CSC254 Assignment#4

Junfei Liu(jliu137)
Pinxin Liu(pliu23)

How to run

We wrote a Makefile for you to run the code. Be sure to enter the src directory, and the following contains the sample codes to run:

Install:

```
$ make compile
```

Run the program and get the results for different threads as required:

```
$ make run
which test threads in range [0, 1, 2, 3, 4, 6, 8, 12, 16, 24, 32, 48]
with a = 0,  n = 1000000, and default d
```

Run extra credits2:

```
$ make extra2
which test threads in range [0, 1, 2, 4, 8, 16]
and delta in range []
with a = 0,  n = 1000000
```

Run extra credits4:

```
$ make extra4
which test threads in range [0, 1, 2, 4, 8, 16]
and # of vertices in range [1, 100, 1000, 10000, 100000, 1000000]
with a = 0,  default d
```

Clean up:

```
$ make end
Which will delete all .class files generated by Java compiler
```

How we design the code:

We followed the standard pseudo codes for this assignment. There are two while loops we need to loop through. The outer loop needs to check the condition of whether there exist any of the buckets that contain any number of vertices. The inner loop will check whether any vertex exists in the current buckets step for each of the threads. In the inner loop, we do the light relaxation because light relaxation will try to find if additional vertices will be added to the current step. During this step, we will assign some vertices to the other threads through the message queue.
In the outer loop, we do the heavy relaxation, where all the new vertices found will be saved either to the further steps of the current buckets or the buckets from the other threads. Eventually, we need to check if there exist any of the buckets still have anything. If so, then we just make the outer loop a second time.

Experiments

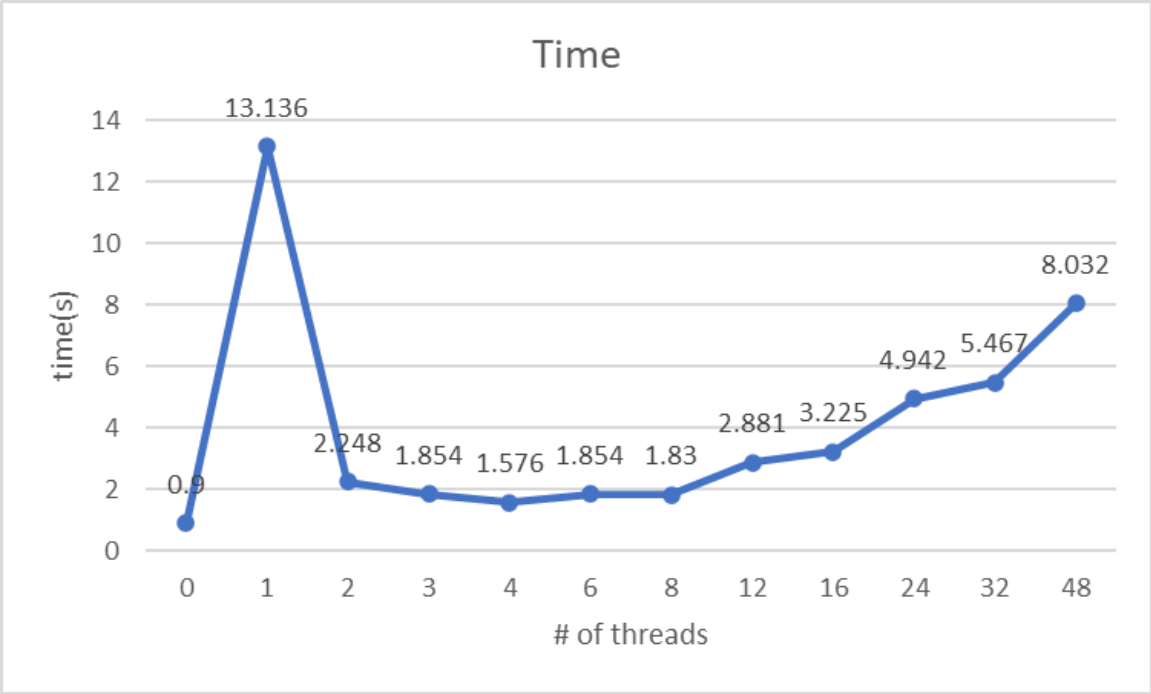
Project Requirement:

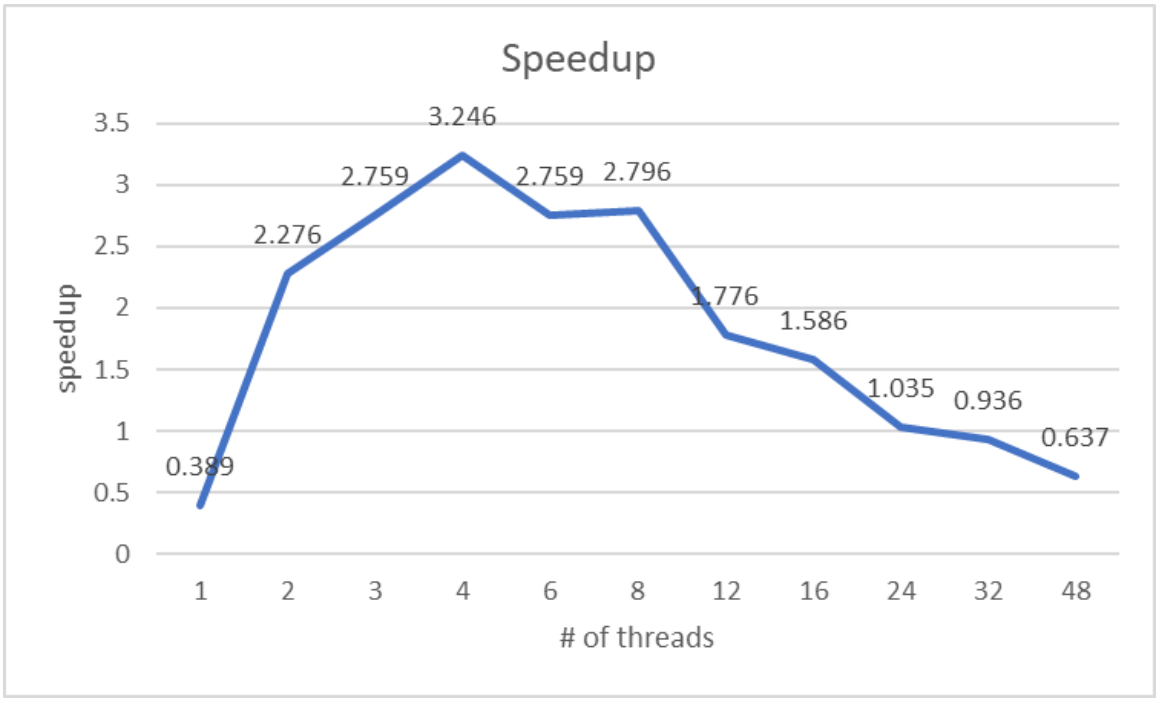
We run the benchmark of our delta-stepping algorithm on node2x14a.csug.rochester.edu The following data is obtained by testing threads in the range [0, 1, 2, 3, 4, 6, 8, 12, 16, 24, 32, 48] with a = 0, n = 1000000, and default d:

# of Threads	Time(s)	Speedup
0	0.9	N/A
1	13.136	0.389
2	2.248	2.276
3	1.854	2.759
4	1.576	3.246
6	1.854	2.759
8	1.83	2.796
12	2.881	1.776
16	3.225	1.586

24	4.942	1.035
32	5.467	0.936
48	8.032	0.637

Where the speedup is calculated by the time it takes for the starter-code to execute with thread # = 1 (5.116s)/ the time it takes for Delta-stepping of different number of threads.





We have the following observations:

1. The parallelization is generally successful since the time cost with more than two threads are significantly smaller than the time cost with one thread.

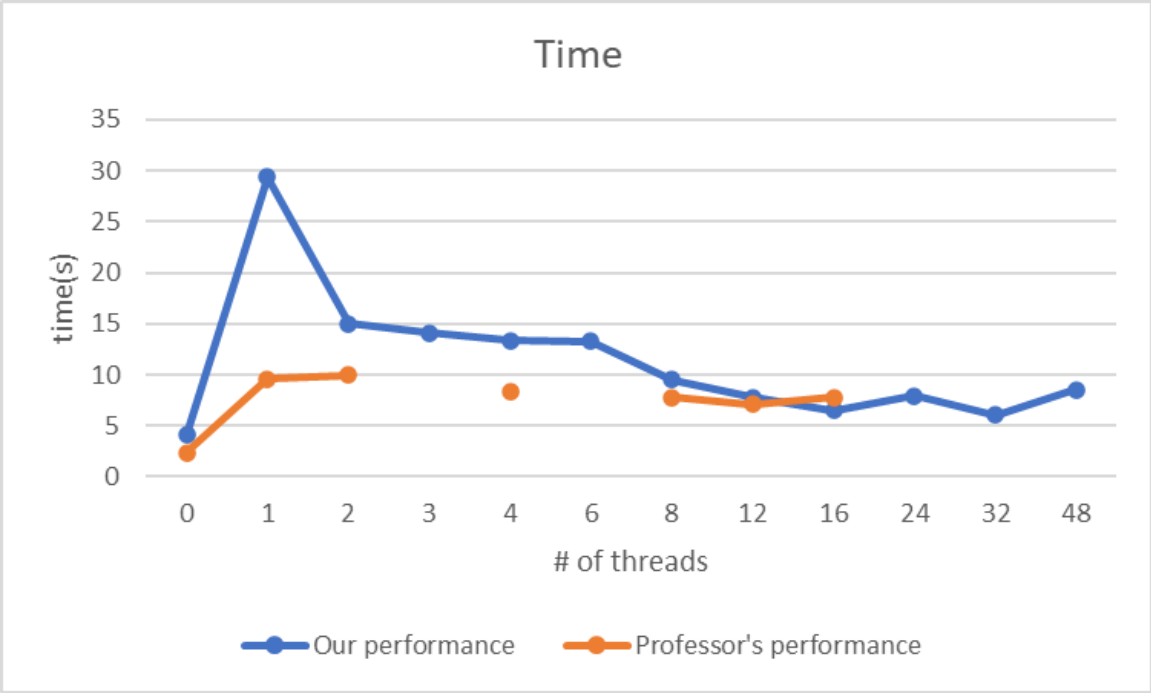
2. The speedup increases with threads number increases from 1 to 4, shows no significant change with threads number 6 to 8, and then drops rapidly with more than 12 threads.

3. We find when in most cases, the running time for delta-stepping will be slower than Dijkstra algorithm. However, there exists some of the cases fortunately, when we will reach a smaller improvements over Dijkstra.

We did not achieve the ideal speed-up rate because the delta-stepping algorithm has lots of overhead when accessing message queues and barriers.

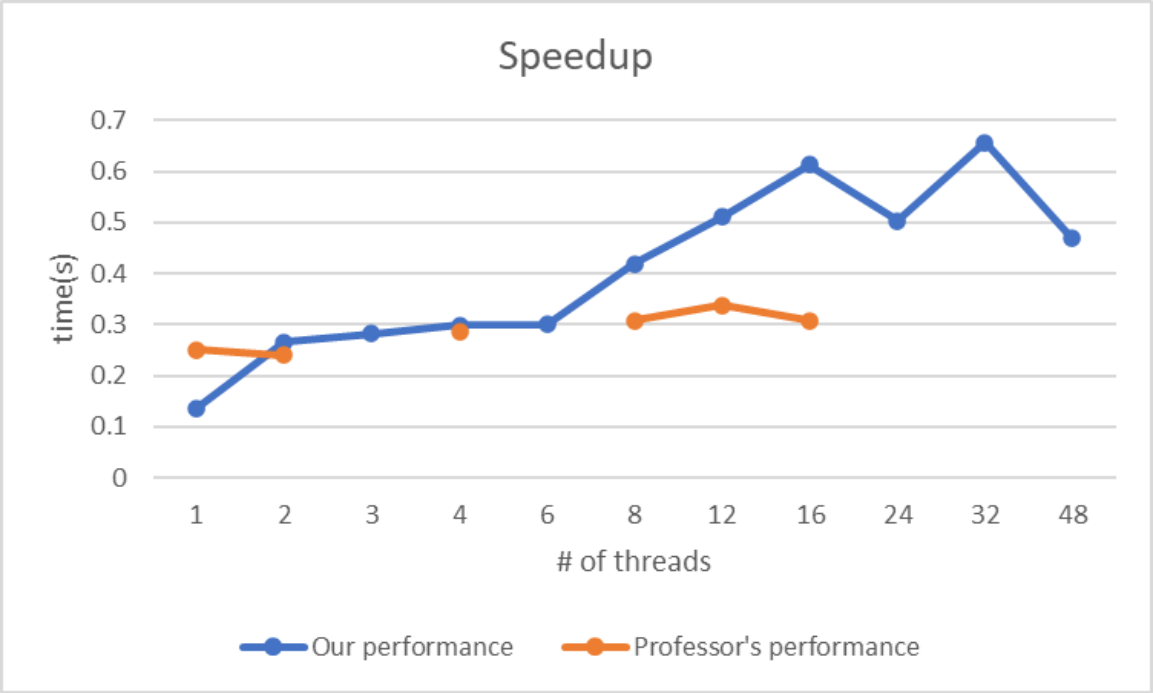
We also tested our delta-stepping algorithm with a = 0, n = 500000, and d = 100 to compare the performance with Professor’s Scott’s "solution".

# of Threads	Our Time(s)	Professor's Time(s)
0	3.988	2.4
1	29.401	9.6
2	14.976	10
3	14.128	
4	13.322	8.4
6	13.302	
8	9.502	7.8
12	7.813	7.1
16	6.502	7.8
24	7.918	
32	6.068	
48	8.51	



Since starter code cannot set delta, we calculate speedup in terms of the time it takes for Dijkstra's algorithm to execute on respective machines / the time it takes for Delta-stepping of different number of threads.

# of Threads	Our Speedup	Professor's Speedup
1	0.136	0.25
2	0.266	0.24
3	0.282	
4	0.299	0.286
6	0.3	
8	0.42	0.308
12	0.51	0.338
16	0.613	0.308
24	0.504	
32	0.657	
48	0.469	



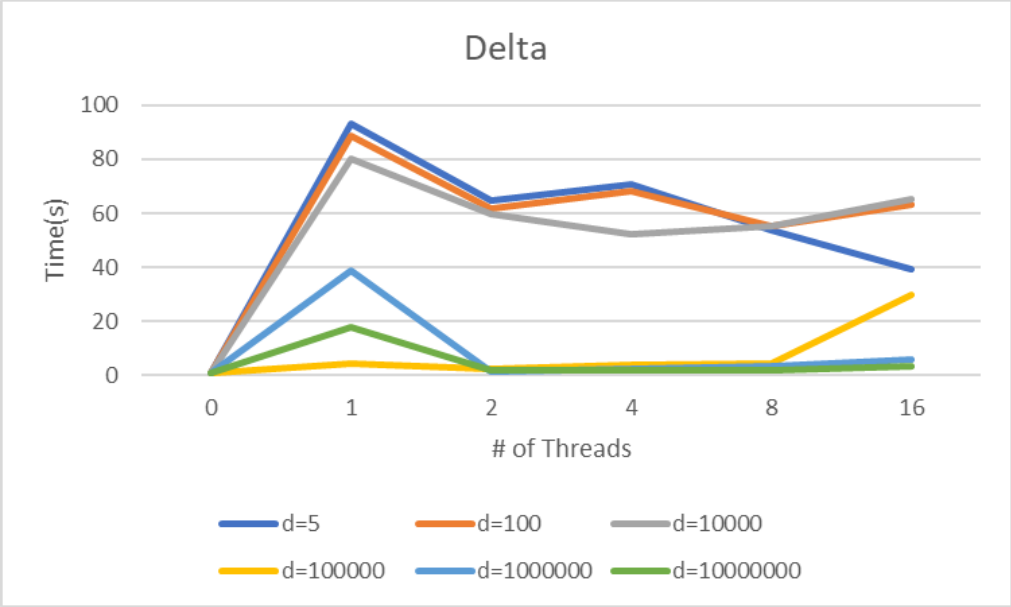
This set of data shows that our code has similar trends of speedup to professor's code, except when thread # = 1. It implies possibilities of improvement.

After this experiment, our understanding of why Dijkstra outperforms the delta-steeping is that in the current computer system, most of the data structures are designed that will be easy for the Dijkstra version of the priority queue to do the iterations. However, for the delta-stepping, we always have different threads that will do a lot of cache hits and rewrite the cache to do the algorithm. In a more idealistic situation, where there is no time consumption on the cache miss, we believe delta-steeping will be much faster than the Dijkstra algorithm.

Extra credit #2:

We added a command-line argument to control the Δ choice and experimented with its impact. The following data is obtained by testing threads in range [0, 1, 2, 4, 8, 16] with a = 0, n = 1000000, and delta in range [5, 100, 10000, 100000, 1000000, 10000000]:

# of threads	0	1	2	4	8	16
D=5	1.13	93.086	64.783	70.917	53.957	39.42
D=100	0.931	88.634	61.888	68.133	55.432	63.269
D=10000	0.984	80.095	59.95	52.209	55.307	65.026
D=100000	0.916	4.583	2.145	4.048	4.535	29.989
D=1000000	0.928	38.866	1.502	2.282	3.427	5.745
D=10000000	0.977	18.029	1.86	1.895	2.032	3.305

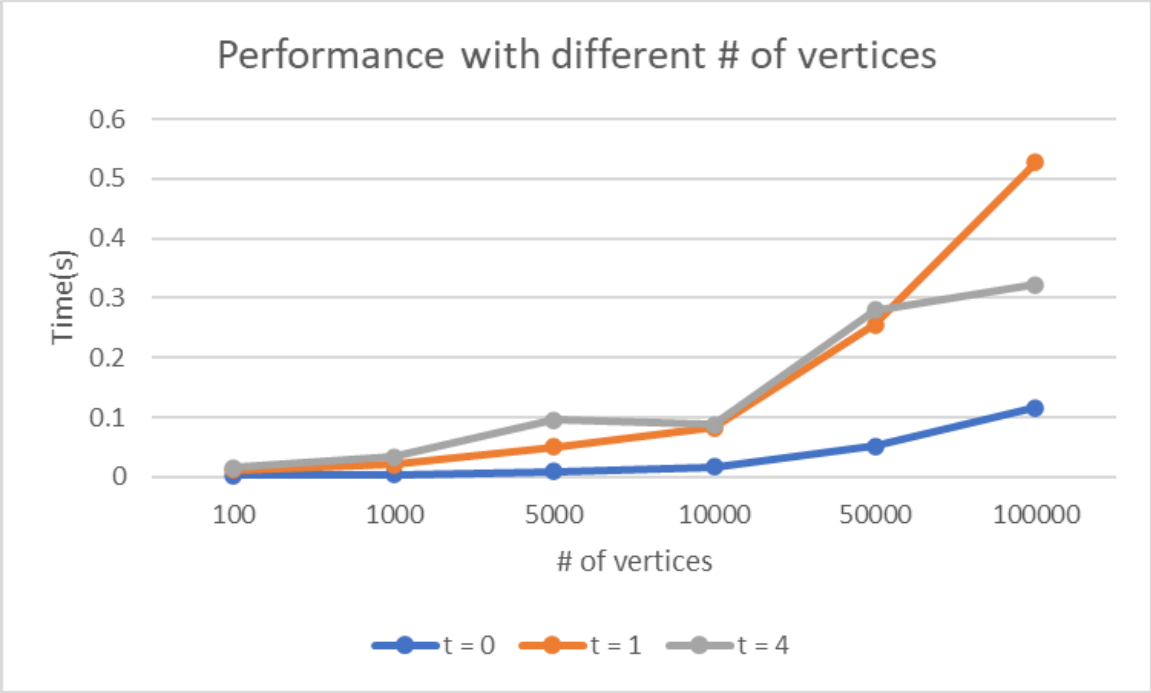


This set of data shows that larger delta generally shows better performance.

Extra credit #4:

For execution on some fixed number of threads, we obtained a set of run time versus the number of vertices. The following data is obtained by testing threads in range [0, 1, 4] with a = 0, n = [100, 1000, 5000, 10000, 50000, 100000]:

# of vertices	100	1000	5000	10000	50000	100000
t = 0	0.003	0.004	0.009	0.017	0.052	0.116
t = 1	0.011	0.02	0.05	0.082	0.255	0.528
t = 4	0.016	0.034	0.096	0.088	0.28	0.323



For execution with the sequential method, the run time increases linearly with the increase in the number of vertices. However, the run time varies in a different pattern when executed with multiple threads.

From the three threads, we can see them having very similar performance and the time increase is very similar when the number of vertices is smaller than 10000.

As a result, we feel the program might be using an L2 cache while the size of vertices is more than 10000. Before that, the program is using L1 cache.

In addition, we also see there is a significant difference between 50000 and 100000. I think it might be because the program uses an L3 cache when the number of vertices is between 50000 and 100000. After that, the program might use disk memory for saving the vertices.