify a program for all possible testing data
  - Impossible to apply it in the real world – need to choose a finite number of testing cases
- Incomplete testing
  - Verify a program for some testing data
  - Can be applied in the real world
  - Can use some intuition about natural boundaries of the problem

```python
def bigger(a, b):
    """ Given two integer numbers a and b
    Returns True if a > b, False otherwise """
    if a > b:
        return True
    return False
```

  - Random testing
    - more tests increase probability that code is correct

# Testing methods: Black box testing

- Choose the testing data based on the specification of algorithms (data, results) without analyzing the code
- Test if the application does what is supposed to do
  - Normal values
  - Boundary conditions on the values e.g empty list, large numbers, etc
  - Error conditions
- Verifies if the application respects the specification
- Designed without looking at the code – can avoid implementation biases

# Testing methods: White box testing

- Choose testing cases based on the code of the algorithms
  - Cover all possible execution flows based on the implementation
  - Path-complete: if every potential path through code is tested at least once

- Recommendations
  - `If`
    - Test all parts of conditionals
  - `While, for`
    - Test all cases to exit the loop
    - Loop not entered
    - Loop executed only once or several times

# Examples
# Black box testing

```
def isPrime(x):
    '''
    checks if a number is prime or not
    Data: x - a positive integer number
    Results: True, if x is prime,
    False if x is composed
    raise ValueError if x < 0
    '''
   if (x < 0):
        raise ValueError("give a positive
         number to be tested...")
   else:
        if (x < 2):
            return False
        else:
            d = 2
            while (d * d <= x):
                if (x % d == 0):
                    return False
                d = d + 1
            return True
```

```
def testIsPrime():
    #black box testing
    #test a prime number
    assert isPrime(5) == True
    #test a composed number
    assert isPrime(15) == False
    #test 0
    assert isPrime(0) == False
    #test a negative number
    try:
        isPrime(-3)
        assert False
    except ValueError as ex:
        print("some errors: " + str(ex))
        assert True
```

```
def testIsPrime():
    for i in range(-100, 1):
        try:
            isPrime(i)
            assert False
        except ValueError:
            pass

    primes = [2, 3, 5, 7, 11, 13, 17, 19]
    for i in range(2, 20):
        assert isPrime(i) == (i in primes), "this is the
value where it fails: " + str(i)
```

# Examples
# White box testing

```
def isPrime(x):
    '''
    checks if a number is prime or not
    Data: x - a potivie integer number
    Results: True, if x is prime,
    False if x is composed
    raise ValueError if x < 0
    '''
S1 if (x < 0):
S2      raise ValueError("give a positive
         number to be tested...")
S3 else:
S4      if (x < 2):
S5          return False
S6      else:
S7          d = 2
S8          while (d * d <= x):
S9              if (x % d == 0):
S10                 return False
S11             d = d + 1
S12         return True
```

```
def testIsPrime():
    #white box testing (cover all paths)
    # x < 0 => S1, S2
    try:
        isPrime(-5)
        assert False
    except ValueError as ex:
        print("some errors: " + str(ex))
        assert True

    #0 <= x < 2 => S3, S4, S5
    assert isPrime(0) == False
    assert isPrime(1) == False

    #x = 2 or x = 3 => S3, S6, S7, S12
    assert isPrime(2) == True
    assert isPrime(3) == True

    #x = 11 => S3,S6,S7,S8,S11,S8,S11,S12
    assert isPrime(11) == True

    #x = 15 => S3,S6,S7,S8,S11,S8,S9,S10
    assert isPrime(15) == False

testIsPrime()
```

# Examples

```python
def sumOfEvenValues(l):
    '''
    computes the sum of even values from a list
    Data: l - a list of integers
    Results: sum of even values of l
    '''
    s = 0
    for i in range(0, len(l)):
        if (l[i] % 2 == 0):
            s = s + l[i]
    return s
```

```python
def testSumOfEvenValues():
    #empty list
    assert sumOfEvenValues([]) == 0

    #no even value
    assert sumOfEvenValues([5,1,7,3]) == 0

    #one even value
    assert sumOfEvenValues([5,2,7,3]) == 2

    #more even values
    assert sumOfEvenValues([5,2,7,4,6,3])==12

    #all values are even
    assert sumOfEvenValues([4,8,2,6]) == 20

testSumOfEvenValues()
```

# Examples

```python
def changeElement(l, pos, el):
    '''
    change the pos-th element of list to el
    Data: a list l, a position, a new element
    Results: list l' with l[pos] == el
    raise IndexError if pos < 0 or
    pos >= len(l)
    '''
    if (pos < 0):
        raise IndexError("pos must be positive")
    else:
        if (pos >= len(l)):
            raise IndexError("position must be
                  smaller to the length of list")
        else: #a valid position
            l[pos] = el
            return l
```

```python
def testChangeElement():
    #black box testing and white box testing

    #negative position
    try:
        changeElement([1,3,9,2], -2, 5)
        assert False
    except IndexError as ex:
        print("some errors: " + str(ex))

    #position > len(l)
    try:
        changeElement([1,3,9,2], 6, 5)
        assert False
    except IndexError as ex:
        print("some errors: " + str(ex))

    #valid data
    assert changeElement([1,3,9,2],2,5)==[1,3,5,2]

testChangeElement()
```

| Black box testing | White box testing |
| --- | --- |
| ***Advantages*** | |
| + Acces to source code is not required | + Knowing about the code:  makes testing it easier |
| + Testing can be **reused** if implementation changes | + Can help find hidden defects |
| + Efficient for large code sources | + Can help optimize code |
| + Separates implementer - tester | + Easier to obtain high test coverage |
| ***Drawbacks*** | |
| - Test coverage might be low | - Problems with code that is completely missing |
| - Testing might be inefficient | - Requires access to the code and good knowledge of the code |

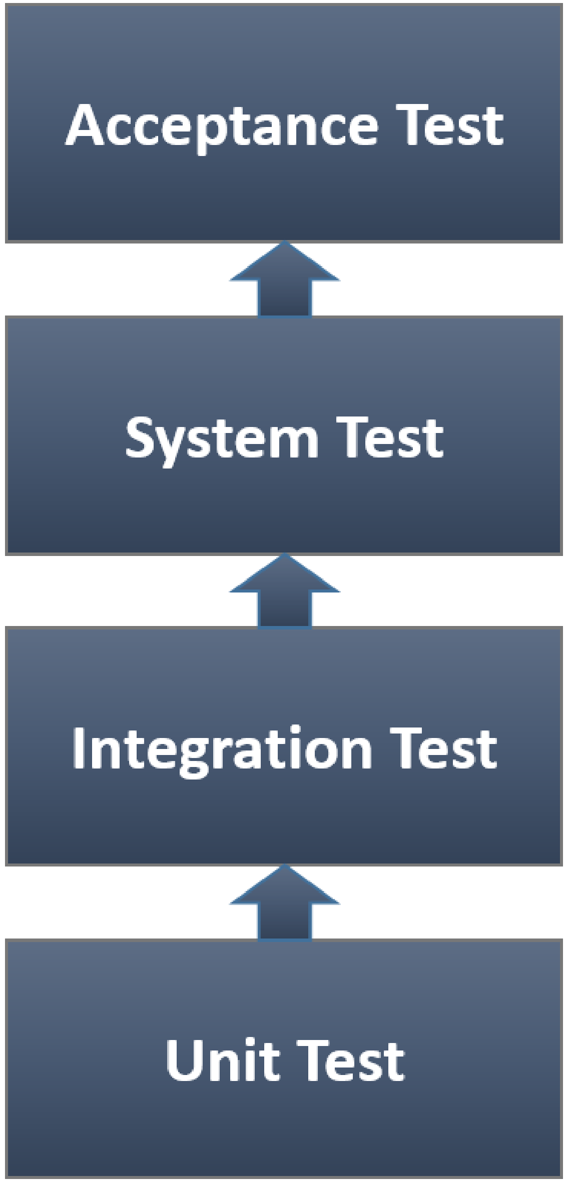
# Testing Levels

- Tests are frequently grouped
  - By where they are added in the software development process
  - By the level of specificity of the test

- Testing
  - Manual testing
  - Automated testing
    - Writing software to do testing that would otherwise need to be done manually
    - PyUnit - Python unit testing framework

# Testing Levels

- Unit Test
  - Verify the functionality of a specific section of code e.g. a function
  - Test small parts of the program independently
- Integration Test
  - Test different parts of the system in combination
  - Bottom-up approach: based on the results of unit testing
- System Test
  - Tests how the program works as a whole after all modules have been tested
- Acceptance Test
  - Check that the system complies with user requirements and is ready for use



# Testing in Python

- Automated Testing
  - The process of writing programs to do testing that would otherwise need to be done manually
  - Use of software to control the execution of tests, the comparison of actual outcomes to predicted outcomes, the setting up of test preconditions
- **unittest**
  - Python framework for writing Unit Tests, Integration Tests and Acceptance Test
  - provides a class **TestCase** and a **main()** method

```
from unittest import TestCase, main OR import unittest
```

# Testing in Python: unittest

- Test classes in Python
  - Test classes should extend TestCase and contain at least one method starting with test_
  - Test methods contain assertions (assertEqual, assertTrue, etc)

```
from unittest import TestCase, main

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

- Running the tests
  - **unittest.main** method looks for all classes derived from TestCase
  - Runs all the tests and reports

```
if __name__ == "__main__":
    main()
```

- Methods setUp() and tearDown() can be used to prepare testing and clean up afterwards

# Example

```python
def isPrime(n):
    """
    Verify if a number is prime
    Return True if n is prime, False otherwise
    Raise ValueError if n <= 0
    """
    if n <= 0:
        raise ValueError("The number needs to be
    if n == 1:
        return False
    if n <= 3:
        return True
    for i in range(2, n):
        if n % i == 0:
            return False
    return True
```

```python
import unittest
from utils import isPrime

class IsPrimeBlackBoxTest(unittest.TestCase):

    def setUp(self):
        unittest.TestCase.setUp(self)

    def tearDown(self):
        unittest.TestCase.tearDown(self)

    def test_IsPrimeBlackBox(self):
        for i in range(-100, 1):
            try:
                isPrime(i)
                assert False
            except ValueError:
                assert True

        primes = [2, 3, 5, 7, 11, 13, 17, 19]
        for i in range(2, 20):
            self.assertTrue(isPrime(i) == (i in primes),
"The value where it fails: " + str(i))

if __name__ == "__main__":
    unittest.main()
```

# Example

```python
def isPrime(n):
    """
    Verify if a number is prime
    Return True if n is prime, False otherwise
    Raise ValueError if n <= 0
    """
    if n <= 0:
        raise ValueError("The number needs to be positiv
```

```
Console  PyUnit
<terminated> test_cami.py [unittest] [C:\Program Files (x86)\Python36-32\python.exe]
Finding files... done.
Importing test modules ... done.

----------------------------------------------------------------------
Ran 2 tests in 0.002s

OK
```

```python
import unittest
from utils import isPrime

class IsPrimeWhiteBoxTest(unittest.TestCase):
    def setUp(self):
        unittest.TestCase.setUp(self)

    def tearDown(self):
        unittest.TestCase.tearDown(self)

    def test_IsPrimeWhiteBox(self):
        try:
            isPrime(-5)
            assert False
        except ValueError:
            assert True

        self.assertFalse(isPrime(1))
        self.assertTrue(isPrime(2))
        self.assertTrue(isPrime(3), 3)
        self.assertFalse(isPrime(6), 6)
        self.assertTrue(isPrime(7), 7)
        self.assertFalse(isPrime(8), 8)

if __name__ == "__main__":
    unittest.main()
```

# Assert methods in unittest.TestCase

| Method | Checks that |
|---|---|
| assertEqual(a, b) | a == b |
| assertNotEqual(a, b) | a != b |
| assertTrue(x) | bool(x) is True |
| assertFalse(x) | bool(x) is False |
| assertIs(a, b) | a is b |
| assertIsNot(a, b) | a is not b |
| assertIsNone(x) | x is None |
| assertIsNotNone(x) | x is not None |
| assertIn(a, b) | a in b |
| assertNotIn(a, b) | a not in b |

| Method | Checks that |
|---|---|
| assertAlmostEqual(a, b) | round(a-b, 7) == 0 |
| assertNotAlmostEqual(a, b) | round(a-b, 7) != 0 |
| assertGreater(a, b) | a > b |
| assertGreaterEqual(a, b) | a >= b |
| assertLess(a, b) | a < b |
| assertLessEqual(a, b) | a <= b |

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

# Example

domain.Person

```
class Person(object):

    def __init__(self, name, age):
        self.__name = name
        self.__age = age

    def __str__(self):
        return self.__name + " , " + str(sel

    def getName(self):
        return self.__name

    def setName(self, name):
        self.__name = name

    def getAge(self):
        return self.__age

    def setAge(self, age):
        self.__age = age

    def incrementAge(self):
        self.__age += 1
```

test.PersonTest

```
import unittest
from domain.Person import Person

class PersonTest(unittest.TestCase):

    def setUp(self):
        self.person = Person("Simpson", 8)

    def test_IncrementAge(self):
        self.person.setAge(9)
        self.person.incrementAge()
        self.assertEqual(self.person.getAge(), 10)

if __name__ == "__main__":
    unittest.main()
```

# Debugging

- When testing indicates the presence of errors -> debugging

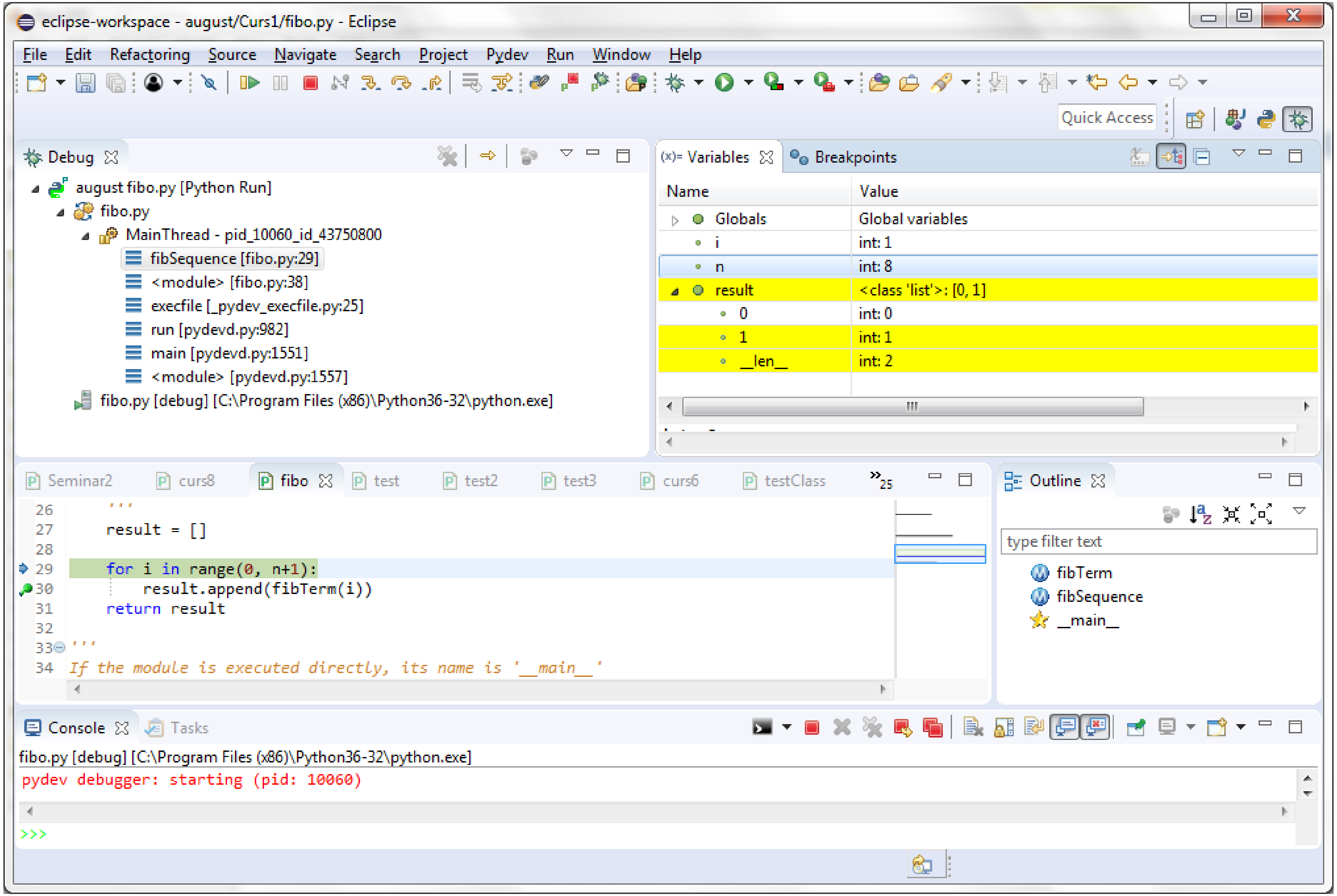
- Debugging the code
  - Identify why a program is not working as expected
  - Study the events that generate an error
  - Use print!

- Rewrite the program with the purpose of eliminating the errors

# Debugging in Eclipse

- Debug view
  - View the current execution trace (stack trace)
  - Execute step by step, resume/pause execution

- Variables view
  - View variable values



eclipse-workspace - august/Curs1/fibo.py - Eclipse
File Edit Refactoring Source Navigate Search Project Pydev Run Window Help
Quick Access
Debug
august fibo.py [Python Run]
fibo.py
MainThread - pid_10060_id_43750800
fibSequence [fibo.py:29]
<module> [fibo.py:38]
execfile [_pydev_execfile.py:25]
run [pydevd.py:982]
main [pydevd.py:1551]
<module> [pydevd.py:1557]
fibo.py [debug] [C:\Program Files (x86)\Python36-32\python.exe]
(x)= Variables
Breakpoints
Name
Value
Globals
Global variables
i
int: 1
n
int: 8
result
<class 'list'>: [0, 1]
0
int: 0
1
int: 1
__len__
int: 2
Seminar2
curs8
fibo
test
test2
test3
curs6
testClass
»25
26 '''
27 result = []
28
29 for i in range(0, n+1):
30 result.append(fibTerm(i))
31 return result
32
33 '''
34 If the module is executed directly, its name is '__main__'
Outline
type filter text
fibTerm
fibSequence
__main__
Console
Tasks
fibo.py [debug] [C:\Program Files (x86)\Python36-32\python.exe]
pydev debugger: starting (pid: 10060)
>>>

# Coding style

- Readability
  - The main attribute of style
  - A good programmer writes code that humans can understand
- Coding style
  - Comments
  - Text formatting (indentation, white spaces)
  - Specification
  - Good names for entities (classes, functions, variables) of the program
  - Meaningful names
  - Use naming conventions

# Recap: Design principles (see Lecture 4)

- Managing dependency:
  - Single Responsability
  - Separation of Concerns
  - Low Coupling
  - High Cohesion
- Create software:
  - Easy to understand, modify, maintain, test
  - Classes – data abstraction, encapsulate, hide implementation
  - Easy to test, easy to reuse
- Example: create an application to manage students
  - CRUD operations - **C**reate **R**ead **U**pdate **D**elete
  - Features – *Create student, List students, Find a student, Delete a student*

# Recap: Layered Architecture (see Lecture 4)

- Layered architecture
    - Low coupling between modules
        - Modules do not need to know details about other modules
    - High cohesion of each module
        - The elements of a module should be highly related
- Layers:
    - User Interface Layer (presentation layer)
    - Application Layer (service layer or controller layer)
    - Infrastructure Layer (data access, other persistence)
    - Domain Layer (business logic layer)
- Coordinator

# GRASP

- General Responsibility Assignment Software Patterns (or Principles)
  - Guidelines for assigning responsibility to classes and objects

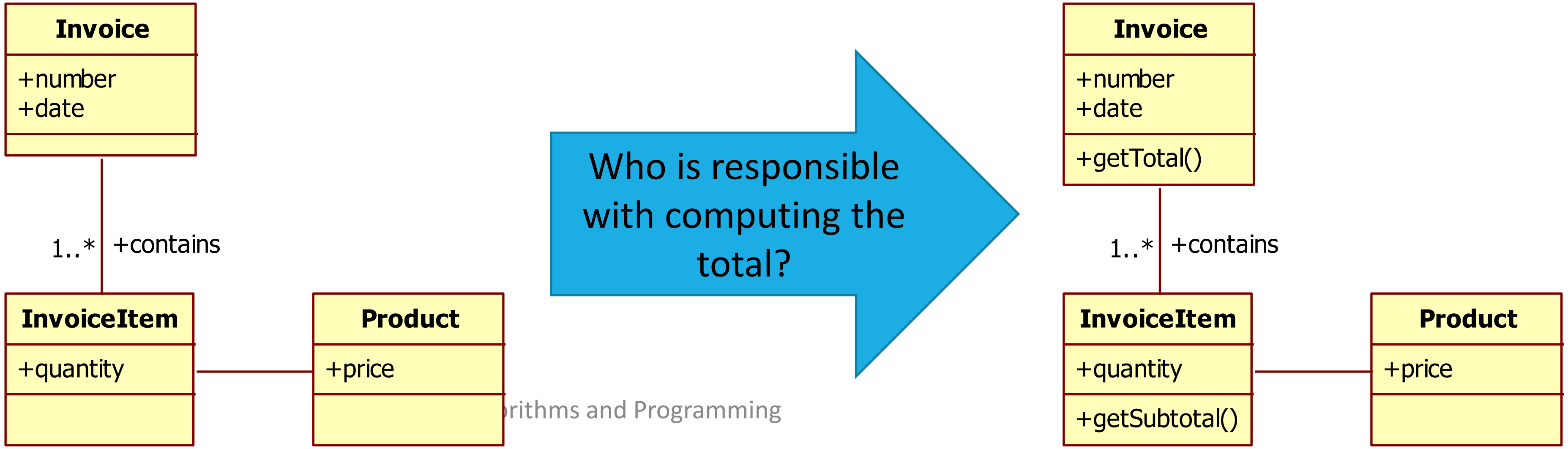
  - High Cohesion
  - Low Coupling
  - Information Expert
  - Creator
  - Pure Fabrication
  - Controller

# GRASP: High cohesion, Low couplimg

- High cohesion
  - The responsibilities of a given element are strongly related and highly focused
  - To increase cohesion: break programs into classes and subsystems
  - Low cohesion means that an element has too many unrelated responsibilities => problems: hard to understand, hard to reuse, hard to maintain
- Low coupling
  - Low dependency between classes
  - Low impact in a class of changes in other classes
  - High reuse potential
  - *Examples*
    - Class A has an attribute that is an instance of class B
    - Class A has a method that references an instance of class B in any form

# GRASP: Information Expert

- Assign a responsibility to the class that has the information necessary to fulfill the responsibility
- The principle of Information Expert:
  - Look at a given responsibility (e.g. method), determine the information needed to fulfill it, and then determine where that information is stored
  - Place the responsibility on the class with the most information required
- Example



# GRASP: Creator

- Which class is responsible for creating objects?
- Creator pattern: responsible for creating an object of the class
  - Class B should be responsible for creating instances of class A if:
    - Instances of B contain instances of A
    - Instances of B closely use instances of A
    - Instances of B have the initializing information for instances of A and can use it for creation
- Example
  - Task 1: Create student
  - Task 2: Store student (Repository)
  - Task 3: Add student (Controller)
  - Task 4: Create UI

# Task 1: Create student

```python
import unittest
from domain.Student import Student

class StudentTest(unittest.TestCase):

    def test_create(self):
        '''
        Testing Student creation
        '''
        st = Student("Zara", 21, 10)
        self.assertEqual(st.getName(), "Zara")
        self.assertEqual(st.getAge(), 21)
        self.assertEqual(st.getGrade(), 10)

if __name__ == "__main__":
    unittest.main()
```

```python
class Student(object):

    def __init__(self, name, age, grade):
        self.__name = name
        self.__age = age
        self.__grade = grade

    def __str__(self):
        return self.__name + " " + str(self.__grade)

    def getName(self):
        return self.__name

    def setName(self, name):
        self.__name = name

    def getAge(self):
        return self.__age

    def setAge(self, age):
        self.__age = age

    def getGrade(self):
        return self.__grade

    def setGrade(self, grade):
        self.__grade = grade
```

# GRASP: Pure Fabrication

- Pure Fabrication - a class added to an application in order to achieve low coupling, high cohesion and reuse
- When an expert violates high cohesion and low coupling => assign a highly cohesive set of responsibilities to an artificial class that does not represent a concept in the problem domain
- Example
  - Task 2: Store student (in memory, file or database)
  - Expert pattern - Student is the "expert" to perform this operation => low cohesion, poor reuse
  - Solution: Pure Fabrication

# Task 2: Store student (Create Repository)

- Solution – Pure Fabrication
  - Create a class with the responsibility to store students (StudentRepository)
  - Student class – easy to reuse, high cohesion, low coupling
  - Repository will manage a list of students (persistent storage)

| **StudentRepository** |
| --- |
| |
| +store(s: Student)<br>+update(s: Student)<br>+find(id: int): Student<br>+delete(s: Student) |

**Repository**

- Represents all objects of a certain type as a conceptual set
- Objects can be added, updated, removed and retrieved from the repository (persistent storage)

# Task 2: Store student (Create Repository)

```python
def test_storeStudent():
    repo = StudentRepository()
    assert repo.size() == 0

    s1 = Student(1, "Zara", 10)
    repo.store(s1)
    assert repo.size() == 1

    s2 = Student(2, "Erin", 10)
    repo.store(s2)
    assert repo.size() == 2

    s3 = Student(2, "Carla", 10)
    try:
        repo.store(s3)
        assert False
    except:
        assert True
```

```python
class StudentRepository(object):

    def __init__(self):
        '''
        Manage a list of Student objects
        '''
        self.__students = {}

    def store(self, student):
        '''
        Stores a student.
        Input: student is of type Student
        Raises an exception if the repository already
        contains a student with the same id.
        '''
        if student.getId() in self.__students:
            raise ValueError("A student with id " +
str(student.getId()) + " already exists.")

        self.__students[student.getId()] = student

    def size(self):
        return len(self.__students)
```

# GRASP: Controller

- Controller: the first object beyond the UI layer that receives and coordinates ("controls") a system operation
  - Delegates to other objects the work that needs to be done
  - Coordinates or controls the activity
  - It does not do much work itself
- Controller encapsulate knowledge about the current state of a use case presentation layer decoupled from problem domain
- Example
  - Task 3: Add student
  - Create controller

# Task 3: Add student (create controller)

```
def testCreateStudent():
    repo = StudentRepository()

    ctrl = StudentController(repo)

    s = ctrl.createStudent(1, "Zara", 10)
    assert s.getId() == 1
    assert s.getName() == "Zara"

    try:
        s = ctrl.createStudent(1, "Erin", 10)
        assert False
    except:
        assert True
```

```
class StudentController():
    '''
    Controller for CRUD operations on Student list.
    '''

    def __init__(self, repo):
        self.__repo = repo

    def createStudent(self, i, name, grade):
        '''
        Creates a student and stores it in the repository.
        Input: the id of student as int, name of student as
        string, age and grade of student as ints
        Returns a student.
        Raises ValueError if id of student already exists.
        '''
        s = Student(i, name, grade)
        self.__repo.store(s)

    def addStudent(self, s):
        self.__repo.store(s)
```

# Task 4: Create UI

```
class StudentUI(object):
    def __init__(self, controller):
         self.__controller = controller

    @staticmethod
    def printMenu():
         ...

    def mainMenu(self):
        while True:
            try:
                StudentUI.printMenu()
                command = input("Enter command: ").strip()
                if command == "0":
                    print("exit...")
                    return
                elif command == "1":
                    s = StudentUI.readStudent()
                    self.__controller.addStudent(s)
                ...
                else:
                    print("Invalid command!")
            except Exception as e:
                print("Error encountered : " + str(e))
```

# Coordinator: App start

```python
from infrastructure.studentRepo import StudentRepository
from application.studentController import StudentController
from ui.console import StudentUI

from domain.Student import Student

def start():
    #create repository
    repo = StudentRepository()
    repo.store(Student(1, "Erin", 10))
    repo.store(Student(2, "Zara", 10))

    #create controller, provide repository
    controller = StudentController(repo)

    # create UI, provide controller
    ui = StudentUI(controller)
    ui.mainMenu()
```

# NumPy

- Acronym for "Numerical Python"

- Useful to perform mathematical and logical operations on arrays

- Library
  - Multidimensional arrays and matrices
  - Collection of routines for processing arrays

- SciPy (Scientific Python) extends NumPy

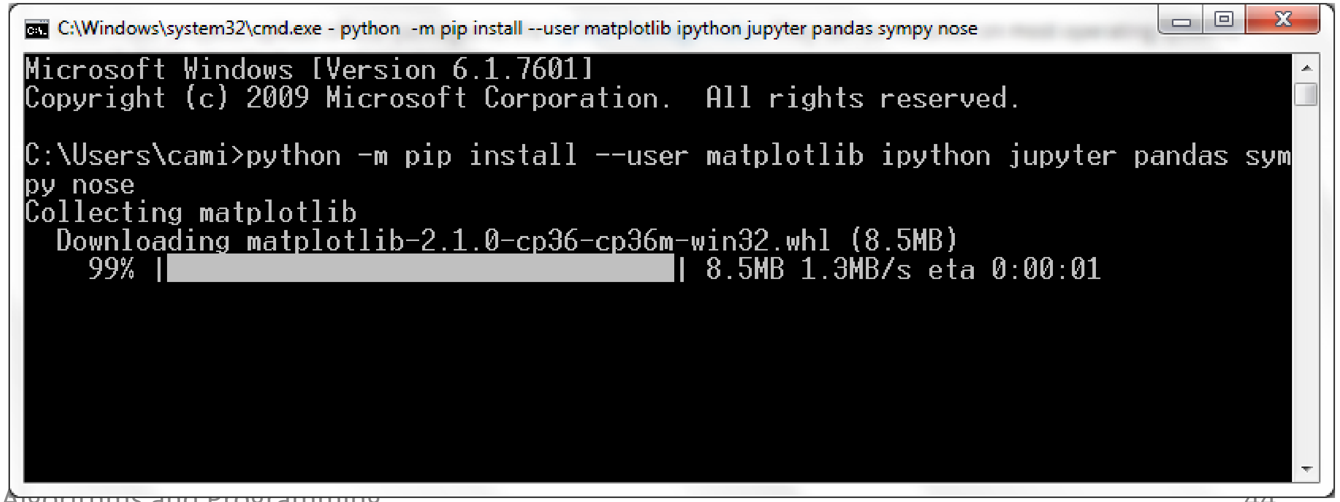
# NumPy

- Has to be installed

  [http://www.numpy.org](http://www.numpy.org)

- Free Python distributions with SciPy for Windows
  - Anaconda, Canopy, Python(x,y)
- Installing via pip (Python's standard package manager)
  - Need to have Python and pip already installed

```
python install numpy
```



# NumPy

```python
import numpy
import numpy as np
```

```
Python 3.6.2 Shell
File Edit Shell Debug Options Window Help
>>> import numpy as np
>>> cvalues = [20.1, 20.8, 21.9, 22.5, 22.7]
>>> C = np.array(cvalues)
>>> C
array([ 20.1,  20.8,  21.9,  22.5,  22.7])
>>> print(C)
[ 20.1  20.8  21.9  22.5  22.7]
>>> print(C * 9 / 5 + 32)
[ 68.18  69.44  71.42  72.5   72.86]
>>> print(C)
[ 20.1  20.8  21.9  22.5  22.7]
>>> type(C)
<class 'numpy.ndarray'>
>>>
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```

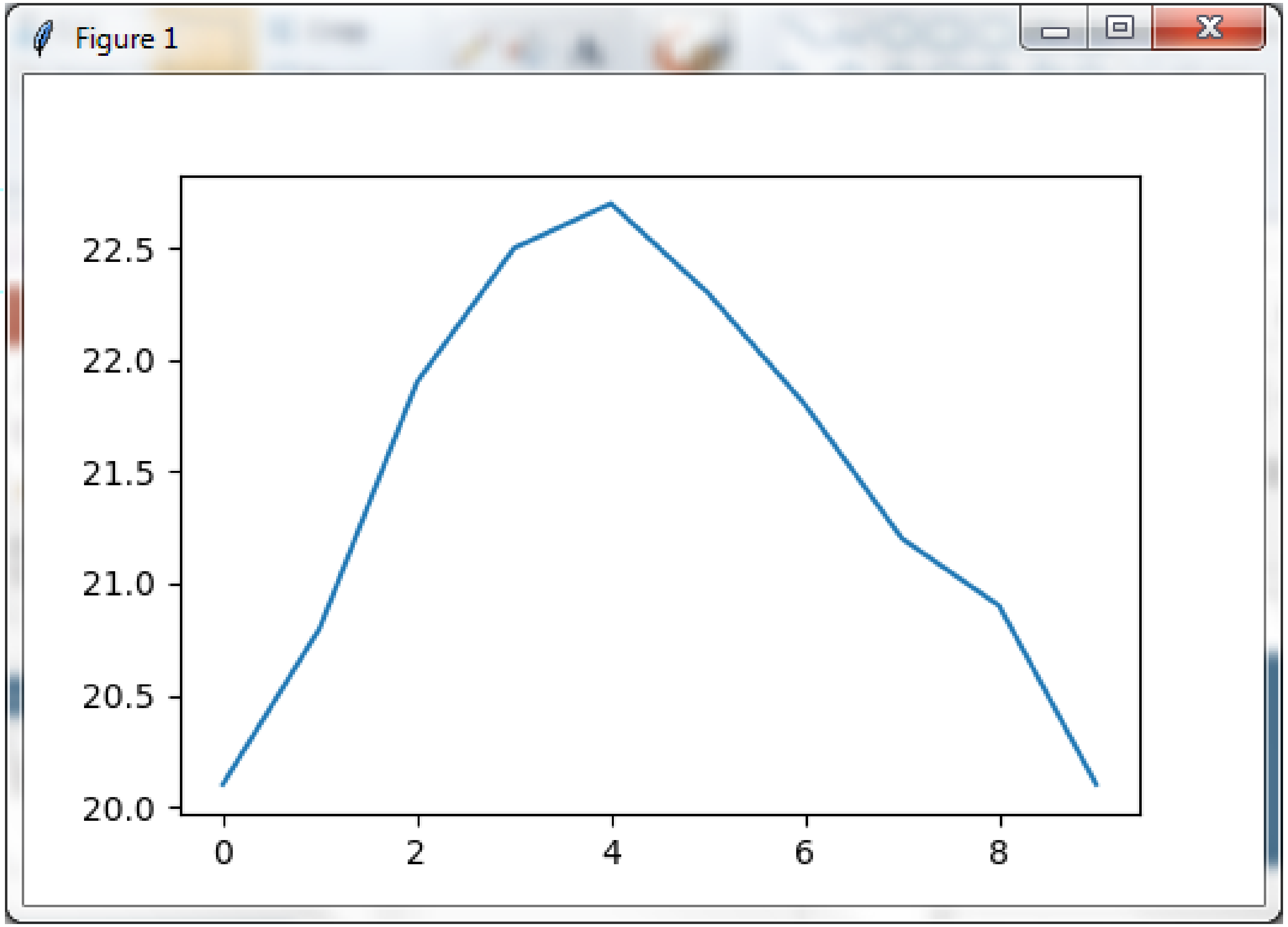
# NumPy

```
>>> b = np.array([(1.5,2,3), (4,5,6)])
>>> print(b)
[[ 1.5  2.   3. ]
 [ 4.   5.   6. ]]
>>> np.arange(10)
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> 
```

```
>>> import numpy as np
>>> a = np.arange(20).reshape(4,5)
>>> print(a)
[[ 0  1  2  3  4]
 [ 5  6  7  8  9]
 [10 11 12 13 14]
 [15 16 17 18 19]]
>>> a.shape
(4, 5)
>>> a.shape[1]
5
>>> a.ndim
2
>>> a.size
20
```

# NumPy

```
>>> import numpy as np
>>> cvalues = [20.1, 20.8, 21.9, 22
>>> C = np.array(cvalues)
>>> import matplotlib.pyplot as plt
>>> plt.plot(C)
[<matplotlib.lines.Line2D object at
>>> plt.show()
```



# NumPy: Array creation

```
>>> a = np.array([1,2,3])
>>> print(a)
[1 2 3]
```

```
a = np.array(1,2,3,4)      # WRONG
a = np.array([1,2,3,4])    # RIGHT
```

```
>>> b=np.array([[1,2,3],[4,5,6]])
>>> print(b)
[[1 2 3]
 [4 5 6]]
```

```
>>> np.random.random(5)
array([ 0.13501571,  0.84082373,  0.9451692 ,  0.0359
4509,  0.96148578])
```

Python 3.6.2 Shell

File Edit Shell Debug Options Window Help

```
>>> np.zeros(3)
array([ 0.,  0.,  0.])
>>> np.zeros((3,4))
array([[ 0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.]])
>>> np.ones(10)
array([ 1.,  1.,  1.,  1.,  1.,  1.,  1.,  1.,  1.,  1.])
>>> np.ones((2,2), dtype=np.int16)
array([[1, 1],
       [1, 1]], dtype=int16)
>>> c=np.ones((2,2), dtype=np.int16)
>>> print(c)
[[1 1]
 [1 1]]
>>> np.arange(10, 50, 5)
array([10, 15, 20, 25, 30, 35, 40, 45])
>>> np.arange(10)
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> x=np.arange(5)
>>> print(x)
[0 1 2 3 4]
>>> y=np.arange(12).reshape(3,4)
>>> print(y)
[[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]]
>>>
```

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# NumPy: Basic operations

```
>>> a=np.arange(10)**2
>>> print(a)
[ 0  1  4  9 16 25 36 49 64 81]
>>> a[1]
1
>>> a[9]
81
>>> a[10]
Traceback (most recent call last):
  File "<pyshell#103>", line 1, in <module>
    a[10]
IndexError: index 10 is out of bounds for axis 0 with
size 10
>>> a[2:5]
array([ 4,  9, 16], dtype=int32)
>>> a[:2]
array([0, 1], dtype=int32)
>>> for el in a:
        print(el)
```

```
>>> a = np.arange(10)
>>> print(a)
[0 1 2 3 4 5 6 7 8 9]
>>> a.reshape(2,5)
array([[0, 1, 2, 3, 4],
       [5, 6, 7, 8, 9]])
>>> print(a)
[0 1 2 3 4 5 6 7 8 9]
```

# NumPy: Basic operations

```
>>> a = np.array([10,20,30])
>>> b = np.arange(3)
>>> b
array([0, 1, 2])
>>> c=a+b
>>> c
array([10, 21, 32])
>>> a-b
array([10, 19, 28])
>>> b**2
array([0, 1, 4], dtype=int32)
>>> np.sin(a)
array([-0.54402111,  0.91294525, -0.98803162])
>>> a<20
array([ True, False, False], dtype=bool)
>>>
```

Elementwise product

```
>>> a*b
array([ 0, 20, 60])
```

Array product

```
>>> a.dot(b)
80
>>> np.dot(a,b)
80
```

# NumPy: Basic operations

```
>>> b += 1
>>> b
array([1, 2, 3])
>>> b *= 2
>>> b
array([2, 4, 6])
>>> a
array([10, 20, 30])
>>> a.sum()
60
>>> a.min()
10
>>> a.max()
30
```

```
>>> b = np.arange(12).reshape(3,4)
>>> print(b)
[[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]]
>>> b.sum()
66
>>> b.sum(axis=0)
array([12, 15, 18, 21])
>>> b.sum(axis=1)
array([ 6, 22, 38])
>>> b.min()
0
>>> b.min(axis=0)
array([0, 1, 2, 3])
>>> b.min(axis=1)
array([0, 4, 8])
```

# Recap today

- Testing
  - Concept
  - Testing data
  - Examples
  - Testing in Python: unittest

- Organize a software application
  - Layers
  - GRASP patterns
  - Examples

# Next time

- Recursivity