**7.i. Table of serial program Run time**

|  |  |
| --- | --- |
| Size of matrices | Time taken (sec) |
| 24\*24 | 0.000000 |
| 124\*124 | 0.023000 |
| 224\*224 | 0.125000 |
| 324\*324 | 0.436000 |
| 424\*424 | 1.215000 |
| 524\*524 | 3.709000 |
| 624\*624 | 4.503000 |
| 724\*724 | 7.359000 |
| 824\*824 | 13.076000 |
| 924\*924 | 19.779000 |
| 1024\*1024 | 30.509000 |

**7.ii. a) Table of Open MP Run time**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Threads/  Size | 2 threads | 4 threads | 8 threads | 16 threads | 32 threads | 64 threads |
| 24\*24 | 0.001304 s | 0.002335 s | 0.001658 s | 0.001576 s | 0.001148 s | 0.0015454 s |
| 124\*124 | 0.012024 s | 0.025004 s | 0.025742 s | 0.025029 s | 0.025584 s | 0.0256454 s |
| 224\*224 | 0.081041 s | 0.036623 s | 0.032484 s | 0.036715 s | 0.032544 s | 0.0520621 s |
| 324\*324 | 0.107675 s | 0.084964 s | 0.062357 s | 0.057841 s | 0.058485 s | 0.1054544 s |
| 424\*424 | 0.314327 s | 0.216765 s | 0.223587 s | 0.215956 s | 0.217885 s | 0.2541541 s |
| 524\*524 | 0.841367 s | 0.410568 s | 0.445851 s | 0.485454 s | 0.448545 s | 0.4551451 s |
| 624\*624 | 1.873978 s | 0.637587 s | 0.593863 s | 0.552541 s | 0.544544 s | 0.7751154 s |
| 724\*724 | 2.675404 s | 1.964082 s | 1.667634 s | 1.404032 s | 1.488415 s | 1.3367052 s |
| 824\*824 | 6.742352 s | 3.554552 s | 3.451425 s | 3.354195 s | 3.315441 s | 3.4826545 s |
| 924\*924 | 11.64094 s | 6.956692 s | 5.88548 s | 5.965731 s | 5.584544 s | 6.5415415 s |
| 1024\*1024 | 28.72011 s | 20.88134 s | 19.58164 s | 19.41541 s | 19.54584 s | 19.785415 s |

**7.ii. b) Table of MPI Run time**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Threads/  Size | 2 threads | 4 threads | 8 threads | 16 threads | 32 threads | 64 threads |
| 24\*24 | 0.018921 s | 0.009257 s | 0.018335 s | 0.037995 s | 0.065876 s | 0.058892 s |
| 124\*124 | 0.011169 s | 0.010040 s | 0.011929 s | 0.055170 s | 0.078321 s | 0.126561 s |
| 224\*224 | 0.159659 s | 0.033020 s | 0.187613 s | 0.835486 s | 3.759123 s | 3.525958 s |
| 324\*324 | 0.234009 s | 0.057675 s | 1.309594 s | 2.707445 s | 4.053291 s | 5.789314 s |
| 424\*424 | 0.586321 s | 0.124577 s | 2.096765 s | 5.073587 s | 4.795318 s | 10.91785 s |
| 524\*524 | 0.825414 s | 0.401367 s | 2.691510 s | 4.458351 s | 6.834815 s | 12.92515 s |
| 624\*624 | 2.854593 s | 0.639078 s | 2.937587 s | 6.583863 s | 7.552541 s | 17.75544 s |
| 724\*724 | 4.819804 s | 0.841545 s | 3.154451 s | 7.345485 s | 16.82525 s | 23.18415 s |
| 824\*824 | 8.256415 s | 1.806247 s | 3.785463 s | 9.741542 s | 25.58484 s | 24.652548 s |
| 924\*924 | 9.604454 s | 3.694094 s | 5.325692 s | 11.36584 s | 29.96573 s | 24.85263 s |
| 1024\*1024 | 29.24696 s | 5.920995s | 6.852478 s | 12.62016 s | 32.28845 s | 28.09128 s |

**7.iii. a) Table of Open MP Speed UP**

**Speedup =Tserial/Tparallel.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Threads/  Size | 2 threads | 4 threads | 8 threads | 16 threads | 32 threads | 64 threads |
| 24\*24 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124\*124 | 1.912841 | 0.919853 | 0.893481 | 0.918934 | 0.898999 | 0.896847 |
| 224\*224 | 1.542429 | 3.413156 | 3.848048 | 3.404603 | 3.840954 | 2.400979 |
| 324\*324 | 4.049222 | 5.131585 | 6.991998 | 7.537906 | 7.454903 | 4.134488 |
| 424\*424 | 3.865401 | 5.605148 | 5.434126 | 5.626146 | 5.576336 | 4.780564 |
| 524\*524 | 4.408302 | 9.033826 | 8.318923 | 7.640271 | 8.268959 | 8.14905 |
| 624\*624 | 2.40291 | 7.062566 | 7.582557 | 8.149621 | 8.269304 | 5.809458 |
| 724\*724 | 2.750613 | 3.746789 | 4.412839 | 5.241334 | 4.944186 | 5.505328 |
| 824\*824 | 1.939383 | 3.678663 | 3.78858 | 3.898402 | 3.94397 | 3.754607 |
| 924\*924 | 1.69909 | 2.843162 | 3.360643 | 3.315436 | 3.541739 | 3.023599 |
| 1024\*1024 | 1.062287 | 1.461065 | 1.558041 | 1.571381 | 1.560895 | 1.541994 |

**7.iii. b) Table of MPI Speed UP**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Threads/  Size | 2 threads | 4 threads | 8 threads | 16 threads | 32 threads | 64 threads |
| 24\*24 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124\*124 | 2.059271 | 2.290837 | 1.928074 | 0.416893 | 0.293663 | 0.181731 |
| 224\*224 | 0.782919 | 3.785584 | 0.666265 | 0.149614 | 0.033252 | 0.035451 |
| 324\*324 | 1.863176 | 7.559601 | 0.332928 | 0.161037 | 0.107567 | 0.075311 |
| 424\*424 | 2.072244 | 9.753004 | 0.579464 | 0.239476 | 0.253372 | 0.111286 |
| 524\*524 | 4.493503 | 9.240919 | 1.378037 | 0.831922 | 0.542663 | 0.28696 |
| 624\*624 | 1.577458 | 7.046088 | 1.532891 | 0.683945 | 0.596223 | 0.253612 |
| 724\*724 | 1.526826 | 8.74463 | 2.332894 | 1.00184 | 0.437378 | 0.317415 |
| 824\*824 | 1.583738 | 7.23932 | 3.454267 | 1.342293 | 0.511084 | 0.530412 |
| 924\*924 | 2.059357 | 5.354222 | 3.713884 | 1.740215 | 0.660054 | 0.795851 |
| 1024\*1024 | 1.043151 | 5.152681 | 4.452258 | 2.417481 | 0.944889 | 1.086067 |

**7.iv. a) Table of Open MP Efficiency**

**Efficiency= SpeedUp / No. threads**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Threads/  Size | 2 threads | 4 threads | 8 threads | 16 threads | 32 threads | 64 threads |
| 24\*24 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124\*124 | 0.95642 | 0.229963 | 0.111685 | 0.057433 | 0.028094 | 0.014013 |
| 224\*224 | 0.771215 | 0.853289 | 0.481006 | 0.212788 | 0.12003 | 0.037515 |
| 324\*324 | 2.024611 | 1.282896 | 0.874 | 0.471119 | 0.232966 | 0.064601 |
| 424\*424 | 1.932701 | 1.401287 | 0.679266 | 0.351634 | 0.174261 | 0.074696 |
| 524\*524 | 2.204151 | 2.258457 | 1.039865 | 0.477517 | 0.258405 | 0.127329 |
| 624\*624 | 1.201455 | 1.765641 | 0.94782 | 0.509351 | 0.258416 | 0.090773 |
| 724\*724 | 1.375306 | 0.936697 | 0.551605 | 0.327583 | 0.154506 | 0.086021 |
| 824\*824 | 0.969691 | 0.919666 | 0.473573 | 0.24365 | 0.123249 | 0.058666 |
| 924\*924 | 0.849545 | 0.71079 | 0.42008 | 0.207215 | 0.110679 | 0.047244 |
| 1024\*1024 | 0.531144 | 0.365266 | 0.194755 | 0.098211 | 0.048778 | 0.024094 |

**7.iv. b) Table of MPI Efficiency**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Threads/  Size | 2 threads | 4 threads | 8 threads | 16 threads | 32 threads | 64 threads |
| 24\*24 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124\*124 | 1.029636 | 0.572709 | 0.241009 | 0.026056 | 0.009177 | 0.00284 |
| 224\*224 | 0.391459 | 0.946396 | 0.083283 | 0.009351 | 0.001039 | 0.000554 |
| 324\*324 | 0.931588 | 1.8899 | 0.041616 | 0.010065 | 0.003361 | 0.001177 |
| 424\*424 | 1.036122 | 2.438251 | 0.072433 | 0.014967 | 0.007918 | 0.001739 |
| 524\*524 | 2.246751 | 2.31023 | 0.172255 | 0.051995 | 0.016958 | 0.004484 |
| 624\*624 | 0.788729 | 1.761522 | 0.191611 | 0.042747 | 0.018632 | 0.003963 |
| 724\*724 | 0.763413 | 2.186158 | 0.291612 | 0.062615 | 0.013668 | 0.00496 |
| 824\*824 | 0.791869 | 1.80983 | 0.431783 | 0.083893 | 0.015971 | 0.008288 |
| 924\*924 | 1.029679 | 1.338556 | 0.464235 | 0.108763 | 0.020627 | 0.012435 |
| 1024\*1024 | 0.521576 | 1.28817 | 0.556532 | 0.151093 | 0.029528 | 0.01697 |

**7.v)Scalability**

-It’s a weakly scalability as, Efficiency is not fixed with increasing number of threads in fixed size problem.  
  
-For example this graph shows Efficiency for 924\*924 matrix size of openMP and MPI programs.

**8. Graph and Comparison**

**Speedup:**

**Efficiency:**

**Compare and Conclusion:**

In openMP speedup graph the worst one is running program in 2 cores and the rest are close to each other.  
in MPI speedup graph the more cores we use , the less speedup we get

Because they don’t share the same memory so it takes time to send data from and to cores.  
  
But in openMp Efficiency 2 cores isn’t the worst at all.  
In both efficiency graphs the more cores we use, the less efficiency we get.

From all of that we conclude that:

1. Speedup isn’t just the only measure for performance.
2. In weak scalability, using more threads/cores isn’t a guarantee for speed up.
3. In some cases there is no need to parallel code like in small input runs.
4. In MPI be careful with data because it may consume a lot of resources.
5. Foster’s methodology is best way to turn a serial program to a parallel one.
6. There is no guarantee if you run the same program and same input amount ,Run time is the same.