

Cloud Infrastructure And Services (CS3204)

Assignment 5: Docker Containerization

- 1. A brief overview of the Docker container technology, including its significance and how it differs from virtual machines.**

Containerization is a software deployment process that bundles an application's code with all the files and libraries it needs to run on any infrastructure. Traditionally, to run any application on your computer, you had to install the version that matched your machine's operating system. However, with containerization, you can create a single software package, or container, that runs on all types of devices and operating systems.

A Virtual Machine, on the other hand, is an emulation of a physical computer. VMs enable teams to run what appear to be multiple machines, with multiple operating systems, on a single computer. VMs interact with physical computers by using lightweight software layers called hypervisors.

- 2. The steps you followed to run the application in the docker (including the necessary installations).**

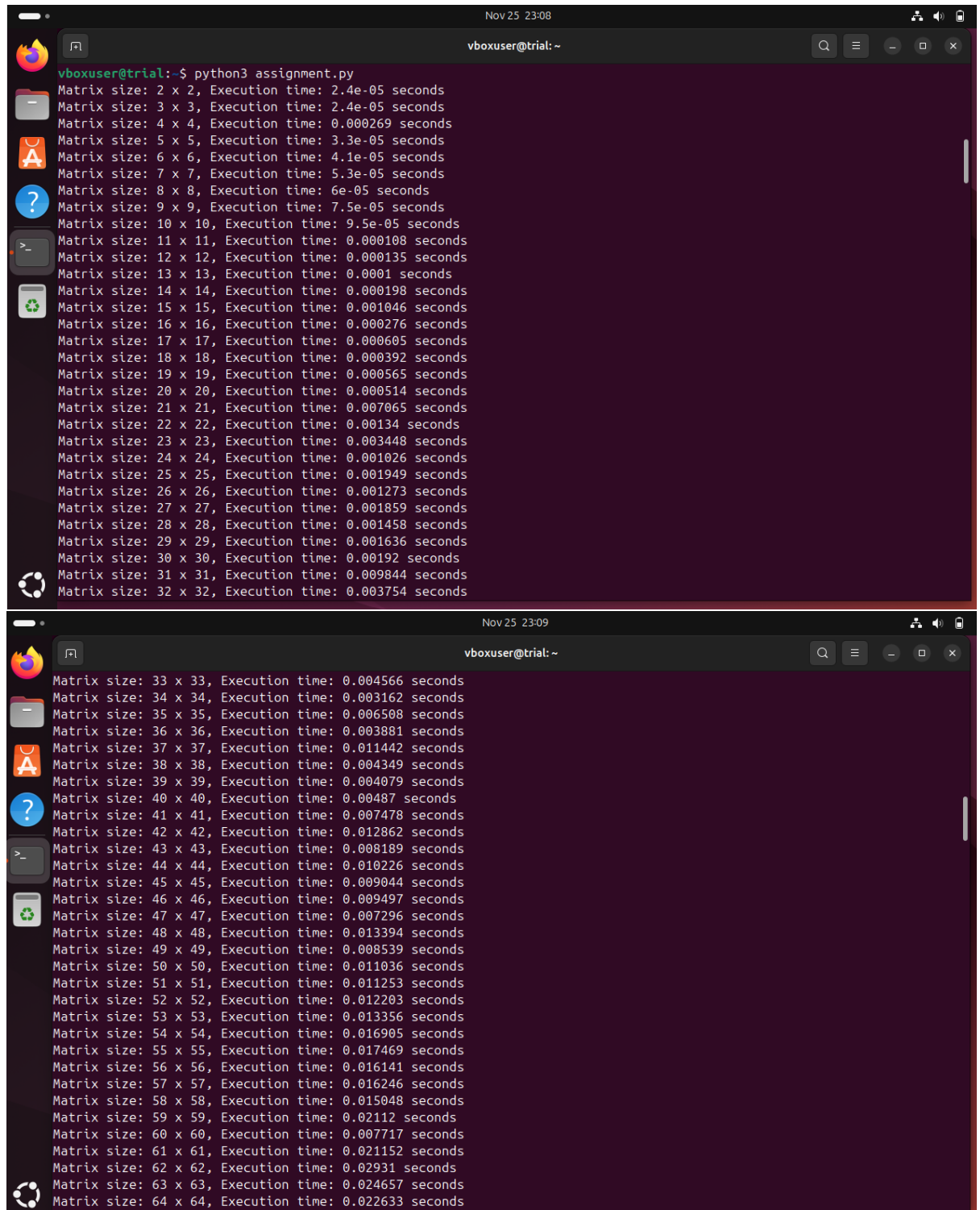
The steps to install Docker I used (Windows 11):

- Install Docker Desktop
- Install Ubuntu (Linux) Image on Docker
- Install Python Image on Docker

3. A comparative analysis of the execution results between the Docker and the virtual machine environment, supported by screenshots, graphs, and any relevant data.

**** VM Configuration same as Assignment 4 ****

The application runtime on Virtual Machine is:



```
vboxuser@trial:~$ python3 assignment.py
Matrix size: 2 x 2, Execution time: 2.4e-05 seconds
Matrix size: 3 x 3, Execution time: 2.4e-05 seconds
Matrix size: 4 x 4, Execution time: 0.000269 seconds
Matrix size: 5 x 5, Execution time: 3.3e-05 seconds
Matrix size: 6 x 6, Execution time: 4.1e-05 seconds
Matrix size: 7 x 7, Execution time: 5.3e-05 seconds
Matrix size: 8 x 8, Execution time: 6e-05 seconds
Matrix size: 9 x 9, Execution time: 7.5e-05 seconds
Matrix size: 10 x 10, Execution time: 9.5e-05 seconds
Matrix size: 11 x 11, Execution time: 0.000108 seconds
Matrix size: 12 x 12, Execution time: 0.000135 seconds
Matrix size: 13 x 13, Execution time: 0.0001 seconds
Matrix size: 14 x 14, Execution time: 0.000198 seconds
Matrix size: 15 x 15, Execution time: 0.001046 seconds
Matrix size: 16 x 16, Execution time: 0.000276 seconds
Matrix size: 17 x 17, Execution time: 0.000605 seconds
Matrix size: 18 x 18, Execution time: 0.000392 seconds
Matrix size: 19 x 19, Execution time: 0.000565 seconds
Matrix size: 20 x 20, Execution time: 0.000514 seconds
Matrix size: 21 x 21, Execution time: 0.007065 seconds
Matrix size: 22 x 22, Execution time: 0.00134 seconds
Matrix size: 23 x 23, Execution time: 0.003448 seconds
Matrix size: 24 x 24, Execution time: 0.001026 seconds
Matrix size: 25 x 25, Execution time: 0.001949 seconds
Matrix size: 26 x 26, Execution time: 0.001273 seconds
Matrix size: 27 x 27, Execution time: 0.001859 seconds
Matrix size: 28 x 28, Execution time: 0.001458 seconds
Matrix size: 29 x 29, Execution time: 0.001636 seconds
Matrix size: 30 x 30, Execution time: 0.00192 seconds
Matrix size: 31 x 31, Execution time: 0.009844 seconds
Matrix size: 32 x 32, Execution time: 0.003754 seconds
Matrix size: 33 x 33, Execution time: 0.004566 seconds
Matrix size: 34 x 34, Execution time: 0.003162 seconds
Matrix size: 35 x 35, Execution time: 0.006508 seconds
Matrix size: 36 x 36, Execution time: 0.003881 seconds
Matrix size: 37 x 37, Execution time: 0.011442 seconds
Matrix size: 38 x 38, Execution time: 0.004349 seconds
Matrix size: 39 x 39, Execution time: 0.004079 seconds
Matrix size: 40 x 40, Execution time: 0.00487 seconds
Matrix size: 41 x 41, Execution time: 0.007478 seconds
Matrix size: 42 x 42, Execution time: 0.012862 seconds
Matrix size: 43 x 43, Execution time: 0.008189 seconds
Matrix size: 44 x 44, Execution time: 0.010226 seconds
Matrix size: 45 x 45, Execution time: 0.009044 seconds
Matrix size: 46 x 46, Execution time: 0.009497 seconds
Matrix size: 47 x 47, Execution time: 0.007296 seconds
Matrix size: 48 x 48, Execution time: 0.013394 seconds
Matrix size: 49 x 49, Execution time: 0.008539 seconds
Matrix size: 50 x 50, Execution time: 0.011036 seconds
Matrix size: 51 x 51, Execution time: 0.011253 seconds
Matrix size: 52 x 52, Execution time: 0.012203 seconds
Matrix size: 53 x 53, Execution time: 0.013356 seconds
Matrix size: 54 x 54, Execution time: 0.016905 seconds
Matrix size: 55 x 55, Execution time: 0.017469 seconds
Matrix size: 56 x 56, Execution time: 0.016141 seconds
Matrix size: 57 x 57, Execution time: 0.016246 seconds
Matrix size: 58 x 58, Execution time: 0.015048 seconds
Matrix size: 59 x 59, Execution time: 0.02112 seconds
Matrix size: 60 x 60, Execution time: 0.007717 seconds
Matrix size: 61 x 61, Execution time: 0.021152 seconds
Matrix size: 62 x 62, Execution time: 0.02931 seconds
Matrix size: 63 x 63, Execution time: 0.024657 seconds
Matrix size: 64 x 64, Execution time: 0.022633 seconds
```

```
Nov 25 23:09
vboxuser@trial: ~
Matrix size: 65 x 65, Execution time: 0.032164 seconds
Matrix size: 66 x 66, Execution time: 0.018532 seconds
Matrix size: 67 x 67, Execution time: 0.029404 seconds
Matrix size: 68 x 68, Execution time: 0.023876 seconds
Matrix size: 69 x 69, Execution time: 0.022272 seconds
Matrix size: 70 x 70, Execution time: 0.032003 seconds
Matrix size: 71 x 71, Execution time: 0.028214 seconds
Matrix size: 72 x 72, Execution time: 0.028391 seconds
Matrix size: 73 x 73, Execution time: 0.028028 seconds
Matrix size: 74 x 74, Execution time: 0.039362 seconds
Matrix size: 75 x 75, Execution time: 0.039002 seconds
Matrix size: 76 x 76, Execution time: 0.028723 seconds
Matrix size: 77 x 77, Execution time: 0.057836 seconds
Matrix size: 78 x 78, Execution time: 0.037026 seconds
Matrix size: 79 x 79, Execution time: 0.042288 seconds
Matrix size: 80 x 80, Execution time: 0.040876 seconds
Matrix size: 81 x 81, Execution time: 0.05207 seconds
Matrix size: 82 x 82, Execution time: 0.043019 seconds
Matrix size: 83 x 83, Execution time: 0.057637 seconds
Matrix size: 84 x 84, Execution time: 0.045067 seconds
Matrix size: 85 x 85, Execution time: 0.04798 seconds
Matrix size: 86 x 86, Execution time: 0.05217 seconds
Matrix size: 87 x 87, Execution time: 0.047246 seconds
Matrix size: 88 x 88, Execution time: 0.055566 seconds
Matrix size: 89 x 89, Execution time: 0.05659 seconds
Matrix size: 90 x 90, Execution time: 0.048311 seconds
Matrix size: 91 x 91, Execution time: 0.07516 seconds
Matrix size: 92 x 92, Execution time: 0.063299 seconds
Matrix size: 93 x 93, Execution time: 0.065135 seconds
Matrix size: 94 x 94, Execution time: 0.052959 seconds
Matrix size: 95 x 95, Execution time: 0.066474 seconds
Matrix size: 96 x 96, Execution time: 0.083628 seconds
```

```
Nov 25 23:10
vboxuser@trial: ~
Matrix size: 97 x 97, Execution time: 0.072663 seconds
Matrix size: 98 x 98, Execution time: 0.07224 seconds
Matrix size: 99 x 99, Execution time: 0.082445 seconds
Matrix size: 100 x 100, Execution time: 0.072486 seconds
Matrix size: 101 x 101, Execution time: 0.076892 seconds
Matrix size: 102 x 102, Execution time: 0.074587 seconds
Matrix size: 103 x 103, Execution time: 0.065394 seconds
Matrix size: 104 x 104, Execution time: 0.076864 seconds
Matrix size: 105 x 105, Execution time: 0.087062 seconds
Matrix size: 106 x 106, Execution time: 0.09307 seconds
Matrix size: 107 x 107, Execution time: 0.096561 seconds
Matrix size: 108 x 108, Execution time: 0.085325 seconds
Matrix size: 109 x 109, Execution time: 0.105674 seconds
Matrix size: 110 x 110, Execution time: 0.098788 seconds
Matrix size: 111 x 111, Execution time: 0.111297 seconds
Matrix size: 112 x 112, Execution time: 0.115629 seconds
Matrix size: 113 x 113, Execution time: 0.110126 seconds
Matrix size: 114 x 114, Execution time: 0.119827 seconds
Matrix size: 115 x 115, Execution time: 0.10313 seconds
Matrix size: 116 x 116, Execution time: 0.072138 seconds
Matrix size: 117 x 117, Execution time: 0.117762 seconds
Matrix size: 118 x 118, Execution time: 0.110047 seconds
Matrix size: 119 x 119, Execution time: 0.140162 seconds
Matrix size: 120 x 120, Execution time: 0.047454 seconds
Matrix size: 121 x 121, Execution time: 0.121264 seconds
Matrix size: 122 x 122, Execution time: 0.1278 seconds
Matrix size: 123 x 123, Execution time: 0.142691 seconds
Matrix size: 124 x 124, Execution time: 0.127826 seconds
Matrix size: 125 x 125, Execution time: 0.155417 seconds
Matrix size: 126 x 126, Execution time: 0.124281 seconds
Matrix size: 127 x 127, Execution time: 0.129276 seconds
Matrix size: 128 x 128, Execution time: 0.185248 seconds
```

```
Nov 25 23:10
vboxuser@trial: ~
Matrix size: 129 x 129, Execution time: 0.167052 seconds
Matrix size: 130 x 130, Execution time: 0.170614 seconds
Matrix size: 131 x 131, Execution time: 0.172752 seconds
Matrix size: 132 x 132, Execution time: 0.159545 seconds
Matrix size: 133 x 133, Execution time: 0.20936 seconds
Matrix size: 134 x 134, Execution time: 0.177198 seconds
Matrix size: 135 x 135, Execution time: 0.170002 seconds
Matrix size: 136 x 136, Execution time: 0.200075 seconds
Matrix size: 137 x 137, Execution time: 0.187583 seconds
Matrix size: 138 x 138, Execution time: 0.06241 seconds
Matrix size: 139 x 139, Execution time: 0.194379 seconds
Matrix size: 140 x 140, Execution time: 0.205981 seconds
Matrix size: 141 x 141, Execution time: 0.21991 seconds
Matrix size: 142 x 142, Execution time: 0.234116 seconds
Matrix size: 143 x 143, Execution time: 0.182825 seconds
Matrix size: 144 x 144, Execution time: 0.205306 seconds
Matrix size: 145 x 145, Execution time: 0.235661 seconds
Matrix size: 146 x 146, Execution time: 0.234811 seconds
Matrix size: 147 x 147, Execution time: 0.228372 seconds
Matrix size: 148 x 148, Execution time: 0.23393 seconds
Matrix size: 149 x 149, Execution time: 0.260078 seconds
Matrix size: 150 x 150, Execution time: 0.236263 seconds
```

The Application Runtime on Docker Container is as follows:

```
root@5bbd990283e1:/project-1# python3 new.py
Matrix size: 2x2, Execution time: 0.000010 seconds
Matrix size: 3x3, Execution time: 0.000012 seconds
Matrix size: 4x4, Execution time: 0.000017 seconds
Matrix size: 5x5, Execution time: 0.000029 seconds
Matrix size: 6x6, Execution time: 0.000046 seconds
Matrix size: 7x7, Execution time: 0.000075 seconds
Matrix size: 8x8, Execution time: 0.000104 seconds
Matrix size: 9x9, Execution time: 0.000168 seconds
Matrix size: 10x10, Execution time: 0.000221 seconds
Matrix size: 11x11, Execution time: 0.000291 seconds
Matrix size: 12x12, Execution time: 0.000415 seconds
Matrix size: 13x13, Execution time: 0.000477 seconds
Matrix size: 14x14, Execution time: 0.000586 seconds
Matrix size: 15x15, Execution time: 0.000694 seconds
Matrix size: 16x16, Execution time: 0.000851 seconds
Matrix size: 17x17, Execution time: 0.001039 seconds
Matrix size: 18x18, Execution time: 0.001148 seconds
Matrix size: 19x19, Execution time: 0.001327 seconds
Matrix size: 20x20, Execution time: 0.001556 seconds
Matrix size: 21x21, Execution time: 0.001787 seconds
Matrix size: 22x22, Execution time: 0.002263 seconds
Matrix size: 23x23, Execution time: 0.003156 seconds
Matrix size: 24x24, Execution time: 0.003507 seconds
Matrix size: 25x25, Execution time: 0.003842 seconds
Matrix size: 26x26, Execution time: 0.004779 seconds
Matrix size: 27x27, Execution time: 0.005337 seconds
Matrix size: 28x28, Execution time: 0.005092 seconds
Matrix size: 29x29, Execution time: 0.004782 seconds
Matrix size: 30x30, Execution time: 0.004342 seconds
Matrix size: 31x31, Execution time: 0.005955 seconds
Matrix size: 32x32, Execution time: 0.007496 seconds
Matrix size: 33x33, Execution time: 0.008415 seconds
Matrix size: 34x34, Execution time: 0.009486 seconds
Matrix size: 35x35, Execution time: 0.009671 seconds
Matrix size: 36x36, Execution time: 0.007505 seconds
Matrix size: 37x37, Execution time: 0.007884 seconds
```

Matrix size: 38x38, Execution time: 0.008488 seconds
Matrix size: 39x39, Execution time: 0.011098 seconds
Matrix size: 40x40, Execution time: 0.012336 seconds
Matrix size: 41x41, Execution time: 0.013683 seconds
Matrix size: 42x42, Execution time: 0.012048 seconds
Matrix size: 43x43, Execution time: 0.012572 seconds
Matrix size: 44x44, Execution time: 0.013484 seconds
Matrix size: 45x45, Execution time: 0.014623 seconds
Matrix size: 46x46, Execution time: 0.015380 seconds
Matrix size: 47x47, Execution time: 0.016336 seconds
Matrix size: 48x48, Execution time: 0.016972 seconds
Matrix size: 49x49, Execution time: 0.018174 seconds
Matrix size: 50x50, Execution time: 0.019299 seconds
Matrix size: 51x51, Execution time: 0.020649 seconds
Matrix size: 52x52, Execution time: 0.022406 seconds
Matrix size: 53x53, Execution time: 0.023013 seconds
Matrix size: 54x54, Execution time: 0.025118 seconds
Matrix size: 55x55, Execution time: 0.027208 seconds
Matrix size: 56x56, Execution time: 0.030194 seconds
Matrix size: 57x57, Execution time: 0.030279 seconds
Matrix size: 58x58, Execution time: 0.032299 seconds
Matrix size: 59x59, Execution time: 0.031996 seconds
Matrix size: 60x60, Execution time: 0.034703 seconds
Matrix size: 61x61, Execution time: 0.038272 seconds
Matrix size: 62x62, Execution time: 0.038804 seconds
Matrix size: 63x63, Execution time: 0.039230 seconds
Matrix size: 64x64, Execution time: 0.041421 seconds
Matrix size: 65x65, Execution time: 0.044313 seconds
Matrix size: 66x66, Execution time: 0.043664 seconds
Matrix size: 67x67, Execution time: 0.046549 seconds
Matrix size: 68x68, Execution time: 0.049891 seconds
Matrix size: 69x69, Execution time: 0.053165 seconds
Matrix size: 70x70, Execution time: 0.053408 seconds
Matrix size: 71x71, Execution time: 0.059474 seconds
Matrix size: 72x72, Execution time: 0.057995 seconds
Matrix size: 73x73, Execution time: 0.060585 seconds
Matrix size: 74x74, Execution time: 0.066535 seconds

Matrix size: 75x75, Execution time: 0.066052 seconds
Matrix size: 76x76, Execution time: 0.067462 seconds
Matrix size: 77x77, Execution time: 0.071003 seconds
Matrix size: 78x78, Execution time: 0.078659 seconds
Matrix size: 79x79, Execution time: 0.083292 seconds
Matrix size: 80x80, Execution time: 0.080767 seconds
Matrix size: 81x81, Execution time: 0.082446 seconds
Matrix size: 82x82, Execution time: 0.086975 seconds
Matrix size: 83x83, Execution time: 0.088358 seconds
Matrix size: 84x84, Execution time: 0.091507 seconds
Matrix size: 85x85, Execution time: 0.095366 seconds
Matrix size: 86x86, Execution time: 0.100266 seconds
Matrix size: 87x87, Execution time: 0.106529 seconds
Matrix size: 88x88, Execution time: 0.108776 seconds
Matrix size: 89x89, Execution time: 0.111716 seconds
Matrix size: 90x90, Execution time: 0.117840 seconds
Matrix size: 91x91, Execution time: 0.125897 seconds
Matrix size: 92x92, Execution time: 0.124756 seconds
Matrix size: 93x93, Execution time: 0.152750 seconds
Matrix size: 94x94, Execution time: 0.134920 seconds
Matrix size: 95x95, Execution time: 0.143501 seconds
Matrix size: 96x96, Execution time: 0.138014 seconds
Matrix size: 97x97, Execution time: 0.162546 seconds
Matrix size: 98x98, Execution time: 0.155245 seconds
Matrix size: 99x99, Execution time: 0.148804 seconds
Matrix size: 100x100, Execution time: 0.160581 seconds
Matrix size: 101x101, Execution time: 0.167906 seconds
Matrix size: 102x102, Execution time: 0.165252 seconds
Matrix size: 103x103, Execution time: 0.168172 seconds
Matrix size: 104x104, Execution time: 0.179905 seconds
Matrix size: 105x105, Execution time: 0.177144 seconds
Matrix size: 106x106, Execution time: 0.186574 seconds
Matrix size: 107x107, Execution time: 0.200939 seconds
Matrix size: 108x108, Execution time: 0.196382 seconds
Matrix size: 109x109, Execution time: 0.226682 seconds
Matrix size: 110x110, Execution time: 0.205117 seconds
Matrix size: 111x111, Execution time: 0.212780 seconds

```

Matrix size: 112x112, Execution time: 0.226758 seconds
Matrix size: 113x113, Execution time: 0.226381 seconds
Matrix size: 114x114, Execution time: 0.230784 seconds
Matrix size: 115x115, Execution time: 0.240342 seconds
Matrix size: 116x116, Execution time: 0.247347 seconds
Matrix size: 117x117, Execution time: 0.262880 seconds
Matrix size: 118x118, Execution time: 0.273473 seconds
Matrix size: 119x119, Execution time: 0.278517 seconds
Matrix size: 120x120, Execution time: 0.267781 seconds
Matrix size: 121x121, Execution time: 0.272924 seconds
Matrix size: 122x122, Execution time: 0.278188 seconds
Matrix size: 123x123, Execution time: 0.289545 seconds
Matrix size: 124x124, Execution time: 0.307216 seconds
Matrix size: 125x125, Execution time: 0.301351 seconds
Matrix size: 126x126, Execution time: 0.324818 seconds
Matrix size: 127x127, Execution time: 0.327203 seconds
Matrix size: 128x128, Execution time: 0.327784 seconds
Matrix size: 129x129, Execution time: 0.343099 seconds
Matrix size: 130x130, Execution time: 0.341990 seconds
Matrix size: 131x131, Execution time: 0.347148 seconds
Matrix size: 132x132, Execution time: 0.370729 seconds
Matrix size: 133x133, Execution time: 0.388464 seconds
Matrix size: 134x134, Execution time: 0.387561 seconds
Matrix size: 135x135, Execution time: 0.397570 seconds
Matrix size: 136x136, Execution time: 0.404418 seconds
Matrix size: 137x137, Execution time: 0.406458 seconds
Matrix size: 138x138, Execution time: 0.416676 seconds
Matrix size: 139x139, Execution time: 0.425333 seconds
Matrix size: 140x140, Execution time: 0.438685 seconds
Matrix size: 141x141, Execution time: 0.440342 seconds
Matrix size: 142x142, Execution time: 0.468426 seconds
Matrix size: 143x143, Execution time: 0.459959 seconds
Matrix size: 144x144, Execution time: 0.471416 seconds
Matrix size: 145x145, Execution time: 0.473377 seconds
Matrix size: 146x146, Execution time: 0.493403 seconds
Matrix size: 147x147, Execution time: 0.498013 seconds
Matrix size: 148x148, Execution time: 0.521256 seconds

```

```

Matrix size: 146x146, Execution time: 0.493403 seconds
Matrix size: 147x147, Execution time: 0.498013 seconds
Matrix size: 148x148, Execution time: 0.521256 seconds
Matrix size: 149x149, Execution time: 0.524363 seconds
Matrix size: 150x150, Execution time: 0.533732 seconds

```

Docker resource usage on running program:

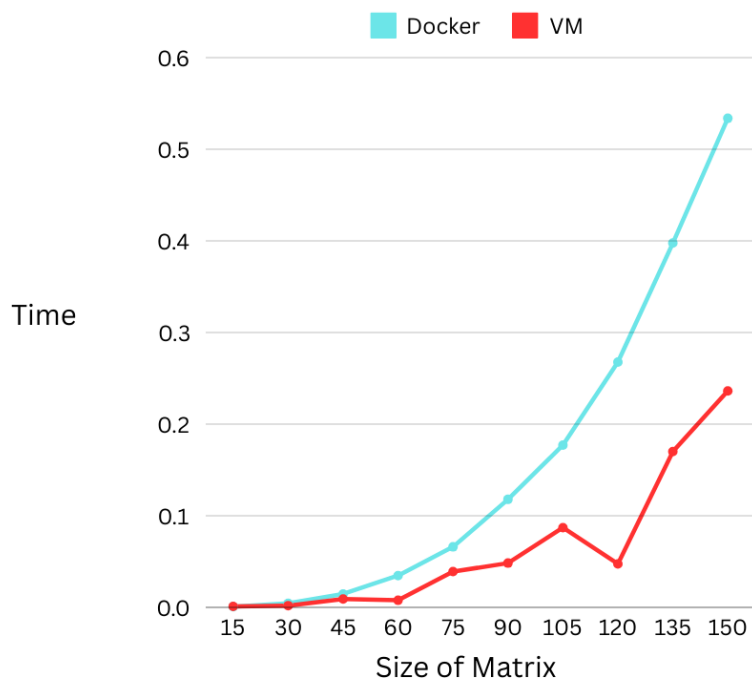
Container CPU usage ⓘ

108.67% / 1600% (16 CPUs available)

Container memory usage ⓘ

12.96MB / 7.43GB

Graph Analysis:



Size Of Matrix	Virtual Machine	Docker
15	0.00104	0.00069
30	0.00192	0.00434
45	0.00904	0.01462
60	0.00771	0.03470
75	0.03900	0.06605
90	0.04831	0.11784
105	0.08706	0.17714
120	0.04745	0.26778
135	0.17000	0.39757
150	0.23626	0.53373

** Table and Graph subject to size of matrix mentioned in the same only. Please refer to screenshots as well **

4. A discussion on the potential reasons behind any performance differences observed between the two environments.

As we see from the above screenshots and graph, the docker container takes slightly more time with matrices of size 60 to 150 and the difference between both executions increases with matrix sizes of 90 to 150.

Although, ideally a container is faster than a VM because there is no additional layer present unlike the VM which has a hypervisor present between the guest OS and the Hardware. But in some cases, the VM configuration and dedicated resources might outperform a container.

5. **A reflection on your experience with Docker, including the challenges you faced and what you learned from using container technology.**

The challenges I faced were beginner level problems with installation and command execution from the command prompt. But, once it was fixed, everything started working correctly.