

## RESULT REPORT

I have used different matrix sizes to evaluate the performance of my parallel algorithm. The various sizes of the matrices are 10x10, 50x50, 100x100, 500x500 and 1000x1000. The following table shows the runtime of various sized matrices for 10, 100 and 1000 iterations.

| MATRIX SIZE | TIME TAKEN FOR 10 ITERATIONS | TIME TAKEN FOR 100 ITERATIONS | TIME TAKEN FOR 1000 ITERATIONS |
|-------------|------------------------------|-------------------------------|--------------------------------|
|             | (in milliseconds)            | (in milliseconds)             | (in milliseconds)              |
| 10x10       | 0.339712                     | 3.35904                       | 32.925983                      |
| 50x50       | 0.37616                      | 3.639904                      | 36.028706                      |
| 100x100     | 0.486688                     | 4.675232                      | 46.450401                      |
| 500x500     | 3.776256                     | 39.59811                      | 386.737091                     |
| 1000x1000   | 11.04448                     | 114.800034                    | 1021.810364                    |

Following screenshots show the output for each matrix size while using parallel computation.

### 10x10 Matrix:

```
kraman1@comet-ln2:~  
Printing the alive state of first 10 rows and columns of 10x10 future generation matrix after 10 iterations  
0 0 0 0 0 0 1 0 1 0 0  
0 0 0 0 0 0 1 0 1 0 0  
0 0 1 1 0 0 0 1 0 0 0  
0 0 0 0 0 0 1 0 0 0 0  
0 0 0 0 0 0 0 1 1 0 0  
0 0 0 0 0 0 1 0 1 0 0  
0 0 0 0 0 0 0 0 0 1 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 0.339712 milliseconds  
Printing the alive state of first 10 rows and columns of 10x10 future generation matrix after 100 iterations  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 3.359040 milliseconds  
Printing the alive state of first 10 rows and columns of 10x10 future generation matrix after 1000 iterations  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 32.925983 milliseconds  
[kraman1@comet-ln2 ~]$
```

## 50x50 Matrix:

```
kraman1@comet-ln2:~  
Printing the alive state of first 10 rows and columns of 50x50 future generation matrix after 10 iterations  
0 0 0 0 0 0 0 0 0 0  
0 1 1 1 0 0 0 0 0 0  
0 1 0 0 1 0 0 0 0 1  
0 1 1 0 0 1 0 0 0 0  
0 0 0 0 0 1 1 0 0 0  
0 0 0 0 0 0 0 1 1 0  
0 0 0 0 1 1 0 1 1 0  
0 0 0 1 1 1 0 0 1 0  
0 0 1 0 1 0 1 1 1 0  
0 0 1 0 1 1 1 1 1 0  
Time taken for this computation = 0.376160 milliseconds  
  
Printing the alive state of first 10 rows and columns of 50x50 future generation matrix after 100 iterations  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 3.639904 milliseconds  
  
Printing the alive state of first 10 rows and columns of 50x50 future generation matrix after 1000 iterations  
0 0 0 0 0 0 0 0 0 0  
0 0 0 1 1 0 0 0 0 0  
0 0 0 1 0 0 1 0 0 0  
0 0 0 0 1 1 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 1 1 0 0  
0 0 0 0 0 0 1 1 0 0  
Time taken for this computation = 36.028706 milliseconds  
[kraman1@comet-ln2 ~]$
```

## 100x100 Matrix:

```
kraman1@comet-ln2:~  
Printing the alive state of first 10 rows and columns of 100x100 future generation matrix after 10 iterations  
0 0 0 0 0 0 0 0 0 1  
0 0 0 1 0 0 0 0 0 1  
0 0 0 0 0 1 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 1 0  
0 0 0 0 0 0 0 0 0 1  
0 1 0 0 0 0 0 0 1 0  
1 1 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
1 1 0 0 0 0 0 0 0 0  
Time taken for this computation = 0.486688 milliseconds  
  
Printing the alive state of first 10 rows and columns of 100x100 future generation matrix after 100 iterations  
0 0 0 0 0 0 0 0 1 1  
0 0 0 1 0 0 0 0 1 0  
0 0 0 0 0 1 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 1 1 1  
0 0 0 0 0 0 0 1 1 1  
0 0 0 0 0 0 0 0 1 1  
0 0 0 0 0 1 1 0 1 0  
0 0 0 1 1 0 1 1 0 0  
0 0 0 1 0 0 0 0 0 0  
Time taken for this computation = 4.675232 milliseconds  
  
Printing the alive state of first 10 rows and columns of 100x100 future generation matrix after 1000 iterations  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 1 1 0 0  
0 0 0 0 0 0 1 1 0 0  
0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 46.450401 milliseconds  
[kraman1@comet-ln2 ~]$
```

## 500x500 Matrix:

```
kraman1@comet-ln2:~  
Printing the alive state of first 10 rows and columns of 500x500 future generation matrix after 10 iterations  
0 0 0 0 0 0 0 0 0 1 1  
0 0 0 0 0 0 0 0 0 1 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 1 1 0 0 1  
1 1 0 0 0 0 1 1 0 0 0  
1 1 0 0 0 0 1 0 0 0 0  
0 0 0 0 0 0 1 1 0 0 0  
Time taken for this computation = 3.776256 milliseconds  
Printing the alive state of first 10 rows and columns of 500x500 future generation matrix after 100 iterations  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 39.598110 milliseconds  
Printing the alive state of first 10 rows and columns of 500x500 future generation matrix after 1000 iterations  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 386.737091 milliseconds  
[kraman1@comet-ln2 ~]$
```

## 1000x1000 Matrix:

```
kraman1@comet-ln2:~  
Printing the alive state of first 10 rows and columns of 1000x1000 future generation matrix after 10 iterations  
0 0 0 0 0 0 1 0 0 0 1  
0 0 0 0 0 1 0 0 1 1 1  
0 0 0 1 1 0 0 1 0 0 1  
0 0 1 1 1 1 1 1 1 0 1  
0 1 1 1 1 0 0 0 0 0 1  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 1 1 1 0 0 0  
0 0 0 0 0 0 1 1 0 0 0  
0 0 0 0 0 0 1 1 0 0 0  
0 0 0 0 0 1 1 0 0 0 0  
Time taken for this computation = 11.044480 milliseconds  
Printing the alive state of first 10 rows and columns of 1000x1000 future generation matrix after 100 iterations  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 1 1 0 0 0 0  
0 0 0 0 1 0 0 1 0 0 0  
0 0 0 0 0 1 1 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 1 0 0 0 0  
0 0 0 0 0 1 0 1 0 0 0  
0 0 0 0 0 1 1 0 0 0 0  
0 0 0 0 0 0 1 0 0 0 0  
Time taken for this computation = 114.800034 milliseconds  
Printing the alive state of first 10 rows and columns of 1000x1000 future generation matrix after 1000 iterations  
0 0 0 0 0 0 0 0 0 0 0  
1 1 1 1 0 0 0 0 0 1 1  
0 0 0 0 0 0 0 0 0 1 1  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
0 0 0 0 0 0 0 0 0 0 0  
Time taken for this computation = 1021.810364 milliseconds  
[kraman1@comet-ln2 ~]$
```

Now let us examine the need for CUDA by comparing the performance of Serial algorithm with Parallel algorithm using CUDA.

Following table shows the computation times for both serial and parallel computation.

| MATRIX SIZE | SERIAL COMPUTATION TIME FOR 1 ITERATION | PARALLEL COMPUTATION USING CUDA FOR 1 ITERATION |
|-------------|---|---|
|             | (in milliseconds)                       | (in milliseconds)                               |
| 10x10       | 0.009                                   | 0.05824   |
| 50x50       | 0.18                                    | 0.04144   |
| 100x100     | 0.654                                   | 0.04336   |
| 500x500     | 16.349                                  | 0.141984  |
| 1000x1000   | 68.466                                  | 0.525952  |

The above table clearly shows that when the matrix size is considerably small, serial computation is effective. This is shown when matrix size is 10x10.

But when the matrix size increases, the serial computation time keeps on increasing at an alarming rate. However, the parallel computation while using CUDA shows very short computation times as compared to serial computation.

Following are the screenshots for the above table.

### 10x10 Serial:

```
koushikraman@koushikraman-virtual-machine: ~/Desktop
-rw-rw-r-- 1 koushikraman koushikraman 5730 Oct 4 23:41 gauss_omp.c
-rwxrwxr-x 1 koushikraman koushikraman 13616 Oct 4 23:50 gauss_pthread*
-rw-rw-r-- 1 koushikraman koushikraman 6210 Oct 4 23:31 gauss_pthread.c
-rwxrwxr-x 1 koushikraman koushikraman 8608 Oct 4 19:36 helloworld*
-rw-rw-r-- 1 koushikraman koushikraman 69 Oct 4 19:27 helloworld.c
-rw-rw-r-- 1 koushikraman koushikraman 459 Nov 3 21:57 helloworldMpi.c
-rwxrwxr-x 1 koushikraman koushikraman 8832 Oct 4 20:26 openmp_hello*
-rw-rw-r-- 1 koushikraman koushikraman 495 Oct 4 20:26 openmp_hello.c
-rwxrwxr-x 1 koushikraman koushikraman 8800 Oct 4 20:16 pthreads_hello*
-rw-rw-r-- 1 koushikraman koushikraman 574 Oct 4 20:16 pthreads_hello.c
-rw-rw-r-- 1 koushikraman koushikraman 125 Nov 8 18:14 random.c
-rw-rw-r-- 1 koushikraman koushikraman 88 Nov 8 16:31 testBash.sh
koushikraman@koushikraman-virtual-machine:~/Desktop$ gcc conway.c -o conway
koushikraman@koushikraman-virtual-machine:~/Desktop$ ./conway 10

Displaying first 10 rows and columns of 10x10 current generation matrix
1 0 1 1 1 1 0 0 1 1
0 1 0 1 1 0 0 0 0 0
1 0 1 1 0 0 0 1 1 1
1 0 0 0 1 1 1 0 1 0
1 1 1 1 0 1 0 0 1 0
1 0 1 0 0 1 0 0 0 1
1 1 0 1 0 1 0 1 1 1
0 1 0 1 0 1 0 0 1 0
1 0 0 0 0 0 1 1 0 1
0 0 0 0 0 1 0 0 0 1

Printing the first 10 rows and columns of 10x10 future generation matrix
0 1 1 0 0 1 0 0 0 0
1 0 0 0 0 1 0 1 0 0
1 0 1 0 0 0 1 1 1 1
1 0 0 0 0 1 1 0 0 0
1 0 1 1 0 0 0 1 1 1
0 0 0 0 0 1 0 1 0 1
1 0 0 1 0 1 0 1 0 1
0 1 0 0 0 1 0 0 0 1
0 0 0 0 1 1 1 1 0 1
0 0 0 0 0 0 0 0 1 0

Time taken for the computation = 0.009000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$
```

## 10x10 CUDA:

```
kraman1@comet-ln3:~$ cat conway.12915207.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 1442 Nov 27 18:05 conway.12914741.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 1807 Nov 27 19:37 conway.12915207.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 223 Nov 27 19:37 conwayBash.sh
-rw-r--r-- 1 kraman1 iit104 7245 Nov 27 19:35 conway.cu
-rw-r--r-- 1 kraman1 iit104 231 Nov 27 14:32 cuda_job.sh
-rwxr-xr-x 1 kraman1 iit104 519232 Nov 27 14:31 gpuvectoradd
-rw-r--r-- 1 kraman1 iit104 168 Nov 25 14:16 gpuvectoradd.12889988.comet-30-03.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:41 gpuvectoradd.12910994.comet-31-07.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:32 gpuvectoradd.12911000.comet-31-18.out
-rw-r--r-- 1 kraman1 iit104 777 Nov 27 14:31 gpuvectoradd.cu
-rw-r--r-- 1 kraman1 iit104 238 Nov 8 15:30 helloWorldBash.sh
-rwxr-xr-x 1 kraman1 iit104 101808 Nov 8 15:33 helloWorldMPI
-rw-r--r-- 1 kraman1 iit104 816 Nov 8 15:40 helloWorldMPI.12502678.comet-17-33.out
-rw-r--r-- 1 kraman1 iit104 520 Nov 8 15:33 helloWorldMPI.c
drwxr-xr-x 3 kraman1 iit104 3 Nov 3 19:58 intel
[kraman1@comet-ln3 ~]$ cat conway.12915207.comet-30-05.out

Printing the alive state of first 10 rows and columns of 10x10 current generation matrix
1 0 1 1 1 1 0 0 1 1
0 1 0 1 1 0 0 0 0 0
1 0 1 1 0 0 0 1 1 1
1 0 0 0 1 1 1 0 1 0
1 1 1 1 0 1 0 0 1 0
1 1 0 1 0 1 0 1 0 1
1 1 0 1 0 1 0 1 1 1
0 1 0 1 0 1 0 1 1 0
1 0 0 0 0 0 1 1 1 1
0 0 0 0 1 0 0 0 0 1

Printing the alive state of first 10 rows and columns of 10x10 future generation matrix after 1 iterations
0 1 1 0 0 1 0 0 0 0
1 0 0 0 0 1 0 0 1 0
1 0 1 0 0 0 1 1 1 1
1 0 0 0 0 1 1 0 0 0
1 0 1 1 0 0 0 1 1 1
0 0 0 0 0 1 1 1 0 1
1 0 0 1 0 1 0 1 0 1
0 1 0 0 0 1 0 0 0 0
0 0 0 0 1 1 1 1 0 1
0 0 0 0 0 0 0 0 1 0

Time taken for this computation = 0.058240 milliseconds
```

## 50x50 Serial:

```
koushikraman@koushikraman-virtual-machine: ~/Desktop
0 1 1 0 0 1 0 0 0 0
1 0 0 0 0 1 0 0 1 0
1 0 1 0 0 0 1 1 0 1
1 0 0 0 0 1 1 0 0 0
1 0 1 1 0 0 0 1 1 1
0 0 0 0 0 1 0 1 0 1
1 0 0 1 0 1 0 1 0 1
0 1 0 0 0 1 0 0 0 0
0 0 0 0 1 0 1 0 0 1
0 0 0 0 0 1 1 1 0 1
0 0 0 0 0 0 0 0 1 0

Time taken for the computation = 0.009000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$ ./conway 50

Displaying first 10 rows and columns of 50x50 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 1 0 0 1 0 0 0 1
1 0 0 0 1 1 1 1 0 0
0 1 0 1 0 1 0 1 1 1
0 0 1 1 1 1 0 0 0 0
1 1 1 0 0 1 0 0 0 0
0 0 0 0 0 1 1 0 1 0
0 0 1 1 0 1 0 0 0 1
0 1 0 0 0 0 0 0 1 0
0 0 0 1 1 1 1 0 0 1

Printing the first 10 rows and columns of 50x50 future generation matrix
0 1 1 1 1 1 0 0 1 1
1 0 1 0 0 0 0 1 0 0
1 0 1 1 0 0 0 0 0 0
0 1 0 0 0 0 0 1 1 1
1 0 0 0 0 1 1 0 1 1
0 1 1 0 1 1 1 0 0 0
0 0 0 1 0 1 1 1 0 1
0 0 1 0 1 1 1 1 1 0
0 0 0 0 0 1 0 1 1 0
0 0 1 1 0 0 0 0 1 1

Time taken for the computation = 0.180000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$
```

## 50x50 CUDA:

```
kraman1@comet-ln2:~$ cat conway.12915221.comet-30-09.out
-rw-r--r-- 1 kraman1 iit104 1807 Nov 27 19:44 conway.12915221.comet-30-09.out
-rw-r--r-- 1 kraman1 iit104 216 Nov 27 19:43 conwayBash.sh
-rw-r--r-- 1 kraman1 iit104 7245 Nov 27 19:35 conway.cu
-rw-r--r-- 1 kraman1 iit104 231 Nov 27 14:32 cuda_job.sh
-rwxr-xr-x 1 kraman1 iit104 519232 Nov 27 14:31 gpuvectoradd
-rw-r--r-- 1 kraman1 iit104 168 Nov 25 14:16 gpuvectoradd.12889988.comet-30-03.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:41 gpuvectoradd.12910994.comet-31-07.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:32 gpuvectoradd.12911000.comet-31-18.out
-rw-r--r-- 1 kraman1 iit104 777 Nov 27 14:31 gpuvectoradd.cu
-rw-r--r-- 1 kraman1 iit104 238 Nov 8 15:30 helloWorldBash.sh
-rwxr-xr-x 1 kraman1 iit104 101808 Nov 8 15:33 helloWorldMPI
-rw-r--r-- 1 kraman1 iit104 816 Nov 8 15:40 helloWorldMPI.12502678.comet-17-33.out
-rw-r--r-- 1 kraman1 iit104 520 Nov 8 15:33 helloWorldMPI.c
drwxr-xr-x 3 kraman1 iit104 3 Nov 3 19:58 intel
[kraman1@comet-ln2 ~]$ cat conway.1215221.comet-30-09.out
cat: conway.1215221.comet-30-09.out: No such file or directory
[kraman1@comet-ln2 ~]$ cat conway.12915221.comet-30-09.out

Printing the alive state of first 10 rows and columns of 50x50 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 1 0 0 1 0 0 0 1
1 0 0 0 1 1 1 0 1 0
0 1 0 1 1 1 0 1 1 1
0 0 1 1 1 0 0 0 0 0
1 1 0 0 0 1 1 0 0 0
0 0 0 0 0 1 1 0 1 0
0 0 1 1 0 1 0 0 1 1
0 1 0 0 0 0 0 0 0 1
0 0 0 0 1 1 1 0 0 1

Printing the alive state of first 10 rows and columns of 50x50 future generation matrix after 1 iterations
0 1 1 1 1 0 0 0 1 1
1 0 1 0 0 0 0 1 0 0
1 0 1 1 0 0 0 0 0 0
0 1 0 0 0 0 0 1 1 1
1 0 0 0 0 1 1 0 1 1
0 1 1 0 1 1 1 0 0 0
0 0 0 1 0 1 1 0 0 1
0 0 1 0 1 1 1 1 1 0
0 0 0 0 0 0 1 0 1 0
0 0 1 1 0 0 0 0 0 1

Time taken for this computation = 0.041440 milliseconds
```

## 100x100 Serial:

```
koushikraman@koushikraman-virtual-machine: ~/Desktop
0 0 1 1 1 1 0 0 1 1
1 0 1 0 0 0 0 0 1 0
1 0 1 1 0 0 0 0 0 0
0 1 0 0 0 0 0 0 1 1
1 0 0 0 0 1 1 0 1 1
0 1 1 0 0 1 1 0 0 0
0 0 0 1 0 1 1 0 0 1
0 0 0 1 0 1 1 1 1 0
0 0 0 1 0 1 1 1 1 1
0 0 1 0 1 1 1 1 1 0

Time taken for the computation = 0.180000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$ ./conway 100

Displaying first 10 rows and columns of 100x100 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 0 0 1 1 1 0 1 0
0 0 1 1 1 0 0 0 0 0
0 0 0 0 0 1 1 0 1 0
0 1 0 0 0 0 0 0 1 0
1 0 0 1 1 1 1 1 0 1
0 1 1 1 1 1 0 0 1 1
0 1 0 0 1 1 1 1 1 1
0 0 0 1 1 1 1 1 1 0
0 0 1 0 1 0 0 1 1 0

Printing the first 10 rows and columns of 100x100 future generation matrix
0 1 0 1 0 0 1 1 1 1
0 0 0 0 0 0 1 1 1 1
0 0 0 1 0 0 0 0 0 1
0 0 0 1 1 1 0 1 0 0
0 0 0 0 0 0 0 0 1 0
1 0 0 0 0 0 1 1 0 0
1 1 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0
0 0 1 1 0 0 0 0 0 0
0 0 1 1 0 0 0 0 0 0

Time taken for the computation = 0.654000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$
```

## 100x100 CUDA:

```
kraman1@comet-ln2:~$ cat conway.12915234.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 1807 Nov 27 19:44 conway.12915221.comet-30-09.out
-rw-r--r-- 1 kraman1 iit104 1817 Nov 27 19:45 conway.12915234.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 217 Nov 27 19:45 conwayBash.sh
-rw-r--r-- 1 kraman1 iit104 7245 Nov 27 19:35 conway.cu
-rw-r--r-- 1 kraman1 iit104 231 Nov 27 14:32 cuda_job.sh
-rwxr-xr-x 1 kraman1 iit104 519232 Nov 27 14:31 gpuvectoradd
-rw-r--r-- 1 kraman1 iit104 168 Nov 25 14:16 gpuvectoradd.12889988.comet-30-03.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:41 gpuvectoradd.12910994.comet-31-07.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:32 gpuvectoradd.12911000.comet-31-18.out
-rw-r--r-- 1 kraman1 iit104 777 Nov 27 14:31 gpuvectoradd.cu
-rw-r--r-- 1 kraman1 iit104 238 Nov 8 15:30 helloWorldBash.sh
-rwxr-xr-x 1 kraman1 iit104 101808 Nov 8 15:33 helloWorldMPI
-rw-r--r-- 1 kraman1 iit104 816 Nov 8 15:40 helloWorldMPI.12502678.comet-17-33.out
-rw-r--r-- 1 kraman1 iit104 520 Nov 8 15:33 helloWorldMPI.c
drwxr-xr-x 3 kraman1 iit104 3 Nov 3 19:58 intel
[kraman1@comet-ln2 ~]$ cat conway.12915234.comet-30-05.out
Printing the alive state of first 10 rows and columns of 100x100 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 0 0 1 1 1 0 1 0
0 0 1 1 1 0 0 0 0 0
0 0 0 0 0 0 1 1 0 1
0 1 0 0 0 0 0 0 0 1
1 0 0 1 1 1 1 1 0 1
0 1 1 1 1 1 0 0 1 1
0 1 0 0 1 1 0 1 1 1
0 0 0 1 1 1 1 1 1 0
0 0 1 0 1 1 0 0 1 0

Printing the alive state of first 10 rows and columns of 100x100 future generation matrix after 1 iterations
0 1 0 1 0 0 1 1 1 1
0 0 0 0 0 0 1 1 1 1
0 0 0 1 0 0 0 0 0 1
0 0 1 1 1 1 1 1 0 0
0 0 0 0 0 0 0 0 1 0
1 0 0 0 0 0 0 1 0 0
1 1 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0
0 0 1 1 0 0 0 0 0 0
0 1 1 1 0 0 0 0 0 0

Time taken for this computation = 0.043360 milliseconds
```

## 500x500 Serial:

```
koushikraman@koushikraman-virtual-machine: ~/Desktop
0 1 0 1 0 0 1 1 1 1
0 0 0 0 0 0 1 1 1 1
0 0 0 1 1 0 0 0 0 1
0 0 1 1 1 1 1 1 0 0
0 0 0 0 0 0 0 0 1 0
1 0 0 0 0 0 0 1 1 0
1 1 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0
0 0 1 1 1 0 0 0 0 0
0 1 1 1 0 0 0 0 0 0

Time taken for the computation = 0.654000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$ ./conway 500
Displaying first 10 rows and columns of 500x500 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 0 1 1 1 1 1 0 1
1 0 1 0 1 1 1 1 0 1
1 0 1 0 1 0 0 0 0 1
0 1 0 1 1 0 0 1 0 1
0 0 1 1 1 0 0 1 1 0
1 1 0 0 0 0 0 0 0 1
0 1 1 0 1 1 1 1 0 0
0 0 0 1 1 1 1 1 0 1
1 0 1 1 1 1 1 1 0 1

Printing the first 10 rows and columns of 500x500 future generation matrix
0 1 1 0 0 0 0 1 1 1
1 0 0 0 0 0 0 0 0 1
1 0 1 0 0 0 0 1 0 1
1 0 1 0 0 0 0 1 0 1
0 1 0 0 1 0 0 1 0 1
1 0 0 0 1 0 0 1 0 0
1 0 0 0 0 1 0 0 0 1
1 1 1 0 0 0 0 1 0 0
0 0 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 0 1

Time taken for the computation = 16.349000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$
```

## 500x500 CUDA:

```
kraman1@comet-ln2:~$ cat conway.12915264.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 1817 Nov 27 19:45 conway.12915234.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 1819 Nov 27 19:49 conway.12915264.comet-30-05.out
-rw-r--r-- 1 kraman1 iit104 217 Nov 27 19:49 conwayBash.sh
-rw-r--r-- 1 kraman1 iit104 7245 Nov 27 19:35 conway.cu
-rw-r--r-- 1 kraman1 iit104 231 Nov 27 14:32 cuda_job.sh
-rwxr-xr-x 1 kraman1 iit104 519232 Nov 27 14:31 gpvectoradd
-rw-r--r-- 1 kraman1 iit104 168 Nov 25 14:16 gpvectoradd.12889988.comet-30-03.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:41 gpvectoradd.12910994.comet-31-07.out
-rw-r--r-- 1 kraman1 iit104 168 Nov 27 14:32 gpvectoradd.12911000.comet-31-18.out
-rw-r--r-- 1 kraman1 iit104 777 Nov 27 14:31 gpvectoradd.cu
-rw-r--r-- 1 kraman1 iit104 238 Nov 8 15:30 helloWorldBash.sh
-rwxr-xr-x 1 kraman1 iit104 101808 Nov 8 15:33 helloWorldMPI
-rw-r--r-- 1 kraman1 iit104 816 Nov 8 15:40 helloWorldMPI.12502678.comet-17-33.out
-rw-r--r-- 1 kraman1 iit104 520 Nov 8 15:33 helloWorldMPI.c
drwxr-xr-x 3 kraman1 iit104 3 Nov 3 19:58 intel
[kraman1@comet-ln2 ~]$ cat conway.12915264.comet-30-05.out
Printing the alive state of first 10 rows and columns of 500x500 current generation matrix
1 0 1 1 1 1 1 1 1 1
1 0 0 1 1 1 1 1 0 1
1 0 1 0 1 1 1 1 0 1
1 0 1 0 1 0 0 0 0 1
0 1 0 1 1 0 0 1 0 1
0 0 1 0 1 0 0 1 1 0
1 1 0 0 0 0 0 0 0 1
0 1 0 0 1 1 1 1 0 0
0 0 0 1 1 1 1 1 0 1
1 0 0 1 1 1 1 1 0 1
Printing the alive state of first 10 rows and columns of 500x500 future generation matrix after 1 iterations
0 1 1 0 0 0 1 1 1 1
1 0 0 0 0 0 0 0 0 1
1 0 1 0 0 0 0 0 1 0
1 0 1 0 0 0 0 0 1 0
0 1 0 0 1 0 1 0 0 1
1 0 0 0 1 0 0 1 0 0
1 0 0 0 0 0 0 0 0 1
1 1 1 0 0 0 0 0 1 0
0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 1
Time taken for this computation = 0.141984 milliseconds
```

## 1000x1000 Serial:

```
koushikraman@koushikraman-virtual-machine: ~/Desktop
0 1 1 0 0 0 0 0 1 1 1
1 0 0 0 0 0 0 0 0 0 1
1 0 1 0 0 0 0 0 1 0 1
1 0 1 0 0 0 0 0 1 0 1
0 1 0 0 0 1 0 0 1 0 1
1 0 0 0 0 0 0 0 1 0 0
1 1 1 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 0 0 1
0 0 0 0 0 0 0 0 0 0 1
Time taken for the computation = 16.349000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$ ./conway 1000
Displaying first 10 rows and columns of 1000x1000 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 1 0 1 1 1 1 0 1
0 1 0 1 1 0 0 1 0 1
1 1 0 0 0 0 0 0 0 1
0 0 0 1 1 1 0 1 0 1
1 0 1 1 0 0 1 0 1 0
1 0 1 0 1 1 1 0 0 1
1 0 0 0 0 0 0 1 0 0
0 1 1 0 1 0 0 1 0 1
0 1 0 0 1 0 1 1 0 0
Printing the first 10 rows and columns of 1000x1000 future generation matrix
0 1 0 0 0 0 1 1 1 1
1 0 0 0 0 0 0 1 0 1
0 0 0 1 1 0 0 1 0 1
1 1 0 0 0 1 1 0 0 1
1 0 0 1 1 1 1 1 0 0
0 0 1 0 0 1 0 0 1 0
1 0 1 0 1 1 0 1 1 1
1 0 1 0 1 0 0 1 0 1
1 1 1 1 0 1 0 1 0 0
1 1 0 0 1 1 1 1 0 0
Time taken for the computation = 68.466000 milliseconds
koushikraman@koushikraman-virtual-machine:~/Desktop$
```



### 1000x1000 CUDA:

```
kraman1@comet-ln2:~$
-rw-r--r-- 1 kraman1 ilt104      1819 Nov 27 19:49 Conway.12915264.comet-30-05.out
-rw-r--r-- 1 kraman1 ilt104      1832 Nov 27 19:50 Conway.12915278.comet-30-05.out
-rw-r--r-- 1 kraman1 ilt104         218 Nov 27 19:50 ConwayBash.sh
-rw-r--r-- 1 kraman1 ilt104       7245 Nov 27 19:35 Conway.cu
-rw-r--r-- 1 kraman1 ilt104        231 Nov 27 14:32 cuda_job.sh
-rwxr-xr-x 1 kraman1 ilt104    519232 Nov 27 14:31 gpuvectoradd
-rw-r--r-- 1 kraman1 ilt104       168 Nov 25 14:16 gpuvectoradd.12889988.comet-30-03.out
-rw-r--r-- 1 kraman1 ilt104       168 Nov 27 14:41 gpuvectoradd.12910994.comet-31-07.out
-rw-r--r-- 1 kraman1 ilt104       168 Nov 27 14:32 gpuvectoradd.12911000.comet-31-18.out
-rw-r--r-- 1 kraman1 ilt104        777 Nov 27 14:31 gpuvectoradd.cu
-rw-r--r-- 1 kraman1 ilt104        238 Nov  8 15:30 HelloWorldBash.sh
-rwxr-xr-x 1 kraman1 ilt104    101808 Nov  8 15:33 HelloWorldMPI
-rw-r--r-- 1 kraman1 ilt104       816 Nov  8 15:40 HelloWorldMPI.12502678.comet-17-33.out
-rw-r--r-- 1 kraman1 ilt104       520 Nov  8 15:33 HelloWorldMPI.c
drwxr-xr-x 3 kraman1 ilt104         3 Nov  3 19:58 Intel
[kraman1@comet-ln2 ~]$ cat Conway.12915278.comet-30-05.out

Printing the alive state of first 10 rows and columns of 1000x1000 current generation matrix
1 0 1 1 1 1 0 0 1 1
1 0 1 0 1 1 1 1 0 1
0 1 0 1 1 0 0 1 0 1
1 1 0 0 0 0 0 0 0 1
0 0 0 1 1 1 0 1 0 1
1 0 1 1 0 0 1 0 1 0
1 0 1 0 1 1 1 0 0 1
1 0 0 0 0 0 0 0 1 0
0 1 1 0 1 0 0 0 1 0
0 1 1 0 1 0 0 1 0 1
0 1 0 0 1 0 1 1 0 0

Printing the alive state of first 10 rows and columns of 1000x1000 future generation matrix after 1 iterations
0 0 1 0 0 0 0 1 1 1
1 0 0 0 0 0 0 1 0 1
0 0 0 1 1 0 0 1 0 1
1 1 0 0 0 1 1 0 0 1
1 0 0 1 1 1 1 1 0 0
0 0 1 0 0 0 0 0 1 0
1 0 1 0 1 1 1 0 1 1
0 0 1 0 1 0 0 1 0 1
1 1 1 1 1 1 1 1 0 0
1 1 0 0 1 1 1 1 0 0

Time taken for this computation = 0.525952 milliseconds
```

### CONCLUSION:

These screenshots and the table clearly shows that CUDA is the better option than serial computation when the input matrix size is large.

Thus, I have learnt from this assignment that CUDA is one of the most efficient ways to implement parallel computation.