Assignment 1 - Basics of Parallel Computing 191.114, SS 2024

`GROUP_NUMBER`=13, `GROUP_SIZE`=2

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2024-04-18

Contents

1. The Tasks

1.1. Compute Speed-up and Parallel Efficiency for 2 Instance Sizes

Speedup

- What difference does parallelization make?
- $S_a(n,p) = \frac{T_{\text{seq}}(n)}{T_{\text{par}}(n,p)}$ = absolute speedup
- $S_r(n,p) = \frac{T_{\text{par}}(n,1)}{T_{\text{par}}(n,p)}$ = relative speedup
- Where:
  - n = input size
  - p = number of processors
  - $T_{\text{par}}(n,p)$ = parallel runtime
  - $T_{\text{seq}}(n)$ = sequential runtime

Efficiency of Parallelization

- What difference does each processor make?
- $E(n,p) = \frac{T_{\text{seq}}(n)}{p \cdot T_{\text{par}}(n,p)} = \frac{1}{p} \cdot S_a(n,p)$

Table for S-Case

size	p	mean runtime (s)	speed-up	par. eff.
155	1	0.276419	1	1.42473
155	2	0.14614	1.89147	1.34742

size	p	mean runtime (s)	speed-up	par. eff.
155	4	0.0850049	3.2518	1.15824
155	8	0.0684728	4.03691	0.71894
155	16	0.0727858	3.7977	0.338169
155	24	0.0845242	3.27029	0.194137
155	32	0.0975262	2.8343	0.126191
1100	1	13.42	1	1.40137
1100	2	6.66189	2.01444	1.41149
1100	4	3.37751	3.97333	1.39203
1100	8	1.72664	7.7723	1.36149
1100	16	0.908652	14.7691	1.29356
1100	24	0.654567	20.5021	1.19713
1100	32	0.564249	23.7838	1.04156

Keep in mind that while the speed-up was calculated using `p=1` as the reference point, the parallel efficiency was calculated using an average of the sequential runtime, by running the following commands 3 times on the Hydra-cluster and averaging the results:

```
srun -p q_student -t 1 -N 1 -c 32 python3 julia.py --size 155 --nprocs 1 # 155;20;1;0.3938230010680
srun -p q_student -t 1 -N 1 -c 32 python3 julia.py --size 1100 --nprocs 1 # 1100;20;1;18.8063849839
```

Table for B-Case

size	p	mean runtime (s)	speed-up	par. eff.
155	1	0.394086	1	0.711286
155	2	0.210897	1.86862	0.66456
155	4	0.121818	3.23504	0.575259
155	8	0.0862224	4.57057	0.406373
155	16	0.0852527	4.62256	0.205497
155	24	0.0963721	4.08921	0.121191
155	32	0.108531	3.6311	0.0807109
1100	1	19.1049	1	0.68691
1100	2	9.67163	1.97536	0.678447
1100	4	4.90018	3.89883	0.669536
1100	8	2.4526	7.78967	0.66885
1100	16	1.28631	14.8525	0.637646
1100	24	0.900398	21.2183	0.607295
1100	32	0.746145	25.6049	0.549633

Keep in mind that while the speed-up was calculated using `p=1` as the reference point, the parallel efficiency was calculated using an average of the sequential runtime, by running the following commands 3 times on the Hydra-cluster and averaging the results:

```
srun -p q_student -t 1 -N 1 -c 32 python3 julia.py --size 155 --nprocs 1 --benchmark # 155;20;1;0.2
srun -p q_student -t 1 -N 1 -c 32 python3 julia.py --size 1100 --nprocs 1 --benchmark # 1100;20;1;1
```

Comparing: Absolute Speed-up vs. Number of Processes

The exec-time plot shows how due to the overhead

Comparing: Relative Speed-up vs. Number of Processes

Comparing: Parallel Efficiency vs. Number of Processes

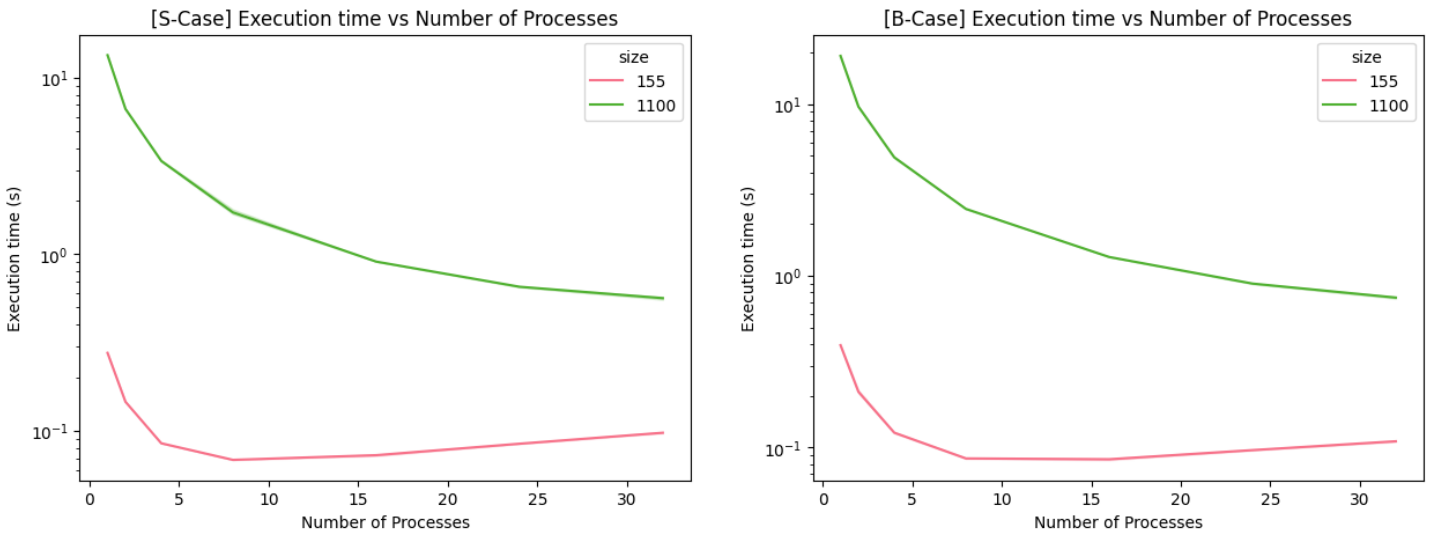

Figure 1: Absolute Runtime vs. Number of Processes

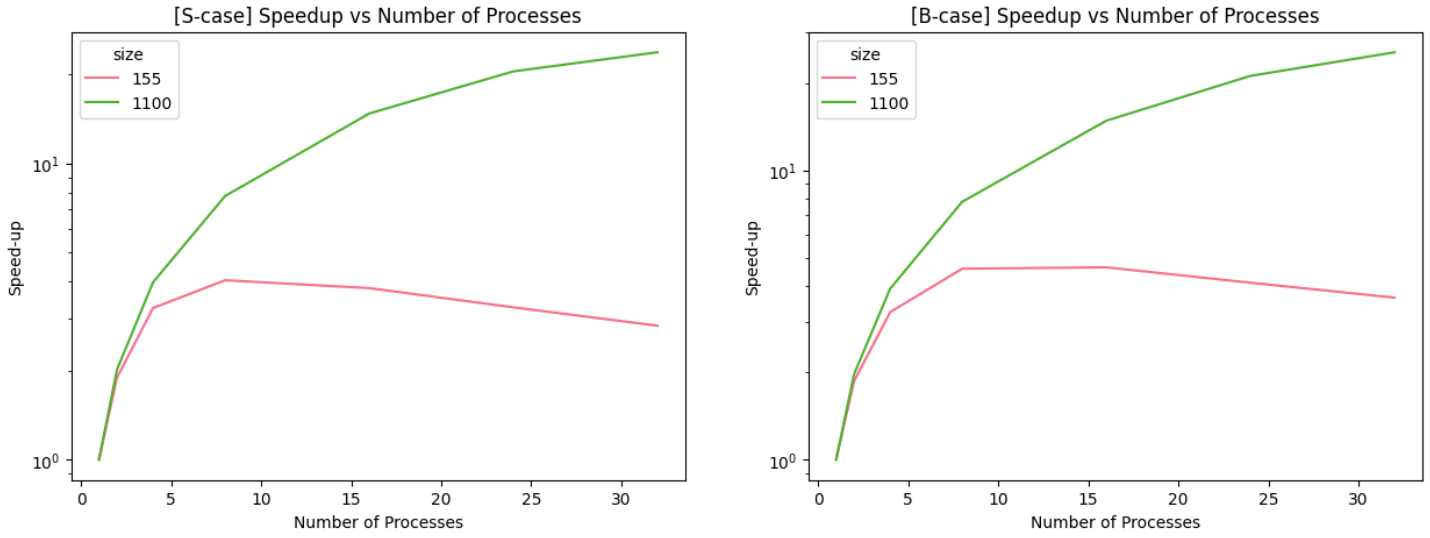

Figure 2: Relative Speed-up vs. Number of Processes

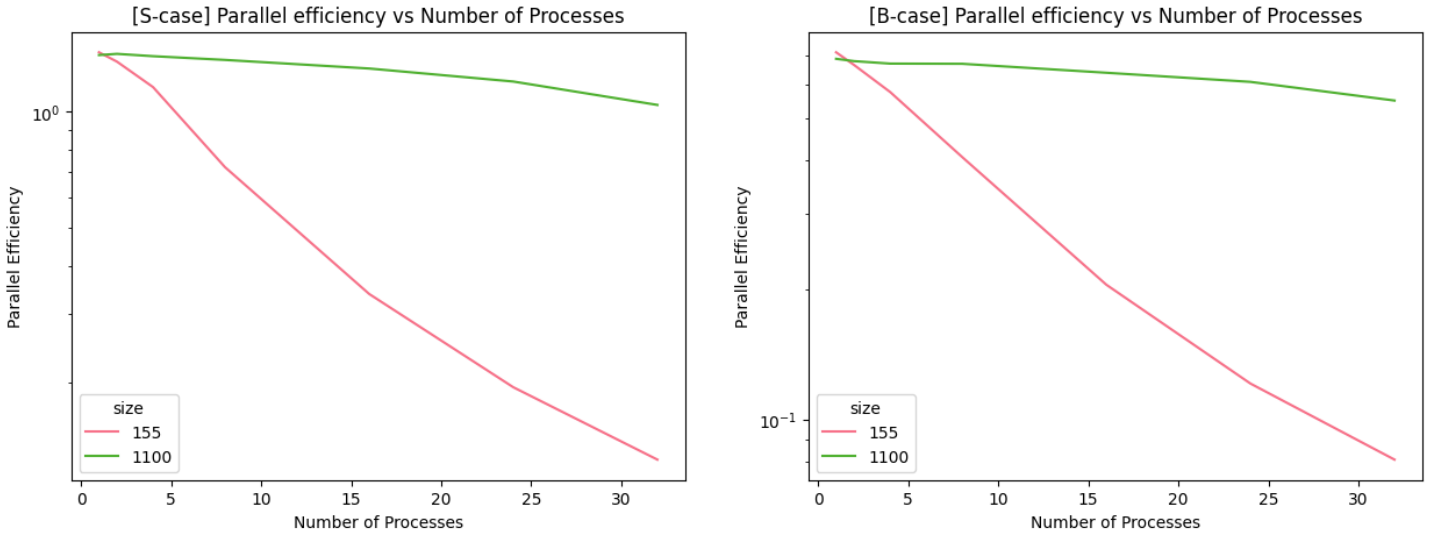

Figure 3: Parallel Efficiency vs. Number of Processes

1.2. Influence of Patch Size

1.3. Finding the Best Patch Size

2. Speed-up Analysis

Comparing two sorting algorithms:

- Algorithm 1: $T_{par}^{\mathcal{A}_1}(n,p) = \mathcal{O}(\frac{n \log n}{p} + \log n)$
- Algorithm 2: $T_{par}^{\mathcal{A}_2}(n,p) = \mathcal{O}(\frac{n \log n}{p} + n)$

The best runtime for a sequential implementation is in $T_{\text{seq}^*}(n) = \mathcal{O}(n \log n)$.

the absolute speed-up of algorithm 1

the absolute speed-up of algorithm 2

3. Weak Scaling Analysis

Appendix

A.1. System Information

```
bopc23s9@hydra-head:~$ lscpu

Architecture:                    x86_64
CPU op-mode(s):                  32-bit, 64-bit
Byte Order:                      Little Endian
Address sizes:                   46 bits physical, 48 bits virtual
CPU(s):                          16
On-line CPU(s) list:             0-15
Thread(s) per core:              1
Core(s) per socket:              16
Socket(s):                       1
NUMA node(s):                    1
Vendor ID:                       GenuineIntel
CPU family:                      6
Model:                           85
Model name:                      Intel(R) Xeon(R) Gold 6130 CPU @ 2.10GHz
Stepping:                        4
CPU MHz:                         1000.151
CPU max MHz:                     3700.0000
CPU min MHz:                     1000.0000
BogoMIPS:                        4200.00
L1d cache:                       512 KiB
L1i cache:                       512 KiB
L2 cache:                        16 MiB
L3 cache:                        22 MiB
NUMA node0 CPU(s):               0-15
...
```

A.2. Raw Data

output_exp22_1.csv

size	patch	nprocs	time
155	26	1	0.27615245105698705
155	26	1	0.27596693905070424
155	26	1	0.2771365772932768
1100	26	1	13.435972596984357

size	patch	nprocs	time
1100	26	1	13.452274681068957
1100	26	1	13.371691829990596
155	26	2	0.14638189878314734
155	26	2	0.14576987363398075
155	26	2	0.1462678317911923
1100	26	2	6.670089309103787
1100	26	2	6.613465172238648
1100	26	2	6.7021133550442755
155	26	4	0.08490922581404448
155	26	4	0.08491231314837933
155	26	4	0.08519301796332002
1100	26	4	3.3561069620773196
1100	26	4	3.3553116391412914
1100	26	4	3.421122542116791
155	26	8	0.06856991816312075
155	26	8	0.06856326712295413
155	26	8	0.06828531296923757
1100	26	8	1.6898975907824934
1100	26	8	1.7937131081707776
1100	26	8	1.6963165369816124
155	26	16	0.07205457100644708
155	26	16	0.0730455950833857
155	26	16	0.07325727492570877
1100	26	16	0.9077705508098006
1100	26	16	0.9078279393725097
1100	26	16	0.9103577299974859
155	26	24	0.0845845378935337
155	26	24	0.08471266506239772
155	26	24	0.08427527407184243
1100	26	24	0.656599803827703
1100	26	24	0.6573387430980802
1100	26	24	0.6497617312707007
155	26	32	0.0973281990736723
155	26	32	0.09837603475898504
155	26	32	0.09687442006543279
1100	26	32	0.5734831769950688
1100	26	32	0.5541784320957959
1100	26	32	0.565086467191577

output_exp22_2.csv

size	patch	nprocs	time
155	26	1	0.392238802742213
155	26	1	0.39877972193062305
155	26	1	0.3912382051348686
1100	26	1	19.34426457900554
1100	26	1	18.90565126761794
1100	26	1	19.064889647066593
155	26	2	0.20706806099042296
155	26	2	0.20968409720808268
155	26	2	0.2159389308653772
1100	26	2	9.65854894882068
1100	26	2	9.758664200082421
1100	26	2	9.597689433023334
155	26	4	0.12078673578798771

size	patch	nprocs	time
155	26	4	0.12187985517084599
155	26	4	0.12278737686574459
1100	26	4	4.8538289330899715
1100	26	4	4.949722504708916
1100	26	4	4.896979348734021
155	26	8	0.08609647722914815
155	26	8	0.08687825128436089
155	26	8	0.0856924457475543
1100	26	8	2.4588615149259567
1100	26	8	2.4403636367060244
1100	26	8	2.4585742950439453
155	26	16	0.08432547515258193
155	26	16	0.08534767106175423
155	26	16	0.08608504896983504
1100	26	16	1.2857805700041354
1100	26	16	1.28942183079198
1100	26	16	1.2837325409054756
155	26	24	0.09584450582042336
155	26	24	0.09703108435496688
155	26	24	0.09624077333137393
1100	26	24	0.9055881663225591
1100	26	24	0.8943913546390831
1100	26	24	0.9012130876071751
155	26	32	0.10889460984617472
155	26	32	0.10903614293783903
155	26	32	0.1076613599434495
1100	26	32	0.7539521278813481
1100	26	32	0.7489344119094312
1100	26	32	0.7355474359355867

`output_exp23.csv`

size	patch	nprocs	time
950	1	32	60.38315498735756
950	1	32	58.993379454128444
950	1	32	59.664796941913664
950	5	32	2.4295669128187
950	5	32	2.457375079859048
950	5	32	2.430592040065676
950	10	32	0.8235339601524174
950	10	32	0.8456530389375985
950	10	32	0.8123667249456048
950	20	32	0.592178599908948
950	20	32	0.5885163000784814
950	20	32	0.5882865060120821
950	55	32	0.640842576045543
950	55	32	0.6622877516783774
950	55	32	0.6463527246378362
950	150	32	1.804339012131095
950	150	32	1.7855969751253724
950	150	32	1.7837719358503819
950	400	32	5.342996523249894
950	400	32	5.354430069215596
950	400	32	5.3442102540284395

output_exp24.csv

size	patch	nprocs	time
800	1	16	51.77733509801328
800	1	16	48.679752216208726
800	1	16	49.604969315230846
800	2	16	12.208631441928446
800	2	16	12.400218938011676
800	2	16	12.67593849496916
800	3	16	5.231156553607434
800	3	16	5.173088782932609
800	3	16	5.30134785734117
800	4	16	2.795454104896635
800	4	16	2.8061751988716424
800	4	16	2.743914455641061
800	5	16	1.7844559531658888
800	5	16	1.795137454289943
800	5	16	1.754671474918723
800	6	16	1.2681594076566398
800	6	16	1.2242525001056492
800	6	16	1.2942032269202173
800	7	16	1.0078809931874275
800	7	16	1.0316235939972103
800	7	16	1.0379106737673283
800	8	16	0.8636039649136364
800	8	16	0.8836448309011757
800	8	16	0.8675666828639805
800	9	16	0.8217232823371887
800	9	16	0.8141451748088002
800	9	16	0.8879383755847812
800	10	16	0.8032627403736115
800	10	16	0.790965499356389
800	10	16	0.7719701924361289
800	11	16	0.775052934885025
800	11	16	0.7863136758096516
800	11	16	0.7699855691753328
800	12	16	0.7268759598955512
800	12	16	0.7416912410408258
800	12	16	0.7239395705983043
800	13	16	0.7274400270543993
800	13	16	0.7136987750418484
800	13	16	0.7242374992929399
800	14	16	0.7333642770536244
800	14	16	0.7298130737617612
800	14	16	0.7357385512441397
800	15	16	0.7113026860170066
800	15	16	0.7115092552267015
800	15	16	0.7147729960270226
800	16	16	0.7343269921839237
800	16	16	0.7277633068151772
800	16	16	0.7470175549387932
800	17	16	0.7087195003405213
800	17	16	0.7273335340432823
800	17	16	0.7066979217343032
800	18	16	0.7008385430090129
800	18	16	0.7211737250909209
800	18	16	0.7053795196115971

size	patch	nprocs	time
800	19	16	0.704965204000473
800	19	16	0.7185817346908152
800	19	16	0.7119517708197236
800	20	16	0.7045390028506517
800	20	16	0.7090244409628212
800	20	16	0.6993431178852916
800	21	16	0.7067825132980943
800	21	16	0.7152607310563326
800	21	16	0.7141714952886105
800	22	16	0.7289159940555692
800	22	16	0.7070880490355194
800	22	16	0.7090400322340429
800	23	16	0.7122855372726917
800	23	16	0.7262964779511094
800	23	16	0.7180132349021733
800	24	16	0.7030764939263463
800	24	16	0.7233439306728542
800	24	16	0.7046146122738719
800	25	16	0.7067729285918176
800	25	16	0.7068284871056676
800	25	16	0.7069635195657611
800	26	16	0.7092408840544522
800	26	16	0.7142819189466536
800	26	16	0.7060380070470273
800	27	16	0.7240377422422171
800	27	16	0.703698709141463
800	27	16	0.7189373909495771
800	28	16	0.7107441178523004
800	28	16	0.7102009649388492
800	28	16	0.7038759361021221
800	29	16	0.7044810829684138
800	29	16	0.7004124890081584
800	29	16	0.7011993718333542
800	30	16	0.7012511510401964
800	30	16	0.7043010322377086
800	30	16	0.7103770151734352