ETH zürich

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Computer Science II

Course at D-BAUG, ETH Zurich

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1. Introduction

Objectives of this Course

Goals of the course

- Understand the design and analysis of fundamental algorithms and data structures.
- Understand how an algorithmic problem is mapped to a sufficiently efficient computer program.

Contents

Software Engineering

Java To Python Introduction

Python Datastructures

data structures / algorithms

The notion invariant, cost model, Landau notation

algorithms design, induction, divide & conquer

searching and sorting

dictionaries: hashing and search trees, balanced trees

dynamic programming

fundamental graph algorithms

Shortest paths, maximum flow

2. From Java to Python

First Python Program, Transfer Java $\rightarrow$ Python, Dynamic Data Structures in Python

Learning Objectives

- see a new programming language (Python) and learn how to transfer from one programming language to another
- learn the most important differences between Java and Python, both from a syntactical and semantical point of view
- learn about the basic data types of Python (list, set, dict, tuple) and operations leveraging the use of such data types
- get used to the new programming language and environment (Python) by re-implementing known algorithms

First Java Program

```
public class Hello {
  public static void main (String[] args) {
    System.out.print("Hello World!");
  }
}
```

First Python Program

```
print("Hello World!")
```

Comments

Comments are preceded by a **#**

```
# prints 'Hello World!' to the console
print("Hello World!")
```

Formatting Matters: Statements

- Whitespace is relevant
- Each line represents a statement
- So, **exactly one** Statement per line
- Comments start with **#**

Example program with two statements:

```
# two print-statements
print("Hurray, finally ...")
print("... no Semicolons!")
```

Formatting Matters: Blocks

- Blocks must be indented.
- All indented statements are part of a block. The block ends as soon as the indentation ends.
- Start of a Block is marked by a colon "`:`"

```python
# in Python
while i > 0:
    x = x + 1 / i
    i = i - 1

print(x)
```

```java
// in Java
while (i > 0) {
    x = x + 1.0 / i;
    i = i - 1;
}
System.out.print(x)
```

Literals: Numbers

- **integer**: `42, -5, 0x1b, 0o33, 772968476231357893257893`
  Arbitrary precise integer numbers
- **float**: `-0.1, 34.567e-4`
  Like **`double`** in Java, but precision depends on platform (CPU/ operating system)
- **complex**: 2 + 3j, (0.21 - 1.2j)
  Complex numbers in the form a**+**b**`j`**. Optional round parentheses.

Literals: Booleans

- `True`
- `False`

Literals: Strings

- `'a single quoted string\nand a second line'`
- `"a doube quoted string\nand a second line"`
- Multi-line strings (tripple double quotes):

```
"""a multiline string
and a second line"""
```

Literals: Sequences

- **arrays**: There are no primitive arrays in Python
- **lists**: `[ 17, True, "abc"]` , `[]`
  Mutable ordered sequence of 0 or more Values of arbitrary types.
- **tuples**: `(17, True, "abc")` , `(42, )`
  Immutable ordered sequence of 1 or more Values of arbitrary types.

Literals: Collections

- **dicts**: `{ "a": 42, "b": 27, False: 0 }`, `{}`
  Mutable Key-Value store. Keys and values may have arbitrary types.
- **sets**: `{17, True, "abc"}`, `{42}`
  Mutable unordered sequence of 0 or more Values of arbitrary types. No duplicates.

Variables

- Variables are automatically created upon the first assignment
- The type of a variable is not checked upon assignment. That is, values of different types can be assigned to a variable over time.
- Assignment of values with the assignment operator: `=`
- Assignment to multiple variables with tuples

```
a = "Ein Text"
print(a) # prints: Ein Text
a = 42
print(a) # prints: 42
```

```
x, y = 4, 5
print(x) # prints: 4
print(y) # prints: 5
```

Variables

- Variables must always be assigned first before it's possible to read their value

Assume b never got a value assigned:

```
a = b
```

Results in the following error

NameError: name 'b' is not defined

Numeric and Boolean Operators

- Numeric operators as in Java: **`+, -, *, /, %, **, //`**
- Caution: " **`/`** " always results in a floating-point number
- **`**`**: Power function, **`a**b`** = a^b.
- **`//`**: Integer division, **`5//2`** results in **`2`**.
- Comparison operators as in Java: **`==, >=, <=, >, <, !=`**
- Logical Operators: **`and, or, not`**
- Membership Operator: " **`in`** " Determines if a value is in a list, set or string.
- Identity Operator: " **`is`** " Checks if two variables point to the same object.

Input/Output

- Reading of inputs using **`input()`**
- A prompt can be provided.
- Output using **`print(...)`**
- **`print`** accepts one or more arguments and prints them separated with a space

```
name = input("What is your name: ")
print("Hello", name)
```

Input/Output

- Input is always read as string
- To read a number, the input must be converted to a number first
- No implicit conversion happens
- Explicit conversion using: **`int(), float(), complex(), list()`**, …

```
i = int(input("Enter a number: "))
print("The", i,"th power of two is", 2**i)
```

Conditions

- No parentheses required around the test
- **`elif`** to test another case
- Mind the indentation!

```
a = int(input("Enter a number: "))
if a == 42:
  print("Naturally, the answer")
elif a == 28:
  print("A perfect number, good choice")
else:
  print(a, "is just some boring number")
```

While-Loops

The well-known Collaz-Folge

```
a = int(input("Enter a number: "))
while a != 1:
  if a % 2 == 0:
    a = a // 2
  else:
    a = a * 3 + 1
  print(a, end=' ')
```

For-Loops

- For-Loops work differently than in Java
- Iterates over the elements of the given set

```
some_list = [14, 'lala', 22, True, 6]
total = 0;
for item in some_list:
  if type(item) == int:
    total += item
print("Total of the numbers is", total)
```

For-Loops over a value range

- The function **`range(start, end, step)`** creates a list of values, starting with **`start`** until **`end`** - exclusive. Stepsize is **`step`**.
- Step size is **`1`** if the third argument is omitted.

```
# the following loop prints "1 2 3 4"
for i in range(1,5):
    print(i, end=' ')

# the following loop prints "10 8 6 4 2"
for i in range(10, 0, -2):
    print(i, end=' ')
```

Methods

- The Cookie Calculator revisited

```
def readInt(prompt, atleast = 1):
  """Prompt for a number greater 0 (or min, if specified)"""
  number = 0;
  while number < atleast:
    number = int(input(prompt))
    if (number < atleast):
      print("Too small, pick a number larger than", atleast)
  return number

kids = readInt("Kids: ")
cookies = readInt("Cookies: ", atleast=kids)
print("Each Kid gets", cookies // kids, "cookies.")
print("Papa gets", cookies % kids, "cookies.")
```

Lists: Basic Operations

- Element-Access (0-based): `a[2]` points to the third element.
- Negative indices count from the last element!

```
a = [ 3, 7, 4]
print(a[-1]) # prints '4'
```

- Add value to the tail: `a.append(12)`
- Test if an element is in a collection:

```
if 12 in a:
    print('12 is in the list, we just added it before')
```

- Anzahl Elemente in einer Collection: `len(a)`

Lists: Slicing

- Slicing: address partition: **`a[start:end]`**
- **`a`** and/or **`b`** are positive or negative indices.
- **`end`** is not inclusive

```
a = [ 1, 2, 3, 4, 5, 6, 7, 8, 9]
print(a[2:4])     # [3, 4]
print(a[3:-3])    # [4, 5, 6]
print(a[-3:-1]) # [7, 8]
print(a[5:])      # [6, 7, 8, 9]
print(a[:3])      # [1, 2, 3]
```

Dictionaries

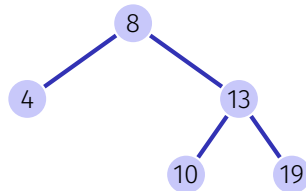
Dictionaries are very important primitive data structures in Python

- Easy and efficient possibility to name and group several fields of data
- Build hierarchical data structures by nesting
- Accessing elements using `[]` Operator

```
record = { 'Firstname': 'Hermann', 'Lastname':'Lehner',
                                'Salary': 420000, 'Mac User': True }
record['Salary'] = 450000
if record['Mac User']:
    print('... one more thing!')
```

Dynamic Data Structures with Dicts

```
tree = {
    'key': 8,
    'left' : {
        'key': 4, 'left' : None, 'right': None
    },
    'right': {
        'key': 13,
        'left' : {
            'key': 10, 'left' : None, 'right': None
        },
        'right': {
            'key': 19, 'left' : None, 'right': None
        }
    }
}
```



Dynamic Data Structures with Dicts

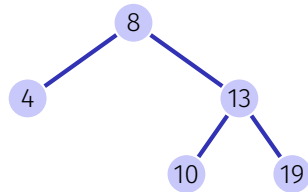
- Working with Dicts (Examples)

```
l = tree['left'] # assign left subtree to variable l
l['key'] = 6    # changes key from 4 to 6

if l['left'] is None: # proper way to test against None
    print("There is no left child here...")
else:
    print("Value of left subtree is", l['left']['key']
```

Dynamic Data Structures with Classes

```
class Node:
    def __init__(self, k, l=None, r=None):
        self.key, self.left, self.right = k, l, r
```




```
# create the tree depicted on the right
rightSubtree = Node(13, l=Node(10), r=Node(19))
tree = Node(8, l=Node(4), r=rightSubtree)

# an example query
print(tree.right.right.key) # prints: 19
```

Modules

Python has a vast amount of libraries in form of modules that can be imported.

- Importaing a whole module:

```
import math
x = math.sqrt(4)
```

```
from math import *
x = sqrt(4)
```

- Importaing parts of a module:

```
from datetime import date
t = date.today()
```