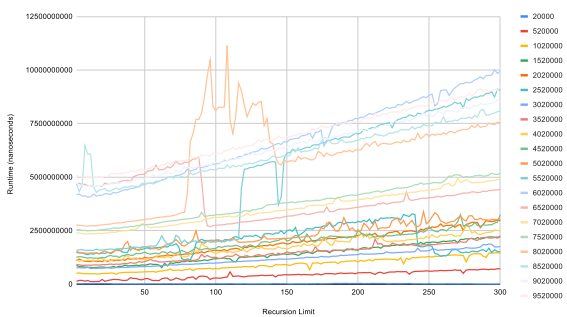


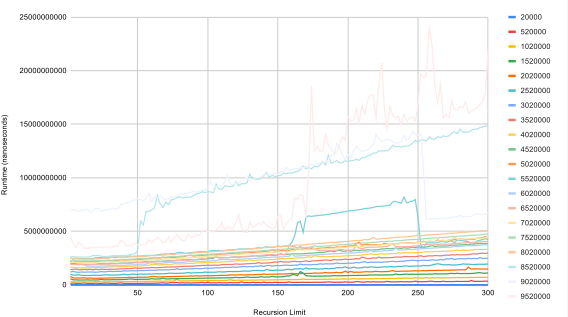
Kasen Teoh CS 1C Assignment #8

Array size	Recursion Limit	Runtime-1 (ns)	Runtime-2 (ns)	Runtime-3 (ns)	Average Runtime (ns)
20000	2	22970700	20233600	14896900	19367033.33
20000	4	16934700	20073700	13903800	16970733.33
20000	6	16859100	23472200	15853900	18727966.67
20000	8	22059000	20497000	9843700	17456566.67
20000	10	22626300	20355900	13171400	18896966.67
20000	12	17039000	10168900	12620000	13275966.67
20000	14	20685500	10354800	13810800	14950366.67
20000	16	22109600	14190400	15060800	17128933.33
20000	18	18831300	12700200	13419800	14893766.67
20000	20	26373200	15278700	9369200	17007033.33
20000	22	19857100	11353800	11242300	14151066.67
20000	24	22717800	14934400	10197100	15949766.67
20000	26	19173200	14893600	7550800	13862533.33
20000	28	7775200	13172300	5015100	8654200
20000	30	9770000	6318400	4529100	7005833.333
20000	32	10632800	7872000	5204700	7903166.667
20000	34	10878100	6492600	5033400	7468033.333
20000	36	7617300	7786200	5028400	6804833.333
20000	38	10330700	6344400	7541500	8074866.667
20000	40	7756100	5263900	7785500	6935166.667
20000	42	7914600	5503500	7402800	6940300
20000	44	8393300	5198000	8172100	7254466.667
20000	46	8843800	5537500	7571800	7317700
20000	48	9306300	6062500	7451400	7613400
20000	50	9385900	5221300	9374600	7930800
20000	52	11700800	5256900	8796100	8584600
20000	54	11664700	6921700	7243200	8609866.667
20000	56	12495200	6306000	6813800	8544533.333
20000	58	12111600	6306500	5897900	8102000
20000	60	10743300	3850900	8696200	7764133.333
20000	62	10596900	5630800	8439400	8222366.667
20000	64	13894200	5874200	10104700	9957700
20000	66	11848600	7495600	8553900	9299700
20000	68	14095100	6028300	10112100	10776500
20000	70	9405900	6287000	1006900	8594566.667
20000	72	11457200	6831000	9960900	9416366.667
20000	74	10515700	6767800	9537800	8940433.333
20000	76	7940900	6532700	6716500	7063366.667
20000	78	10487200	4459900	6344000	7096900
20000	80	11712200	3811000	10784800	8769266.667
20000	82	11793500	7039200	11412800	10081833.33
20000	84	7884300	6805100	10680900	8456766.667
20000	86	14477100	6738600	7354000	9523233.333
20000	88	14660400	6529800	5039000	8741733.333
20000	90	14284300	7037200	6221200	9180900
20000	92	10676700	5359400	6529900	7755333.333
20000	94	14081600	5918000	8137200	9378933.333
20000	96	15061800	8729000	7816400	10535733.33
20000	98	9701800	6985300	6569900	7751333.333
20000	100	15946300	6517500	6873900	9812566.667
20000	102	13289000	4655300	8445700	8798000
20000	104	12162700	6568400	9410300	9380466.667
20000	106	13088800	3976500	7081100	8048800
20000	108	13399500	4553500	7560900	8504833.333
20000	110	17367700	4678500	9017800	10354866.67
20000	112	15067000	3738900	6952700	8586200
20000	114	9073000	6218200	10542000	8611066.667
20000	116	9977200	6568500	11909600	9485100
20000	118	11019300	6532500	7756300	8469366.667
20000	120	18361400	6448800	8032300	10294066.67
20000	122	8752000	6901400	8888800	8080666.667
20000	124	9307900	6697700	10430600	8812066.667
20000	126	7191300	6588200	8483900	7421033.333
20000	128	9196100	6884500	10775700	8854533.333
20000	130	10091900	6701200	7823100	8502066.667
20000	132	9256500	7201300	6639400	7699066.667
20000	134	9361800	4244600	8324300	7310233.333
20000	136	8557000	3992500	6676400	6408533.333
20000	138	9693000	4299600	7042500	7008366.667
20000	140	18579500	4259200	5912700	9592466.667
20000	142	17975200	7678800	6652900	10769300
20000	144	17688900	5687700	8489900	10608833.33
20000	146	15925300	4135900	7934400	9331866.667
20000	148	17904300	4442000	7043300	9796533.333
20000	150	12013800	5082900	8417900	8504866.667
20000	152	8594000	5090400	6278200	5977533.333
20000	154	8763700	5289300	9686800	7913266.667
20000	156	13349800	7279900	10761300	10463533.33

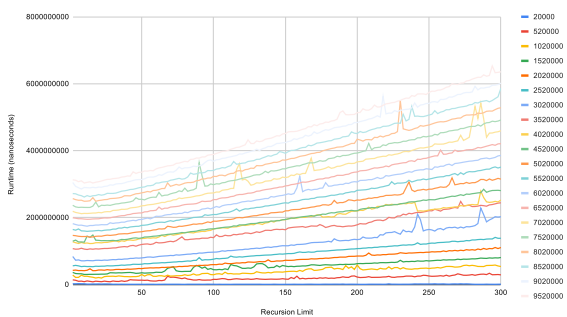
Runtime vs Recursion Limit (Run 1)



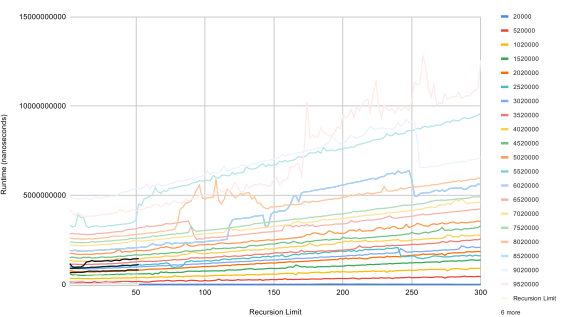
Runtime vs Recursion Limit (Run 3)



Runtime vs Recursion Limit (Run 2)

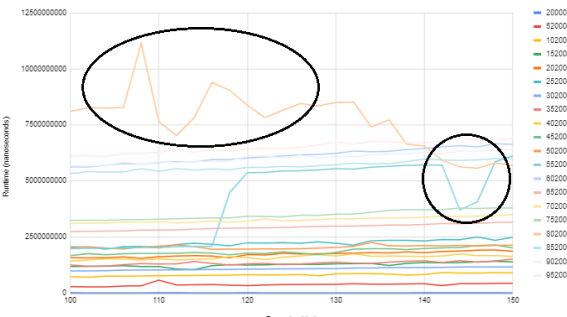


Runtime vs Recursion Limit (Average Runtime)



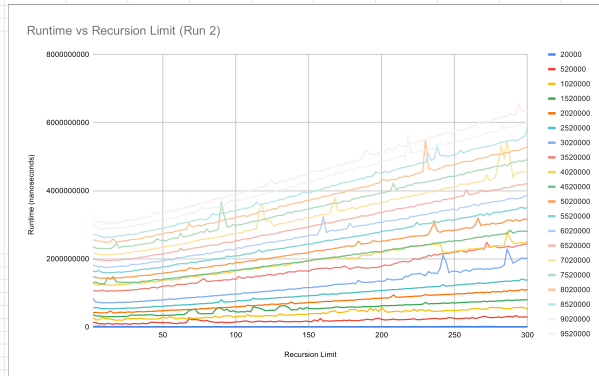
Annotations

Zoom in of Run 1 Graph (Recursion Limit 100-150)



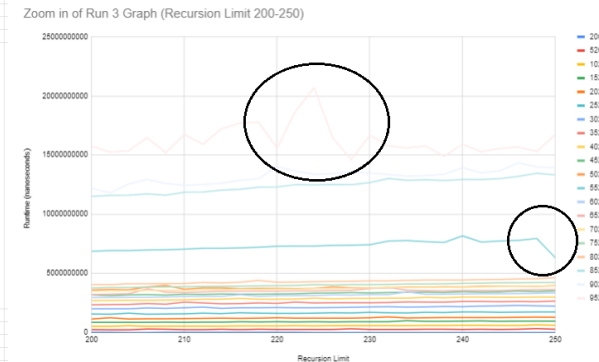
To the left, is a zoomed in part of the first run graph between the recursion limit of 100 and 150. I had picked this part to zoom in because every line seems to be straight with the exception of two lines. The 5,520,000 (light orange) and 8,020,000 (light blue) lines. The light orange line, although in this section, as the recursion limit increased, the runtime was decreasing; however, if we look at the entire graph the overall trend is that as the recursion limit increases, the runtime increases as well. As for the light blue line, its overall trend had followed the rest of the lines, that is as the recursion limit increased, the runtime increased as well. However, I had also noticed in the light blue line, between 140 and 150 recursions, it had a significant drop in the runtime which was a bit surprising.

20000	158	13097400	5707300	6448700	8418133.333
20000	160	11968100	5796000	7944100	8569400
20000	162	14224300	4603300	10805300	9910986.667
20000	164	8907700	6740200	10805000	8817633.333
20000	166	17814600	7817900	8271100	11301200
20000	168	17045200	8210100	8280000	11178433.33
20000	170	15443200	5858500	7076200	9459300
20000	172	22453100	6250900	7045500	11583166.67
20000	174	12865700	4799000	6726200	8130300
20000	176	15926900	7621400	6508200	10018833.33
20000	178	16420800	8554000	11466600	12147133.33
20000	180	19671400	7595300	17862100	15076266.67



For the second run, I chose not to zoom in on a section of the graph because throughout the graph, the varying array sizes are somewhat uniform. The overall trend of the graphs is that as the recursion limit increases, the runtime increases as well. An important observation from this graph would be that as the array size increases, runtime increases as well. If we compare this graph with the other two runs, we see that this graph is more "normal" than the others because the first and third run both have array sizes that have steep drops and sudden increases.

20000	182	25619100	7627700	15109600	16138800
20000	184	33571800	8793400	18286100	19877100
20000	186	31794700	8507800	16640000	18980833.33
20000	188	29359500	7559600	20874100	19297733.33
20000	190	33383200	11513400	24562500	23153033.33
20000	192	34379000	5760300	20273400	20137566.67
20000	194	25078400	7552300	25715700	15468133.33
20000	196	30555200	7813700	22085800	20151566.67
20000	198	28502500	7289400	13781100	16524333.33
20000	200	25712900	5755100	15749000	15739000
20000	202	34603500	4024100	14895000	17870866.67
20000	204	21255100	4094800	13411200	12620300
20000	206	27617700	4106300	14728900	15484300
20000	208	23971800	7120900	16749900	15947533.33
20000	210	32103600	7607200	17460100	19056966.67
20000	212	29643100	7330700	19434700	18802833.33
20000	214	27960800	7168200	21889600	19050200
20000	216	26096200	7223200	18028900	17779433.33
20000	218	28336900	5778900	16111400	16742400
20000	220	17721700	6947000	20289700	14986133.33
20000	222	14110500	17863000	15104400	15692833.33
20000	224	21504800	7805700	12897900	14150800
20000	226	22901800	8079900	13328000	14769900
20000	228	19084700	7076700	10900600	12354000
20000	230	18465900	6233600	10002100	11567200
20000	232	22182600	7461800	8609900	12751433.33
20000	234	23124900	7368700	9746500	13413366.67



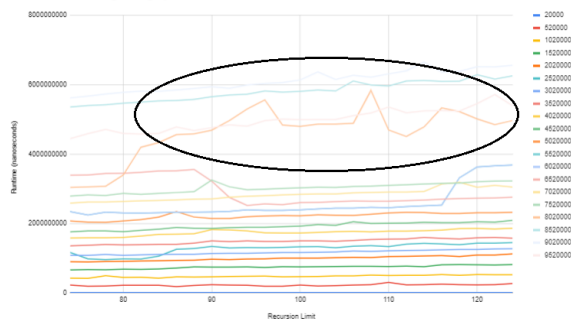
To the left is the zoomed in portion of the third run. In this section of the graph, we see that the only line that is significantly difference is the light pink like or the one of the value 9,520,000. This graph does follow the outlying shape, with runtime increasing as the recursion limit increases; however, it also includes a steep increase and decrease in the middle when the recursion limit is around 225. As for the middle blue line, with the value of 5,520,000 we see that at the 250 recursion limit, the runtime begins to decrease. We see that this is consistent with the zoomed in portion of run 1 where an array size of 5,520,000 has a portion during the run where it decreases significantly.

20000	236	29930000	7405000	10225100	15853366.67
20000	238	18174000	9984300	9784100	12647466.67
20000	240	13580300	15689400	12929200	140606300
20000	242	18040300	13611700	12363700	14015033.33
20000	244	15789700	14743500	12897700	14505200
20000	246	12028600	13615200	9542800	11728200
20000	248	10098300	13974000	11611700	11894666.67
20000	250	17129500	13881200	11216300	14075666.67
20000	252	11377900	14541800	11730600	1250100
20000	254	10140800	18793700	10033300	12995966.67
20000	256	10045400	13067800	6415300	9842833.333
20000	258	11398400	14015500	6780500	10731466.67
20000	260	10064400	16716000	8433900	11738100
20000	262	15402500	1098500	7699100	11362833.33
20000	264	14122000	8670900	6471900	9754833.333
20000	266	12426500	14411700	6469800	11102666.67
20000	268	12056800	16029900	6616700	11567800
20000	270	10633300	13449000	6676700	10253000
20000	272	11335200	19211800	6623100	12389966.67
20000	274	15399000	1410900	6521000	1199966.67
20000	276	13476000	17082200	7625400	12727866.67
20000	278	14994000	13696400	5586100	11425500
20000	280	12323800	7975000	5358500	8552433.333
20000	282	7214000	5025400	5307300	5848900
20000	284	5948300	5214400	6463100	5874600
20000	286	5911600	5012800	5432800	5452400
20000	288	5896200	5434100	7172800	6168633.333
20000	290	5417500	8580800	6787800	6628633.333
20000	292	4809000	6103200	5673300	5528500

[illegible]

Number of nodes	Average run time (20000 nodes)	Average run time (50000 nodes)	Average run time (100000 nodes)
2	1200		
4	1200		
6	1200		
8	1200		
10	1200		
12	1200		
14	1200		
16	1200		
18	1200		
20	1200		
22	1200		
24	1200		
26	1200		
28	1200		
30	1200		
32	1200		
34	1200		
36	1200		
38	1200		
40	1200		
42	1200		
44	1200		
46	1200		
48	1200		
50	1200		
52	1200		
54	1200		
56	1200		
58	1200		
60	1200		
62	1200		
64	1200		
66	1200		
68	1200		
70	1200		
72	1200		
74	1200		
76	1200		
78	1200		
80	1200		
82	1200		
84	1200		
86	1200		
88	1200		
90	1200		
92	1200		
94	1200		
96	1200		
98	1200		
100	1200		
102	1200		
104	1200		

Zoomed in of Average run graph



To the left is the zoomed in portion of the average runtime graph between the recursion limits of 74 and 124. In this section, we can see that they most varying graph is the light orange or of the array size value 8,020,000. Other lines towards the bottom of the graph seem to have no fluctuations or very minimal change in the runtime as the recursion limit increases.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

3520000	240	1805963100	2137977000	2639628900	2194623000
3520000	242	1788917300	2154214000	2635673300	2192934867
3520000	244	1825295800	2150074200	2622910900	2199426967
3520000	246	1836074100	2165057000	2631386900	2210840233
3520000	248	1839408400	2182172700	2616599200	2212726453
3520000	250	1867972000	2203825000	2659400800	2243732600
3520000	252	1844341000	2199666800	2709918300	2251308867
3520000	254	1842796900	2246231000	2824122000	2237718633
3520000	256	1874005400	2221145100	2865448400	2233532967
3520000	258	1883140200	2191348700	2770907500	2281165467
3520000	260	1894573800	2241675100	2698792000	2274343633
3520000	262	1903048500	2247318300	2726410600	2292259133
3520000	264	1905575800	2255572700	2716260000	2292469500
3520000	266	1926814300	2281154600	2701057900	2302942067
3520000	268	1929100300	2300648800	2725934700	2318581000
3520000	270	1931799400	2281344900	2778488200	2330544167
3520000	272	1990183600	2480291500	2746807000	2405760700
3520000	274	1955458500	2347218000	2805057500	2369244667
3520000	276	1965221200	2359965300	2774107200	2366428233
3520000	278	2122954000	2368134100	2832830000	2441525967
3520000	280	2130725300	2327923900	2784380800	2414343000
3520000	282	2088965200	2329703300	2806305500	2401658000
3520000	284	2041284900	2341260800	2800133600	2394228433
3520000	286	2159863300	2364494200	2827869900	2400342467
3520000	288	2175354200	2335871300	2891345100	2436422333
3520000	290	2183503900	2338783700	2895097700	2472461967
3520000	292	2154802800	2376998100	2886732600	2466177833
3520000	294	2148594100	2388099000	2925403800	2487689867
3520000	296	2178685000	2408554500	2955508100	2514249200
3520000	298	2143538400	2431115800	2917795500	2497494233
3520000	300	2281261200	2435966400	2981951600	2561059733
4020000	2	1176134900	1274179600	1640511000	1336308500
4020000	4	1070533600	1247572100	1630565900	1316223867
4020000	6	1114300100	1224169300	1591571400	1310013600
4020000	8	1089248700	1254588000	1577204200	1306879533
4020000	10	1120849800	1230470800	1569342200	1306887600
4020000	12	1093671300	1239054200	1577314300	1303346600
4020000	14	1122798600	1221470100	1555700700	1299989800
4020000	16	1070807900	1225334700	1580705400	1294776000
4020000	18	1219707700	1240705900	1585737700	1330717100
4020000	20	1017889600	1248799600	1600141100	1348842233
4020000	22	1103385500	1243263200	1597730100	1314792933
4020000	24	1117729900	1255978600	1601638500	1325115667
4020000	26	1091952100	1265741700	1618944600	1322546133
4020000	28	1114109300	1274860500	1651535200	1356053467
4020000	30	1152835300	1287962100	1674116700	1371644100
4020000	32	1151099400	1303690700	1677804800	1377531633
4020000	34	1128073500	1272760600	1724464100	1375099400
4020000	36	1296802000	1304795300	1681866800	1427820767
4020000	38	1324330300	1289288100	1692517000	1432051133
4020000	40	1189652900	1323845200	1686028200	1400842100
4020000	42	1205377500	1328299700	1706565800	1413414333
4020000	44	1231342300	1317327600	1729165900	1425946567
4020000	46	1162313200	1330972200	1729443200	1405777867
4020000	48	1189788100	1360130600	1744136700	1422685100
4020000	50	1149675300	1373647100	1761494800	1428339067
4020000	52	1175930700	1375119000	1736546500	1429198733
4020000	54	1189935900	1391629000	1778162500	1453242467
4020000	56	1218451800	1382003400	1804837700	1468364300
4020000	58	1281017700	1393578200	1821479500	1489681800
4020000	60	1240162500	1387094900	1887050700	1504771033
4020000	62	1254813900	1418399400	1891265200	1521420067
4020000	64	1235389600	1468317900	1872016500	1525241333
4020000	66	1291175200	1433481200	1853969000	1526215133
4020000	68	1240328200	1472625200	1876251700	1526625033
4020000	70	1296955900	1495133900	1920137900	1572362933
4020000	72	1432438000	1472842400	1887198700	1597493033
4020000	74	1355189900	1488198400	1899753500	1581047267
4020000	76	1280651100	1504726000	1969197900	1584858333
4020000	78	1278712900	1524321700	1953438900	1584832767
4020000	80	1286202700	1548890700	1950017200	1596363200
4020000	82	1397748800	1555375400	1951549000	1634891067
4020000	84	1552735200	1548322600	1960848500	1687302100
4020000	86	1549146400	1539999900	1984084900	1691077067
4020000	88	1542021100	1564273000	2002839200	1703043433
4020000	90	1914598800	1572332900	1984473700	1823801733
4020000	92	1784837800	1586206900	2006052300	1810555667
4020000	94	1736529300	1583029500	2041868600	1787142467
4020000	96	1531979600	1606013300	2056413200	1731408033
4020000	98	1450398400	1616069300	2074315100	1727127600
4020000	100	1428602300	1657080400	2080100000	1721627567
4020000	102	1474397600	1671746400	2083375600	1743173200
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4020000	106	1520960400	1696381100	2109643300	1775654933
4020000	108	1478982500	1687806700	2114342200	1759710467
4020000	110	1528212500	1680589100	2128533800	1778446533
4020000	112	1471808500	1719268700	2149959500	1780357667
4020000	114	1514682500	1716871000	2148906600	1793420033
4020000	116	1534717500	1724696999	2170482100	1809965533
4020000	118	1623348600	1743192601	2181571200	1849370134
4020000	120	1591426400	1767881900	22119692200	1859666633
4020000	122	1498022300	1763238900	2261394400	1840865067
4020000	124	1609455900	1773678600	2207996500	1863710333
4020000	126	1651053600	1791697300	2258179300	1900310067
4020000	128	1714319900	1783781700	2248127900	1915409533
4020000	130	1692275500	1821844699	2259761400	1933986033
4020000	132	1759037900	1815884001	2255964000	1942295267
4020000	134	1647568300	1782636000	2284873100	1906359133
4020000	136	1654879900	1836793800	2311006300	1934226667
4020000	138	1648431400	1849350100	2306387500	1934056333
4020000	140	1637402000	1889716301	2317556200	1948325100
4020000	142	1659576200	1864942200	2322439600	1947685100
4020000	144	1746356900	1910673700	2349282200	2002104267

[illegible]

[illegible]

[illegible]

[illegible]

60200000	186	7403191100	2972613400	2875382600	4417062367
60200000	188	7509135900	2990233600	2896673300	4456347600
60200000	190	7538664400	2989278800	2903538700	4477160633
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