Report Oblig 3 IN3030

Haiyuec

Processor:

Intel I7-8550u

Base frequency: 1.80 GHz

Max Turbo frequency: 4.00 GHz

4 cores 8 Threads

How to run the program:

javac *.java

java Main {N} {number of threads} {test-flag}(optional)

test-flags:

- test-primes:
  run both the sequential and the parallel version of the sieve to compare their results.
- test-seq:
  Run the sequential factorization implementation and output the results using the Oblig3Precode, as well as printing the factorizations to the terminal.
  This can be used together with the **check.py** script to verify the correctness with the following command in a Linux terminal:
  java Main {N} {number of threads} test-seq | python check.py

  or

  java Main {N} {number of threads} test-seq | ./check.py
- test-para:
  Run the parallel factorization implementation and output the results using the Oblig3Precode, as well as printing the factorizations to the terminal.
  This can be used together with the **check.py** script to verify the correctness with the following command in a Linux terminal:
  java Main {N} {number of threads} test-para| python check.py

  or

  java Main {N} {number of threads} test-para | ./check.py

Implementation explanation:

Parallel Sieve:

- To generate all the prime numbers up to N, first generate all the prime numbers up to $\sqrt{n} + 1$ sequentially, using the code published on the IN3030 GitHub. Then distribute the primes evenly among the threads, e.g.
    - Thread 1: 2, 11……
    - Thread 2: 3, 13……
    - Thread 3: 5, 17……
    - Thread 4: 7, 19……
- The threads would then cross off the multiples of the primes in a common table.
- The threads were also assigned a section of the value from 3 to N of length N/number of threads. When all the threads have done crossing off numbers in the table, they would go and count the number of primes that are in their section of the table and add the result to a counter in the monitor.
- When this phase is done, the main thread would call the **get_primes()** method of the monitor. Using the number of prime numbers counted by the threads, an array is created and the main thread loops over the table and get all the prime numbers.
- I have chosen to implement the table as a Boolean array, because the crossing of in the table is not synchronized and would cause error if a byte array implementation was used.

Sequential factorization:

- To find the prime factorization of N, first generate the prime numbers up to $\sqrt{n} + 1$.
- Try to find a number p in in the prime numbers that was generated, that can cleanly divide the N. If p was found, p is stored as a factor and N is divided by p.
- This process continues until N becomes 1 or no more p can be found in the list of prime numbers.
    - If N becomes 1:
        - All the prime factors of N is found.
    - If no more p is found:
        - The current value of N is also a prime number, and it will be stored.
- To make this more efficient, after a p is found, the search would continue from p, not from the beginning of the table, e.g. if 7 is found as a factor, then the search for the next p would begin from 7, skipping 2, 3 and 5.

Parallel factorization:

- To find the prime factorization of N, the prime numbers up to $\sqrt{n} + 1$ is generated using the parallel implementation of the sieve as described above.
- The prime numbers are then evenly distributed to the threads in the same manner as the prime number distribution in the parallel sieve implementation.
- Each thread would then fetch the N from the monitor, and try to find all prime factors of N in their **local** table. This is the same for-loop inside a while-loop as the sequential factorization implementation. When the loop is done, the individual threads adds the factors it found to the monitor in an ArrayList. There are two scenarios when adding factors to the monitor:
    - This is the last thread that returns:
        - It will add the factors it found to the result bucket.
        - Then multiply the factors to see if it adds up to N.
            - If it adds up:
                - Set up the next task
            - If it does not adds up
                - Add the missing factor to the result bucket
                - Set up the next task
        - Signals the other threads
    - This is not the last thread that returns:
        - It will add the factors it found
        - Wait for signal
- This process continues until 0 is fetched from the monitor, signaling that there are no more tasks.

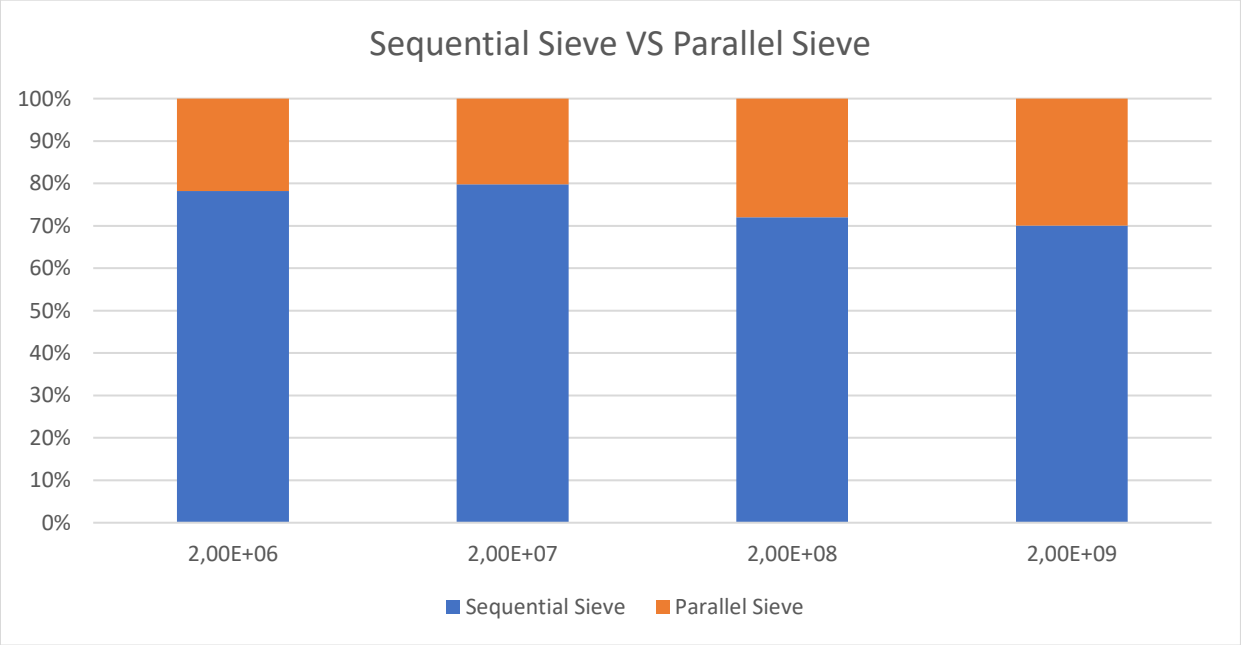
Runtime data:

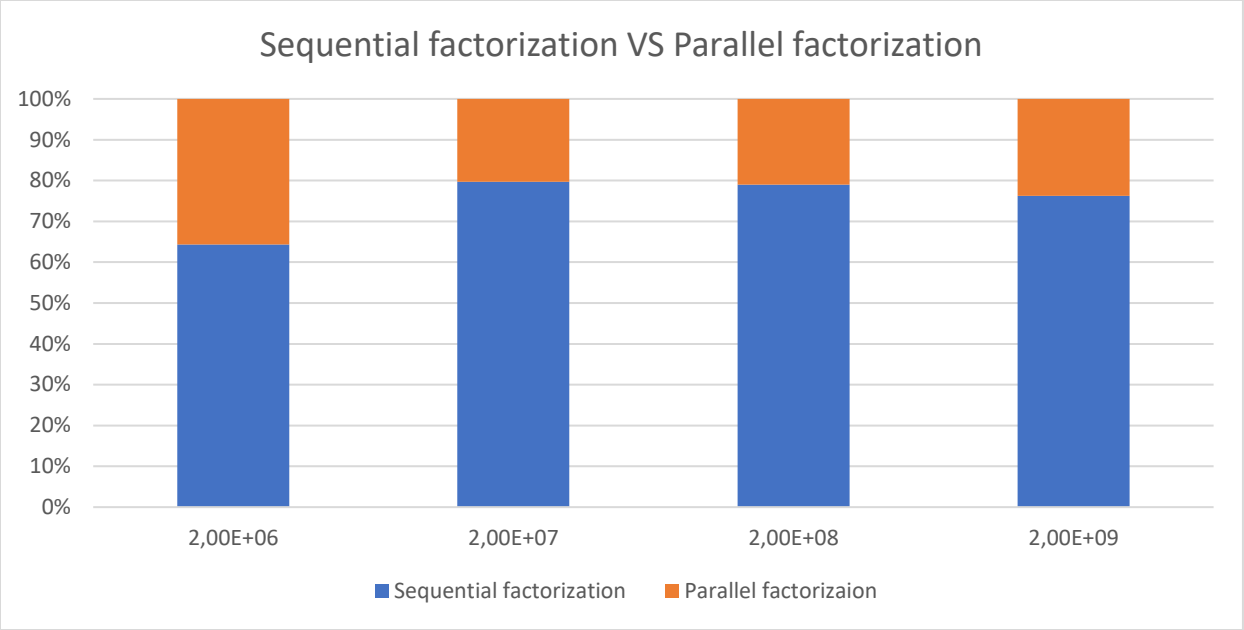
Runtime measured in ms

n	Sequential Sieve	Parallel Sieve
2,00E+06	64,11	17,86
2,00E+07	456,55	115,49
2,00E+08	3586,44	1393,17
2,00E+09	32939,77	14102,11

n	Sequential factorization	Parallel factorizaion
2,00E+06	291,81	161,98
2,00E+07	2673,80	679,21
2,00E+08	19765,39	5251,93
2,00E+09	161344,81	50346,51

Charts:





Conclusion:

Parallel Sieve VS Sequential Sieve:

We can see that the performance of the parallel implementation is better than the sequential version, but we can also see that its performance is not as good when N is becoming very big. I think that this is caused by the sequential part of generating the initial prime numbers and the part at the end where the prime numbers are gathered by iterating the table by a single thread. The increase in running time of those two parts of the algorithm is bigger than the increase of running time of the parallel table crossing, thus resulting a worse speed up compared to the sequential implementation.

Parallel factorization VS Sequential factorization:

We can see a similar pattern in the performance improvements here. The factorization of N = $2 * 10^7$ had the best performance improvement compared to the sequential implementation, and the improvements for the higher numbers of N are slightly worse. I think there are multiple reasons for this. First, the generation of the prime numbers are slower, as the $\sqrt{n}$ also become greater. This takes up precious time that the multiple threads could have used more efficiently (two threads could in theory check double the amount of prime numbers than a single thread in a given time). Having larger numbers to factorize could also causes the threads to wait more. There could be situations where all the prime factors are assigned to a single thread, and thus it must run the factorization loops again and again. The other threads would only run the loops once and be put to sleep, waiting for the single thread to finish. In situations like this, the parallel implementation is in fact slower than the sequential implementation.