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ECE 2230,1

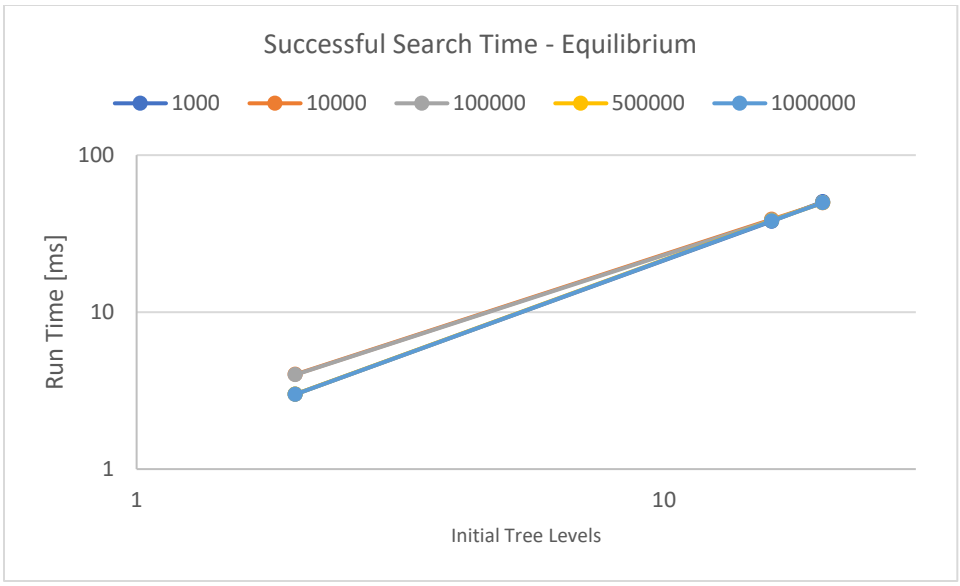
MP5 – Performance Analysis

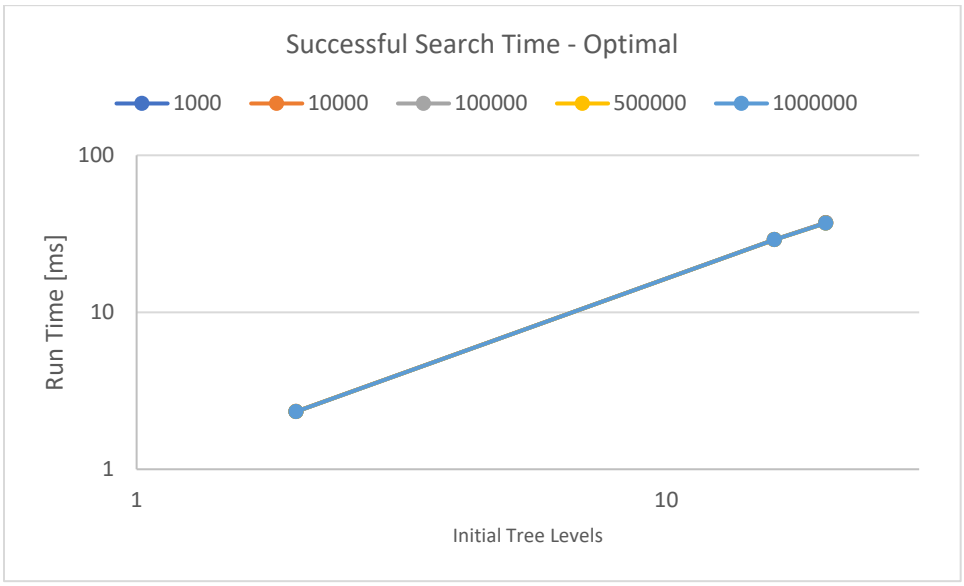
11/09/2023

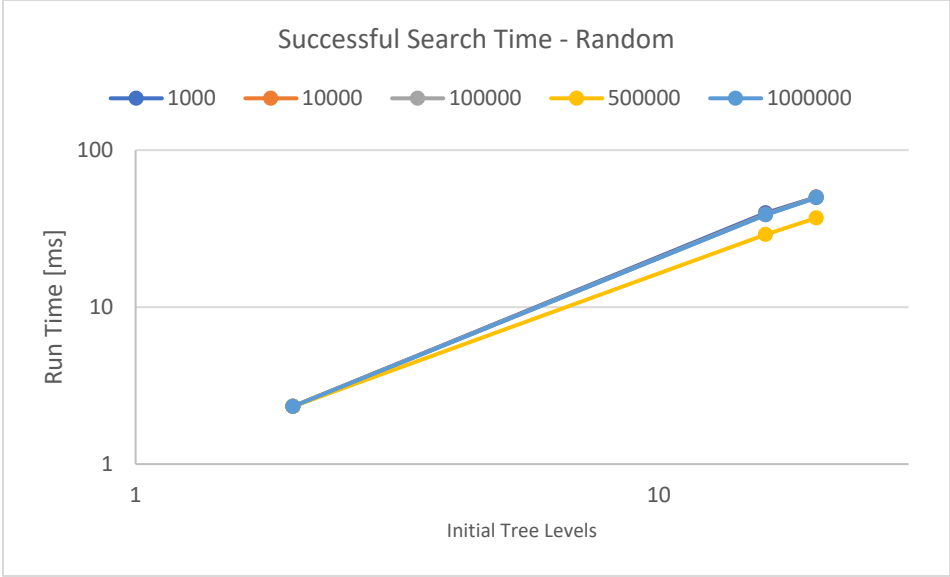
From the data provided in this document, we can conclude that as the number of initial levels in the binary search tree increases, the percent difference between the expected and measured successful search / insert / remove times improve at an exponentially decreasing rate. This is less apparent at low initial tree levels (2 in this case) as the results are subjected to greater range of error with small changes in the actual tree structure. Unsuccessful search times follow a similar pattern when testing against randomly created trees and does not appear to exist when using the equilibrium driver. Additionally, the optimal driver had measured unsuccessful search times equal to the expected time in all instances of the optimal case as each tree branch is generally the same length. Again, we can see that at low initial tree level sizes, the percent difference is drastically higher than at greater initial levels.

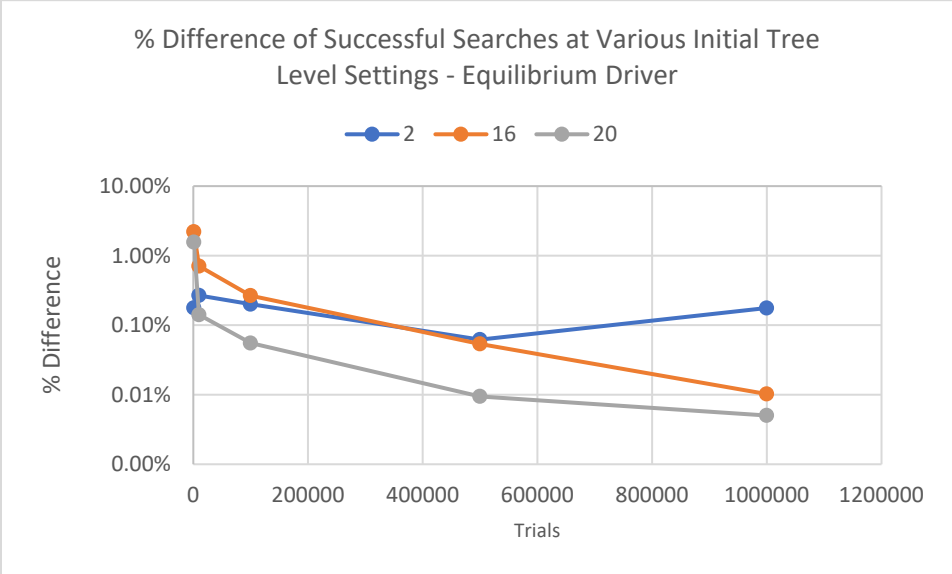
If we were to implement a “worst case” tree generation function, we should expect to see binary search trees with long, narrow branches that result in significantly longer search times than either of the two previous generation methods. As the tree becomes taller with less branching, each unsuccessful search begins to take longer, and the overall search time complexity class will drift away from O(log(n)) and approach O(n).

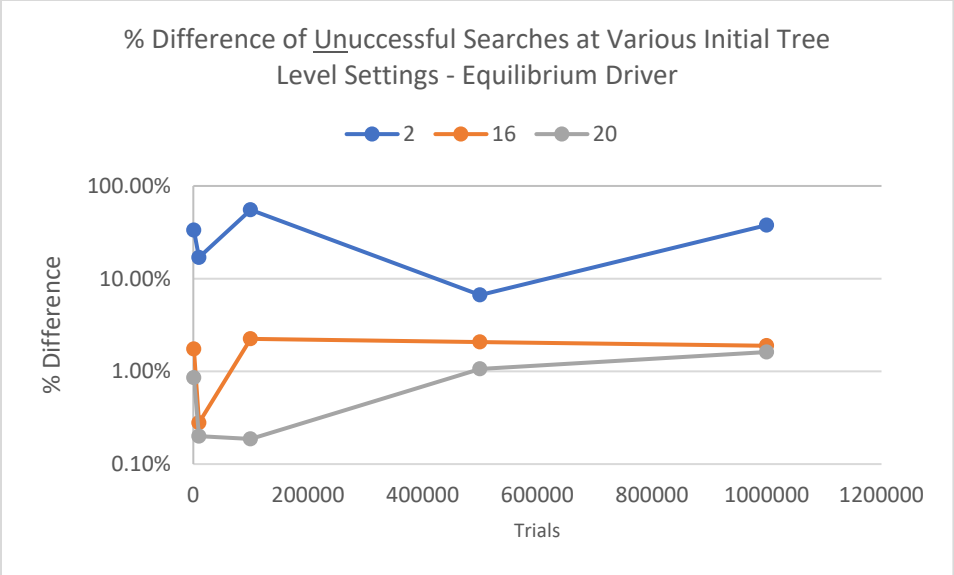
From this data, we can confirm that this binary search tree access algorithm is essentially O(log(n)) as the successful and unsuccessful search times, when graphed on a logarithmic scale, appear to be linear. This is also backed by the fact that as the amount of trials increase, the successful search time is only impacted by the number of levels that are in the tree.

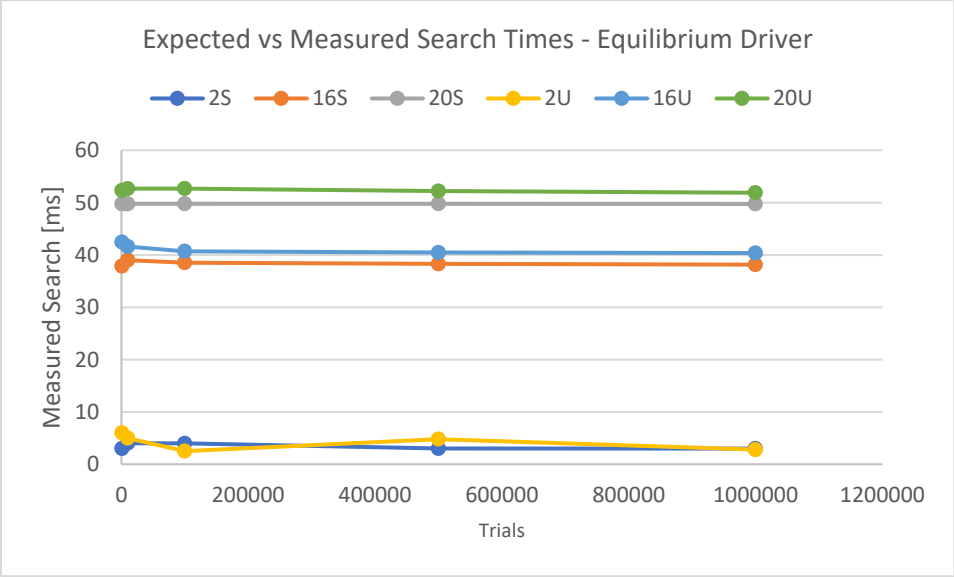

Successful Search Time - Equilibrium
1000
10000
100000
500000
1000000
100
10
1
Run Time [ms]
1
10
Initial Tree Levels

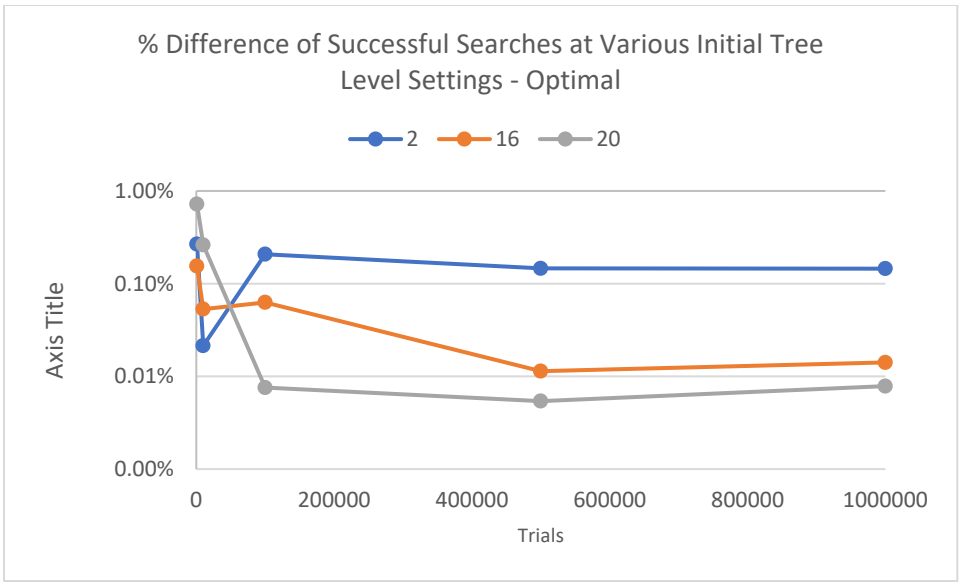

Successful Search Time - Optimal
1000
10000
100000
500000
1000000
100
10
1
Run Time [ms]
1
10
Initial Tree Levels

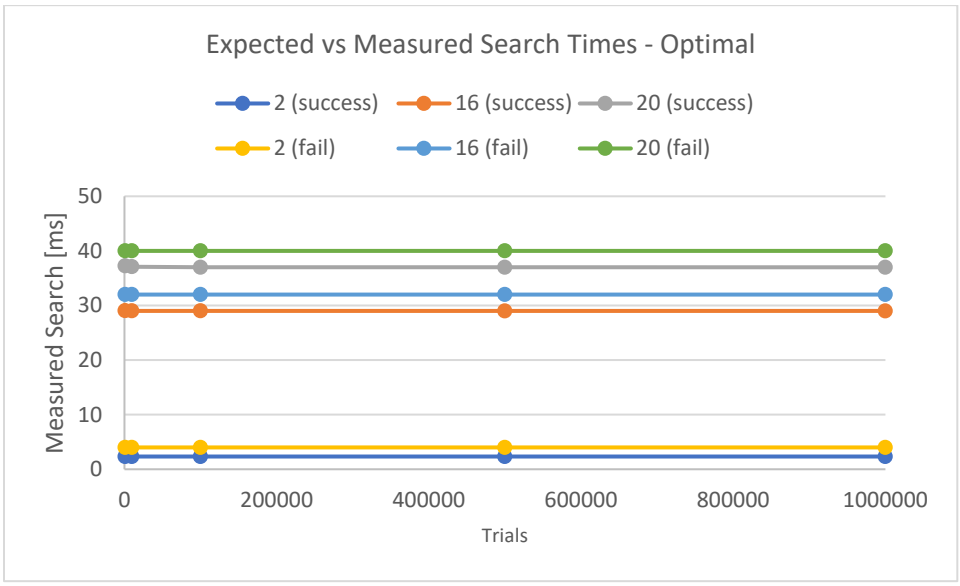

Successful Search Time - Random
1000
10000
100000
500000
1000000
100
10
1
Run Time [ms]
1
10
Initial Tree Levels

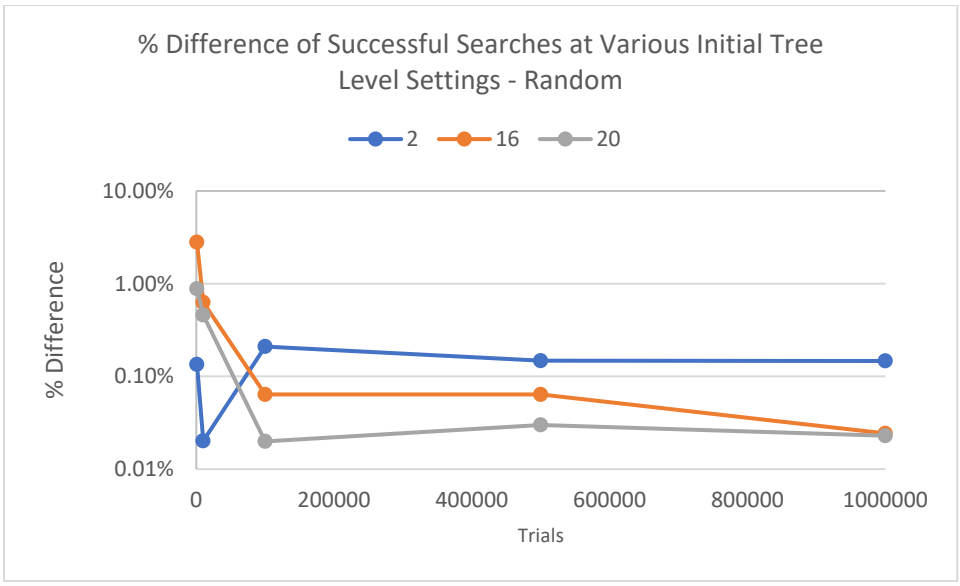

% Difference of Successful Searches at Various Initial Tree Level Settings - Equilibrium Driver
2
16
20
10.00%
1.00%
0.10%
0.01%
0.00%
% Difference
0
200000
400000
600000
800000
1000000
1200000
Trials

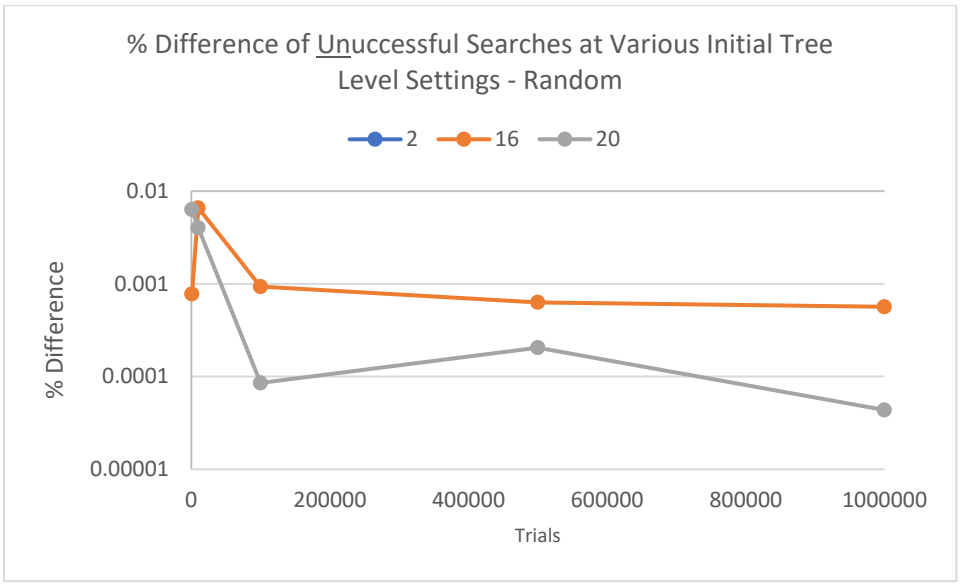

% Difference of Unuccessful Searches at Various Initial Tree Level Settings - Equilibrium Driver
2
16
20
100.00%
10.00%
1.00%
0.10%
% Difference
0
200000
400000
600000
800000
1000000
1200000
Trials

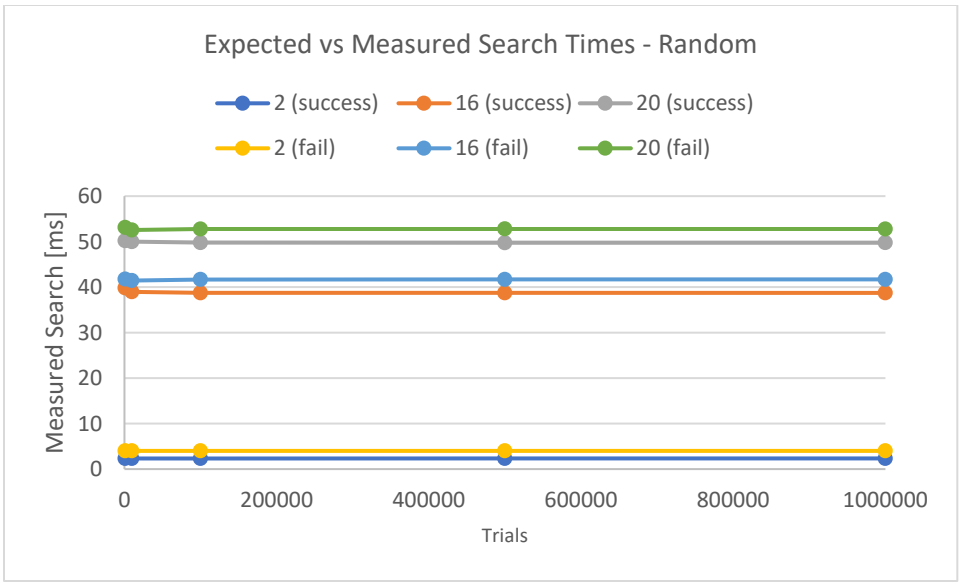

Expected vs Measured Search Times - Equilibrium Driver
2S
16S
20S
2U
16U
20U
60
50
40
30
20
10
0
Measured Search [ms]
0
200000
400000
600000
800000
1000000
1200000
Trials

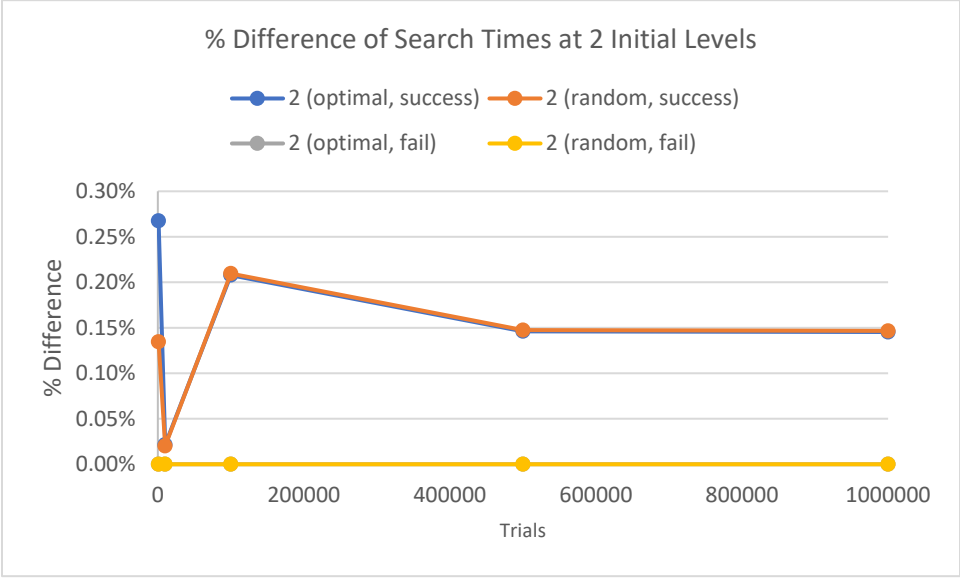

% Difference of Successful Searches at Various Initial Tree Level Settings - Optimal
2
16
20
1.00%
0.10%
0.01%
0.00%
Axis Title
0
200000
400000
600000
800000
1000000
Trials

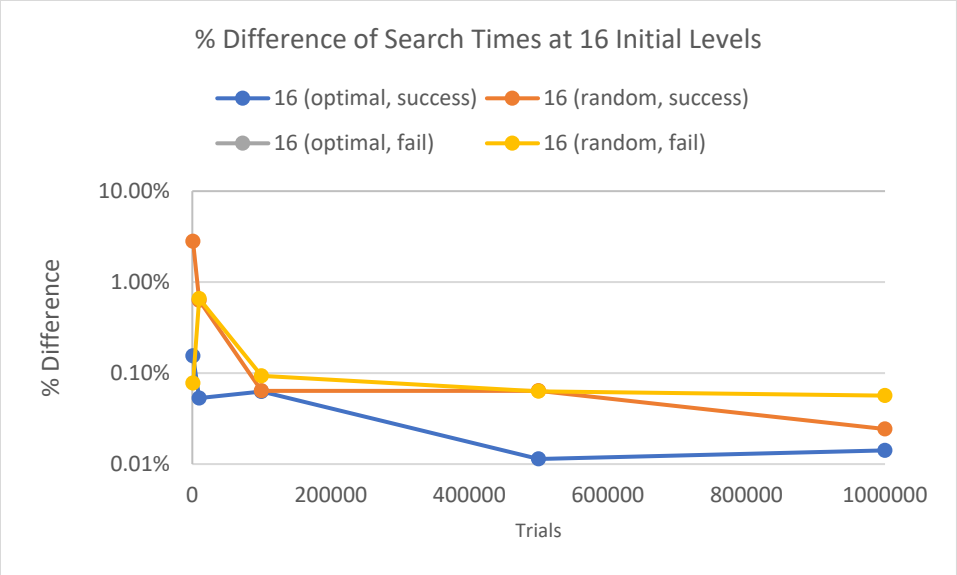

Expected vs Measured Search Times - Optimal
2 (success)
16 (success)
20 (success)
2 (fail)
16 (fail)
20 (fail)
50
40
30
20
10
0
Measured Search [ms]
0
200000
400000
600000
800000
1000000
Trials

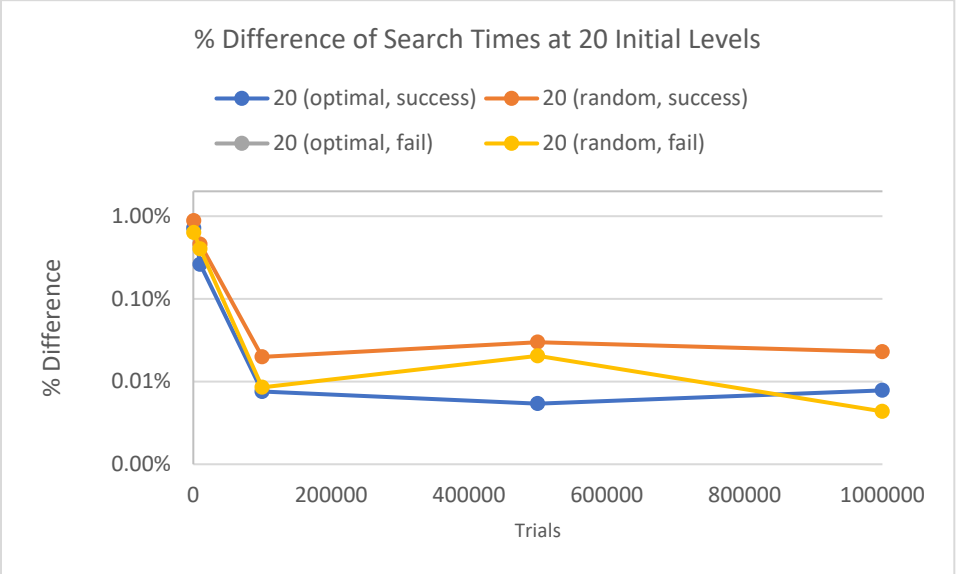

% Difference of Successful Searches at Various Initial Tree Level Settings - Random
2
16
20
10.00%
1.00%
0.10%
0.01%
% Difference
0
200000
400000
600000
800000
1000000
Trials


% Difference of Unuccessful Searches at Various Initial Tree Level Settings - Random
2
16
20
0.01
0.001
0.0001
0.00001
% Difference
0
200000
400000
600000
800000
1000000
Trials


Expected vs Measured Search Times - Random
2 (success)
16 (success)
20 (success)
2 (fail)
16 (fail)
20 (fail)
Measured Search [ms]
60
50
40
30
20
10
0
0
200000
400000
600000
800000
1000000
Trials


% Difference of Search Times at 2 Initial Levels
2 (optimal, success)
2 (random, success)
2 (optimal, fail)
2 (random, fail)
% Difference
0.30%
0.25%
0.20%
0.15%
0.10%
0.05%
0.00%
0
200000
400000
600000
800000
1000000
Trials


% Difference of Search Times at 16 Initial Levels
16 (optimal, success)
16 (random, success)
16 (optimal, fail)
16 (random, fail)
10.00%
1.00%
0.10%
0.01%
% Difference
0
200000
400000
600000
800000
1000000
Trials


% Difference of Search Times at 20 Initial Levels
20 (optimal, success)
20 (random, success)
20 (optimal, fail)
20 (random, fail)
1.00%
0.10%
0.01%
0.00%
% Difference
0
200000
400000
600000
800000
1000000
Trials

						successful				unsuccessful			
equilibrium	w	t	time	init size	post size	expected	measured	%diff	trials	expected	measured	%diff	trials
	2	1000	0.031	3	3	3	2.99467	0.18%	375	4.5	6	33.33%	625
	2	10000	0.271	3	6	4	4.0107	0.27%	7474	6	4.98496	16.92%	2526
	2	100000	2.807	3	4	4	3.99199	0.20%	50049	5.6	2.50518	55.26%	49951
	2	500000	14.4	3	3	3	3.00186	0.06%	187464	4.5	4.7997	6.66%	312536
	2	1000000	26.751	3	3	3	2.9947	0.18%	374368	4.5	2.80061	37.76%	625632
	16	1000	0.27	65535	65519	38.7215	37.8692	2.20%	474	41.7208	42.4487	1.74%	526
	16	10000	2.456	65535	65466	38.7337	39.0079	0.71%	5077	41.7331	41.6165	0.28%	4923
	16	100000	22.806	65535	65381	38.6328	38.5301	0.27%	49784	41.6322	40.6987	2.24%	50216
	16	500000	105.41	65535	65206	38.3236	38.303	0.05%	248629	41.323	40.4667	2.07%	251371
	16	1000000	222.438	65535	65730	38.1415	38.1376	0.01%	500548	41.1409	40.3626	1.89%	499452
	20	1000	1.407	1048575	1048546	49.7685	50.5484	1.57%	496	52.7684	52.3175	0.85%	504
	20	10000	11.85	1048575	1048514	49.7696	49.6992	0.14%	5026	52.7695	52.6639	0.20%	4974
	20	100000	103.339	1048575	1048520	49.7772	49.8047	0.06%	49975	52.7772	52.6787	0.19%	50025
	20	500000	490.064	1048575	1049276	49.7712	49.7665	0.01%	250459	52.7711	52.21	1.06%	249541
	20	1000000	897.283	1048575	1049483	49.7435	49.746	0.01%	501055	52.7435	51.8908	1.62%	498945
						successful				unsuccessful			
optimal	w	t	time	init size	post size	expected	measured		trials	expected	measured		trials
	2	1000	0.036	3	3	2.3333	2.32706	0.27%	425	4	4	0	575
	2	10000	0.307	3	3	2.3333	2.3338	0.02%	4260	4	4	0	5740
	2	100000	3.09	3	3	2.3333	2.32845	0.21%	42612	4	4	0	57388
	2	500000	13.041	3	3	2.3333	2.32989	0.15%	213709	4	4	0	286291
	2	1000000	26.024	3	3	2.3333	2.32991	0.15%	427896	4	4	0	572104
	16	1000	0.237	65535	65535	29.0005	29.0454	0.15%	485	32	32	0	515
	16	10000	3.229	65535	65535	29.0005	29.0159	0.05%	4908	32	32	0	5095
	16	100000	18.321	65535	65535	29.0005	29.0187	0.06%	49923	32	32	0	50077
	16	500000	88.869	65535	65535	29.0005	29.0038	0.01%	250456	32	32	0	249544
	16	1000000	192.001	65535	65535	29.0005	29.0046	0.01%	500331	32	32	0	499669
	20	1000	1.443	1048575	1048575	37	37.2664	0.72%	533	40	40	0	467
	20	10000	11.036	1048575	1048575	37	37.0968	0.26%	4979	40	40	0	5021
	20	100000	82.385	1048575	1048575	37	37.0028	0.01%	50001	40	40	0	49999
	20	500000	377.736	1048575	1048575	37	36.998	0.01%	250232	40	40	0	249768
	20	1000000	763.489	1048575	1048575	37	36.9971	0.01%	499900	40	40	0	500100
						successful				unsuccessful			
random	w	t	time	init size	post size	expected	measured		trials	expected	measured		trials
	2	1000	0.028	3	3	2.33333	2.33019	0.13%	424	4	4	0	576
	2	10000	0.262	3	3	2.33333	2.3338	0.02%	4260	4	4	0	5740
	2	100000	2.69	3	3	2.33333	2.32844	0.21%	42611	4	4	0	57389
	2	500000	13.089	3	3	2.33333	2.32989	0.15%	213706	4	4	0	286294
	2	1000000	26.098	3	3	2.33333	2.32991	0.15%	427895	4	4	0	572105
	16	1000	0.335	65535	65535	38.7197	39.8064	2.81%	501	41.7191	41.7515	0.08%	499
	16	10000	2.38	65535	65535	38.7197	38.9636	0.63%	4998	41.7191	41.4442	0.66%	5002
	16	100000	22.118	65535	65535	38.7197	38.7444	0.06%	50110	41.7191	41.6802	0.09%	49890
	16	500000	113.683	65535	65535	38.7197	38.7444	0.06%	250905	41.7191	41.6928	0.06%	249095
	16	1000000	224.911	65535	65535	38.7197	38.7291	0.02%	500436	41.7191	41.6955	0.06%	499564
	20	1000	1.066	1048575	1048575	49.7681	50.2073	0.88%	492	52.7681	53.1024	0.63%	508
	20	10000	9.903	1048575	1048575	49.7681	49.9964	0.46%	5030	52.7681	52.5561	0.40%	4970
	20	100000	100.58	1048575	1048575	49.7681	49.778	0.02%	50017	52.7681	52.7636	0.01%	49983
	20	500000	512.134	1048575	1048575	49.7681	49.7532	0.03%	250140	52.7681	52.7789	0.02%	249860
	20	1000000	1009.6	1048575	1048575	49.7681	49.7567	0.02%	500344	52.7681	52.7704	0.00%	499656