Introducing Python Programming in the Algorithms Design Course

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Talk Outline

- Course Curricula Background
- Motivation
- Introducing Python
- Course Upgrade with Python topics
- Facts about Using Python
- Conclusions
**Overview**

- **Algorithms Design** (former *Programming Techniques*)
  - Analysis, design, programming, experimenting fundamental algorithms
  - Alignment with CS curricula recommended by ACM and IEEE
  - 1st year, 2nd semester

- Courses that must be passed before AD:
  - Computer Programming

- Courses that benefit from AD:
  - Object-Oriented Programming
  - Data Structures and Algorithms
  - Artificial Intelligence
Overview – Learning Objectives

- **LO1:** To introduce the principles of algorithm analysis, modular programming and data abstraction.

- **LO2:** To introduce fundamental algorithms and the fundamental methods of algorithm design.

- **LO3:** To develop practical experience in programming small-scale experiments involving implementation, testing and evaluation of algorithms.
Overview – Topics

- Introduction to analysis and design of algorithms
- Divide and conquer
- Correctness and testing of algorithms
- Sorting algorithms
- Abstract data types
- Stacks and queues
- Graphs and trees
- Dynamic programming
- Greedy algorithms
- Backtracking
- Introduction to NP-completeness
Overview – Structure

- No single textbook; a good base is CLRS3 book.

- 2 modules:
  - Course (4 ECTS points)
  - Project (1 ECTS points)

- Both duration is 14 weeks:
  - Course: 2 h lectures/week (28h) + 2 h lab/week (28h)
  - Project: 1 h project/week (14h)
Overview – Grading

- **Course module: final exam (70%)**
  - Exercise: discuss, analyze, improve simple algorithm
  - Exercise: design and code a small-scale C program for solving an algorithmic problem
  - Exercise: algorithm design using fundamental method

- **Course module: laboratory assignments (30%)**

- **Project module: project assignment**
  - 20% intermediary delivery
  - 80% final delivery
Practical Aspects – Programming Language

- We are using **Standard C**

- Reasons:
  - Students learn C in 1st semester at Computer Progr.
  - C gives base for learning C-like lang: C++, Java, C#
  - C is defined as *high-level assembly language*, useful for:
    - Operating systems
    - Embedded systems
    - Compilers
  - C enables efficient implementation of algorithms
World of Programming Languages

- Imperative vs Declarative Paradigms:
  - Imperative (state-oriented): focused on “how?”
    - Procedural (von Neumann): C, Ada, Fortran
    - Object-oriented: C++, Smalltalk, Eiffel, Java
  - Declarative (goal-oriented): focused on “what?”
    - Functional: Lisp, Haskell, ML, F# (a kind of ML), Erlang, Haskell
    - Logic: Prolog, spreadsheets

- Compiled vs Interpreted Languages:
  - Compiled: C, Assembler
  - Interpreted (scripting): Perl, Python, PHP, JavaScript
  - Partly compiled & partly interpreted: Java, C#
Why Python?

- Python is an interpreted language, different from C compiled language
- Python is close to pseudocode
- Python is higher-level than C
- Python supports different styles of programming enabling various comparisons in terms of readability / comprehensibility and efficiency / speed
- Python enables fast prototyping & algorithm testing
IEEE Interactive Top of Programming Languages

- 11 metrics and 9 sources => popularity ranking
- Started from more than 300 languages
- Filtered out those with low searches on “X programming”
- Manually narrow down the rest to most “interesting”
- Labeled with one or more categories:
  - Web, mobile, enterprise / desktop, embedded
- Ranking based on metrics, sources + source weights
- 4 default rankings (IEEE Spectrum, Trending, Jobs, Open) as well as manually customizable rankings
## 2018 vs 2015 Interactive Top

### Choose a Ranking
- IEEE Spectrum
- Trending
- Jobs
- Open
- Custom

### Choose a Comparison
- IEEE Spectrum
- Trending
- Jobs
- Open
- Custom

### Language Types (click to hide)
- Web
- Mobile
- Enterprise
- Embedded

### Language Rank

<table>
<thead>
<tr>
<th>Language Rank</th>
<th>Types</th>
<th>Spectrum Ranking</th>
<th>Custom Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Python</td>
<td>🌐</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2. C++</td>
<td>🌐</td>
<td>99.7</td>
<td>99.9</td>
</tr>
<tr>
<td>3. Java</td>
<td>🌐</td>
<td>97.5</td>
<td>99.4</td>
</tr>
<tr>
<td>4. C</td>
<td>🌐</td>
<td>96.7</td>
<td>96.6</td>
</tr>
<tr>
<td>5. C#</td>
<td>🌐</td>
<td>89.4</td>
<td>91.5</td>
</tr>
<tr>
<td>6. PHP</td>
<td>🌐</td>
<td>84.9</td>
<td>85.1</td>
</tr>
<tr>
<td>7. R</td>
<td>🌐</td>
<td>82.9</td>
<td>84.5</td>
</tr>
<tr>
<td>8. JavaScript</td>
<td>🌐</td>
<td>82.6</td>
<td>83.3</td>
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<tr>
<td>9. Go</td>
<td>🌐</td>
<td>76.4</td>
<td>76.2</td>
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<tr>
<td>10. Assembly</td>
<td>🌐</td>
<td>74.1</td>
<td>73.1</td>
</tr>
<tr>
<td>11. Matlab</td>
<td>🌐</td>
<td>72.8</td>
<td>72.6</td>
</tr>
<tr>
<td>12. Scala</td>
<td>🌐</td>
<td>72.1</td>
<td>71.3</td>
</tr>
</tbody>
</table>

### Compare a ranking. Click a data source to toggle its inclusion in the ranking and drag its slider to reweight it.

- Use data from:
  - 2018
  - 2017
  - 2016
  - 2015
  - 2014

- Google (search)
  - Slider: 50
- Github (active)
  - Slider: 50
- Stack Overflow (questions)
  - Slider: 30
- Stack Overflow (views)
  - Slider: 30
- Reddit
  - Slider: 20
- Hacker News
  - Slider: 20
- Career Builder
  - Slider: 5
- Dice
  - Slider: 5
- Twitter
  - Slider: 100

### Cancel
### Save as Custom
Introducing Python

- Python is an *interpreted* language.
- Python is characterized by:
  - Simple and readable syntax
  - Dynamic typing
  - High-level data types
- A Python program is a collection of functions and variables grouped into *modules*.
- A text file `.py` containing Python statements is called a *script*.
- A *module* is a `.py` file (or script) that contains more functions.
- A Python program can be run:
  - Using the Python *interaction mode*
  - Running a script from the command line under Python ctrl in *script mode*.
Upgrading AD Course with Python Topics

- Introduce Python using examples of simple algorithms.
- Present Python high-level data types close to the related AD topic – *abstract data types*.
- Use Python flexibility to show how different solutions of the same problem can be implemented, evaluating and comparing:
  - Readability
  - Time complexity
- Use Python tools to explore algorithmic solutions.
Educational Issues I

- Python already provides a variety of high-level data structures of “sequence” type including lists.
- This might be a source of confusion for students, between Python lists and linked lists.

Approach:
- When introducing linked lists with algorithms following CLRS textbook, we present also its explicit Python implementation.
- Then we discuss separately Python lists, highlighting differences, as well as the many features of this structure.
Educational Issues II

- Issues of **aliases, shallow and deep copy** of Python complex objects is better explained using pointer diagrams.
- This is easier to understand after students are **firstly exposed to low-level details of pointers and references**, that in our opinion are better introduced using C.
- This discussion **closes the gap between high-level Python structures and low-level details** that are needed to correctly understand their implementation.
Python Tools

Jupyter Notebook

```python
In [78]:

    """Reciprocal cycles
Problem 26
A unit fraction contains 1 in the numerator. The decimal representation of the unit fractions with denominators 2 to 10 are given:

    1/2= -0.5
    1/3= -0.(3)
    1/4= -0.25
    1/5= -0.2
    1/6= -0.1(6)
    1/7= -0.(142857)
    1/8= -0.125
    1/9= -0.(1)
    1/10= -0.1

where 0.1(6) means 0.166666..., and has a 1-digit recurring cycle. It can be seen that 1/7 has a 6-digit recurring cycle.

Find the value of d < 1000 for which 1/d contains the longest recurring cycle in its decimal fraction part."""

def cycle_length(n):
    l = 1
    a = 10
    a = (a % n) * 10
    while a != 10:
        l += 1
        a = (a % n) * 10
    return l

Dlim = 1000
Lmax = 0
Dmax = 0
for d in range(2, dlim):
    if d % 2 != 0 and d % 5 != 0:
        l = cycle_length(d)
        if l > Lmax:
            Lmax = l
            Dmax = d
print(Dmax)
```

983
Python Tools

LaTeX2e in Markdown Cells

Quadratic primes

Problem 27

Euler discovered the remarkable quadratic formula:

\[ n^2 + n + 41 \]

It turns out that the formula will produce 40 primes for the consecutive integers 40, 41, 43, ..., 79, and 81 is divisible by 41, and ce...

The incredible formula \( n^2 - 79n + 1601 \) was discovered, which produces the product of the coefficients, -79 and 1601, is -126479.

Considering quadratics of the form:

\[ n^2 + an + b \]

where \( |a| < 1000 \) and \( |b| \leq 1000 \)

Find the product of the coefficients, \( a \) and \( b \), for the quadratic expression that starts with \( n = 0 \).

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Python Tools

Magic Commands

- `%time` will time whatever you evaluate
- `%timeit` will time whatever you evaluate multiple times and give you the best, and the average times
- `%latex` will render cell contents as LaTeX

```
In [14]: %latex
$$
\sum_{i=1}^{n} i = \frac{n(n+1)}{2}
$$
```
Python Flexibility

- Using high-level features of list and set comprehension can result in very compact representation of some algorithms …
- But they are not always efficient.
- Nevertheless, they can be read as a mathematical language.
- E.g.: How many distinct terms are in the sequence generated by $a^b$ for $2 \leq a \leq 100$ and $2 \leq b \leq 100$?
- In mathematical notation:
  \[ | \{ a^b | 2 \leq a \leq 100, 2 \leq b \leq 100 \} | \]
- In Python:
  ```python
  len( { a**b for a in range(2,101) for b in range(2,101) } )
  ```
- or a totally different solution … (on the next slide)
def is_power(n):
    s = int(pow(n,0.5))
    for i in range(2,s+1):
        if n % i == 0:
            p = 1
            m = n // i
            while m % i == 0:
                p += 1
                m = m // i
        if m == 1:
            return p
    return 0

vmax = 100
counter = 0
for a in range(2,vmax+1):
    p = is_power(a)
    if p == 0:
        counter += vmax-1
    else:
        delta = vmax - 1
        for b in range(2,vmax+1):
            for q in range(1,p):
                if ((p*b) % q == 0) \ 
                   and (((p*b)//q) \ 
                          <= vmax):
                    delta -= 1
                    break
        counter += delta
print(counter)
How Can We Compare Them?

- **Comprehensibility:** Homework
- **Theoretical Time Complexity:** Homework
- **Running Time:**

```python
%%timeit -n50 -r10
```

produces:

- **1st solution:**
  - 19.6 ms ± 1.62 ms per loop (mean ± std. dev. of 10 runs, 50 loops each) for the 1st solution

- **2nd solution:**
  - 3.2 ms ± 502 µs per loop (mean ± std. dev. of 10 runs, 50 loops each) for the 2nd solution
Python Usage Figures

Web site containing a list of computational problems intended to be solved with computer programs.
- Total of 829911 registered members.
- 101 programming languages are used to solve the problems.

Number of members using:
- Python 50588
- C/C++ 42919
- Java 29012
- C# 13539
- Haskell 6797
Python Usage Figures in AI Course

- Course assignment of Artificial Intelligence (AI) course:
  - Compare two search algorithms for a given problem
  - Students could choose the programming language. Suggested languages were: C, C++, Java, Prolog, and Python

- 66 students from 120 submitted their homework.

- Statistics:

<table>
<thead>
<tr>
<th>Language</th>
<th>Count</th>
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</thead>
<tbody>
<tr>
<td>Java</td>
<td>19</td>
</tr>
<tr>
<td>C++</td>
<td>21</td>
</tr>
<tr>
<td>Python</td>
<td>21</td>
</tr>
<tr>
<td>C#</td>
<td>1</td>
</tr>
<tr>
<td>Prolog</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
</tbody>
</table>
Conclusions

- We proposed approaches for introducing Python to AD course.
- We presented few issues regarding our proposal and proposed measures how to deal with them.
- More results are needed to properly assess our proposals.
Thank You