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Advanced Programming (CO2039)

FUNCTIONAL PROGRAMMING IN PYTHON

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Contents

1 INTRODUCTION

In computer science, functional programming is a declarative paradigm where programs are built by applying and composing functions. Unlike imperative programming, which uses sequences of statements to change the program's state via variables, functional programming relies on expressions that map inputs to outputs.

Functional programming originated in academia and developed from lambda calculus, a formal computational system based solely on functions and was introduced by the mathematician Alonzo Church in the 1930s. This system involves creating lambda terms and applying reduction operations to them. In the simplest form of lambda calculus, terms are built using only the following rules:[1]

- x: A variable is a character or string representing a parameter.
- $(\lambda x.M)$: A lambda abstraction is a function definition, taking as input the bound variable x and returning the body M.
- (MN): An application, applying a function M to an argument N, both M and N are lambda terms.

Lambda calculus is Turing complete, meaning it is a universal computational model capable of simulating any Turing machine. The Greek letter λ is used in lambda expressions and terms to represent the binding of variables in functions. This is why many programming languages dedicated to functional programming have their logos resemble the λ letter:

(a) Clojure (b) Haskell (c) Common Lips (d) Racket (e) Scheme

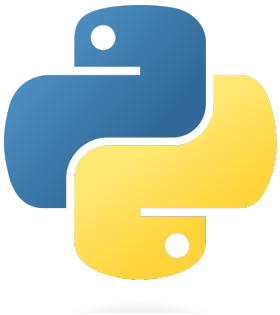
Figure 1: Several languages supporting functional programming

[1]Wikipedia, *Lambda calculus*, https://en.wikipedia.org/wiki/Lambda_calculus, 22/5/2024

2 THE PYTHON PROGRAMMING LANGUAGE

Python is a programming language created by Guido van Rossum and first released in 1991. It has grown to become one of the most popular programming languages in the world.

(a) Guido van Rossum (2006)



(b) Python

Figure 2: The Python programming language and its creator

Python is widely-used and praised for its versatility, simplicity, and strong community support. It achieves its position in today's world for several compelling reasons:

- *High-level language*: It abstracts many details of the computer's operation, allowing focusing more on programming solutions than on technical minutiae.
- *Versatility*: It supports multiple programming paradigms, including procedural, object-oriented, and functional programming.
- *Readability and simplicity*: Python's syntax is simple, makes it easier to understand than code written in other languages.
- *Extensive library and ecosystem*: Python comes with a vast standard library that supports many common programming tasks, and there are also numerous third-party libraries and frameworks that significantly extend Python's capabilities.

We will now explore several key features of Python. While we are not covering everything about this vast programming language, we will focus on some of its most notable aspects.

2.1 Simple syntax

A basic "Hello World!" program can be write in Python:

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

That is it! This single line of code prints "Hello, World!" to the console. Python is designed to be simple and readable, making it easy for beginners to start programming. On the other hand, using C++:

```
#include <iostream>

int main()
{
```

```
    std::cout << "Hello, World!" << std::endl;
    return 0;
}
```

As can be seen, Python requires minimal setup and has a straightforward syntax, while C++ demands a deeper understanding of programming concepts and structure.

A feature that plays a critical role in the Python's simplicity is that Python is a dynamically typed and interpreted language, meaning the types of variables are determined while the program is running.

```
x = 10        # x is an integer
x = "hello"   # now x is a string
```

On the contrary, C++ is a statically typed languages, where type checking is performed right at compile time.

```
int x = 10;     // x is an integer
x = "hello";    // compile-time error, cannot assign a string to an integer
    variable
```

The type of a variable must be explicitly stated during its initialization. This adds a layer of complexity on the C++ and similar programming languages.

2.2 Data structures

In Python, data structures can be categorized as mutable or immutable based on whether their contents can be changed after creation.

2.2.1 Mutable data structures

Mutable data structures allow modifications after creation. Common examples in Python include:

Lists are ordered collections of items. We can change, add, or remove elements from a list.

```
my_list = [1, 2, 3]
my_list.append(4)  # Modifying the list
```

Dictionaries are key-value pairs where keys are unique. We can add, remove, or update key-value pairs.

```
my_dict = {'a': 1, 'b': 2}
my_dict['c'] = 3  # Modifying the dictionary
```

Sets are unordered collections of unique items. We can add or remove elements from a set.

```
my_set = {1, 2, 3}
my_set.add(4)  # Modifying the set
```

2.2.2 Immutable data structures

Immutable data structures, once created, cannot be changed. Any operation that appears to modify an immutable data structure actually creates a new copy with the desired changes. Common examples in Python include:

Tuples are ordered collections of items, similar to lists, but immutable.

```
my_tuple = (1, 2, 3)
```

Strings in Python are sequences of characters and are immutable.

```
my_string = "Hello"
```

Frozensets are similar to sets, but immutable.

```
my_frozenset = frozenset({1, 2, 3})
```

2.3 Function

2.3.1 Defining and calling

In Python, a function can be defined using the `def` keyword followed by the function name and parentheses. The parameters (if any) are listed inside the parentheses. A function is called by using its name directly, followed by parentheses.

```
# Defining a function
def add(x, y):
    print("Hello, world!")
    return x + y

# Calling a function
print(add(x, y))
```

This program will return:

```
Hello, world!
5
```

2.3.2 Pass-by-value or pass-by-reference?

In C++ for example, pass-by-value means that a copy of the argument is passed to the function, whilst pass-by-reference means that the function receives a reference to the argument. Surprisingly, Python uses neither of the above. Let us take a look at an example:

```
def f(x_f):
    print(f'inside function x_f before -> {id(x_f)}, {x_f}')
    x_f = 10
    print(f'inside function x_f after -> {id(x_f)}, {x_f}')

x = 5
print(f'outside function x before -> {id(x)}, {x}')
f(x)
print(f'outside function x after -> {id(x)}, {x}')
```

The result is:

```
outside function x before -> 139920842981744, 5
inside function x_f before -> 139920842981744, 5
inside function x_f after -> 139920842981904, 10
outside function x after -> 139920842981744, 5
```

Before invoking the function `f`, we assigned an integer to variable `x`. The function then receives this as an argument. Within the function, `x_f` is initialized to the same memory location as `x`. However, a new integer object with the value 10 is created within the function and bound to `x_f`, without affecting the object bound to `x` outside the function. This is confirmed by the memory locations obtained using the `id()` function and the final print statement showing `x` still being bound to 5.

The argument was surely neither passed by reference because the function did not change the value bound to `x`, nor was it passed by value because initially `x_f` was pointing to the same memory location as x. This indicates that Python's argument passing involves a hybrid pattern, by passing a reference by value, also known as *pass-by-assignment*.

2.4 Other features

Just like any other Turing-complete programming language, Python offers a huge amount of other features such as control flow, file I/O, object-oriented programming (OOP), exception handling, libraries and modules, etc.

Nonetheless, within this introduction to Python programming, we have exclusively addressed only those features that will be further elaborated and utilized within the context of this report.

3 IMMUTABILITY, PURITY and SIDE EFFECTS

Immutability in programming languages refers to the concept where data, once created, cannot be changed. Instead of modifying an existing object, any update results in the creation of a new object with the modified values. In Haskell, for example, once a value is assigned to a variable, it cannot be changed:

```haskell
-- Define a list of integers
originalList :: [Int]
originalList = [1, 2, 3, 4, 5]

-- Function to double each element in the list
doubleList :: [Int] -> [Int]
doubleList = map (* 2)

-- Function to sum the elements of the list
sumList :: [Int] -> Int
sumList = sum

main :: IO ()
main = do
    let doubled = doubleList originalList
    let total = sumList originalList
    putStrLn $ "Original list: " ++ show originalList
    putStrLn $ "Doubled list: " ++ show doubled
    putStrLn $ "Sum of original list: " ++ show total
```

In this example, the original list remains unchanged throughout the program. The operations create new lists or values without modifying the original data, which is a core principle of functional programming and immutability in Haskell.

```
Original list: [1, 2, 3, 4, 5]
Doubled list: [2, 4, 6, 8, 10]
Sum of original list: 15
```

Side effects refer to changes in the state of a system that occur as a result of executing a function or expression. A ***pure function*** in programming is a function that adheres to the following principles:

- *Deterministic*: Given the same input, it always returns the same output.
- *No side effects*: It does not modify any state or interact with the outside world (e.g., modifying a global variable, performing I/O operations, etc).

These properties make pure functions predictable and easier to test and debug. They are fundamental in functional programming but can be used in any programming paradigm.

Here is a simple example of a pure function in Python that calculates the square of a number:

```python
def square(x):
    return x * x
```

- *Deterministic*: For any given value of `x`, the function `square(x)` will always return the same result. For example, `square(4)` will always return 16.
- *No side effects*: The function does not modify any external variables or states. It only returns a new value based on the input.

To contrast, here is an impure function that modifies a global variable:

```
result = 0
def add(x, y):
    global result
    result = result + x + y
    return result
```

- *Not deterministic*: This function can behave differently based on the previous state of the global variable `result`.
- *Side effects*: It modifies the global variable `result`, which can affect other parts of the program that rely on this variable.

4 FUNCTIONAL PROGRAMMING FEATURES IN PYTHON

4.1 Functions being first-class citizens

In Python, functions are ***first-class citizens***. This is because functions have the same characteristics as values like strings and numbers. Anything we would expect to be able to do with a string or number can be applied to a function as well.

For example, a function can be assigned to a variable, which can be used the same as the function itself. In addition, Python allows displaying a function to the console with `print()`, includimg it as an element in a composite data object like a list, or even using it as a dictionary key:

```
# Variale binding
def func(): print("Hello!")
func()
another_name = func
another_name()

# Displaying using print()
print("cat", func, 42)

# List element
objects = ["cat", func, 42]
objects[1]
objects[1]()

# Dictionary element
d = {"cat": 1, func: 2, 42: 3}
d[func]
```

Running this program, we see that `func()` appears in all the same contexts as the values `"cat"` and `42`, and the interpreter handles it just fine:

```
Hello!
Hello!
cat <function func at 0x7fdea479bd90> 42
<function func at 0x7fdea479bd90>
Hello!
2
```

The fact that Python treats functions as first-class citizens promotes a declarative and composable style, allowing developers to create programs by combining small, modular functions. Based on this, many concepts of a higher level of abstraction are formed.

4.2 Higher-order function

A ***higher-order function*** (HOF) is a function that does at least one of the following:

- Take other function(s) as argument(s).
- Return function(s) as result(s).

As can be seen, the concept of HOF is based on functions being treated as first-class citizens Python. A normal function takes argument(s) and returns basic data types (such as numbers, strings, etc.) or composite data types (like arrays, objects, etc.). When we replace those basic data types with functions, we obtain a HOF.

We will now go through 3 very typical HOFs, which are built in the Python programming language: `map()`, `filter()` and `reduce()`.

4.2.1 map()

The `map()` function applies a given function to all items in an input list (or any iterable) and returns an iterator that produces the results. This given function is taken as an argument, thus `map()` is a HOF:

```
# Defining a modification function
def square(x): return x * x

# Applying map() on a list
numbers = [1, 2, 3, 4]
result = map(square, numbers)

# Displaying the result
print(result)
print(list(result))
```

It is worth noting that `map()` does not return a list, but an iterator called a map object. To obtain the values from the iterator, we need to either iterate over it or use `list()`. If the result is called directly, the map object's address is returned.

```
<map object at 0x7f3cc455c0d0>
[1, 4, 9, 16]
```

4.2.2 filter()

The `filter()` function is used to filter elements of an iterable according to a predicate that tests each element for a condition. The predicate itself is a function, taken as an argument, so `filter()` is a HOF:

```
# Defining a predicate
def is_odd(n): return n % 2 == 1

# Applying filter() on a list
numbers = [1, 2, 3, 4]
odd_numbers = filter(is_odd, numbers)

# Displaying the result
print(odd_numbers)
for i in odd_numbers: print(i)
```

Similarly to `map()`, `filter()` does not return a list, but an iterator called a filter object. The values from the iterator can be obtained by either iterate over it or use `list()`:

```
<filter object at 0x7f6df31240d0>
1
3
```

4.2.3 reduce()

The `reduce()` function iterates over the items in a collection, applying a specified function to combine two items at a time (with or without an initial value) until a single result is obtained. While once a part of Python's built-in functions, Guido van Rossum expressed his disfavor towards `reduce()`, ultimately advocating for its removal from the language altogether[2].

```
from functools import reduce
# Defining a function
def add(x, y): return x + y

# Applying filter() on a list
numbers = [1, 2, 3, 4]
sum = reduce(add, numbers, 1000)

# Displaying the result
print(sum)
```

In the above snippet code, `reduce()` starts with the initializer value, which is 1000, then apply the add function to the initializer and the first item of the iterable: 1000 + 1 = 1001. After that, it takes the result and apply the add function to it and the next item: 1001 + 2 = 1003.

The process continues until a single final value is obtained, which is 1010 here. Unlike `map()` and `filter()`, the `reduce()`'s value can be displayed directly using `print()`:

```
1010
```

Note that we can achieve all of this without `reduce()`:

```
1000 + sum([1, 2, 3, 4])
```

Usually, in cases a task can be accomplished using `reduce()`, it is also possible to find a more straightforward and Pythonic way without it. Maybe it is not so hard to understand why `reduce()` was removed from the core language after all. However, not only can the single result returned by `reduce()` be a basic data type such as number or string, but a composite object like a list or a tuple as well. For that reason, `reduce()` is a very generalized higher-order function from which many other functions can be implemented.

As a matter of fact, any operation on a sequence of objects can be expressed as a reduction. Let implement the function `map()` in terms of `reduce()` as an example:

```
from functools import reduce


```

[2]Guido van Rossum, *The fate of reduce() in Python 3000*, https://www.artima.com/weblogs/viewpost.jsp?thread=98196, 10/3/2005

```
def reduced_map(func, iterable):
    # Defining a function to apply 'func' to each element and accumulate the results
    def accumulate(result, element):
        result.append(func(element))
        return result
    # Use reduce to apply the 'accumulate' function to the iterable
    return reduce(accumulate, iterable, [])
```

4.3 Lambda functions

A lambda function, or lambda expression refers to an anonymous function defined using the lambda keyword. These functions are small, nameless, and are often used for short-term operations where defining a full function would be overkill. The syntax of Python's lambda function is more or less based on that of lambda calculus. Let us take a look at an example.

In lambda calculus, a function that takes two arguments, x and y, and returns its sum would be:

$$\lambda x.\lambda y.x + y \tag{1}$$

Note that the equation 1 does not yet define the addition operation. In Python, a lambda expression can be constructed using the `lambda` keyword:

```
lambda x, y: x + y
```

Lambda functions are especially useful in functional programming, which emphasizes calling and passing around functions. This paradigm often involves defining numerous functions. Frequently, a function is created for a single use, making it cumbersome for programmers to name each one. Lambda expressions, which can be defined and invoked in place, effectively address this issue. They follow a pattern known as Immediately Invoked Function Expression (IIFE), allowing for concise and efficient function handling.

Recall that we have constructed the `map()` function using `reduce()`:

```
from functools import reduce

def reduced_map(func, iterable):
    # Defining a function to apply 'func' to each element and accumulate the results
    def accumulate(result, element):
        result.append(func(element))
        return result
    # Use reduce to apply the 'accumulate' function to the iterable
    return reduce(accumulate, iterable, [])
```

Using lambda function, we can create an anonymous function on the fly instead of defining the entire `accumulate()` function:

```
from functools import reduce

def reduced_map(func, iterable):
```

```
    return reduce(lambda result, element: result + [func(element)],
iterable, [])
```

4.4 Recursion

Recursion in programming refers to the concept of a function calling itself in order to solve a problem. A function that calls itself is said to exhibit recursive behavior when it can be defined by two properties:

- *Base case(s)*: a terminating scenario that does not involve using recursion to produce an answer.
- *Recursive steps*: a set of rules reducing all successive cases toward the base case(s).

Let us walk through a simple example of recursion in Python:

```
def factorial(n):
    if n == 0 or n == 1: return 1
    else: return n * factorial(n - 1)
```

In this example, `factorial()` is a recursive function that calculates the factorial of a given number n:

- *Base case(s)*: If `n == 0` or `n == 1`, the function returns 1
- *Recursive steps*: The function calls itself recursively with n-1 until it reaches the base case

Most programming problems can be solved without recursion, making it generally unnecessary. However, some scenarios are particularly suited to recursive solutions. Tree-like data structures are typical example. Their nested nature fits well with recursive definitions, whereas a non-recursive algorithm to traverse a nested structure tends to be cumbersome.

On the other hand, recursive implementations often use more memory than non-recursive ones. Thus, in some cases, recursion can lead to slower execution times. In reality, code readability is often the deciding factor, but it varies by situation.

4.5 Comprehensions and Generators

4.5.1 List comprehension

One of Python's most distinctive features is the ***list comprehension***, allowing to create powerful functionality within a single line of code. They consist of brackets containing an expression followed by a `for` clause, and potentially additional `for` or `if` clauses. The result is a new list resulting from evaluating the expression in the context of the `for` and `if` clauses which follow it.

For example, using a list comprehension, we can create a new list whose elements is the vowels of a string:

```
vowels = [char for char in "advanced programming" if char in "aeiou"]
```

and the result is:

```
['a', 'a', 'e', 'o', 'a', 'i']
```

This is certainly a shorter and simpler accomplishment compared to using `for()` loop:

```
vowels = []
for char in "advanced programming":
    if char in "aeiou":
        vowels.append(char)
```

or `filter()` with lambda expression:

```
vowels = list(filter(lambda char:char in "aeiou", "advanced programming"))
```

4.5.2 Set comprehension

A ***set comprehension*** is almost exactly the same as a list comprehension, except that they make sure the output contains no duplicates. A set comprehension is created by using curly braces instead of brackets:

```
vowels = {char for char in "advanced programming" if char in "aeiou"}
```

with the result of:

```
{'e', 'i', 'o', 'a'}
```

Again, there are alternative but longer ways by using `for()` loop and `filter()`:

```
# Using loops
vowels = set()
for char in "advanced programming":
    if char in "aeiou":
        vowels.append(char)

# Using filter()
vowels = set(filter(lambda char: char in "aeiou", "advanced programming"))
```

4.5.3 Dictionary comprehension

Dictionary comprehensions are similar, with the additional requirement of defining a key:

```
squares = {number: number * number for number in range(10)}
```

returning:

```
{0: 0, 1: 1, 2: 4, 3: 9, 4: 16, 5: 25, 6: 36, 7: 49, 8: 64, 9: 81}
```

Once more, there are alternative ways by using `for()` loop and `zip()`, another HOF:

```
# Using loops
squares = {}
for number in range(10): result[number] = number * number

```

```
# Using filter()
squares = dict(zip(range(10), (x * x for x in range(10))))
```

4.5.4 Generator

In Python, a list comprehension functions by assembling the entire output list into memory. This approach suits small to medium-sized lists well. For instance, if we aim to calculate the sum of squares for the first one thousand integers, a list comprehension handles this task efficiently:

```
sum([number * number for number in range(1000)]) # 332833500
```

Attempting summing the squares of the initial billion integers could be overwhelming. Python endeavors to create a list containing a billion integers, which may exceed a computer's memory capacity.

An alternative approach is ***generator***. Unlike a list comprehensions, generators rely on the concept of *lazy evaluation*, also known as *call-by-need*, which is a programming technique used to defer the evaluation of an expression until its value is actually needed. In other words, instead of computing the value of an expression immediately, generators delay the computation until the value is required by another part of the program.

Therefore, summing the squares of the first billion integers using a generator may take some time to execute, yet it would not be overwhelming:

```
sum(number * number for number in range(1_000_000_000))
# 333333332833333333500000000
```

5 AN EXAMPLE PROGRAM

Let us consider a task where we need to evaluate a list of students and their scores to determine scholarship awards based on specific score ranges. This list of students is given a the form of a Python dictionary:

```
students = {
    "Alice": 7.2, "Bob": 8, "Charlie": 6, "David": 7.8, "Eve": 5.5,
    "Frank": 2, "Grace": 3, "Hannah": 1, "Isaac": 10, "Julia": 8.5,
    "Kevin": 6.7, "Linda": 5.9, "Michael": 9.5, "Nancy": 2, "Olivia": 4.6,
    "Peter": 4.1, "Quinn": 6.1, "Rachel": 7, "Samuel": 5, "Tracy": 4
}
```

The scholarship amount is determined as follows:

Score	Scholarship
score ≥ 9	\$10_000
$8 \leq$ score < 9	\$5_000
$7 \leq$ score < 8	\$2_000
$6 \leq$ score < 7	\$1_000

We now construct a Python program following functional programming. We will use several features that have been discussed before, including HOFs (`map()` and `filter()`), lambda expression and dictionary comprehension:

```
def foo(student, amount):
    global scholarship
    scholarship += amount
    name, score = student
    # Use a dictionary to keep track of whether an amount has been seen
    before
    if 'processed_amounts' not in foo.__dict__:
        foo.processed_amounts = {}
    if amount not in foo.processed_amounts:
        print(f"Students with ${amount:_} scholarship:")
        foo.processed_amounts[amount] = True
    # Display a student
    print(f" - {name}: {score}")

scholarship = 0

# Selecting out students using dictionary comprehension
list(map(lambda student: foo(student, 10_000), list({name: score for name,
    score in students.items() if score >= 9}.items())))
# Selecting out students using filter()
list(map(lambda student: foo(student, 5_000),
     filter(lambda x: x[1] >= 8 and x[1] < 9, students.items())))
list(map(lambda student: foo(student, 2_000),
     filter(lambda x: x[1] >= 7 and x[1] < 8, students.items())))
list(map(lambda student: foo(student, 1_000),
     filter(lambda x: x[1] >= 6 and x[1] < 7, students.items())))

print("Total scholarship value:", f"${scholarship:_}")
```

The function `foo(student, amount)` serves as the core mechanism for awarding scholarships. Upon invocation, it increments the global `scholarship` variable by the specified `amount`. Before processing a particular scholarship amount, it checks if the amount has been processed before. If not, it prints a message indicating the scholarship amount. The function unpacks the `student` tuple into separate variables `name` and `score`. Then, it prints the name and score of that student receiving the scholarship.

After processing scholarships for all eligible students, the program prints the total scholarship value accumulated in the `scholarship` variable, whose value is initialized to be 0.

As can be seen, this program utilizes a declarative paradigm, whose several benefits are:

- The comprehension and filter operations clearly express the logic for selecting students and awarding scholarships based on their scores, even though using `filter()` appears to be more concise in this case. This helps to gain the expressiveness of the entire program.
- The use of lambda functions within `map()` and `filter()` allows for the creation of reusable, anonymous functions that can be applied to different datasets or scenarios with minimal modification, increasing modularity.
- The `foo()` function encapsulates the logic for processing scholarships, promoting abstraction as without concerns about the detailed implementation of it, the main program, which orchestrates the process and handles global variables, can be understood with ease.

```
Students with $10_000 scholarship:
 - Isaac: 10
 - Michael: 9.5
Students with $5_000 scholarship:
 - Bob: 8
 - Julia: 8.5
Students with $2_000 scholarship:
 - Alice: 7.2
 - David: 7.8
 - Rachel: 7
Students with $1_000 scholarship:
 - Charlie: 6
 - Kevin: 6.7
 - Quinn: 6.1
Total scholarship value: $39_000
```

The entire program can be rewritten in Python following a purely imperative paradigm:

```
scholarship = 0

print("Students with $10_000 scholarship:")
for name, score in students.items():
    if score >= 9:
        print(f" - {name}: {score}")
        scholarship += 10_000

print("Students with $5_000 scholarship:")
for name, score in students.items():
```

```
    if 8 <= score < 9:
        print(f" - {name}: {score}")
        scholarship += 5_000

print("Students with $2_000 scholarship:")
for name, score in students.items():
    if 7 <= score < 8:
        print(f" - {name}: {score}")
        scholarship += 2_000

print("Students with $1_000 scholarship:")
for name, score in students.items():
    if 6 <= score < 7:
        print(f" - {name}: {score}")
        scholarship += 1_000

print("Total scholarship value:", f"${scholarship:_}")
```

In this version, the code involves explicit iteration over the `students` dictionary multiple times, each time for a different scholarship category. Despite both versions having roughly the same length (26 and 27 lines of code), the imperative approach risks becoming longer and more convoluted as the program expands, especially when additional scholarship award scenarios are introduced.

Additionally, this imperative paradigm directly exposes the iteration and conditional logic. While it may not pose a significant issue in this instance, as the processing scholarships logic gets more complicated, this style of coding can obscure the underlying intent of the code and make it harder to understand.

6 CONCLUSION

This report has explored the integration of functional programming principles within the Python programming language. By delving into Python's simple syntax and diverse data structures, including both mutable and immutable types, we have laid the groundwork for understanding how functional programming concepts can be applied.

The discussion expanded to encompass functions as first-class citizens, higher-order functions, lambda functions, recursion, and comprehension techniques like list, set, and dictionary comprehensions, along with generators. Through these features, Python facilitates a functional programming style that promotes immutability, purity, and the minimization of side effects.

An example program provided a practical demonstration of these concepts in action, illustrating how functional programming techniques can enhance code reusability, abstraction, and expressiveness.

In essence, while Python is not a purely functional programming language like Haskell or Lisp, its support for functional programming features empowers developers to write concise, readable, and efficient code that leverages the principles of functional programming where appropriate.

7 REFERENCES

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