

Project #3 – A Real Application Parallel Challenge

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1. What machine you ran this on?

The program was conducted on a Predator HELIOS 300 (2022).

CPU: 12th Gen Intel(R) Core™ i9-12900H
Motherboard: Mainboard PH315-55 Intel Ci912900H GN20-E6
Memory: 16GB DDR5

2. What operating system you were using?

Operating System: Windows 11 Home

3. What compiler you used?

Compiler: g++ (GCC) 4.8.5 20150623 (Red Hat 4.8.5-44)

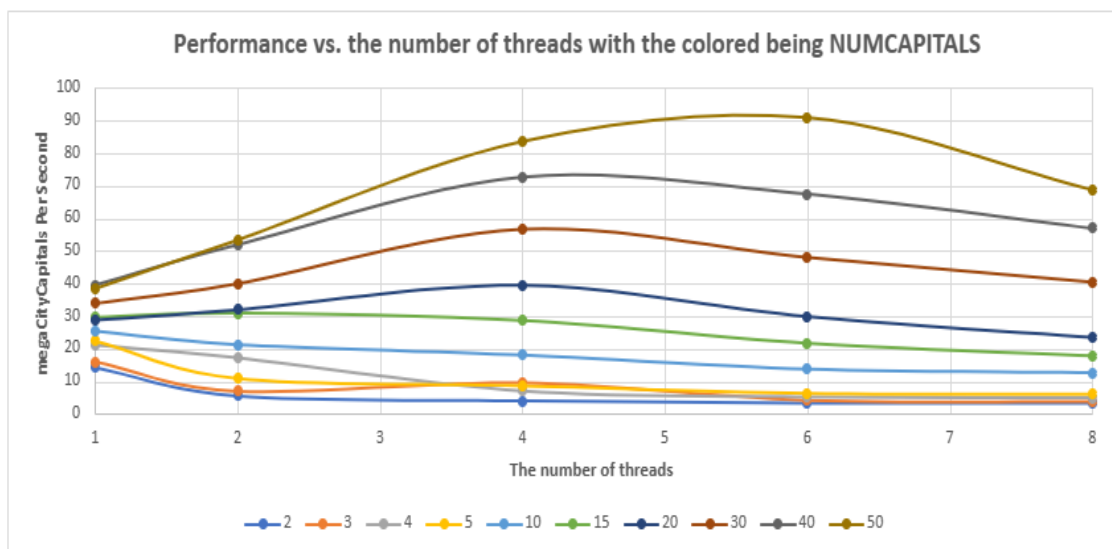
4. The table of performance data

NUMT \ NUMCAPITALS	2	3	4	5	10	15	20	30	40	50
1	14.203	15.964	21.089	22.388	25.375	29.66	28.738	33.881	39.524	38.424
2	5.454	6.897	17.172	10.819	21.245	30.9	31.899	39.916	51.904	53.344
4	3.957	9.5	7.006	8.584	18.012	28.681	39.457	56.649	72.645	83.62
6	3.283	4.148	5.206	6.275	13.736	21.679	29.84	48.029	67.482	90.965
8	3.219	3.694	4.929	6.009	12.624	17.773	23.433	40.412	56.935	68.754

The table above shows the relationship between the number of threads and capitals. The floating-point numbers denote the performance depending on the number of threads and capitals (megaCityCapitalsPerSecond). When the number of

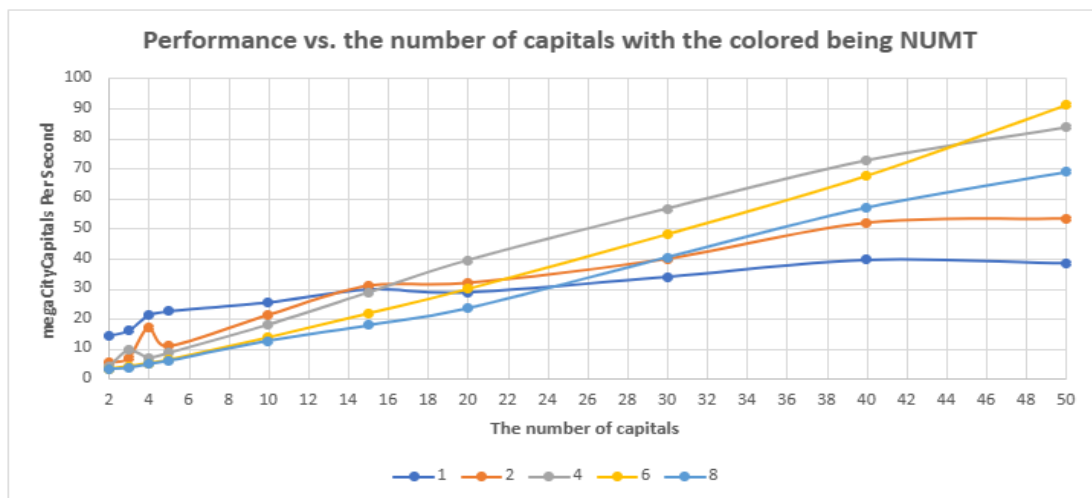
capitals increases, most of the performances also gradually increase, implying that the number of threads can affect the performance. Unlike our expectation, the increase in the number of threads does not necessarily guarantee better performance. As can be seen, When NUMCAPITALS is 50, six-threads case shows the best performance.

5. A graph of performance vs. NUMT with the colored curves being NUMCAPITALS.



The graph above shows the performance of the number of threads when the number of capitals is different. In general, all the threads show the higher performance if the number of capitals increases more and more. In the graph, six-threads case has the best performance, which is nearly 90 megaCityCapitalPerSecond. When the number of capitals is small, the performance of the least number of threads, which is just one thread, results the best performance, displaying 14 megaCityCapitalPerSecond, and is even better than the performance of six or eight threads. This implies that there are some factors affecting the performance when the number of works is small enough.

6. A graph of performance vs. NUMCAPITALS cities with the colored curves being NUMT.



As shown in the graph above, it shows the performance of the number of capitals when the number of threads is different. Until reaching 40 capitals, four-threads have best performance. When the number of capitals is 50, however, six threads are the best case, which has approximately 90 megaCityCapitalsPerSecond.

7. What you discovered by doing this? What patterns are you seeing in the graphs?

Two graphs above means that the increase in the number of threads will not always guarantee the best performance. If the number of threads guarantee the better and even best performance, these graphs are contradiction. In the lecture note "Data Composition", we may guess why this happens. One of the reasons this phenomenon occurs may be false sharing between cores. Another reason is that, as shown in two graphs, if I am not utilizing enough cores, then I am not bringing enough compute power to bear. On the other hand, if I am utilizing too many cores, then each core doesn't have enough to do and too much time is being spent getting

values from the memory that another core is computing with. These patterns can be explained with the performance graphs.

8. [Extra Credit] When you are done computing the final longitudes-latitudes of the NUMCAPITALS, go through the list of cities and print the name of the city that is closest to each capital's longitude-latitude.

The number of Capitals: 2				
Capital Number	Longitude	Latitude	City Name	State
0	116.27	37.16	LasVegas	NV
1	85.82	36.04	Murfreesboro	TN

The number of Capitals: 3				
Capital Number	Longitude	Latitude	City Name	State
0	118.27	37.15	Visalia	CA
1	80.23	36.8	Winston-Salem	NC
2	97.21	35.3	Norman	OK

The number of Capitals: 4				
Capital Number	Longitude	Latitude	City Name	State
0	120.21	45.92	Bend	OR
1	97.4	35.14	Norman	OK
2	117.89	35.43	Lancaster	CA
3	80.36	36.89	Winston-Salem	NC

The number of Capitals: 5				
Capital Number	Longitude	Latitude	City Name	State
0	120.21	45.92	Bend	OR
1	97.91	35.05	OklahomaCity	OK
2	117.89	35.43	Lancaster	CA
3	83.84	35.09	Knoxville	TN
4	74.24	40.72	Newark	NJ

The number of Capitals: 10				
Capital Number	Longitude	Latitude	City Name	State
0	120.86	45.93	Gresham	OR
1	93.79	40.52	DesMoines	IA
2	121.65	37.98	Antioch	CA
3	82.25	29.6	Gainesville	FL
4	77.91	37.26	Richmond	VA
5	117.76	34.12	Pomona	CA
6	85.76	40.39	Fishers	IN
7	96.68	31.65	Waco	TX
8	73.26	41.57	Waterbury	CT
9	109.07	36.87	RioRancho	NM

The number of Capitals: 15				
Capital Number	Longitude	Latitude	City Name	State
0	121.88	37.88	Antioch	CA
1	107.05	39.44	Boulder	CO
2	86.1	41.07	SouthBend	IN
3	94.48	44.87	Minneapolis	MN
4	95.56	32.1	Tyler	TX
5	81.93	27.81	Lakeland	FL
6	117.15	33.24	Escondido	CA
7	117.91	34.32	WestCovina	CA
8	121.77	45.89	Gresham	OR
9	118.07	41.12	Sparks	NV
10	94.28	38.9	Lee'sSummit	MO
11	82.56	34.7	Athens	GA
12	111.32	33.42	Mesa	AZ
13	99.1	30.18	SanAntonio	TX
14	74.24	40.72	Newark	NJ

The number of Capitals: 20				
Capital Number	Longitude	Latitude	City Name	State
0	121.88	37.88	Antioch	CA
1	111.72	39.85	Provo	UT
2	90.68	40.28	Springfield	IL
3	93.92	45.2	Minneapolis	MN
4	95.73	31.78	Tyler	TX
5	95.2	37.54	Olathe	KS
6	117.15	33.24	Escondido	CA
7	117.91	34.32	WestCovina	CA
8	121.77	45.89	Gresham	OR
9	118.07	41.12	Sparks	NV
10	95.77	41.79	Omaha	NE
11	82.87	41.49	Toledo	OH
12	111.15	33.14	Gilbert	AZ
13	98.44	29.39	SanAntonio	TX
14	73.18	41.57	Waterbury	CT
15	104.61	38.1	Pueblo	CO
16	87.64	42.02	Chicago	IL
17	41.13	27.46	PalmBay	FL
18	85.92	34.77	Huntsville	AL
19	78.42	36.11	Raleigh	NC

The number of Capitals: 30				
Capital Number	Longitude	Latitude	City Name	State
0	117.55	42.11	Nampa	ID
1	111.41	40.32	Provo	UT
2	90.49	39.94	Springfield	IL
3	94.96	45.9	SaintPaul	MN
4	96.48	32.05	Mesquite	TX
5	95.25	37.96	Olathe	KS
6	117.15	33.24	Escondido	CA
7	115.34	35.89	Henderson	NV
8	121.08	39	Roseville	CA
9	119.66	36.04	Visalia	CA
10	95.77	41.79	Omaha	NE
11	82.25	41.78	Cleveland	OH
12	111.15	33.14	Gilbert	AZ
13	98.39	28.95	SanAntonio	TX
14	74.51	41.09	Paterson	NJ
15	104.61	38.1	Pueblo	CO
16	88.34	42.43	Elgin	IL
17	80.88	26.8	PortSt.Lucie	FL
18	85.58	39.1	Indianapolis	IN
19	76.62	37.67	NewportNews	VA
20	92.48	43.65	Rochester	MN
21	79.67	35.04	Fayetteville	NC
22	122.09	37.69	Hayward	CA
23	85.41	42.11	GrandRapids	MI
24	121.81	45.9	Gresham	OR
25	71.66	42.12	Worcester	MA
26	90.53	31.93	Jackson	MS
27	86.32	34.84	Huntsville	AL
28	118.01	34.07	ElMonte	CA
29	83.34	32.41	Macon	GA

The number of Capitals: 40				
Capital Number	Longitude	Latitude	City Name	State
0	117.96	33.9	Fullerton	CA
1	89.04	36.53	Clarksville	TN
2	122.49	44.38	Eugene	OR
3	104.34	33.41	Lubbock	TX
4	122.15	37.74	Oakland	CA
5	121.05	38.56	Roseville	CA
6	96.91	33.11	Levisville	TX
7	117.41	34.01	JurupaValley	CA
8	85.55	40.09	Fishers	IN
9	87.67	32.09	Tuscaloosa	AL
10	111.89	40.51	WestJordan	UT
11	81.96	28.02	Lakeland	FL
12	115.63	35.5	Henderson	NV
13	113	35.38	Surprise	AZ
14	111.37	32.92	Scottsdale	AZ
15	71.33	42.27	Cambridge	MA
16	88.97	41.99	Rockford	IL
17	95.14	38.22	Olathe	KS
18	75.92	39.62	Baltimore	MD
19	80.29	26.67	WestPalmBeach	FL
20	94.32	30.16	Beaumont	TX
21	80.51	34.66	Charlotte	NC
22	82.88	41.6	Toledo	OH
23	77.46	36.27	Chesapeake	VA
24	94.58	43.88	Minneapolis	MN
25	98.05	27.36	CorpusChristi	TX
26	119.53	35.74	Bakersfield	CA
27	118.52	34.24	SantaClarita	CA
28	76.74	42.4	Syracuse	NY
29	84.73	34.42	SandySprings	GA
30	82.35	30.62	Jacksonville	FL
31	97.89	30.77	RoundRock	TX
32	104.93	39.71	Denver	CO
33	110.24	43.28	SaltLakeCity	UT
34	119.76	46.49	Kent	WA
35	80.23	26.04	Davie	FL
36	73.68	41.14	Stamford	CT
37	117.24	33.06	Carlsbad	CA
38	81.99	26.65	CapeCoral	FL
39	112.09	33.44	Phoenix	AZ

The number of Capitals: 50				
Capital Number	Longitude	Latitude	City Name	State
0	117.88	33.92	Fullerton	CA
1	89.04	36.53	Clarksville	TN
2	120.68	39.41	Reno	NV
3	122.87	38.09	SantaRosa	CA
4	121.92	37.8	Concord	CA
5	96.91	33.11	Levisville	TX
6	117.41	34.04	JurupaValley	CA
7	85.89	40.91	FortWayne	IN
8	87.67	32.09	Tuscaloosa	AL
9	111.89	40.51	WestJordan	UT
10	82.46	27.94	Tampa	FL
11	117.14	33.1	Escondido	CA
12	113	35.38	Surprise	AZ
13	111.61	33.16	Gilbert	AZ
14	71.33	42.27	Cambridge	MA
15	88.97	41.99	Rockford	IL
16	95.14	38.22	Olathe	KS
17	75.92	39.62	Baltimore	MD
18	80.29	26.67	WestPalmBeach	FL
19	94.32	30.16	Beaumont	TX
20	79.74	35.8	Greenboro	NC
21	82.88	41.6	Toledo	OH
22	76.97	36.42	Chesapeake	VA
23	94.58	43.88	Minneapolis	MN
24	98.05	27.36	CorpusChristi	TX
25	119.53	35.74	Bakersfield	CA
26	118.48	34.23	Burbank	CA
27	76.74	42.4	Syracuse	NY
28	84.73	34.42	SandySprings	GA
29	82.75	30.16	Gainesville	FL
30	97.89	30.77	RoundRock	TX
31	104.91	40.48	Greeley	CO
32	110.24	43.28	SaltLakeCity	UT
33	116.77	45.22	Meridian	ID
34	80.28	25.89	Hialeah	FL
35	73.68	41.14	Stamford	CT
36	118.03	33.77	GardenGrove	CA
37	81.99	26.65	CapeCoral	FL
38	112.25	33.49	Glendale	AZ
39	105.06	35.2	Albuquerque	NM
40	80.83	33.03	NorthCharleston	SC
41	84.87	38.45	Lexington	KY
42	80.96	28.18	Orlando	FL
43	122.19	42.95	Everett	WA
44	80.2	26.12	FortLauderdale	FL
45	104.94	39.55	Centennial	CO
46	115.75	35.64	LasVegas	NV
47	122.58	45.04	Salem	OR
48	122.27	47.47	Renton	WA

The pictures above show the number of Capitals, Capital Number, Longitude, Latitude, City Name, and State. The number of Capitals are 2, 3, 4, 5, 10, 15, 20, 30, 40, and 50, and Capitals are randomly chosen by Ranf() function, which generates

arbitrary integer number. The closest cities are selected by the Capital's longitude and latitude, which are the average of nearby cities.