BABEŞ-BOLYAI UNIVERSITY
Faculty of Mathematics and Computer Science

Fundamentals of 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

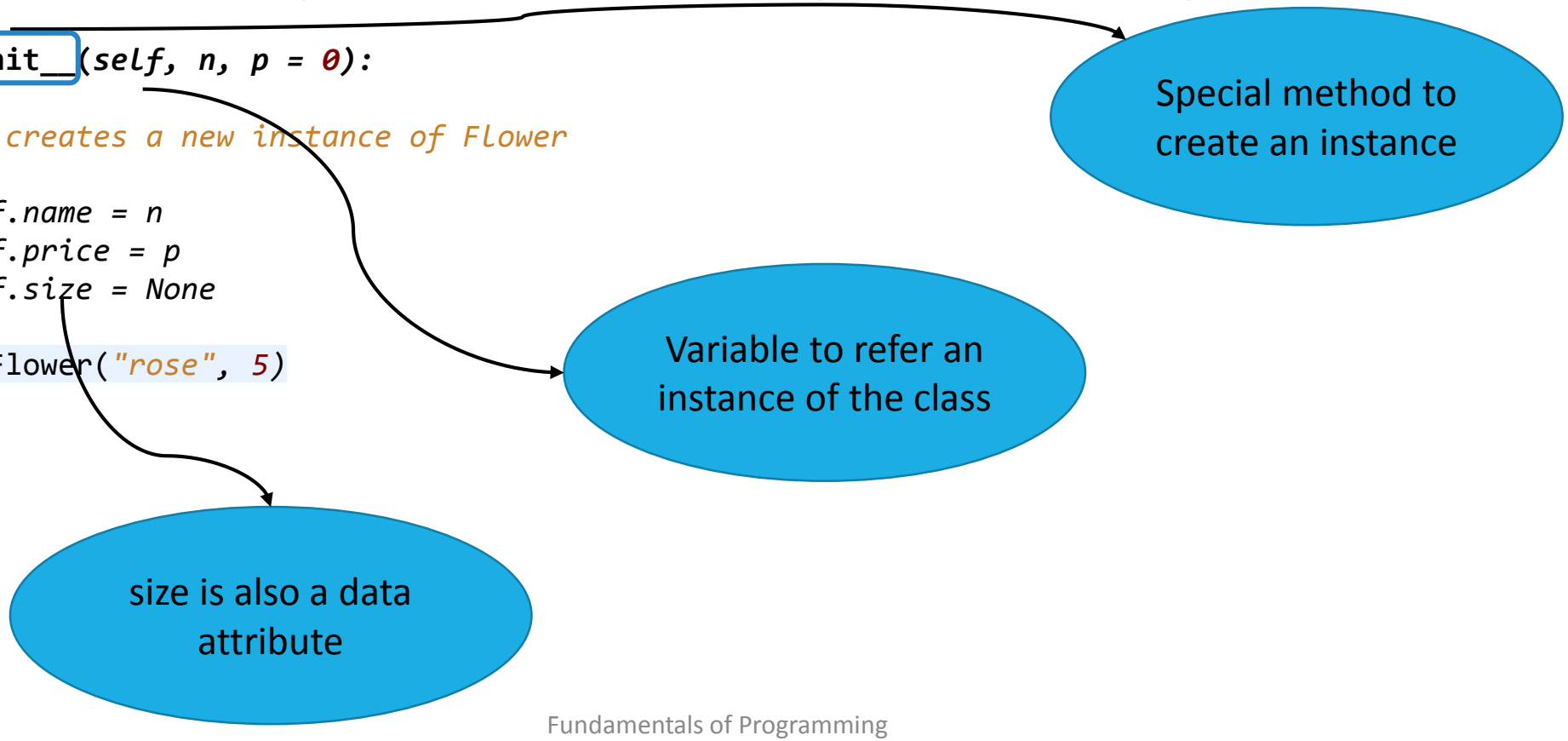
    $$\{(name, price), name\ -string, price \in N\}$$
  - Operations:
    - Initialization
    - Acces to attribute values
    - Copy
    - Comparison
    - …

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)
```



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)

```
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)`

```
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
```

```
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
```

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

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

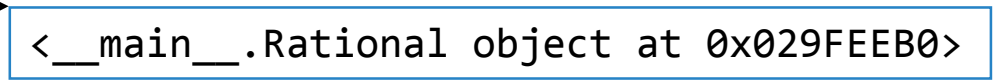
Adding methods to a class

```
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
```

```
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

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

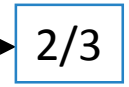


```
<__main__.Rational object at 0x029FEEB0>
```

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

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

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



```
2/3
```

Special methods – Python

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

```
>>> 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
>>>
```

```
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

```
class Rational:
    '''
    A rational number is composed by 2 numbers: numerator and d
    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):
        ...
```

```
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

```
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

```
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

```
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)
```

```
# 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
- Create classes using

test-driven development

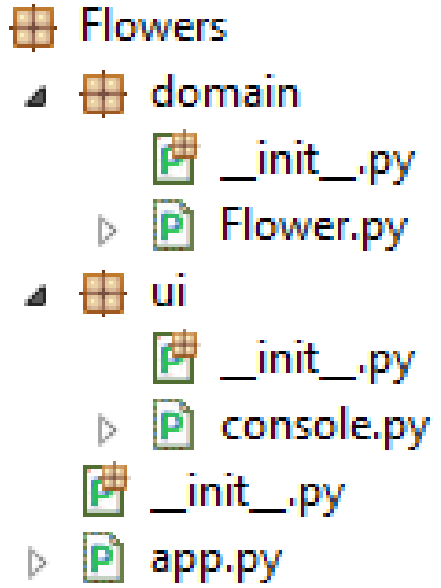
  - Create test functions for
    - Creating an instance of the class
    - Each method of the class

```
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):

...
```

ADT Examples in detail

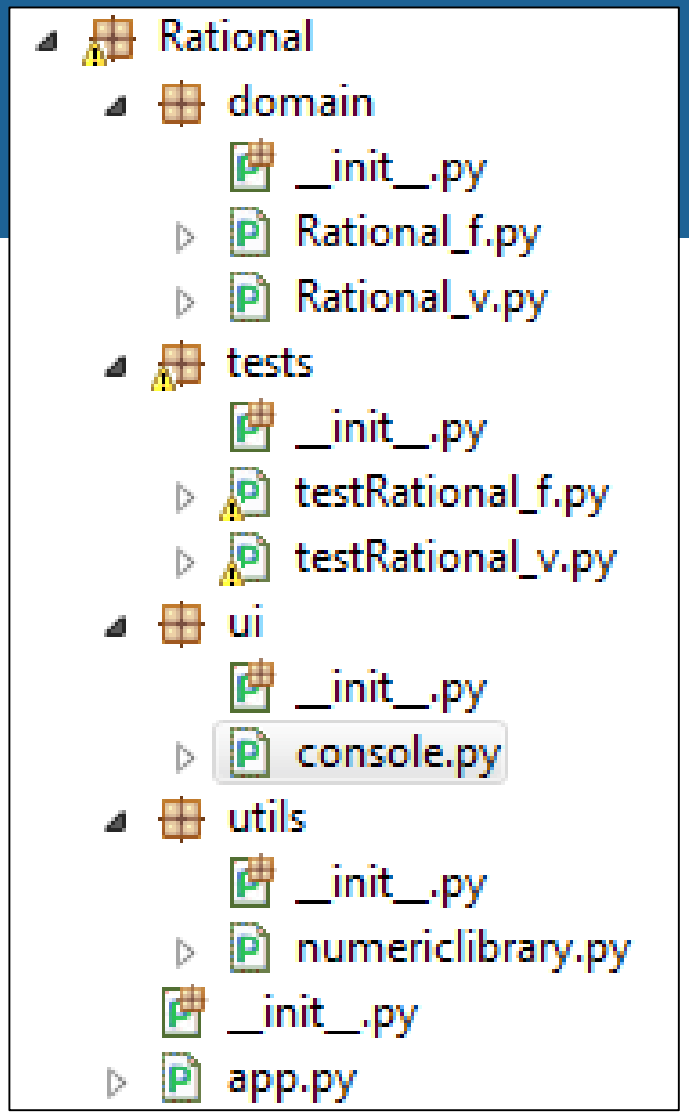
- ADT `Flower`
  - 1 representation
    - Coupling two pieces of information (name, price)

- 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

Next time

- Testing and debugging

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

Bibliography

The content of this course has been prepared using the reading materials from previous slide, different sources from the Internet as well as lectures on Fundamentals of Programming held in previous years by:

- Prof. Dr. Laura Dioşan - www.cs.ubbcluj.ro/~lauras
- Conf. Dr. Istvan Czibula - www.cs.ubbcluj.ro/~istvanc
- Lect. Dr. Andreea Vescan - www.cs.ubbcluj.ro/~avescan
- Lect. Dr. Arthur Molnar - www.cs.ubbcluj.ro/~arthur