BABEŞ-BOLYAI UNIVERSITY
Faculty of Mathematics and Computer Science

Algorithms and Programming

Lecture 5 – Classes

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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

- Software Design Principles
- Working with files in Python

Today

- Abstract data types (ADT) or user-defined data types

- Developing classes using Python

Abstract data types

- Object-oriented programming
  - Concepts
  - Working principles

- Classes
  - Concept
  - How to define and use in Python

Object-oriented programming (OOP)

- Develop programs using
  - Objects – basic unit, each an instance of a class
  - Classes – links and inheritance

- Objects
  - Ex. “abc”, 12, [1, 2, 3]
  - Each object has a type, internal data representation and a set of procedures that can be used to interact with the object
  - An object is an instance of a type

OOP Concepts

- Class
  - Defines in an abstract way the characteristics of a thing:
    - Characteristics (attributes, fields, properties)
    - Behaviour (methods, operations)
  - Implementation
  - Creating a class: define the class name and the class attributes
  - Using a class: creating new instances of the class and using operations on it
- Object
  - Instance of a class
  - Attributes (the internal representation defined by the class)
  - Interface with the object using methods or functions (define the behavior)
- Method
  - They form the interface of an object
  - Objects communicate via methods

OOP: Example

- `my_list = [1, 2, 3]`
  - list in Python
  - An object
  - Internal representation?
  - Methods?
    - `len(my_list)`
    - `my_list.append(4)`
    - `del(my_list[1])`
    - etc

OOP characteristics

- **Encapsulation**
  - Capturing data and keeping it safely and securely from outside interfaces
  - Hiding the implementation – control the access
- **Inheritance**
  - A class can be derived from a base class with all features of base class and some of its own
  - Increases code reusability (reuse and improve code from a class)
- **Polymorphism**
  - An object of a class can be used in the same way as if it were a different object belonging to a different class
  - Flexibility and loose coupling – code can be extended and easily maintained over time

Creating your own types with classes

- Abstract Data Type
  - Export a name (a data type)
  - Define a domain of values for the data
  - Define an interface (the operation possible with the new data type)
  - Restrict access to the components of the new type (access only through methods)
  - Hide the implementation of the new type
- Create the class vs. using an instance of the class
- Use the `class` keyword to define a new type

Creating your own types: example 1

- Abstract Data type: Rational Number
  - Name: `Rational`
  - Domain

    $\{(a, b), a, b \in Z, b \neq 0, \gcd(a, b) = 1\}$
  - Operations:
    - Initialization
    - Acces to components (nominator, denominator)
    - Copy
    - Comparison
    - Add/subtract/multiply/divide/etc
    - ...

Creating your own types: example 2

- User-defined type: Flower
  - Name: `Flower`
  - Domain

    $$\{(name, price), name\ - string, price \in N\}$$
  - Operations:
    - Initialization
    - Acces to attribute values
    - Copy
    - Comparison
    - …

Abstract Data Type (ADT)

- Exporting a name (a data type)
- Define a domain of values for the data
- Define an interface (the operation possible with the new data type)
- Restrict access to the components of the ADT (access only through methods)
- Hide the implementation of ADT

How to define a class

```
class Flower:
    '''
    a flower is a structure of two elements: name (a string) and price (an integer)
    '''
    def __init__(self, n, p = 0):
        '''
            creates a new instance of Flower
        '''
        self.name = n
        self.price = p
        self.size = None

myFlower = Flower("rose", 5)
```

Special method to create an instance

Variable to refer an instance of the class

size is also a data attribute

Abstract Data Type (ADT)

- Define the class
  - Specify:
    - Data attributes
    - Methods
  - The name of the new type is the class name: `class Flower:`
  - Use `self` to refer to instances while defining the class:
    - `self.name, self.size < 10`
    - `self` is a parameter of methods
  - Data and methods in the class are the same for all instances of class
- An instance is a specific object: `f1 = Flower("rose", 5)`
  - Attribute values can vary `f2 = Flower(“tulip", 3)`

Creating a class in Python

- Class
  - Describes objects that follow the same specification and have the same characteristics
  - Attributes
    - The data describing the objects
  - Methods (procedural attributes)
    - The operations that can be performed on the data
- Class definition

```
class ClassName:
#statement1
#...
#statement n
```

```
class Rational:
    '''
    A rational number is composed by 2 numbers: numerator and denominator > 0
    denominator <> 0, gcd(numerator, denominator) == 1
    '''
    def __init__(self, num, denom):
        '''
            creates a new instance of Rational
        '''
        self.numerator = num
        self.denominator = denom
```

In Python, use a special method called **__init__** to initialize data attributes

Creating an instance of the class

- Object
  - An instance of a class
  - When a new object variable is created, the type has to be indicated (e.g. Rational)

```python
class Rational:
    '''
    A rational number is composed by 2 numbers: numerator and denominator > 0
    denominator <> 0, gcd(numerator, denominator) == 1
    '''
    def __init__(self, num, denom):
        '''
            creates a new instance of Rational
        '''
        self.numerator = num
        self.denominator = denom

r = Rational(2, 3)
```

```
>>> r
<__main__.Rational object at 0x02E74F30>
>>> r.numerator
2
>>> r.denominator
3
>>>
```

Creating classes: remarks

- Defining a class creates a new namespace (used as local scope – the variables and functions defined by the class will belong to this namespace)
- Every object (instance of the class) has its own namespace / symbol table that contains the attributes and functions of the object
- To initialize an object, a class uses the `__init__` method which:
  - Is automatically called when a new object is created
  - Has at least one parameter (***self***) which refers to the object created
  - Can have other parameters (***num, denom***)
    - Can have default values

```
class Rational:

def __init__(self, num = 0, denom = 1):
        '''
            creates a new instance of Rational
        '''
        self.numerator = num
        self.denominator = denom
```

```
r1 = Rational(2,3) #r1 = 2/3
r2 = Rational(3)   #r2 = 3/1
r3 = Rational()    #r3 = 0/1
r4 = Rational(denom=5) #r4= 0/5
```

Adding methods to a class

- Methods
  - Functions defined inside a class that can access data (values, attributes) from the class
  - The first parameter of any method is the current instance (object) – `self`
  - Methods can be called by `objectName.methodName(parameterList)`

```python
class Rational:
    '''
    A rational number is composed by 2 numbers: numerator and denominator > 0
    denominator <> 0, gcd(numerator, denominator) == 1
    '''
    def __init__(self, num = 0, denom = 1):
        # creates a new instance of Rational
        self.numerator = num
        self.denominator = denom

    def getNumerator(self):
        # getter method
        # return the numerator of the rational number
        return self.numerator

     def getDenominator(self):
        # getter method
        # return the denominator of the rational number
        return self.denominator
```

```python
def test_create():
    r1 = Rational(2,3)
    assert r1.getNumerator() == 2
    assert r1.getDenominator() == 3

    r2 = Rational(5,4)
    assert r2.getNumerator() == 5
    assert r2.getDenominator() == 4
```

```python
r1 = Rational(2,3)  #r1 = 2/3

print("r1 = ", r1.getNumerator(), "/", r1.getDenominator())
```

Adding methods to a class

```python
from utils import gcd
class Rational:
    ...
    def __init__(self, num = 0, denom = 1):
        # ...

    def getNumerator(self):
        # ...

    def getDenominator(self):
        # ...

    def add(self, other):
        '''
            add two rational numbers (self + other)
            return a new rational number self = self + other
        '''
        a = self.numerator * other.denominator + self.denominator * other.numerator
        b = self.denominator * other.denominator
        d = gcd(a, b)
        self.numerator = a // d
        self.denominator = b // d
        return self
```

```python
def test_add():
    r1 = Rational(2,3)
    r2 = Rational(5,4)
    r3 = r1.add(r2)
    assert r3.getNumerator() == 23 and r3.getDenominator() == 12
```

Special methods

```python
r1 = Rational(2,3)
print(r1)
```

```
<__main__.Rational object at 0x029FEEB0>
```

Provide a __str__ (double underscores before/after) method in the class

```python
def __str__(self):
    return str(self.numerator) + "/" + str(self.denominator)
```

```python
r1 = Rational(2,3)
print(r1)
```

```
2/3
```

Special methods – Python

```
>>> r1 = Rational(2,3)
>>> str(r1)
'2/3'
>>> r2 = Rational(2,3)
>>> r1 == r2
True
>>> r3 = Rational(5,3)
>>> r1 == r3
False
>>> r1 != r3
True
>>>
```

- String conversion- define: `__str__` , use: `str(...)`
- Comparisons- define `__eq__` , use `==`, `!=`

```
class Rational:
    ...
    def __str__(self):
        '''
            provides a string representation of a rational number
            return a string
        '''
        return str(self.numerator) + "/" + str(self.denominator)

    def __eq__(self, other):
        '''
            compares 2 rational numbers: self and other
            return True, if self == other
                   False, otherwise
        '''
        if ((self.numerator == other.numerator) and (self.denominator == other.denominator)):
            return True
        else:
            return False
```

```
def test_str():
    r1 = Rational(2,3)
    assert r1.__str__() == "2/3"

def test_eq():
    r1 = Rational(2,3)
    r2 = Rational(2,3)
    assert r1 == r2
    r3 = Rational(5,3)
    assert r1 != r3
```

Special methods

`__str__(self)`	`print(self)` `str(...)`
`__eq__(self, other)`	`self == other`
`__add__(self, other)`	`self  + other`
`__sub__(self, other)`	`self - other`
`__lt__(self, other)`	`self < other`
`__len__(self)`	`len(self)`
...	

https://docs.python.org/3/reference/datamodel.html#basic-customization

Methods – follow the specifications

```python
class Rational:
    '''
    A rational number is composed by 2 numbers: numerator and de
    denominator <> 0, gcd(numerator, denominator) == 1
    '''
    def __init__(self, num = 0, denom = 1):
        '''
            creates a new instance of Rational
        '''
        if (denom == 0):
            raise ValueError("0 denominator not allowed")
        if (num < 0) or (denom < 0):
            raise ValueError("numerator and denominator must be
        d = gcd(num, denom)
        self.numerator = num // d
        self.denominator = denom // d

    def getNumerator(self):
        ...

    def getDenominator(self):
        ...
```

```python
def test_create():
    r1 = Rational(2,3)
    assert r1.getNumerator() == 2 and r1.getDenominator() == 3
    r2 = Rational(5,4)
    assert r2.getNumerator() == 5 and r2.getDenominator() == 4
    r3 = Rational(25, 15)
    assert r3.getNumerator() == 5 and r3.getDenominator() == 3

    try:
        r4 = Rational(2, 0)
        assert False
    except ValueError as er:
        print("something goes wrong...", er)
        assert True

    try:
        r5 = Rational(2, -3)
        assert False
    except ValueError as er:
        print("something goes wrong...", er)
        assert True

    try:
        r6 = Rational(-2, 3)
        assert False
    except ValueError as er:
        print("something goes wrong...", er)
        assert True

    try:
        r7 = Rational(-2, -3)
        assert False
    except ValueError as er:
        print("something goes wrong...", er)
        assert True
```

Getter and setter methods

```python
class Flower:
    '''
    a flower is a structure of two elements: name (a string) and price (an integer)
    '''
    def __init__(self, n = "", p = 0):
        self.name = n
        self.price = p

    def getName(self):
        return self.name
    def getPrice(self):
        return self.price

    def setName(self, n = ""):
        self.name = n
    def setPrice(self, p):
        if (p < 0):
            raise ValueError("the price must be positive...")
        self.price = p

    def __str__(self):
        return self.name+ "-" + str(self.price)
```

Access data

```python
class Flower:
    ...
    def getName(self):
        return self.name
    def getPrice(self):
        return self.price

    def setName(self, n = ""):
        self.name = n
    def setPrice(self, p):
        if (p < 0):
            raise ValueError("the price must be positive...")
        self.price = p

    def __str__(self):
        return self.name+ "-" + str(self.price)

myFlower = Flower("rose", 5)
myFlower.name
myFlower.getName()
```

- Class definition changes => errors!
- ***Recommended:*** use getters and setters to access data attributes

✓ *Good style*
✓ *Easy to maintain code*
✓ *Prevents bugs*

Default arguments

```python
class Flower:
    def __init__(self, n = "", p = 0):
        self.name = n
        self.price = p

    def getName(self):
        return self.name
    def getPrice(self):
        return self.price

    def setName(self, n = ""):
        self.name = n
    def setPrice(self, p):
        self.price = p

    def __str__(self):
        return self.name+ "-" + str(self.price)
```

```python
# default arguments for formal parameters are used
# if no actual argument is given
f1 = Flower("rose")
print(f1)

f2 = Flower(p=3)
print(f2)

f3 = Flower()
print(f3)

f3.setName("daisy")
print(f3)

f3.setName()
print(f3)

f3.setPrice()
```

```
rose-0
-3
-0
daisy-0
-0
Traceback (most recent call last):
  File "C:\Users\cami\Desktop\c.py", line 122, in <module>
    f3.setPrice()
TypeError: setPrice() missing 1 required positional argument: 'p'
>>>
```

ADT Recommendations

- Create getter and setter methods to access the data attributes
- Hide the implementation details
  - The class is an abstraction (a black box)
  - The interface of the class stays the same while internal changes can occur
  - Client code should work without any changes even when internal changes occur in the class
- Document each class
  - Short description
  - What objects can be created (based on the data attributes)
  - Restrictions that apply to data

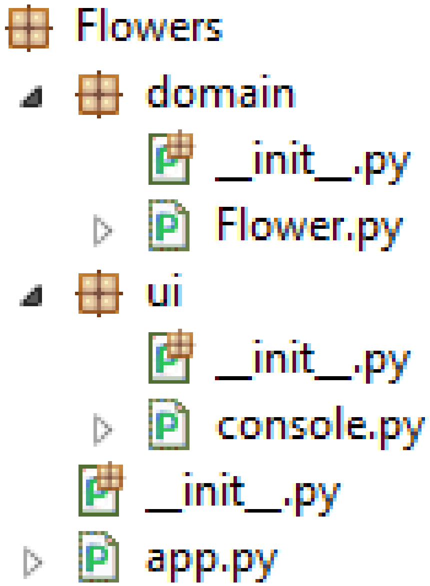
```
class Rational:
    """
    Abstract data type rational numbers
    A rational number is composed by 2 numbers: numerator and denominator
    Domain:{a/b where a,b integer numbers, b!=0, greatest common divisor =1}
    Invariant:b!=0, greatest common divisor a, b =1
    """
    def __init__(self, num = 0, denom = 1):

...
```

- Create classes using ***test-driven development***
  - Create test functions for
    - Creating an instance of the class
    - Each method of the class

ADT Examples in detail

- ADT `Flower`
  - 1 representation
    - Coupling two pieces of information (name, price)

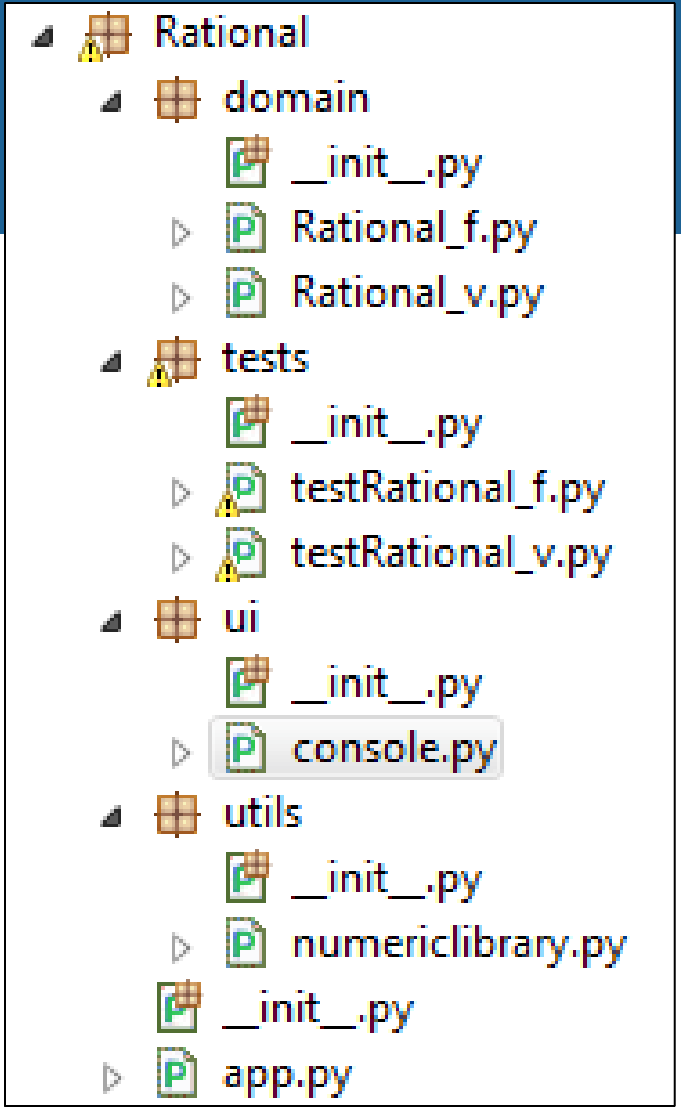
- Example: `05Flowers.zip`



ADT Examples in detail

- ADT `Rational`
  - 2 representations
    - Coupling two pieces of information (numerator, denominator)
    - List with 2 elements: numerator and denominator

- Example: `05Rational.zip`



Recap today

- Classes
- Examples
  - Flower
  - Rational

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