ASSIGNMENT 3 Dsicussion

Question 1

Part 4: Compare and comment on the efficiency of approaches 1, 2, and 3. Measure the runtime of the three functions for different numbers of particles. In your tests make N large enough so that the CPU version runs for up to 30 seconds.

As can be obviously observed ion following char, as the NMAX doubles, the CPU times increase by n^2, which follows the time complexity estimation of serial code O(N^2). However, GPU codes running time keeps steady which shows powerful speedup effect of GPU in situation of large-scale calculation!

NMAX	CPU time(s)	GPU k1 time(s)	GPU k2 time(s)
16384	~1.2	5*10^-6	4*10^-6
32768	~4.2	7*10^-6	5*10^-6
65536	~17.4	5*10^-6	5*10^-6
92682	~33.8	5*10^-6	4*10^-6 **

```
[qdai3@mcs2 question1]$ ./min_dist.x
No 0 of particle pair: (0.8402, 0.3944)
No 1 of particle pair: (0.7831, 0.7984)
No 2 of particle pair: (0.9116, 0.1976)
CPU Time: 1.054137e+00
Min distance between 16384 particle pair: GPU k1(0.0000321) vs CPU(0.0000321) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 4.000000e-06
Min distance between 16384 particle pair: GPU k2(0.0000321) vs CPU(0.0000321) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 3.000000e-06
No 0 of particle pair: (0.7010, 0.8097)
No 1 of particle pair: (0.0888, 0.1215)
No 2 of particle pair: (0.3483, 0.4220)
CPU Time: 1.227085e+00
Min distance between 16384 particle pair: GPU k1(0.0000617) vs CPU(0.0000617) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 6.000000e-06
Min distance between 16384 particle pair: GPU k2(0.0000617) vs CPU(0.0000617) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 6.000000e-06
No 0 of particle pair: (0.5614, 0.2250)
No 1 of particle pair: (0.3931, 0.4439)
No 2 of particle pair: (0.2850, 0.1448)
CPU Time: 1.186068e+00
Min distance between 16384 particle pair: GPU k1(0.0000151) vs CPU(0.0000151) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 3.000000e-06
Min distance between 16384 particle pair: GPU k2(0.0000151) vs CPU(0.0000151) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 3.000000e-06
```

```
[qdai3@mcs2 question1]$ ./min_dist.x
No 0 of particle pair: (0.8402, 0.3944)
No 1 of particle pair: (0.7831, 0.7984)
No 2 of particle pair: (0.9116, 0.1976)
CPU Time: 4.201947e+00
Min distance between 32768 particle pair: GPU k1(0.0000206) vs CPU(0.0000206) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 3.000000e-06
Min distance between 32768 particle pair: GPU k2(0.0000206) vs CPU(0.0000206) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 4.000000e-06
No 0 of particle pair: (0.7010, 0.8097)
No 1 of particle pair: (0.0888, 0.1215)
No 2 of particle pair: (0.3483, 0.4220)
CPU Time: 4.152661e+00
Min distance between 32768 particle pair: GPU k1(0.0000524) vs CPU(0.0000524) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 4.000000e-06
Min distance between 32768 particle pair: GPU k2(0.0000524) vs CPU(0.0000524) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 4.000000e-06
No 0 of particle pair: (0.5614, 0.2250)
No 1 of particle pair: (0.3931, 0.4439)
No 2 of particle pair: (0.2850, 0.1448)
CPU Time: 4.523103e+00
Min distance between 32768 particle pair: GPU k1(0.0000151) vs CPU(0.0000151) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 1.400000e-05
Min distance between 32768 particle pair: GPU k2(0.0000151) vs CPU(0.0000151) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 7.000000e-06
```

```
[qdai3@mcs2 question1]$ ./min_dist.x
No 0 of particle pair: (0.8402, 0.3944)
No 1 of particle pair: (0.7831, 0.7984)
No 2 of particle pair: (0.9116, 0.1976)
CPU Time: 1.738378e+01
Min distance between 65536 particle pair: GPU k1(0.0000119) vs CPU(0.0000119) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 4.000000e-06
Min distance between 65536 particle pair: GPU k2(0.0000119) vs CPU(0.0000119) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 4.000000e-06
No 0 of particle pair: (0.7010, 0.8097)
No 1 of particle pair: (0.0888, 0.1215)
No 2 of particle pair: (0.3483, 0.4220)
CPU Time: 1.755265e+01
Min distance between 65536 particle pair: GPU k1(0.0000081) vs CPU(0.0000081) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 6.000000e-06
Min distance between 65536 particle pair: GPU k2(0.0000081) vs CPU(0.0000081) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 6.000000e-06
No 0 of particle pair: (0.5614, 0.2250)
No 1 of particle pair: (0.3931, 0.4439)
No 2 of particle pair: (0.2850, 0.1448)
CPU Time: 1.722348e+01
Min distance between 65536 particle pair: GPU k1(0.0000122) vs CPU(0.0000122) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 4.000000e-06
Min distance between 65536 particle pair: GPU k2(0.0000122) vs CPU(0.0000122) (relative error 0.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 4.000000e-06
```

```
[qdai3@mcs2 question1]$ ./min_dist.x
No 0 of particle pair: (0.8402, 0.3944)
No 1 of particle pair: (0.7831, 0.7984)
No 2 of particle pair: (0.9116, 0.1976)
CPU Time: 3.366343e+01
Min distance between 92682 particle pair: GPU k1(0.0000077) vs CPU(0.0000077) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 4.000000e-06
Min distance between 92682 particle pair: GPU k2(0.0000000) vs CPU(0.0000077) (relative error 1.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 3.000000e-06
No 0 of particle pair: (0.7010, 0.8097)
No 1 of particle pair: (0.0888, 0.1215)
No 2 of particle pair: (0.3483, 0.4220)
CPU Time: 3.416568e+01
Min distance between 92682 particle pair: GPU k1(0.0000081) vs CPU(0.0000081) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 7.000000e-06
Min distance between 92682 particle pair: GPU k2(0.0000000) vs CPU(0.0000081) (relative error 1.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 5.000000e-06
No 0 of particle pair: (0.5614, 0.2250)
No 1 of particle pair: (0.3931, 0.4439)
No 2 of particle pair: (0.2850, 0.1448)
CPU Time: 3.364842e+01
Min distance between 92682 particle pair: GPU k1(0.0000122) vs CPU(0.0000122) (relative error 0.000000e+00)
GPU kernel1(OneThreadPerParticle) Time: 4.000000e-06
Min distance between 92682 particle pair: GPU k2(0.0000000) vs CPU(0.0000122) (relative error 1.000000e+00)
GPU kernel2(OneThreadPerPair) Time: 5.000000e-06
```

** k2 code failed to get correct result for some unknown reason.

Part 5: Discuss what improvements could be made to the algorithm to improve the speed of the calculation. How does the runtime of algorithms in 1,2 and 3 scale with the number of particles? Could the algorithm be redesigned to obtain a different, better scaling?

Possible improvement will be discussed in different aspects:

- *Portion of parallelized code: Since the codes utilize the fastest algorithm discussed in Exercises week11, namely, atomic algorithm which maximize the*

chance of parallel execution of code. And the performance monitor above reflects the efficiency of GPU code.

- *More efficient execution of code: as hinted, maybe we can use integer calculation to replace float-point calculation.*

To sum up, there may be some space to improve the efficiency further, but the extent is limited because the performance of existing code is very good already!

Question 2

Since the limit of time, there's more direction can be analyzed for sampling method:

I will keep updating on:

https://github.com/daiqing2009/AdvParallelProgramming/blob/main/assignment3/question2/sampling_movietv.ipynb

I use this as preprocessing of my Data Analysis project. Spark is really a powerful tool!