Parallel Coursework 1

Testing Document

Correctness Testing – Manual vs Sequential vs Parallel

The correctness testing aims to demonstrate that both the sequential and parallel programs compute the correct answer.

A set square array is formed and relaxed manually to find the expected output. The same initial array is then fed into the sequential program and parallel programs. If the expected array is returned, the program has passed the test. The tests are then repeated with a different array of different size and desired precision. All tests are conducted 3 times to help increase accuracy.

Value set 1: valSet1.txt – dimension: 4x4, precision: 0.1, parallel threads: 1, 2, 4, 8

Value set 2: valSet2.txt – dimension: 6x6, precision: 1.0, parallel threads: 1, 2, 4, 8

|  |  |  |
| --- | --- | --- |
|  | **Value Set 1 – 4x4, 0.1**  **(Pass for result identical to manual)** | **Value set 2 – 6x6, 1.0**  **(Pass for result identical to manual)** |
| **Manual** | - | - |
| **Sequential** | Pass x 3 | Pass x 3 |
| **Parallel T:1** | Pass x 3 | Pass x 3 |
| **Parallel T:2** | Pass x 3 | Pass x 3 |
| **Parallel T:4** | Pass x 3 | Pass x 3 |
| **Parallel T:8** | Pass x 3 | Pass x 3 |

This suggests that both the Sequential and the Parallel code compute the correct answer, and that the Parallel code computes it correctly irrespective of number of threads used. This stands as the foundation for future tests, and is enough evidence to suggest the program is correct, irrespective of precision, threads or dimension size.

Thread Count Tests – Amdahl’s Law

These tests determine the average speed of running the program sequentially and in parallel for varying numbers of threads, using a fixed array and precision. The first set of tests demonstrate how speed up changes with a fixed problem size and increasing hardware (Amdahl’s Law), and the second set begin to demonstrate the same but for fixed hardware and an increased problem size (Gustafson’s Law).

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| --- | --- | --- | --- | --- |
| **Threads** | **Array Dimensions** | **Precision** | **Average Completion Time**  **over 3 Attempts** | **Speed up**  **(s/p)** |
| **Sequential** | 500x500 | 0.1 | 0.335612060 seconds | 1 |
| **1** | 500x500 | 0.1 | 0.500871186 seconds | 0.67 |
| **2** | 500x500 | 0.1 | 0.290115700 seconds | 1.157 |
| **4** | 500x500 | 0.1 | 0.185762405 seconds | 1.807 |
| **8** | 500x500 | 0.1 | 0.134877214 seconds | 2.488 |
| **16** | 500x500 | 0.1 | 0.140009392 seconds | 2.397 |
| **32** | 500x500 | 0.1 | 0.140220868 seconds | 2.393 |
| **64** | 500x500 | 0.1 | 0.164402960 seconds | 2.041 |

Graph Here

For an array of 500x500 and precision 0.1, the program continues to speed up with an increasing number of threads, until 16 threads are used where the program then slows. This shows the overhead generated exceeds the benefit of more threads at this array size. 32 and 64 threads increasingly slowed the program.

It is also seen the overhead of creating 1 thread to compute the program, as opposed to sequentially completing the program without creating any threads, as the average time increases slightly.

The tests were repeated with an array size 5000x5000. It is expected that increasing the problem size for a fixed amount of threads will improve the relative speedup, and as such I hypothesize that 16 threads will instead run faster than 8 threads for this size problem.

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| --- | --- | --- | --- | --- |
| **Threads** | **Array Dimensions** | **Precision** | **Average Completion Time**  **over 3 Attempts** | **Speed up**  **(s/p)** |
| **Sequential** | 5000x5000 | 0.1 | 51.704399473 seconds | 1.000 |
| **1** | 5000x5000 | 0.1 | 81.532672780 seconds | 0.634 |
| **2** | 5000x5000 | 0.1 | 44.595699940 seconds | 1.159 |
| **4** | 5000x5000 | 0.1 | 26.177496806 seconds | 1.975 |
| **8** | 5000x5000 | 0.1 | 16.931951042 seconds | 3.054 |
| **16** | 5000x5000 | 0.1 | 12.621520786 seconds | 4.097 |
| **32** | 5000x5000 | 0.1 | 13.844825517 seconds | 3.735 |
| **64** | 5000x5000 | 0.1 | 13.981570211 seconds | 3.698 |

Graph Here

As hypothesized, the speedup increases for a fixed set of hardware, and as such 16 threads is now has a higher speed up than 8 threads, as the problem size grew larger. The hardware we’re using is limited to 16 cores, so more than 16 threads begins to slow the program.

Dimension Tests – Gustafson’s Law

These tests demonstrate in more detail Gustafson’s Law, by incorporating fixed hardware of 16 threads, but an increasing problem size. The speed up increases as the dimensions grow larger. The same problems were computed sequentially, and those speeds were used to calculate the speed up.

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| --- | --- | --- | --- | --- |
| **Threads** | **Array Dimensions** | **Precision** | **Average Completion Time**  **over 3 Attempts** | **Speed up**  **(s/p)** |
| **16** | 10x10 | 0.1 | 0.005228751 seconds | 0.457 |
| **16** | 100x100 | 0.1 | 0.012128109 seconds | 0.793 |
| **16** | 1000x1000 | 0.1 | 0.475328199 seconds | 3.998 |
| **16** | 10000x10000 | 0.1 | 51.290416832 seconds | 4.229 |

Graph Here

As shown above, for a fixed hardware size, the speed up increases as the problem size increases, as per Gustafson’s Law.

Precision Tests – Gustafson’s Law

These tests again demonstrate Gustafson’s Law, with fixed hardware of 16 threads, but this time increasing the problem size through means of precision. The speed up increases as the program aims to be more precise. The same problems were computed sequentially, and those speeds were used to calculate the speed up.

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| --- | --- | --- | --- | --- |
| **Threads** | **Array Dimensions** | **Precision** | **Average Completion Time**  **over 3 Attempts** | **Speed up**  **(s/p)** |
| **16** | 500x500 | 1 | 0.083644602 seconds | 0.9998 |
| **16** | 500x500 | 0.1 | 0.139587870 seconds | 2.3860 |
| **16** | 500x500 | 0.001 | 33.199836617 seconds | 4.5450 |
| **16** | 500x500 | 0.00001 | 148.644991221 seconds |  |

Graph here

Again, the speed up increases as the problem gets more difficult. However, throughout these tests, we have only examined speed up. There is another important measure which is efficiency of the hardware use.

Efficiency Results

Using the above tests and their computed speed ups, we will look into efficiency. I hypothesize that with a fixed problem size but an increasing set of hardware, the speed up will increase, but the efficiency will decrease. With a fixed set of hardware but an increasing problem size, I believe the speed up FINISH THIS. READ ABOUT AMDAHL AND GUSTAFSON

For this section, we will use the results from the Thread Count Tests, and the Dimension Tests, as both the Precision tests and Dimension tests demonstrate increasing problem size.

Thread Count Tests:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Threads** | **Array Dimensions** | **Precision** | **Speed up**  **(s/p)** | **Efficiency**  **(speed up/threads)** |
| **Sequential** | 5000x5000 | 0.1 | 1.000 | 1.000 |
| **1** | 5000x5000 | 0.1 | 0.634 | 0.634 |
| **2** | 5000x5000 | 0.1 | 1.159 | 0.580 |
| **4** | 5000x5000 | 0.1 | 1.975 | 0.494 |
| **8** | 5000x5000 | 0.1 | 3.054 | 0.382 |
| **16** | 5000x5000 | 0.1 | 4.097 | 0.256 |
| **32** | 5000x5000 | 0.1 | 3.735 | 0.117 |
| **64** | 5000x5000 | 0.1 | 3.698 | 0.058 |

Dimension Tests:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Threads** | **Array Dimensions** | **Precision** | **Speed up**  **(s/p)** | **Efficiency**  **(speed up/threads)** |
| **16** | 10x10 | 0.1 | 0.457 | 0.029 |
| **16** | 100x100 | 0.1 | 0.793 | 0.050 |
| **16** | 1000x1000 | 0.1 | 3.998 | 0.250 |
| **16** | 10000x10000 | 0.1 | 4.229 | 0.264 |

As hypothesized, the efficiency decreases as the hardware set grows larger on a fixed problem, whereas on fixed harder and an increasing problem, the efficiency increases.