Comparing Computational Efficiencies of MATLAB, Mathematica, and Maple

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Introduction

Modern advances in technology have allowed for the creation and distribution of Computer Algebra Systems (CAS), which have quickly become highly utilized tools within the scientific and mathematic communities. While most CAS have their own unique syntax, many of these systems have similar capabilities in terms of the types of problems they can execute and solve. It should be noted, however, that if the same input (in its proper syntax) is written across multiple programs discrepancies may arise. This is especially problematic for those starting to learn and use the programs, as new users are more likely to treat the CAS as a "black box" and assume the output is always correct. This project addresses several discrepancies that arise among MATLAB, Mathematica, and Maple in terms of the accuracy of their results and computation times. In this project the times to factor closely spaced large numbers were measured and the accuracy of numerical integration was investigated.

Background

Computer algebra systems were first introduced in the 1960s to serve the needs of those working in both academia and industry settings and have since evolved to be able to carry out practically any computation today (without the need for a user to do any programming on their own). The three CAS that were utilized throughout this project were MATLAB, Mathematica, and Maple. While these CAS all have nearly the same capabilities in terms of the types of computations that they can carry out, it is important to note that they each have their own unique strengths and weaknesses. The goal of this project was to quantitatively analyze the similarities between the three CAS. To achieve this, numerous tests were carried out across four separate computer systems – each with different operating systems (specifically Windows and Mac), memory availability, speed, etc.

Tests Used & Results

The tests that were carried out throughout this project focused mainly on the amount of time it took for each CAS to provide an output for a computation, the accuracy of each CAS' output compared to both one another and the real/accepted value, and the "cost" of using a certain method or CAS to solve a problem/perform a computation. Throughout the project, four computers were utilized to make sure results weren't dependent on a particular computer:

	Operating System	Usable RAM	Processor
Computer 1	Mac OS Big Sur	8.00 GB	1.6 GHz Dual-Core Intel Core i5
Computer 2	Windows 10 Pro	47.9 GB	Intel® Core™ i7-6700K @4.00 GHz
Computer 3	Windows 10	11.8 GB	Intel® Core™ i5-8265U @1.6 GHz
Computer 4	Windows 10 Education	7.89 GB	Intel® Core™ i7-2640M @ 2.80 GHz

TEST 1: TIME TO FACTOR LARGE NUMBERS

We first chose to factor large numbers that were very close to one another. This elicited large variances in timing among the three platforms and gives insight into how well the algorithms for each CAS behave. We chose a beginning number that all three platforms performed almost instantaneously, then added one to the number, remeasured the results, and repeated the process until 21 numbers had been tested. The starting point was 50!; the number was increased by one to 50!+1, 50!+2, and so on up to 50!+20.

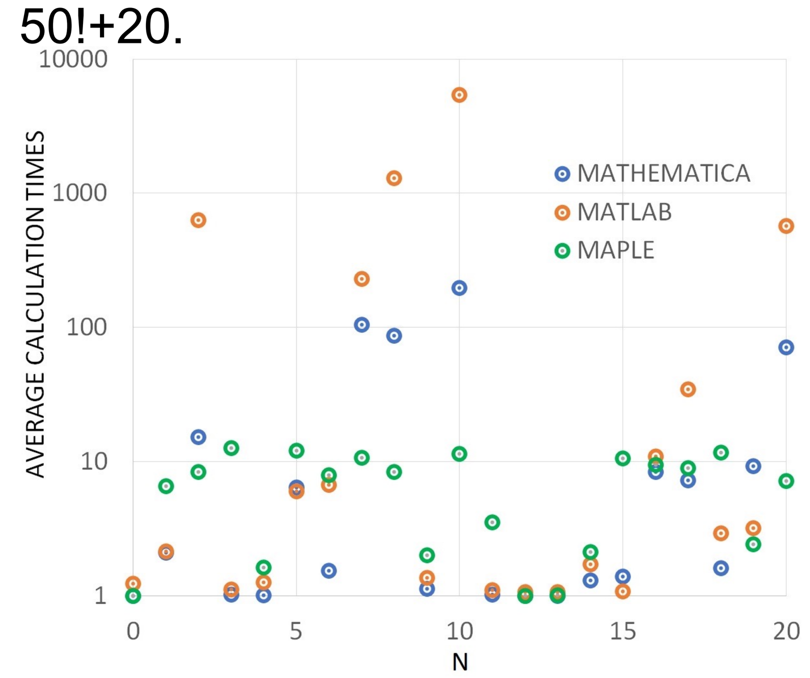

Figure 1a

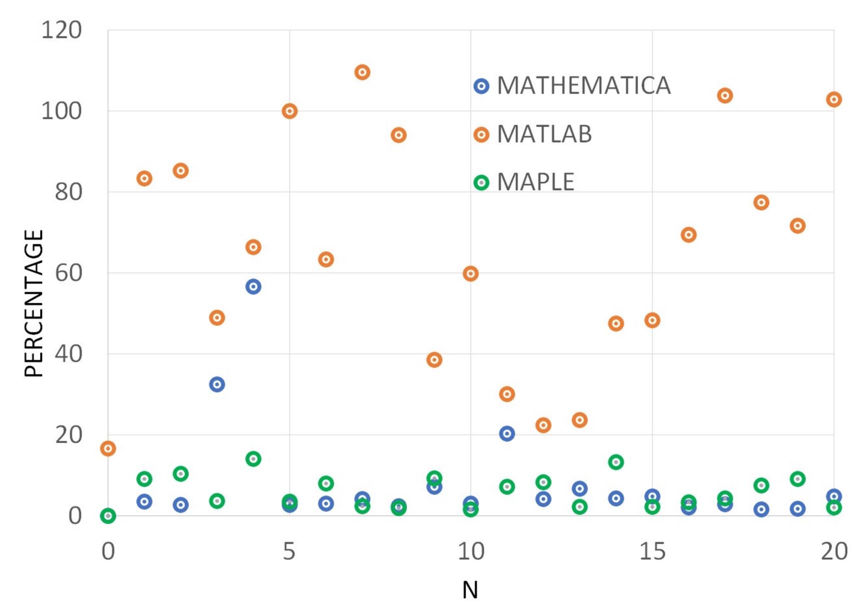

Figure 1b

Figure 1a: Comparison of MATLAB, Maple and Mathematica average calculation times for 50!+N using a log plot; times were averaged for several computers, each of which took 10 trials of the time. Figure 1b: Percent of Standard deviations compared to the averages for each of the three CAS. Note the enormity of MATLAB's standard deviations as compared to the other two CAS.

TEST 2: ACCURACY OF NUMERICAL ANALYSIS

In this project the accuracy of results between the three CAS was explored by first evaluating an exact integral (closed-form solution) of Eq (1) to 15 digits of precision then repeating the calculation for all three CAS by numerical integration of Eq (1) to 15 digits of precision.

$$\int_{-k}^{k} \sin(x^2 + y^2)\,dxdy \qquad \text{Eq (1)}$$

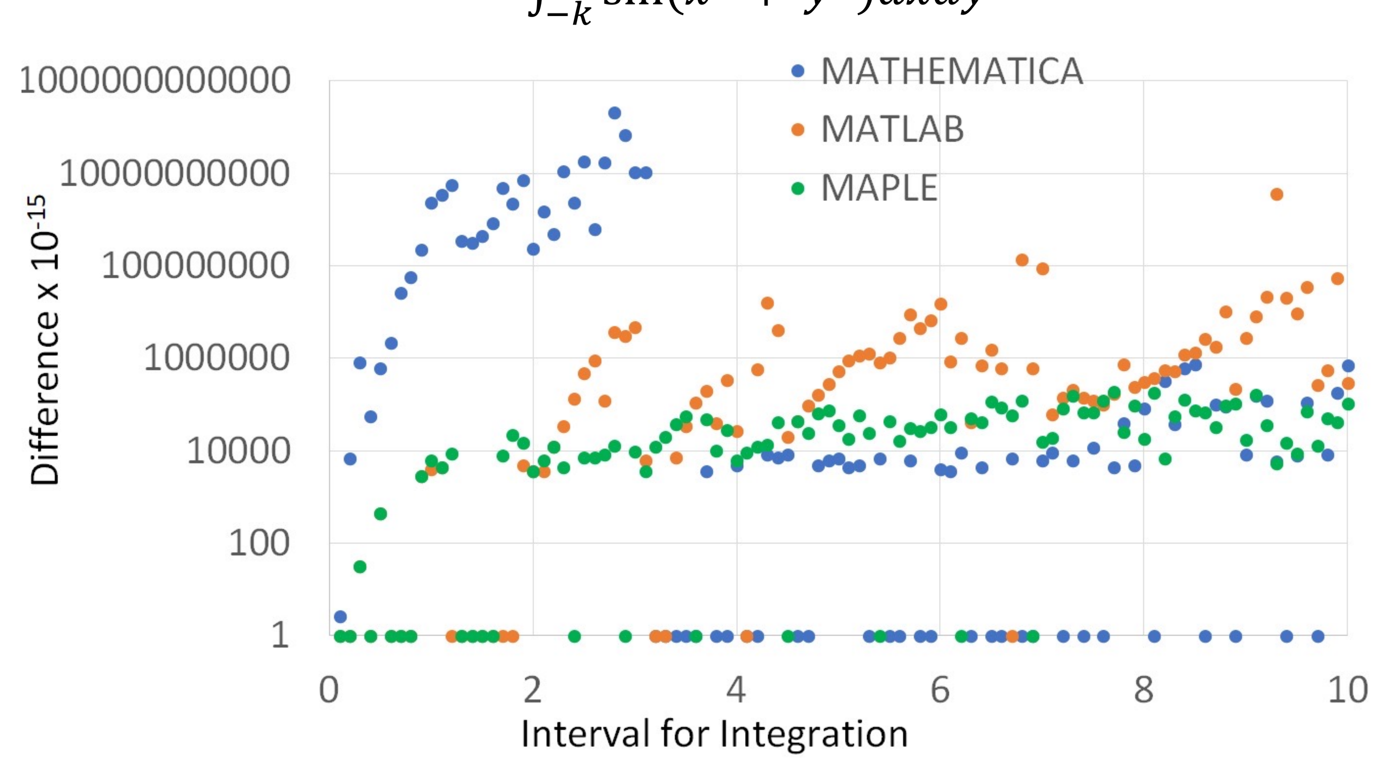

Figure 2: Difference between the numerical integration output and the actual (closed form) integral output. Note the large discrepancy for Mathematica for low integration limits. Mathematica however always produced results for 15-digit precision. Maple exhibits the highest times and did not return results for about 40% of the computations above the interval from -3.3 to 3.3 evaluated to 15 digits.

TEST 3: TIME TO CALCULATE NUMERICAL INTEGRAL

Times to output results of numerical integration of Equation 1 were compared across all three platforms. Ten measurements of time were carried out for each interval.

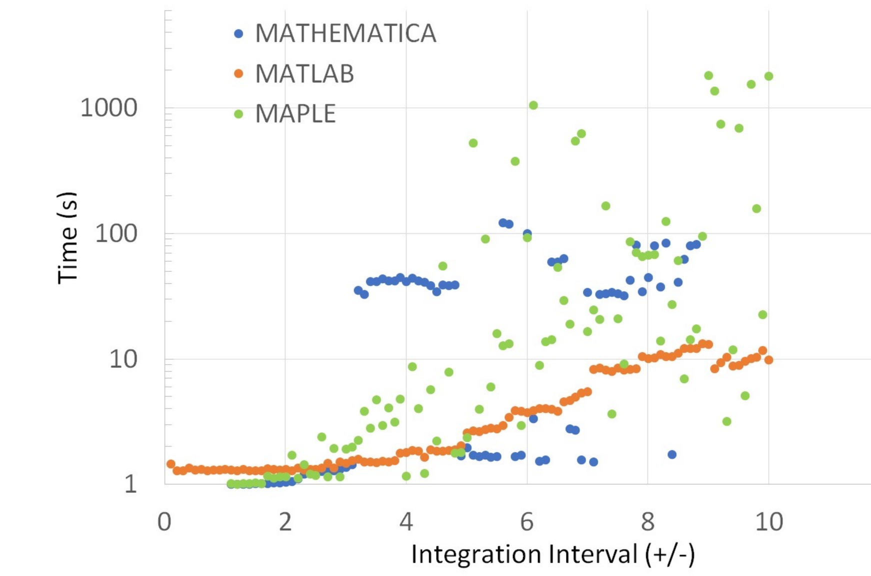

Figure 3: Time of integration for each interval. Note that Mathematica displays discrete jumps in timing; Maple takes the longest times.

Conclusion & Future Work

In this project we compared the timing and accuracy obtained by MATLAB, Mathematica, and Maple for several different computations. The results from Test 1 indicate that Maple provides the fastest computation speeds for factoring large numbers, while MATLAB is the slowest; MATLAB also had enormous standard deviations. Test 2 shows a high variability amongst all platforms for the accuracy of numerical integration. Maple could not produce results for 15-digit precision; however, it would produce results when the precision was decreased to 14 digits. Future endeavors include investigating graphics capabilities amongst the three CAS, such as density and contour plots.

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