

# A Comparative Study of Numerical Analysis Packages

Kamran Shaukat, Fatima Tahir, Umar Iqbal, and Sidra Amjad

**Abstract**—Numerical Analysis packages provide a convenient command line that helps in solving several mathematical problems and experiments. Matrix laboratory (MATLAB) is the most popular numerical analysis package all around the world. Some other open source numerical packages such as GNU Octave, FREEMAT and SCILAB are also available in the market and are similar to MATLAB. The focus here is on, which is the best numerical package that provides best performance, availability in different operating system, good interoperability and less hardware specification? This study presents a comparison of MATLAB, GNU Octave, FREEMAT and SCILAB based on different. Hardware specifications and operating support were also considered. After performing the comparison, we conclude that MATLAB and GNU Octave have the best execution, Octave proves to be finest in term of operating system support as it is supported in most of the operating systems. In hardware specification, FREEMAT itself does not seem to use much memory and can run on systems with minimum 1 GB RAM. All packages give satisfactory result based on interoperability.

**Index Terms**—MATLAB, numerical packages, numerical analysis software, octave.

## I. INTRODUCTION

Numerical packages are used for prototyping and investigating data. They are mostly used for education and research purposes [1]. High level languages like MATLAB have been widely used in engineering and science institute for study and research [2]. These numerical packages provide ease of usability and several built-in mathematical functions. They can be used to solve large mathematical and statistical problem with less lines of codes [1]. The main advantage of such packages is hundreds of built-in numerical functions.

MATLAB is most popular numerical package for development of algorithms [3]. It can be used for multiple purposes. It is a high-level programming language originally developed to provide engineers a platform for numerical computations. However, it can also be used for visualization and manipulations [4]. MATLAB provides a wide range of numerical functions that are helpful in computations. It lets in matrix manipulation, numerical computations, graphical representation, image processing, and solution of large mathematical problems and data analysis [5]. The working can be further improved by using additional toolboxes that are available freely at their official website [4].

SCILAB is an open-based numerical analysis package and numerical-oriented language just like Octave and

FREEMAT [6]. It provides a friendly environment for scientific and engineering purposes. It is used for numerical and scientific computations like statistical computations, engineering formulations, face recognition [7], dynamical structures and symbolic manipulations. It is powerful enough to work on signal and image processing like MATLAB [8].

SCILAB is an open source alternative to MATLAB [9], and work faster in purely mathematical functions as MATLAB [8]. It nevertheless places a lot less emphasis on syntactic compatibility with MATLAB than GNU Octave does [10]. However, SCILAB syntax is somewhat different from MATLAB.

GNU Octave is a high-level programming language, with the goal of providing numerical computations [11]. It is used for fixing linear and nonlinear issues numerically and calculating different numerical experiments that is nicely suitable with MATLAB [12]. It can also be used as a batch-orientated language.

GNU Octave is one of the common open source option to MATLAB [1], like FREEMAT and SCILAB. It includes a list of characteristic calls or a script. The syntax is matrix-based totally and gives diverse functions for matrix operations [13]. It supports diverse statistics structures and lets in object-orientated programming. Its syntax is similar to MATLAB [13], and cautious programming of a script will permit it to run on each GNU Octave and MATLAB.

FREEMAT is also an open source numerical package and an alternative to MATLAB [1]. In addition to having same syntax as MATLAB, FREEMAT provides a list of visualization and processing techniques. It is being used in engineering and clinical information processing and prototyping [14]. It also provides an interface to connect its code with C, C++ and FORTAN. Besides all the advantages, FREEMAT lacks some of the numerical built-in functions [1]. While, compared to syntax, FREEMAT, GNU Octave and MATLAB have most similarities.

These numerical packages are not initially designed to develop a complete application. These packages are attached with other programming languages or tools to develop a complete application. Numerical packages like MATLAB help to compute a numerical computation faster and can be integrated with other programming languages. They may be simply used for numerical computation purposes.

In our simulation, we have compared these numerical packages based on different attributes and concluded the best option with respect to all attributes. The study includes executing different complex algorithms, built-in function and their execution time. To achieve this goal twelve problems have been applied which include large matrixes and their multiplication. The focus here is on performance of benchmark algorithm while comparing these numerical analysis packages. Further, the packages are compared with

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respect to operating system support, interoperability and hardware specification. These comparisons help to conclude the easiest approach for all users. Then the results are compared between the four packages.

## II. RELATED WORK

Numerical packages are widely used in research and education. MATLAB is the most popular one in the world today [1]. Numerical packages are a great subject for many researchers but not much research has been done in this field. For analyzing performance of the numerical packages computations have been done using different algorithms.

Numerical Packages are used for computing linear equation, calculating Eigenvalues and Eigenvectors, 2-D plotting from the data file and annotated plotting from computed data [15]. It shows that GNU Octave is more likely similar to MATLAB than any other package with respect to performance, usability and syntax.

Another article has used different architectures that is i386 and different operating systems Such as Windows, Mac OS and Ubuntu for testing the performance of these computational packages [16]. The result shows that the MATLAB and GNU Octave failed to compute t-student distribution while SCILAB presented the best result in it. In all other computations MATLAB and SCILAB were the best.

On the other hand, a comparison between these computational packages also has been conducted to check the open-source computational packages such as FREEMAT, SCILAB and GNU Octave as the best alternative of MATLAB for computation on large datasets up to 30GB. The study uses Gaussian Elimination technique for this purpose [1], [15].

The comparison results show that FREEMAT [3] and Octave syntax is likely similar with MATLAB. But FREEMAT does not support some functions like PCG function for conjugate method, KRONFOR. But FREEMAT occupies less space as compare to Octave and MATLAB.

Image Processing and Analysis are fields of computer science whose objective is to enhance digital images and extract information from them [17], [18]. This allows automatic identification, classification or characterization of objects and patterns. Image processing is the new research topic. MATLAB can be an effective tool to process images and can help to collect meaning full data from them. To achieve this goal, original MATLAB software is required. A good alternative in this perspective is SCILAB.

From a methodical point of view, a conventional solution for developing complex embedded control software is to use the MATLAB that has been commercially available for use. For instance, a [19] rapid controller prototyping system was developed based on MATLAB. Automatic generation of executable codes directly from MATLAB; models may not always be supported. It is also possible that the generated codes do not perform satisfactorily on embedded platforms, even if the corresponding MATLAB model are able to achieve very good performance in simulations on PC. Consequently, the developers must spend significant time dealing with such situations.

## III. COMPARATIVE ATTRIBUTES

To compare the numerical packages in our study, we specified certain attributes for comparison that are execution time, operating system support and hardware specifications. This paper seeks to answer the following questions: Which numerical package has the best execution time? Which numerical package is supported in most operating system? Which numerical package requires less hardware specification for installation and execution? Do these packages provide interoperability with other languages?

We use four structures, MATLAB 2016a, GNU Octave 4.0.0, FREEMAT v 4.2 and SCILAB 5.5.1. In all instances, window 10 and Intel core i7-7500U CPU with two cores of 2.70GHz and 8 GB RAM have been used. Double precision of algorithm and test was enforced for accuracy of the results. All the tests have been practically performed and checked.

### A. Execution Time

In this section, we present the operations used to compare the execution time of MATLAB, FREEMAT, GNU Octave, and SCILAB. Test includes twelve basic functions that are mostly used in the field of linear algebra, standard mathematics, numerical mathematics and statistics. MATLAB, GNU Octave and FREEMAT [20] are more comparable according to the syntax and commands while, SCILAB differs the most from other packages [21] but the execution time is different in all.

To examine the execution time and speed of a numerical package, we have performed certain tests on the packages. Tests included different functions and algorithms which were executed on the packages. The functions used in our study are defined below.

- Loop test used nested loop with 14000x14000 iterations. Looping is the key technique used by developers all over the world. It helps to optimize code.
- Normal Distribution considered the 2000x2000 normal distributed random matrix with power up to 1000. It is used to represent real-valued variables whose values are unknown. It is also highly used in probability and recommendation techniques.
- Sorting test uses sort () function in MATLAB, FREEMAT and GNU octave and gsort () in SCILAB to sort 1000000 random values. Sorting technique is widely used in computer field.
- Fast Fourier Transform (FFT) is used to multiply the polynomials without duplication of so much effort. It is mostly used in signal processing and representing frequency domain. In test, it is applied on over 1048576 values by FFTW function.
- We calculate the determinant of a 1400x1400 random matrix by using det () function. Determinant is a linear algebra function.
- For inverse, the inverse of a 1400x1400 random matrix is found by using inv () functions. Same as determinant, inverse is also a linear algebra function.
- Eigenvalues of a 1400x1400 random matrix is calculated by the help eig () function in MATLAB, GNU octave and FREEMAT while spec function is used in SCILAB. It is greatly used in physics and engineering techniques.

- A Cross Product matrix, we achieve it by the product of inverse and the original 1400 \* 1400 matrix. It is a physics concept.
- 10000000 Fibonacci numbers is computed to get the execution time of large number multiplications.
- Gamma and Gaussian error function of a 1400 \* 1400 matrix is also calculated in the test. They are an extension of factorial function. Gaussian error is computed by using erf () function in packages. On the other hand, Gamma function is computed by gamma () function.
- Linear regression of a random 1000x1000 matrix is computed to get the speed of division of matrixes.

All the functions were executed double time to get the estimate time. The average computation of each package is shown in Table I.

**B. Operating System Support**

While measuring the performance of numerical packages, it is also important to note that software is available on different operation systems. Today many home users use Windows operating system on Laptops and personal computers as it gives user-friendly environment. Whereas professionals prefer Linux and Mac as it provides more good working and flexibility. With the advancement of the technology, people are using mobile technology more and more. The availability of software in these operating systems increase their worth and usability. The results were searched from the official websites of the numerical packages.

**C. Hardware Specifications**

We live in a world of dual core and multiprocessors where RAM goes from 1 GB to 128 GB. The performance of a software also depends on the specification of the server as the RAM and processor play a vital role in it. However, if the software requires less hardware specification than it assumed to be efficient software. As people, all around the world use different types of server and old technologies.

Table III shows the result we searched in our study. We illustrate the hardware specifications for installing these four computational packages. The specifications were searched from the official websites of the packages.

**D. Interoperability**

Interoperability is a powerful tool as it enables the developers to use various strengths of many programming language in one platform [22]. C++ and java object-oriented features and data abstraction but do not provide numerical computations as MATLAB. The comparison is conducted with numerical packages based on their interoperability feature. Interoperability contain two parts, that are Numerical packages integration with other languages and extend packages from other languages.

**IV. RESULTS**

This section provides the detail analysis of the results of comparative attributes. Specially, the three attributes namely execution time, operating system support, interoperability and hardware specification results are shown in the tables.

The execution time of applied tests on numerical packages are the results computed for first comparison. The

problems used in this study contain very large matrices and many iterations to get the right working of package.

Table I presents the execution time of all four numerical packages in the form of seconds. The tic and toc function are used to get the result of execution time. The analysis is conducted based on several algorithms. The study also shows the increasing execution time with the increasing complexity of algorithm. In linear regression, looping and Fibonacci all four numerical packages presented the best execution time. In eigenvalue, inverse, cross product, FFT and determinant MATLAB, GNU Octave and SCILAB gave acceptable result but FREEMAT failed to achieve the goal. The function normal distribution was the main problem in this test and all four packages took way too long to execute than in any other function. This is a serious problem as this function is widely applied in statistics.

TABLE I: EXECUTION TIME IN SECONDS

Algorithms	Numerical Packages			
	MATLAB	GNU Octave	SCILAB	FREEMAT
Normal Distributed	114.779	131.12	249.612	67.959
Values sorted ascending	10.656	13.334	73.932	283.426
Gaussian	3.2793	5.7334	20.546	12.012
Gamma	5.7519	11.105	14.987	14.986
Linear Reg	5.3603	6.671	6.323	396.491
Looping	1.896	2.133	5.845	2.230
FFT	3.6479	17.251	8.3603	67.142
Determinant	14.481	5.799	18.197	191.941
Inverse	33.784	61.369	62.241	153.715
Eigenvalue	2.240	5.126	5.707	62.12
Cross Product	13.022	31.623	32.412	97.374
Fibonacci	3.119	3.334	3.245	6.623
Average execution time	17.668	24.549	41.784	113.002

The results show that MATLAB has the best execution time. While, FREEMAT had large execution time with the increasing complexity of function.

TABLE II: AVAILABILITY IN OPERATING SYSTEMS

Operating Systems	Numerical Packages			
	MATLAB	GNU Octave	SCILAB	FREEMAT
Windows	Yes	Yes	Yes	Yes
Linux	Yes	Yes	Yes	Yes
Unix	Yes	Yes	Yes	Yes
MacOS	Yes	Yes	Yes	Yes
Android	No	Yes	Yes	No
DOS	No	Yes	No	No

Through Table II, it is clear that all four numerical packages work on Windows, Linux, UNIX and Mac operating system which are broadly in the use of people today. Also, it shows that MATLAB and FREEMAT do not support android and DOS which is a drawback for them as android operating system is also commonly used in mobiles.

Table III shows that MATLAB requires 2 GB RAM to

execute. It involves almost 10 to 12 GB of hard disk for installation. Octave does not need any extra specifications it can run within 1 GB of RAM and installed within 1 GB of hard disk. SCILAB requires minimum 1 GB of RAM or 2 GB if want smooth working. It uses about 600 MB after installation to run efficiently. FREEMAT also does not require any extra memory or hardware specification. FREEMAT can easily run within 1 GB RAM size. It can be installed within 250 MB of hard disk.

TABLE III: HARDWARE SPECIFICATIONS

Hardware	Numerical Packages			
	MATLAB	GNU Octave	SCILAB	FREEMAT
RAM	2-4 GB	1 GB	1-2 GB	1 GB
Hard Disk	10-12 GB	1 GB	600 MB	250 MB

Table IV shows that FREEMAT, GNU Octave and SCILAB do not require any extra hardware specifications whereas MATLAB require a lot of hardware space and 2 GB RAM for smooth working.

TABLE IV: EXTEND PACKAGES FROM OTHER LANGUAGES

Languages	Numerical Packages			
	MATLAB	GNU Octave	SCILAB	FREEMAT
Java	Yes	Yes	Yes	Yes
C/C++	Yes	Yes	Yes	Yes
Python	Yes	Yes	Yes	Yes
Tcl	No	No	Yes	No
.Net	Yes	Yes	No	No
Fortan	Yes	Yes	Yes	Yes
Ocaml	No	No	Yes	No

TABLE V: INTEGERATE PACKAGES WITH OTHER LANGUAGES

Languages	Numerical Packages			
	MATLAB	GNU Octave	SCILAB	FREEMAT
Java	Yes	Yes	Yes	Yes
C/C++	Yes	Yes	Yes	Yes
Python	Yes	Yes	Yes	Yes
Tcl	No	No	No	No
Julia	Yes	Yes	Yes	No
Fortan	Yes	Yes	No	Yes
Ocaml	No	No	No	No

Table V shows the comparison with respect to interoperability shows that all the numerical packages support C/C++ and other common languages. The main problem is in languages like tcl, ocaml and Julia.

### V. COMPARATIVE EVALUATION AND DISCUSSION

This section includes an overview of all the results computed in this study. The research shows the better package compared to others with respect to different attributes. The results are shown in Fig. 1 and 2. The results

have been summarized through graphs for easy understanding and comparison.

It is understandable through Fig. 1 that MATLAB has less execution time than any other package in the list. The only drawback of MATLAB is that it is a commercial package and not an open source [15]. On the other hand, other three packages are open source and easily available all over internet. In these open-based packages, the acceptable performance was given by GNU Octave.

Fig. 1 shows that GNU Octave has almost same result as MATLAB. We can also say that GNU octave is the best alternative to MATLAB with respect to performance. As GNU Octave is a free source and provides good performance. SCILAB is also an acceptable package as it an open source and has average performance but FREEMAT was not compatible in the performance. Functions such as normal distribution and inverse function have the most execution time in all packages. These problems should be taken under consideration as the wide use of these function in statistics and engineering.

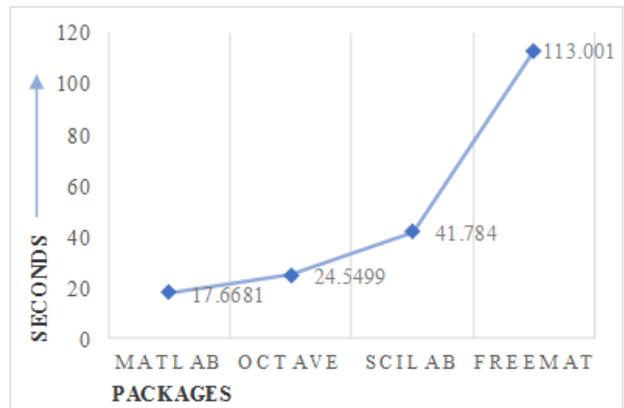


Fig. 1. Average execution time of numerical packages.

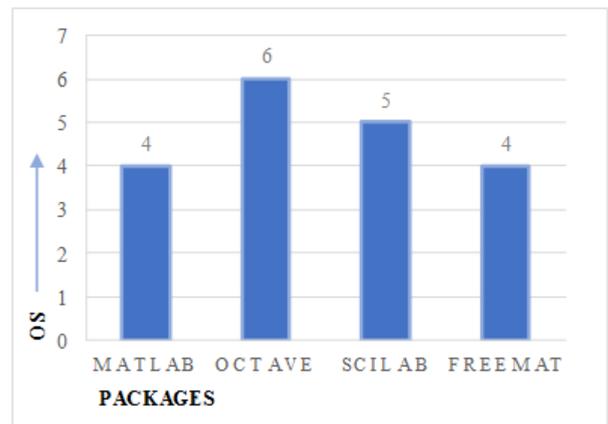


Fig. 2. Availability of numerical packages in different operation systems.

After performing the tests, we conclude that MATLAB and GNU Octave have the best execution speed compared to other packages. Whereas, both FREEMAT and SCILAB show large execution time and performance problems in our study.

GNU Octave is rapidly improving and introducing new developments. Fig. 2 shows that GNU Octave is supported in most operating systems than any other packages. SCILAB is also acceptable with respect to availability in operating systems as it has good number of availability. Besides this,

MATLAB is the most popular numerical package but cannot be used in many operating system. Same is the case of FREEMAT, it cannot be used in many operating systems.

In the terms of operating system, GNU octave proves to be finest as it is supported in many operating systems. While MATLAB being the most commonly used package, failed to achieve this.

The third comparison with respect to hardware specification (Table III) concludes that FREEMAT requires the least hardware specification. Less hardware specification here means that not the latest and fastest technology is needed for installation and not much memory is used. SCILAB and GNU Octave also require less hardware specification and can be used on more servers. While MATLAB requires latest systems and more memory space than any other package. However, GNU Octave, FREEMAT and SCILAB have provided satisfactory result related to this comparison.

In the last interoperability comparison, we deduce the fact that SCILAB provides more extension than any other package. Octave and MATLAB provide acceptable results in integration with other languages. While FREEMAT provides the least extension and integration with other languages.

## VI. CONCLUSION AND FUTURE WORK

We have discussed several numerical packages and their comparison based on different attributes that are execution time, hardware specification and operating systems support. Experimental results show that MATLAB and GNU Octave have best performance and usability. Though MATLAB shows the best performance and a built-in support for complex functions, it is also an expensive tool and is not easily accessible. Whereas, GNU Octave is an open source tool and proves to have acceptable execution time as compared to performance. GNU Octave is supported in most of the operating systems than any other numerical package. MATLAB being the most expensive and commonly used numerical package failed in this perspective. In hardware specifications comparison, GNU Octave, FREEMAT and SCILAB provide less hardware specification but MATLAB requires more RAM and hard disk space. SCILAB provides more extension while MATLAB and GNU Octave provide more integration with other languages.

We conclude that GNU Octave proves to be the best numerical package available as it has given satisfactory results in all compared fields. In future, we look forward to adding new attributes and more numerical packages for new comparison such as Mathematica, RLAB and Maple. Also, the comparison on the base of most built-in function will be conducted.

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