Question – How much does the virtualization impact the performance of threads compared to native system in two of the following languages - :

Languages:-

1) C
2) Java
3) Python

Question: My experimental setup

Answer -

Native Machine Configurations:-

1) Operating System: Ubuntu, 20.04 LTS on Google Cloud Platform

   Machine Type: 8vCPUs or 8 core CPU, 32GB Memory

2) Operating System: macOS Mojave Version 10.14.6

   Machine Type: 1.4 GHz Intel Core i5, 8GB Memory

Docker Configurations:

Docker version 20.10.0

Question: Do you have variation in your test code?

Variation in Test Code:

Answer: I have used four threaded applications with different time complexities to compare the performance of threads:

Threaded Application	Time Complexity
1) Merge Sort	nlogn
2) Matrix Multiplication	n3
3) Linear Search	n
4) Binary Search	logn

Variation in Data

I have used array with sizes of 5, 10, 100, 1000, 10000 and 100000 elements and matrices of 5 by 5, 10 by 10, 100 by 100, 1000 by 1000, 10000 by 10000 and 100000 by 100000 elements.

Used random numbers as input generated by rand library function.

Number of threads in each case: 4

Question: How you ran your tests?

Answer -: I ran all my tests manually to note down the reading of elapsed time each time I executed the program. I used rand library function to get random numbers as input.

Library Functions Used for noting elapsed time

1) C - **clock_t clock(void)**
2) Java – **System.nanoTime()**
3) Python – time.time()

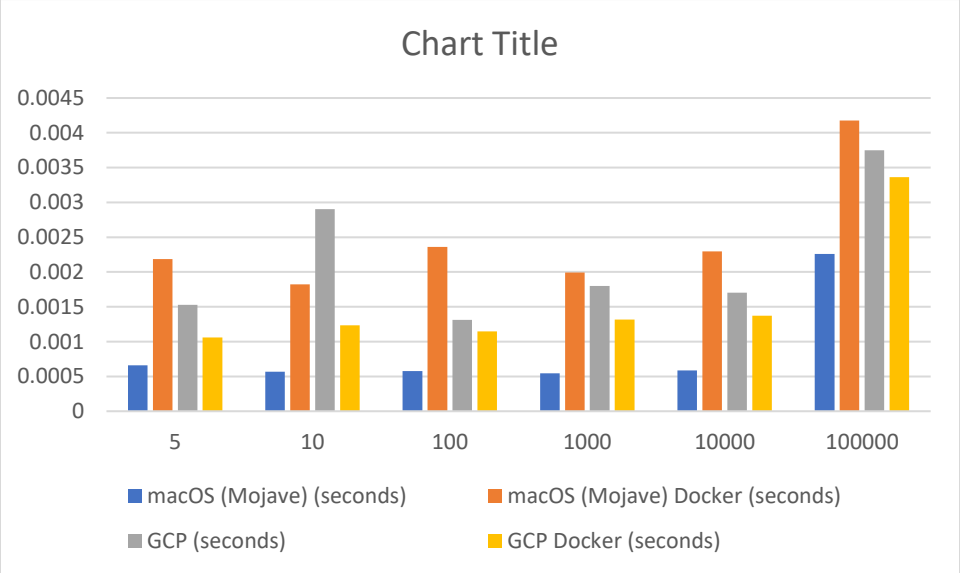
Test results:

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

JAVA:

Linear Search Java –

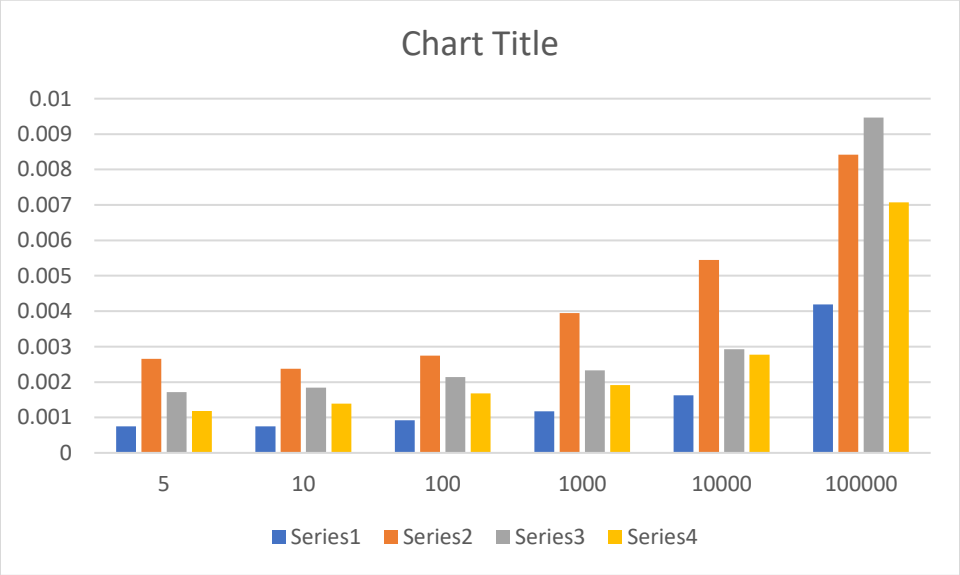


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000659233	0.0021844	0.001530598	0.001058998
10	0.000566554	0.0018206	0.002901207	0.001232953
100	0.000576784	0.0023628	0.001311958	0.001149013
1000	0.000546759	0.0019909	0.0017975	0.001315969
10000	0.00058594	0.0022953	0.001701839	0.001372706
100000	0.002259258	0.0041781	0.003750459	0.003361903

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

BinarySearch Java

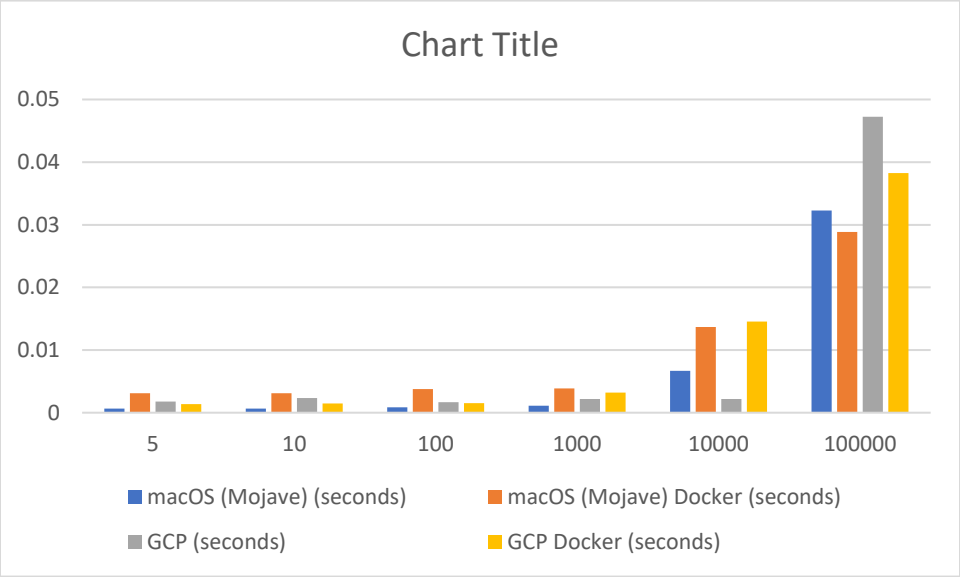


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000748456	0.0026525	0.001719777	0.001186782
10	0.000745076	0.0023796	0.001843136	0.001390079
100	0.000923904	0.0027493	0.002142747	0.001682688
1000	0.001170925	0.0039502	0.002327839	0.001913991
10000	0.001626652	0.0054484	0.002924975	0.002768748
100000	0.004189109	0.0084183	0.009463451	0.00707601

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

MergeSort Java

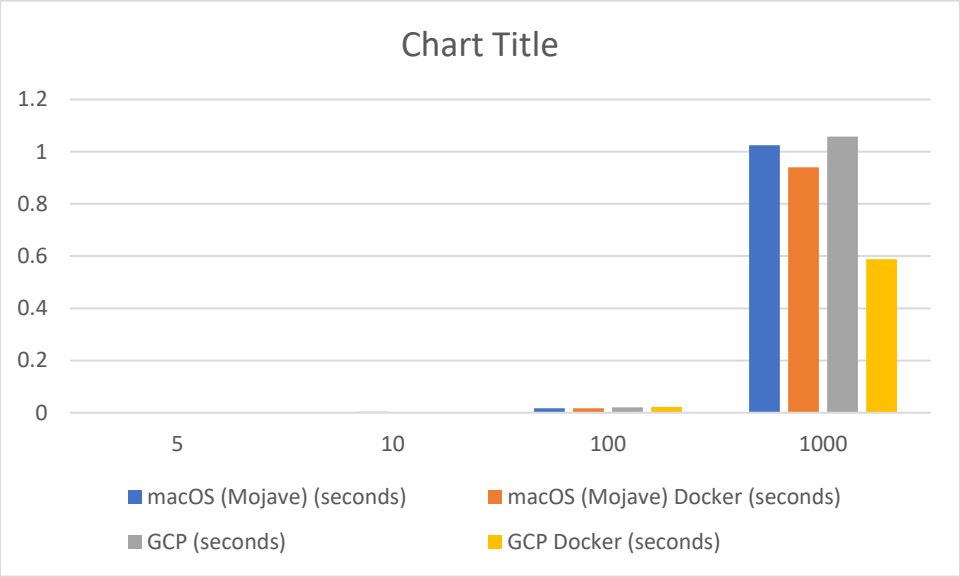


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000645975	0.0030837	0.001762666	0.001387455
10	0.000634766	0.0030877	0.002349834	0.001476158
100	0.000855289	0.0037935	0.001667962	0.001530873
1000	0.001122453	0.0038767	0.002195885	0.00321992
10000	0.006659232	0.0136752	0.002195885	0.014550656
100000	0.03224993	0.0288319	0.047223134	0.038257747

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Matrix Multiplication Java



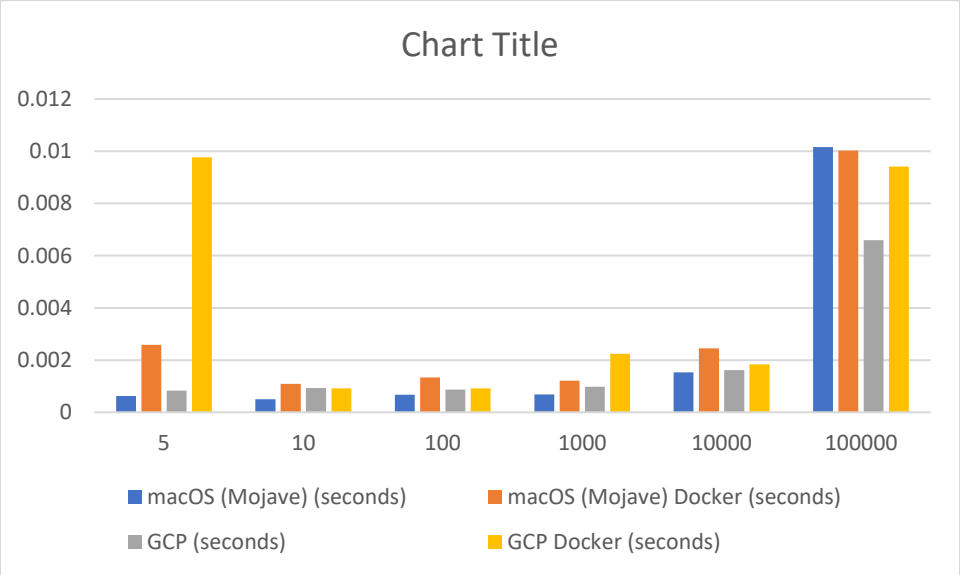
Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000702829	0.0027597	0.001543404	0.001449932
10	0.000725467	0.0029235	0.001670886	0.001286441
100	0.017265609	0.0174305	0.020810688	0.02184987
1000	1.024975366	0.9405257	1.058107357	0.588705198

Python :

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Linear Search Python

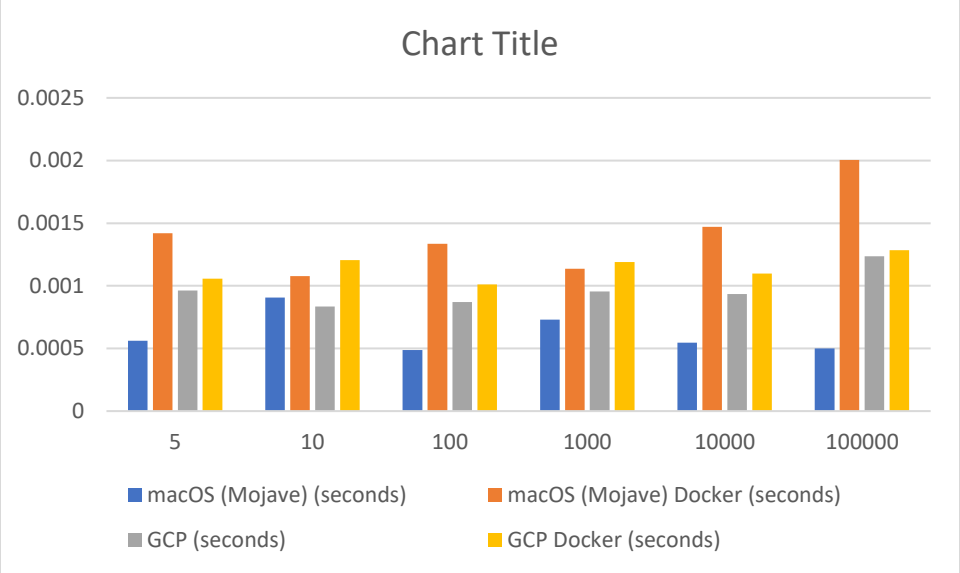


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000626802	0.002584457	0.00083375	0.009762287
10	0.000505924	0.001094103	0.000925541	0.000922441
100	0.000669956	0.001330137	0.000867367	0.000921488
1000	0.000688791	0.001207829	0.0009799	0.002235413
10000	0.001531839	0.002443552	0.001614809	0.001839876
100000	0.010164976	0.010019779	0.006597996	0.009417057

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Binary Search Python

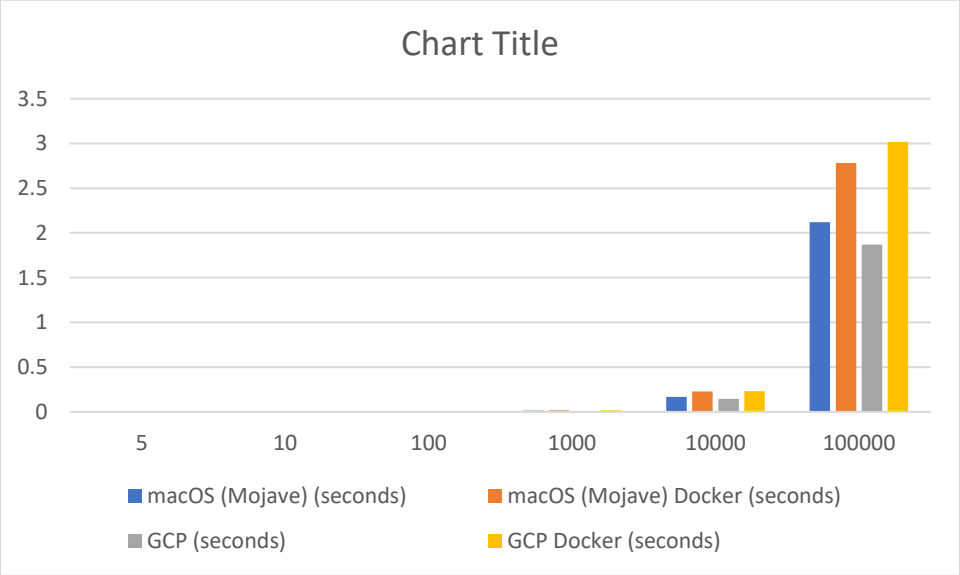


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000560999	0.001418591	0.000962734	0.00105691
10	0.000906944	0.001077414	0.00083518	0.001205206
100	0.000486135	0.001334667	0.000869751	0.001011848
1000	0.000728846	0.001137257	0.000954151	0.001188517
10000	0.000545025	0.001470566	0.000933409	0.001098156
100000	0.000499964	0.002005577	0.0012362	0.001284838

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Merge Sort Python

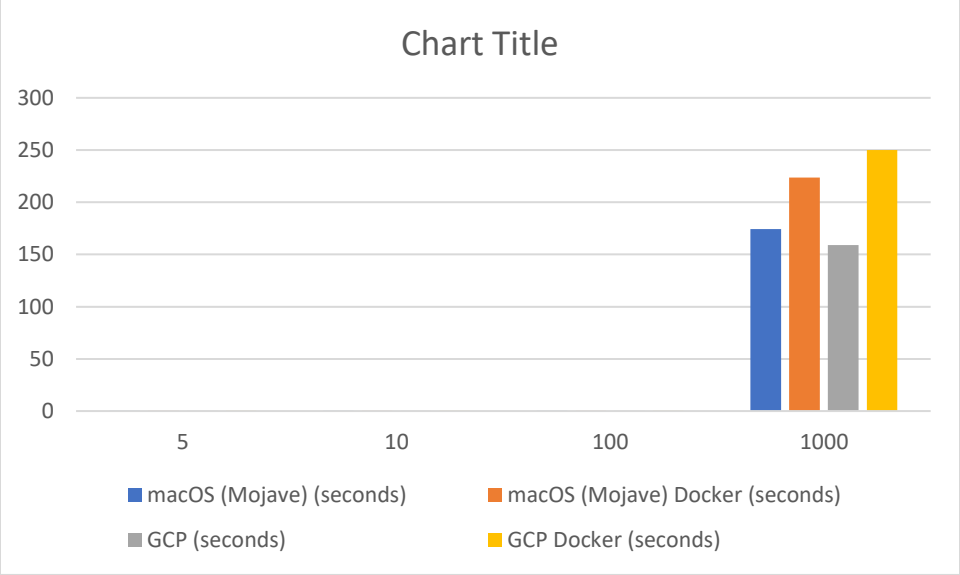


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000745058	0.001553059	0.001012802	0.001256943
10	0.001112938	0.001701832	0.001056194	0.00123477
100	0.002901077	0.002679348	0.001707077	0.002587795
1000	0.014178991	0.016524553	0.011401415	0.018471479
10000	0.167813063	0.22920084	0.144711733	0.232206106
100000	2.121235132	2.781701803	1.867905378	3.01830554

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Matrix Multiplication Python



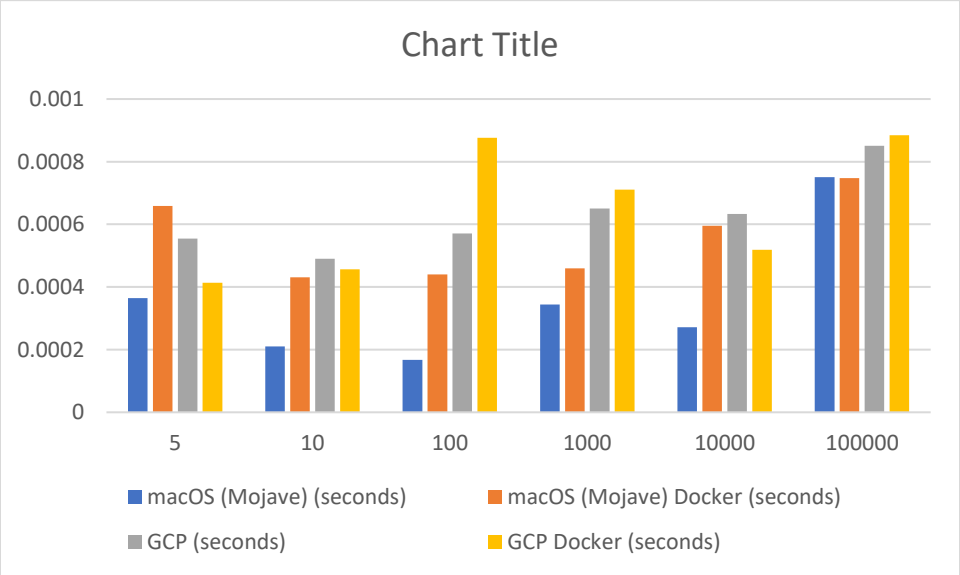
Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000989914	0.001284361	0.001174212	0.001393795
10	0.001870871	0.001380205	0.001559973	0.00153923
100	0.188896894	0.21668911	0.221670866	0.240695
1000	174.4348962	223.7264972	158.9420576	249.8707681

C :

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Linear Search C

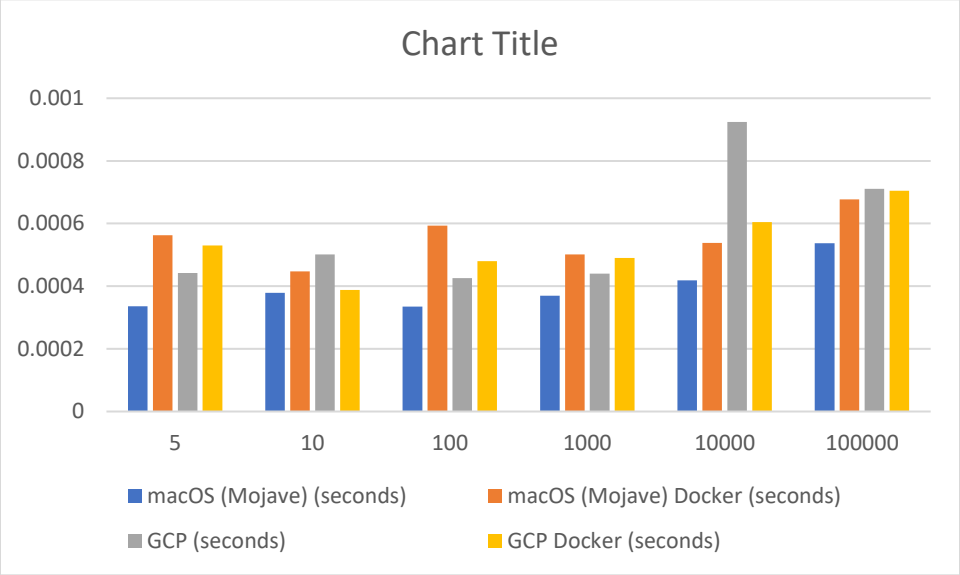


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000364	0.000659	0.000555	0.000414
10	0.00021	0.000431	0.00049	0.000456
100	0.000167	0.00044	0.000571	0.000876
1000	0.000344	0.00046	0.000651	0.000711
10000	0.000272	0.000595	0.000633	0.000519
100000	0.000751	0.000748	0.000851	0.000885

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Binary Search C

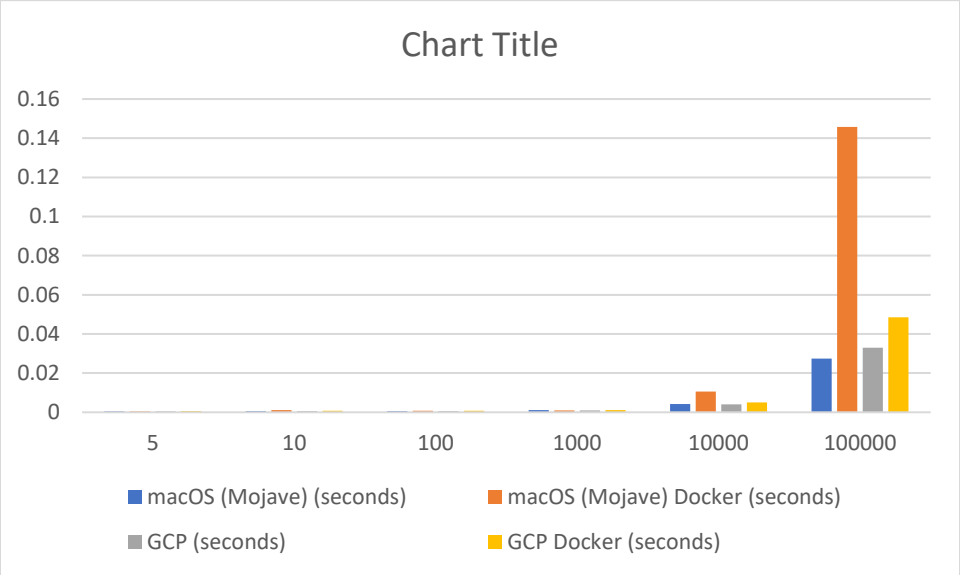


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000336	0.000563	0.000442	0.00053
10	0.000379	0.000447	0.000501	0.000388
100	0.000335	0.000593	0.000426	0.00048
1000	0.00037	0.000501	0.00044	0.00049
10000	0.000419	0.000538	0.000924	0.000605
100000	0.000537	0.000677	0.000711	0.000705

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

MergeSort C

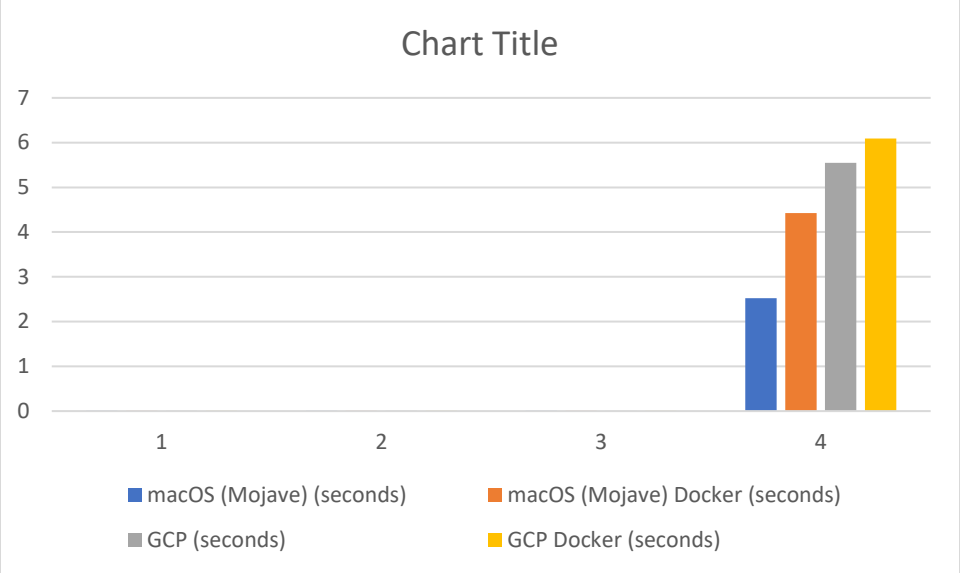


Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000387	0.000467	0.000494	0.000567
10	0.000634	0.001058	0.000585	0.00084
100	0.000559	0.00081	0.000616	0.000751
1000	0.001089	0.000985	0.000931	0.001051
10000	0.004274	0.010665	0.00409	0.005025
100000	0.027438	0.14572	0.032917	0.04858

X Axis: Size of Array/Dimensions of Matrix

Y Axis: Runtime in seconds

Matrix Multiplication C



Size	macOS (Mojave) (seconds)	macOS (Mojave) Docker (seconds)	GCP (seconds)	GCP Docker (seconds)
5	0.000343	0.000551	0.000396	0.000523
10	0.000216	0.000455	0.000505	0.000625
100	0.003096	0.006445	0.007871	0.009177
1000	2.526697	4.42745	5.545509	6.090742

How accurate are the results?

Sum of all timings- 841.560708755 seconds

Sample Size – 264 runs

Standard Deviation - 25.046838226495 seconds

Mean - 3.187729957405 seconds

Calculation of margin of error:

Formula:–

$$n = \left(\frac{z_c \sigma}{E}\right)^2$$

- n - the sample size
- Z_c - Critical value (used for confidence value)
    - 95% confident use Z_c of 1.96
    - 99% confident use Z_c of 2.78

- σ - Standard Deviation ● E - margin of error
    - If you are measuring in seconds how many seconds do you want the average away from the “true” run time

Here n = 264

For 99% Confidence, $Z_c = 2.78$

$\sigma = 25.046838226495$

Putting these in the formula we get:

E = 3.971 seconds

Hence, for 99% confidence the margin of error is 3.971 seconds.

Total of timings for each environment -

macOS (Mojave) (native system) - 180.622208905 seconds
macOS (Mojave) Docker - 232.66801274 seconds
Google Cloud Platform (Ubuntu 20.04 LTS) (native system) - 167.985920225 seconds
Google Cloud Platform Docker (Ubuntu 20.04 LTS) - 260.284566885

Conclusion –

1) Performance of threads in Python is much worse as compared to C and Java.

2) Performance of threads on native systems is better than performance of threads in Docker virtualization environment.

Docker Lost the battle!!!

Question: What you learned from answering the question

Answer: Following are my observations for this experiment:

1) Docker does impose performance costs. Processes running within a container will not be quite as fast as those run on the native OS.

2) Performance of python really deteriorates as compared to C and Java in case of larger Input.

Motivation:

Threads are a really important part of OS. Threads provide a way to improve application performance through parallelism. Threads represent a software approach to improving performance of operating system by reducing the overhead thread is equivalent to a classical process. So, comparing the performance of threads in different languages and environments according to me is really important to figure out the best Language and environment for writing threaded applications in operating systems. Also, since docker enables more efficient use of system resources and enables application portability, it is important to figure out whether docker virtualization of native system enhances the performance of threads or not