BABEŞ-BOLYAI UNIVERSITY
Faculty of Mathematics and Computer Science

Algorithms and Programming

Lecture 4 – Software design principles

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Course content

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

Last time

- Modular programming
  - Modules
  - Packages
  - `import` statement

- Exceptions
  - Concept
  - Mechanism
  - Examples

Today

- Exceptions
- Architecture of an application
- Principles of organizing the code
- Working with files

Eclipse IDE

- Eclipse is an advanced IDE
  - Free, configurable and easy to use
- Provides lots of plugins to allow development in many languages, including Java, C/C++, Python...
- **Eclipse + PyDev:** setting up for Python development
  - By default, Eclipse can be used to develop Java software
  - To develop in Python: get the **PyDev plugin** (www.pydev.org)
  - PyDev links Eclipse to the installed Python interpreter and libraries, provides wizards for project creation, syntax highlighting and code completion
- Working with projects, navigating and editing source files and program resources, testing and debugging

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

Error messages

- SyntaxError

```
a = input("First number is“
b = input("First number is“)
```

- NameError

```
>>> a
Traceback (most recent call last):
  File "<pyshell#7>", line 1, in <module>
    a
NameError: name 'a' is not defined
>>> a=5
>>> a
5
```

- TypeError

```
a = input('First number is')
int(a)
b = a % 2
print (b)
```

- IndexError

```
>>> my_list = [1, 2, "a", 3]
>>> my_list[1]
2
>>> my_list[5]
Traceback (most recent call last):
  File "<pyshell#2>", line 1, in <module>
    my_list[5]
IndexError: list index out of range
```

- AttributeError
- IOError

Easy to fix

Exceptions

- Concept
  - Exceptions are raised when errors are detected during program execution
  - Exceptions can interrupt the normal execution of a block
- Mechanism
  - Exceptions are identified and thrown by the Python interpretor
  - Use the code to indicate the special situations

```
d = int(input("Enter a number: ")) # d = 0
print(5 / d)
x = d * 10
```

```
Traceback (most recent call last):
  File "C:\cami\work\work-ubb\teaching
est.py", line 33, in <module>
    print(5 / d)
ZeroDivisionError: division by zero
```

Exceptions: mechanism

- Identify exceptions
  - raise statement
  - Python interpretor

```
def functionThatRaiseAnException(a, b):
    if (cond):
        raise ValueError("message")
    # code
```

- Catch and treat an exception
  - try..except(..finally) statement

```
try:
    # main code
except ExceptionType1 as e1:
    #if e1 appears, this code is executed
except ExceptionType2 as e2:
    #if e2 appears, this code is executed
else:
    #if there is no exception, this code is executed
```

```python
def gcd(a, b):
    if (a == 0):
        if (b == 0):
            return -1   # a == b == 0
        else:
            return b    # a == 0, b != 0
    else:
        if (b == 0):    # a != 0, b == 0
            return a
        else:           # a != 0, b != 0
            while (a != b):
                if (a > b):
                    a = a - b
                else:
                    b = b - a
            return a    # a == b

def run_gcd():
    a = int(input("Input the first number: "))
    b = int(input("Input the second number: "))
    print(“GCD of ", a, "and ", b, " is ", gcd(a,b))

run_gcd()
```

```python
def gcd_v2(a, b):
    if (a == 0):
        if (b == 0):
            raise ValueError("one number must be != 0")
        else:
            return b    # a == 0, b != 0
    else:
        if (b == 0):    # a != 0, b == 0
            return a
        else:           # a != 0, b != 0
            while (a != b):
                if (a > b):
                    a = a - b
                else:
                    b = b - a
            return a    # a == b

def ru
    a
    b
    pr                                                    )

run_gc
```

```
Input the first number: 0
Input the second number: 0
Traceback (most recent call last):
  File "C:\cami\work\work-ubb\teaching\Fundament
est.py", line 31, in <module>
    run_gcd()
  File "C:\cami\work\work-ubb\teaching\Fundament
est.py", line 28, in run_gcd
    print("Greatest Common Divisor of ", a, "and
  File "C:\cami\work\work-ubb\teaching\Fundament
est.py", line 11, in gcd
    raise ValueError("one number must be != 0")
ValueError: one number must be != 0
```

Exceptions

- Mechanism
  - Catch exceptions – Python code can include handlers for exceptions
  - Statement `try...except`
  - The clause `finally` - statements that will always be executed (clean-up code)

```
try:
    #code that may raise exceptions
except ValueError:
    #code to handle the error
finally:
    #code that is executed in all the cases
```

```
try:
    d = 0
    print (5 / d)
    x = d * 10
except ZeroDivisionError:
    print("division by zero error...")
finally:
    print("all cases...")
```

```
def run_gcd():
    a = int(input("Input the first number: "))
    b = int(input("Input the second number: "))
    try:
        div = gcd_v2(a,b)
        print("gcd of ", a, " and ", b, " is ", div)
    except ValueError as ex:
        print("exceptional case: ", ex)
    finally:
        print("do you
```

```
Input the first number: 0
Input the second number: 0
exceptional case:  one number must be != 0
do you want to try again?
```

Exceptions: more examples

```
try:
    a = int(input("Enter the first number: "))
    b = int(input("Enter the second number: "))
    print("a+b = ", a+b)
    print("a/b = ", a/b)
    print("a**b = ", a**b)
except ValueError:
    print("The value you entered is not a number!")
except ZeroDivisionError:
    print("The second number can not be zero: division by zero!")
except:
    print("An exception occurred...")
```

Exceptions and testing

```python
def gcd_v2(a, b):
    if (a == 0):
        if (b == 0):
            raise ValueError("one number must be != 0")
        else:
            return b    # a == 0, b != 0
    else:
        if (b == 0):    # a != 0, b == 0
            return a
        else:           # a != 0, b != 0
            while (a != b):
                if (a > b):
                    a = a - b
                else:
                    b = b - a
            return a    # a == b
```

```python
def run_gcd():
    a = int(input("Input the first number: "))
    b = int(input("Input the second number: "))
    try:
        div = gcd_v2(a,b)
        print("gcd of ", a, " and ", b, " is ", div)
    except ValueError as ex:
        print("exceptional case: ", ex)
    finally:
        print("do you want to try again?")
```

```python
def test_gcd_v2():
    assert gcd_v2(0, 2) == 2
    assert gcd_v2(2, 0) == 2
    assert gcd_v2(3, 2) == 1
    assert gcd_v2(6, 2) == 2
    assert gcd_v2(4, 6) == 2
    assert gcd_v2(24, 9) == 3

    try:
        gcd_v2(0, 0)
        assert False
    except ValueError:
        assert True
```

Exceptions

- When should exceptions be used?

  - Identify special situations
    - Ex1: A function does not receive parameters according to its specification
    - Ex2: Operating on data from files that do not exist or can not be accessed
    - Ex3: Impossible operations (division by 0)

  - Force compliance with specifications (pre-conditions)

Organize the code of an application

- Layered architectures
  - Decomposing by features – 2 perspectives:
    - Functional perspective – identifying different features specified by the problem
    - Technical perspective – introducing technical features (such as user interaction, file management, databases, networks , etc)
  - Recommended solution:
    - Decompose a complex application on layers
    - Concentrate the code related to the domain of the problem in a single layer and isolate it
    - Ensure cohesive layers

Organize the code of an application

- How to organize the code
  - Create modules for
    - User interface
      - Functions dealing with user interaction
      - Contains read operations and display methods
      - The only module used to read and output data
    - Domain of the application
      - Functions dealing with the problem domain
    - Infrastructure
      - Useful functions that are highly to be reused (e.g. logging, network I/O)
    - Application coordinator
      - Initializes and starts the application

Organize the code of an application

- Good software design:
  - ✓ Code easy to understand
  - ✓ Easy to test
  - ✓ Easy to maintain
  - ✓ Easy to develop and modify (e.g. add features)
- Key design principles
  - Single Responsibility Principle
  - Separation of Concerns Principle
  - Reuse Principle
  - Cohesion and Coupling Principle

Organize the code of an application

- Single Responsibility Principle
  - Responsibility = a reason to change something
  - Responsibility
    - Of a function = to compute something
    - Of a module = responsibilities of all functions in the module
  - The principle of a single responsibility
    - A function / module should have one responsibility
  - Multiple responsibilities:
    - Difficulties in understanding and using
    - Impossibility of testing
    - Impossibility of reusing
    - Difficulties in maintenance and development

```
#Function with multiple responsibilities
#implement user interaction (read/print)
#implement a computation (filter)
def filterScore():
    global l
    left = input("Start score:")
    right = input("End score:")
    for el in l:
        if ((el > left) and (el < right)):
            print el
```

Organize the code of an application

- Separation of concerns
  - Process of separating a program based on features that overlap as little as possible

```python
def filterScoreUI():
    global l
    inf = input("Start sc:")
    sup = input("End sc:")
    rez = filterScore(l, inf, sup)
    for e in rez:
        print(e)

def filterScore(l, left, right):
    """
    filter elements of list l
    st, end - integers limits
    return list of elements
    filtered by left and right limits
    """
    rez = []
    for el in l:
        if ((el > left) and (el < right)):
            rez.append(el)
    return rez
```

```python
def testFilterScore():
    l = [5, 2, 6, 8]
    assert filterScore(l, 3, 4) == []
    assert filterScore(l, 1, 30) == l
    assert filterScore(l,3,7)==[5, 6]
```

Organize the code of an application

- Reuse Principle
  - Using modules improves the maintenance of an application
    - For instance:
      - it is easier to isolate and correct mistakes
      - modify existing functionalities
  - Using modules facilitates reuse of elements defined in the application
    - Ex. Numericlibrary module (isPrime, gcd,...) can be used in several applications
  - Managing the dependencies increases reuse
    - Dependencies between functions
      - A function invokes (calls) another function / other functions
    - Dependencies between modules
      - The functions from a module invoke functions from other modules

Organize the code of an application

- Cohesion and Coupling Principle
  - The definition of modules should consider:
    - The cohesion degree
      - – how dependent are some elements on other elements of the module
    - The coupling degree
      - – how dependent is a module on other modules

Organize the code of an application

- Cohesion and Coupling Principle
  - Cohesion
    - Measures the degree to which a module has a single, well-focused purpose

  - A module can have:
    - High cohesion – the elements of the module are highly dependent on each other
      - Ex. Rational module contains operations specific to rational numbers
    - Low cohesion – the elements relate more to other activities (and not to each other)
      - Ex. Rational module uses functions from numericlibrary module

  - A highly cohesive module performs only one task
    - Needs reduced interaction with other parts of the program
    - Advantages:
      - Such modules are easier to maintain and not frequently changed
      - More usable because they are modules designed for a well-focused purpose

Organize the code of an application

- Cohesion and Coupling Principle
  - Coupling
    - Measures the intensity of connections between modules (how much a module knows of another module)

  - Modules can have:
    - High coupling – modules that are highly dependent on each other
      - A high coupling between modules leads to difficulties in:
        - Understanding the code
        - Reuse the code
        - Isolate possible mistakes
    - Low coupling – independent modules
      - Low coupling facilitates development of applications that are easy to modify (as the interdependency between functions/modules is minimal)

  - A low coupling between modules is desired
    - ✓ Good design principle

Organize the code of an application

- Layered architecture
  - Organizing the application on layers should consider:
    - Low coupling between modules
      - Modules do not need to know details about other modules – futures changes are easier to make
    - High cohesion of each module
      - The elements of a module should be highly related

Organize the code of an application

- Layered architecture
  - Organizing the application on layers should follow an architectural design pattern that:
    - Allows design of systems
      - Flexible
      - Using components (as independent as possible)

  - Each layer communicates with the previous layer

  - Each layer has a well-defined interface that is used by the superior layer (implementation details are hidden)

Organize the code of an application

- Layered architecture
  - Generally, the architecture of a system can be designed using the following layers:
    - User Interface Layer
      - Functions, modules, classes for the user interface
      - *User Interface Layer / UI Layer / View Layer / Presentation Layer*
    - Domain Layer
      - All functions generated by the use cases (the logic of the application)
      - *Domain Layer / Business Logic Layer / Model Layer*
    - Infrastructure Layer
      - Functions with a general character, reusable
    - Coordinator

Example

```python
#UI
def filterScoreUI():
    global l
    inf = input("Start sc:")
    sup = input("End sc:")
    rez = filterScoreDomain(l, inf, sup)
    for e in rez:
        print(e)
```

```python
#domain
l = [5, 2, 6, 8]
def filterScoreDomain(left, right):
    global l
    rez = filterScore(l, left, right)
    l = rez
    return rez
```

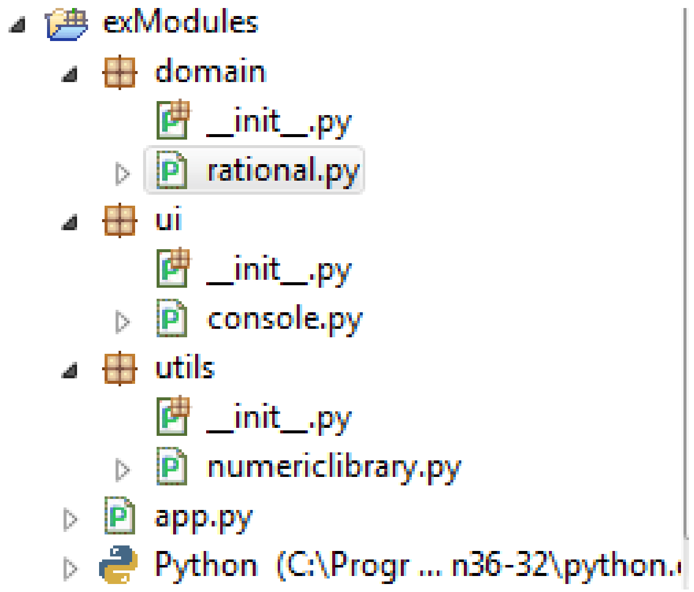
```python
#utility function (infrastructure)
def filterScore(l, left, right):
    """
    filter elements of list l
    st, end - integers limits
    return list of elements
    filtered by left and right limits
    """
    rez = []
    for el in l:
        if ((el > left) and (el <right)):
            rez.append(el)
    return rez

def testFilterScore():
    l = [5, 2, 6, 8]
    assert filterScore(l, 3, 4) == []
    assert filterScore(l, 1, 30) == l
    assert filterScore(l,3,7)==[5, 6]

testFilterScore()
```

Other examples

- Rational
  - Example from lecture 3
  - Application to manage rational numbers
  - Layers: domain, ui, utils, app



- More examples
  - Next lecture

Reading materials and useful links

1. The Python Programming Language - https://www.python.org/
2. The Python Standard Library - https://docs.python.org/3/library/index.html
3. The Python Tutorial - https://docs.python.org/3/tutorial/
4. M. Frentiu, H.F. Pop, Fundamentals of Programming, Cluj University Press, 2006.
5. MIT OpenCourseWare, Introduction to Computer Science and Programming in Python, https://ocw.mit.edu, 2016.
6. K. Beck, Test Driven Development: By Example. Addison-Wesley Longman, 2002. http://en.wikipedia.org/wiki/Test-driven_development
7. M. Fowler, Refactoring. Improving the Design of Existing Code, Addison-Wesley, 1999. http://refactoring.com/catalog/index.html