Project #3

A Real Application Parallel Challenge

Name: Manoj Kumar Gummadi

OSU ID: 934565108

Email: gummadm@oregonstate.edu

1. Tell what machine you ran this on
   MacBook Pro - Apple M3 Pro

2. Tell what operating system you were using
   macOS – 14.4.1

3. Tell what compiler you used
   g++ version:
   Apple clang version 15.0.0 (clang-1500.3.9.4)
   Target: arm64-apple-darwin23.4.0
   Thread model: posix

4. Include the table of performance data.

Threads	Cities	Capitals	Performance
1	331	2	23.732
1	331	3	62.163
1	331	4	74.043
1	331	5	78.882
1	331	10	106.793
1	331	15	138.831
1	331	20	146.912
1	331	30	165.934
1	331	40	197.625
1	331	50	194.442
2	331	2	21.359
2	331	3	23.664
2	331	4	35.598
2	331	5	38.564
2	331	10	89.569
2	331	15	118.322
2	331	20	154.257
2	331	30	207.211
2	331	40	259.498
2	331	50	312.683
4	331	2	13.036
4	331	3	20.619
4	331	4	25.015
4	331	5	33.055
4	331	10	60.362
4	331	15	95.526
4	331	20	150.904
4	331	30	225.132
4	331	40	276.282
4	331	50	359.667
6	331	2	10.846
6	331	3	10.335
6	331	4	25.474
6	331	5	29.539
6	331	10	42.456
6	331	15	97.312
6	331	20	134.788
6	331	30	130.563
6	331	40	108.674
6	331	50	301.808
8	331	2	12.975
8	331	3	3.448
8	331	4	12.368
8	331	5	22.685
8	331	10	30.92
8	331	15	65.281
8	331	20	66.268
8	331	30	125.829
8	331	40	250.147
8	331	50	232.939

Extra Credit Data:

Capital City Index	Longitude	Latitude	Closest City	State of Closest City
0	85.82	36.04	Murfreesboro	TN
1	116.27	37.16	LasVegas	NV
0	77.42	39.58	Washington	DC
1	90.98	33.99	Memphis	TN
2	116.71	37.28	LasVegas	NV
0	74.24	40.72	Newark	NJ
1	83.91	35.14	Knoxville	TN
2	98.01	35	OklahomaCity	OK
3	118.27	37.15	Visalia	CA
0	74.24	40.72	Newark	NJ
1	108.1	36.56	RioRancho	NM
2	82.85	34.2	Athens	GA
3	94.64	35.37	BrokenArrow	OK
4	119.45	37.39	Clovis	CA
0	74.1	40.73	JerseyCity	NJ
1	92.01	41.15	CedarRapids	IA
2	111.39	33.45	Mesa	AZ
3	81.58	28.82	Orlando	FL
4	120.86	45.93	Gresham	OR
5	117.77	34.11	Pomona	CA
6	96.7	31.77	Waco	TX
7	106.77	39.74	Boulder	CO
8	83.57	37.95	Lexington	KY
9	121.65	37.98	Antioch	CA
0	73.03	41.52	Waterbury	CT
1	112.53	35.42	Peoria	AZ
2	119.66	36.04	Visalia	CA

3	96.97	31.62	Waco	TX
4	120.86	45.93	Gresham	OR
5	80.99	27.33	PortSt.Lucie	FL
6	86.47	33.49	Birmingham	AL
7	78.58	36	Raleigh	NC
8	82.22	41.8	Cleveland	OH
9	87.51	40.93	Joliet	IL
10	94.56	40.89	DesMoines	IA
11	105.34	38.45	ColoradoSprings	CO
12	118.41	34.17	Burbank	CA
13	117.47	33.72	Corona	CA
14	121.8	38.07	Antioch	CA
0	71.89	42.1	Worcester	MA
1	121.03	47.58	Bellevue	WA
2	120.46	39.63	Reno	NV
3	96.22	29.13	SugarLand	TX
4	88.08	41.5	Joliet	IL
5	78.79	35.47	Cary	NC
6	119.66	36.04	Visalia	CA
7	97.41	33.42	Denton	TX
8	85.75	32.61	Montgomery	AL
9	117.65	34.02	Ontario	CA
10	80.98	27.1	PortSt.Lucie	FL
11	106.77	39.74	Boulder	CO
12	75.05	40.63	Allentown	PA
13	82.76	41.65	Dearborn	MI
14	121.75	38.23	Antioch	CA
15	111.39	33.45	Mesa	AZ
16	86.22	36.62	Nashville	TN

17	120.73	44.6	Bend	OR
18	94.4	41.06	DesMoines	IA
19	122.18	37.54	Hayward	CA
0	74.5	40.78	Woodbridge	NJ
1	121.67	37.41	SanJose	CA
2	78.82	42.17	Buffalo	NY
3	120.93	39.1	Roseville	CA
4	94.48	44.87	Minneapolis	MN
5	119.6	36.65	Clovis	CA
6	105.18	39.06	ColoradoSprings	CO
7	89.23	42.98	Madison	WI
8	113.17	42.36	SaltLakeCity	UT
9	80.98	27.1	PortSt.Lucie	FL
10	73.1	41.67	Waterbury	CT
11	86.03	32.56	Montgomery	AL
12	76.62	37.67	NewportNews	VA
13	122.87	38.09	SantaRosa	CA
14	111.39	33.45	Mesa	AZ
15	94.79	38.59	Olathe	KS
16	88.97	41.07	Peoria	IL
17	118.02	34	ElMonte	CA
18	116.93	34.01	MorenoValley	CA
19	97.95	32.87	FortWorth	TX
20	119.26	34.53	Ventura	CA
21	79.93	34.72	Concord	NC
22	86.39	36.37	Nashville	TN
23	71.21	42.29	Cambridge	MA
24	121.03	47.58	Bellevue	WA
25	94.57	30.38	Beaumont	TX

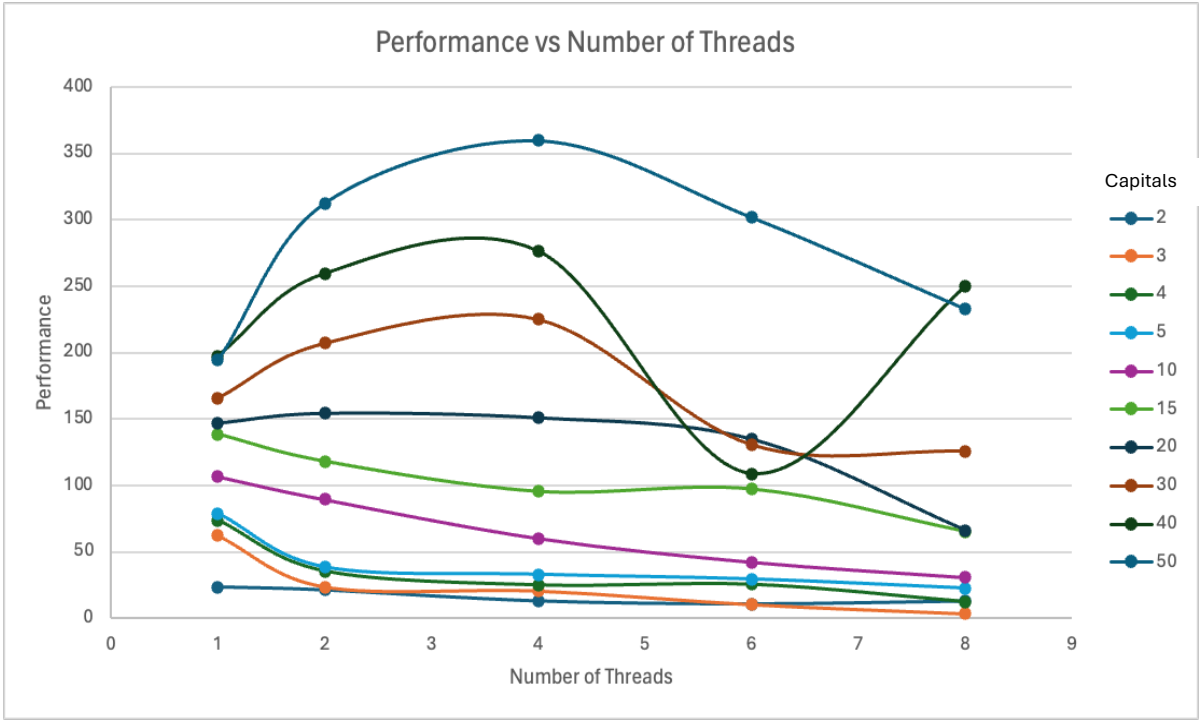
26	122.58	45.04	Salem	OR
27	98.17	27.57	CorpusChristi	TX
28	84.14	41.3	Toledo	OH
29	122.17	37.92	Berkeley	CA
0	78.15	42.39	Buffalo	NY
1	95.65	36.07	BrokenArrow	OK
2	122.46	37.89	Richmond	CA
3	122.26	47.55	Renton	WA
4	119.6	36.65	Clovis	CA
5	117.67	33.81	Anaheim	CA
6	96.88	32.97	Carrollton	TX
7	97.76	26.57	Edinburg	TX
8	79.48	35.57	Greensboro	NC
9	84.23	40.98	FortWayne	IN
10	99.49	27.56	Laredo	TX
11	82.36	27.69	St.Petersburg	FL
12	113.32	38.49	St.George	UT
13	76.62	37.67	NewportNews	VA
14	94.47	41.29	DesMoines	IA
15	87.6	34.06	Tuscaloosa	AL
16	110.66	33.44	Mesa	AZ
17	122.21	44.06	Bend	OR
18	80.29	25.92	Hialeah	FL
19	97.61	30.46	RoundRock	TX
20	80.32	33.26	NorthCharleston	SC
21	88.76	41.47	Aurora	IL
22	82.75	30.16	Gainesville	FL
23	84.31	33.96	SandySprings	GA
24	74.35	40.58	Woodbridge	NJ

25	80.26	27.01	WestPalmBeach	FL
26	101.58	33.02	Lubbock	TX
27	93.92	30.15	Beaumont	TX
28	80.96	28.18	Orlando	FL
29	81.61	32.68	Savannah	GA
30	73.1	41.67	Waterbury	CT
31	105.21	40.18	Boulder	CO
32	122.73	45.43	Portland	OR
33	119.03	34.54	Ventura	CA
34	120.46	39.63	Reno	NV
35	80.2	26.15	FortLauderdale	FL
36	71.13	41.85	Brockton	MA
37	116.77	45.22	Meridian	ID
38	71.24	42.48	Cambridge	MA
39	121.72	37.85	Antioch	CA
0	74.08	40.68	JerseyCity	NJ
1	98.1	26.77	Edinburg	TX
2	83.9	39.64	Dayton	OH
3	85.24	33.6	SouthFulton	GA
4	85.45	36.84	Louisville	KY
5	119.6	36.65	Clovis	CA
6	77.31	36.38	NewportNews	VA
7	119.04	35.35	Bakersfield	CA
8	83.74	42.42	AnnArbor	MI
9	82.42	28.83	Gainesville	FL
10	80.43	34.46	Columbia	SC
11	114.74	36.4	NorthLasVegas	NV
12	85.94	40.5	Fishers	IN
13	112	33.37	Tempe	AZ

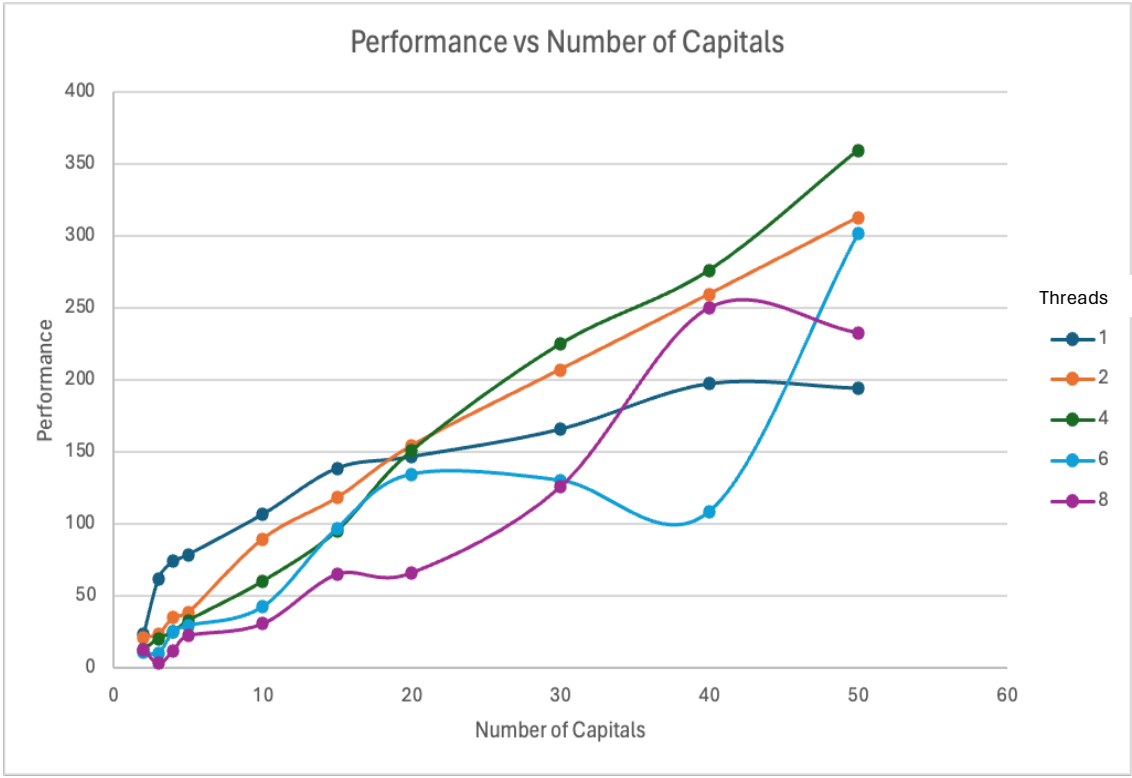
14	122.26	47.55	Renton	WA
15	117.33	34.47	Victorville	CA
16	117.44	34.03	JurupaValley	CA
17	108.55	45.79	Billings	MT
18	101.58	33.02	Lubbock	TX
19	88.97	41.99	Rockford	IL
20	81.06	41	Akron	OH
21	91.08	31.55	BatonRouge	LA
22	88.77	37.08	Clarksville	TN
23	104.93	39.71	Denver	CO
24	122.17	37.92	Berkeley	CA
25	71.21	42.29	Cambridge	MA
26	117.13	32.95	SanDiego	CA
27	95.18	29.78	Pasadena	TX
28	77.54	43.03	Rochester	NY
29	76.9	39.01	Washington	DC
30	94.34	44.32	Minneapolis	MN
31	75.31	40.3	Philadelphia	PA
32	116.4	43.6	Meridian	ID
33	121.67	37.41	SanJose	CA
34	97.61	30.46	RoundRock	TX
35	95.04	38.65	Olathe	KS
36	120.93	39.1	Roseville	CA
37	111.98	40.69	WestValleyCity	UT
38	73.03	41.77	Waterbury	CT
39	111.65	40.25	Provo	UT
40	117.17	33.58	Murrieta	CA
41	117.33	47.67	Spokane	WA
42	119.63	34.47	Ventura	CA

43	106.64	33.64	LasCruces	NM
44	80.4	26.36	CoralSprings	FL
45	117.93	33.85	Fullerton	CA
46	118.38	34.23	Burbank	CA
47	96.94	33.22	Frisco	TX
48	122.58	45.04	Salem	OR
49	122.87	38.09	SantaRosa	CA

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



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



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

The first graph, showing performance as a function of the number of capitals, suggests a clear trend where performance improves significantly as the number of capitals increases, reaching a peak before plateauing or even declining slightly. This improvement could be attributed to the division of the computational workload into smaller, more manageable parts that can be processed in parallel more efficiently. As the number of capitals increases, each processing thread (or group of threads) might be dealing with fewer cities, thus reducing the computational burden per thread, and enhancing performance. However, the plateauing or decline in performance at higher numbers of capitals could indicate overhead costs associated with managing a larger number of capitals, such as increased communication between threads or synchronization costs.

In contrast, the second graph illustrates performance versus the number of threads. Here, performance increases as the number of threads is increased but only up to a certain

point, after which it begins to decline. This peak in performance indicates an optimal point where the hardware resources (such as CPU cores) are fully utilized without causing significant overhead from context switching or resource contention. Beyond this optimal point, the costs associated with managing additional threads likely outweigh the benefits of parallel execution, leading to reduced efficiency. This graph vividly demonstrates the principle of diminishing returns in parallel computing, where increasing the number of threads beyond the capabilities of the hardware and the nature of the task can lead to a decrease in performance efficiency.