

A Comparative Study of the Significance of Different Programming Languages

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Abstract: This paper delves into the characteristics, application scenarios, and efficiency differences of four mainstream programming languages: C, C++, C#, and Java, aiming to establish a solid theoretical foundation for language selection in software development. In terms of efficiency and execution time, C excels in speed due to its close-to-the-metal nature, while C++ demonstrates outstanding overall efficiency. Java matches C++ in efficiency for small tasks, benefiting from its automatic memory management, which reduces development complexity. At the syntactic level, each language possesses distinct features: C is structured around functions; C++ introduces classes and objects, enriching programming paradigms; Java achieves cross-platform compatibility through a virtual machine and incorporates a garbage collection mechanism. These characteristics determine their precise positioning in practical applications: C dominates low-level and system-level development; Java is widely used in enterprise and mobile domains; C++ showcases its strength in various fields such as gaming, office software, databases, and browser development. Through a comprehensive analysis and comparison of these four programming languages, this study not only deepens the understanding of programming language characteristics and application scenarios but also provides a scientific and comprehensive reference for language selection in the software development process.

Keywords: Programming language, application fields, C, C++, C#, Java

1. Introduction

1.1 The evolution of programming languages

A programming language is a set of English-like instructions that includes a set of rules (syntax) for putting the instructions together to create commands. A programming language is a formal computer language or constructed language designed to communicate instructions to a machine, particularly a computer. Programming languages can be used to create programs to control the behavior of a machine or to express algorithms^[1]. (Ogala & et al., 2022)

Programming language evolution refers to the changes in functionality, syntax, and design of a programming language over time. From the earliest machine languages and assembly languages, to higher-level programming languages such as C and Java, each generation of programming languages has a specific purpose and advantage. With the continuous development of computer technology, people's needs for programming are becoming more and more diverse. As a result, over the past few decades, we have witnessed the emergence and popularity of many new programming languages. These new programming languages often have more concise and readable code structures, more powerful and flexible features, and greater efficiency. After the 1990s, Object-oriented programming (OOP) began to become popular, and gave rise to many new programming paradigms that support object-oriented ideas and have good maintainability and extensibility. These include Java, Python, Ruby, and more. In general, it is very natural and inevitable that various types and styles of programming evolution emerge in different periods and different backgrounds, but each has its own unique value and advantages.

1.2 Programming languages in common use today

Common programming languages today include Java, Python, C++, JavaScript, PHP, etc. These programming languages have their own unique characteristics and advantages to meet the needs of different types of applications. For example, Java is an object-oriented programming language with strong cross-platform and easy to learn and use. Python is popular for its simplicity and efficiency; C++

is widely used in the field of system development, and has been widely used in game development; JavaScript is one of the essential skills for Web front-end development, which can achieve dynamic interactive effects. PHP is mainly used in the field of Web backend development. In addition, there are many other popular programming languages like Swift, Kotlin, etc. that have emerged and become widely used.^[1](Ogala et al., 2022)

2. Basics (or) state of the article

2.1 A variety of programming languages

Each programming language has its own unique characteristics and use cases.

Python is an interpreted, object-oriented, dynamically typed high-level programming language. Python third-party libraries are reusable code libraries created and maintained by other developers or organizations. Its syntax is concise and clear, and it supports a large number of third-party libraries and modules, so it is widely used in web development, data analysis, artificial intelligence and other fields. The advantages of Python are that it is efficient to develop and easy to learn and use. However, the downside of Python is that it is relatively slow and may not be ideal for applications that require high performance.

Java is an object-oriented programming language, which is platform-independent and portable. The advantage of Java is that it has garbage collection (GC) mechanism and can automatically manage memory, which is suitable for the development of large enterprise applications. Reclaim objects in memory that are no longer used; The method used for recycling in GC is called the collector. Because GC consumes some resources and time, Java collects objects in the way of the new generation and the old generation after analyzing the characteristics of the object's life cycle, so as to shorten the suspension caused by GC to the application as much as possible.^[1](Ogala et al., 2022) In addition, Java has a large number of open source frameworks and libraries that make it easy to implement various functions. However, Java has a relatively complex syntax and is relatively slow to run, which may not be ideal for applications that require fast responses.

C language is a procedural language, which emphasizes the process of operation, through Simple code flow for programming with various syntax forms. In the actual application process In, C language does not need to formulate the operating environment, which is beneficial to simplify man-machine communication .The meaning of the pole. At the same time, C language has a certain degree of independence and can be used in information exchange between different computers, for the later independent operation, independent operation Technical support is provided.^[2](Yang, 2019)

C++ is an object-oriented high-level programming language based on C language. C++ has efficient running speed and powerful low-level access ability, which is suitable for the development of system software, games, embedded devices and other fields that need high performance. The downside of C++, however, is that the syntax is complex and requires manual memory management, which can be difficult for newcomers to master.^[3](Wang et al., 2016)

In short, different programming languages have their specific application scenarios, advantages and disadvantages, and choosing the right programming language needs to consider the requirements of the project, the skills of the developers, and the performance of the language.

2.2 Different applications of the same programming language

For example, in data analysis and artificial intelligence and machine learning, Python is a popular data analysis language that can be used for data cleaning, data preprocessing which means some processing of the data prior to the main processing, machine learning, deep learning, and other data analysis tasks. Java is a programming language widely used in enterprise application development, as well as in data analysis and machine learning. Because it is more flexible, the writer can optimize and adjust it appropriately according to the actual writing needs, which is of great significance to improve the modernization and intelligent development of all kinds of mobile devices.^[4](Zhang, 2020) Many AI and machine learning projects are developed using Python, Java, and other high-level languages. These languages are commonly used to build models, train algorithms, and process large amounts of data.

2.3 The same application uses different programming languages

Similarly in desktop app development and mobile development, many mobile apps such as iOS and Android apps are developed using programming languages such as Java, Python, and C. These languages can be used to develop aspects such as interface, logic, and data storage of applications. Many programming languages such as C++, Java, and C# are widely used to develop desktop applications. These languages are commonly used to handle graphical user interface (GUI) interactions, file manipulation, multimedia processing, and other tasks related to desktop applications.

These are just a few common application areas, in fact, there are many other areas where programming languages can be used to solve problems and create value.

3. Comparative analysis of Programming languages

3.1 Efficiency and Execution time

In the comparison of computer languages, the efficiency of different languages should be compared on the same platform according to the different characteristics of different languages. In the comparison process, we should compare and measure the basic concepts of each language, and the most important thing is to measure in the actual 'operating environment', and then compare the real running time of each language according to the measured results. ^[1](Ogala & et al.,2022)

However, when comparing in the actual environment, due to the variability of the actual environment, the actual running result of the language code will be affected, and the accuracy of the running result will be reduced. For example, debugging in Java is very difficult because the code runs in a client-side environment, where errors are difficult to pinpoint or impossible to reproduce. The Java language is dynamically type-safe, which means that a virtual machine is required to ensure that programs do not violate language semantics or access unstructured memory. At an implementation level, this means that the virtual machine must perform frequent dynamic checks, such as checking upper and lower bounds for array element access, checking inheritance relationships for type conversions, and so on. Although the compiler will try to optimize the check behavior, it still consumes a lot of running time. ^[1] (Ogala & et al.,2022)

However, it is difficult to avoid this in current computer operating systems, and there is no need to do so. Because the language algorithm chosen when writing the program can run in a variety of environments. And for different languages, even if the same calculation method is used, the test results will be completely different. Therefore, in order to be able to accurately test the runtime of both languages, it is necessary to experiment with C and Java. When testing, you need to use Java language and C language to edit a small piece of program, and then run the program, and test the running time of the two by continuously executing the program, and then calculate the average value of the overall running time, and find the standard deviation of the running time, You can easily see that C executes faster.

In the process of C programming, some commonly used functional modules are often written as independent functions and placed in the function library for the public to choose. If you can skillfully use functions in the programming process, you can shorten the length of the entire program and reduce the workload of repeated programming segments, but complex calling functions will affect the efficiency of program execution.

Java language is a high-level language improved on the basis of C language, for the various advantages of C language, Java language is also included. But it's hard to avoid more verbosity. Therefore, when comparing the operation efficiency of these two languages, it is necessary to go through repeated tests to get accurate comparison results.

3.2 Grammar

When comparing programming syntax, it should be more hierarchical to compare a low-level language with a high-level language.

C, for example, is a procedural-oriented programming language. It takes function as the basic unit, uses semicolon as the end of the statement, and uses braces to represent code blocks. ^[5](Subramanyam.R, et.al, 2003)

C++ is a programming language that extends on the basis of C language. It retains the syntactic

features of C language, introduces the concept of object orientation, and adds syntactic structures such as class and object. The Java language is also an object-oriented programming language. It uses braces to represent code blocks and semicolons as statement terminators. Unlike C++, the Java language has a garbage collection mechanism that automatically manages memory. Because of the special syntax, Java can use D3, Echarts and other visualization libraries to achieve chart presentation and data visualization, flexible and variable.

3.3 Practical application

3.3.1 Usage of various programming languages

Usually we would like to choose the appropriate programming language for software development work. However, choosing an inappropriate programming language will increase the overall workload and cost of software development^[6] (Li,X.2018). The main application field of C language is operating system, embedded and server these three blocks, it's a powerful is widely used in the low-level high-level language, such as Microsoft's Windows system occupies more than 90% of the world's operating system share, and its kernel is written in C language.

Java is mainly used for enterprise application development, website platform development, mobile games and mobile android development in the mobile field Java is currently the most available but also the most competitive language on the market, compared to C language. Java will bring a great deal to the development of the industry and the computing paradigm itself . A certain degree of influence. The development of different styles and different types of programming languages will further accelerate language-oriented development. But to fix everything, It can't be done by relying on object languages alone. It's mainly about style and length Place, based on the object that needs to face, cooperate with the effective compatibility of the rest of the style again, can form a new language.^[7](Xiang,2018)

c++ is mainly used in games, office software, relational databases, browsers, software development and many other fields. Specific points. Analysis of c++ shows that its popularity is mainly due to its ability to compile and process low-level memory in an easy way and produce a small amount of machine code.^[8](Li,P.2018) The main application areas of Python are crawler, data analysis, automated testing and machine learning, and some small and medium-sized enterprises will use it to do back-end development, and it's also a relatively easy language to learn.

3.3.2 Popularity comparison

In many cases, the usage of a programming language can be measured by its popularity. The TIOBE ranking is a great way. The TIOBE ranking is based on the number of experienced programmers, courses, and third party vendors on the Internet and using search engines Q (such as Google, Bing, Yahoo!). (From Baidu) As well as Wikipedia, Amazon, YouTube, and Baidu, ranking data only reflects the popularity of a programming language, not whether a programming language is good or not, or how much code is written in a language (See figure 1).

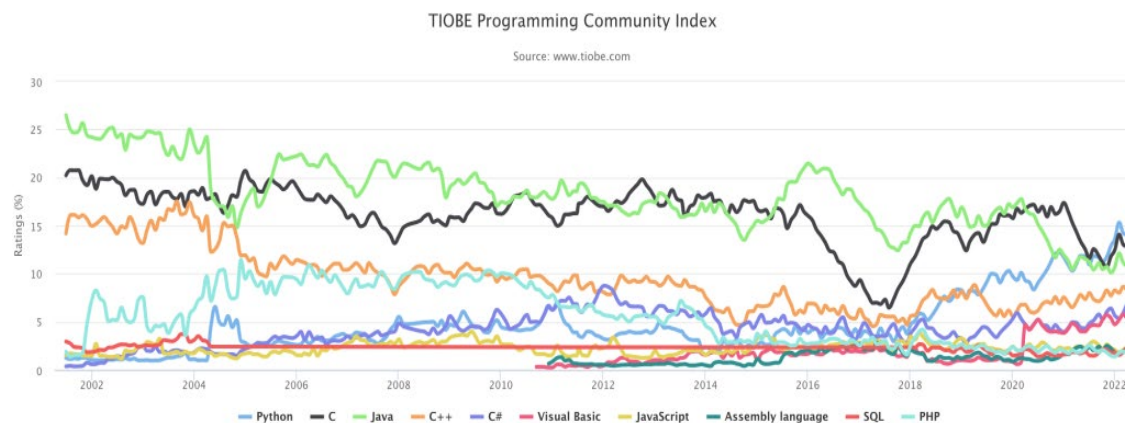


Figure 1. TIOBE Programming Community Index

We have talked about Python being probably the most frequently used language nowadays. Although Python is currently ranked number one among all programming languages, it is still controversial, which is not surprising, after all, Python is not only learned and used by programmers, but also by people in other jobs , such as operations and even finance (See figure 2).

Jun 2023	Jun 2022	Change	Programming Language	Ratings	Change
1	1		 Python	12.46%	+0.26%
2	2		 C	12.37%	+0.46%
3	4	▲	 C++	11.36%	+1.73%
4	3	▼	 Java	11.28%	+0.81%
5	5		 C#	6.71%	+0.59%
6	6		 Visual Basic	3.34%	-2.08%
7	7		 JavaScript	2.82%	+0.73%
8	13	▲	 PHP	1.74%	+0.49%
9	8	▼	 SQL	1.47%	-0.47%
10	9	▼	 Assembly language	1.29%	-0.56%
11	12	▲	 Delphi/Object Pascal	1.26%	-0.07%
12	24	▲	 MATLAB	1.11%	+0.48%
13	25	▲	 Scratch	1.02%	+0.43%
14	15	▲	 Go	1.00%	-0.02%
15	26	▲	 Fortran	0.99%	+0.44%
16	11	▼	 Classic Visual Basic	0.96%	-0.36%
17	16	▼	 R	0.94%	-0.04%
18	19	▲	 Ruby	0.94%	+0.19%
19	10	▼	 Swift	0.93%	-0.62%
20	27	▲	 Rust	0.91%	+0.38%

Figure 2. Ranking of Programming Languages

4. Conclusion

4.1 Result of analysis

In terms of execution time, C and Java languages dominate the tests, but C is superior in speed. In terms of overall efficiency, c++ dominates. However, python has low compilation difficulty and high compilation speed for small size tasks. Tests show that Java and c++ can handle small tasks while maintaining overall efficiency compared to other languages. In all tests, the programming language c# performs the worst in terms of execution time, overall efficiency, and what the language can handle before task overhead takes over.^{[1](Ogala & et al.,2022)}

4.2 Opinions and suggestions for future programming language selection

There is great potential for further research in this area, and a comparison between programming languages and their respective parallel programming models will prove beneficial for future software development.

Due to the lack of our ability, there is no more suitable and unified method to judge all languages, and now the popular programming language is difficult to distinguish the pros and cons, this is the defect, we hope that later people can further analyze and judge.

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