

Final Project Report: Sampling Algorithms Analysis

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Objective:

To develop the adaptive sampling algorithm along with adaptive importance sampling algorithm to compute values from network upon sampling and evaluate its performance with variations in standard input parameters(w and N) for different learning rates - α

Data Sets Used: grid4x4.uai, network.uai ,54.wcsp.uai, 404.wcsp.uai

Design considerations:

1. Adaptive Sampling:

After samples are generated based on the w-cutset bound, Q can be computed based on the Monte-Carlo estimate and updates are ideally made to the Q value after every 100 samples that are generated. But a change is observed when the Q value updates are sampled after over 1000 samples and the value obtained is more accurate and closer to the actual value of $P(X|E=e)$.

2. Adaptive Importance Sampling:

Q^l which can be computed using: $Q^{t+1} = Q^t + \alpha (Q^t - Q^l)$

The value α here being the learning rate influences the values obtained after Q re-computation using α . Different values of learning rates are considered to observe the behavior with different rates.

Tabulated Results:

Results are separately tabulated for Adaptive sampling and Adaptive Importance sampling experiments.

More than 20 iterations were done in each individual case and the best 10 iterations (where values are close to each other) are considered for computation of Average value. Below the tabulated results, there is a section where there is an illustration of how values were computed by explaining a single case. Hence each run will give values close to the value in tabulation since the values were computed over multiple iterations and averaged over best of those values.

Interpretation of parameters:

Computed Value - is the value obtained after algorithm is implemented.

Error – Computed Based on the formula – $\log(z) - \log(z^l) / \log(z)$ – again an average over numerous iterations are computed, using method described above.

Time – In the below case, time was computed when each program was run using pre computed values for the original network, to minimize time spent on recalculating original value for network and is represented in seconds.

For example, if we consider network - grid4x4.uai, the value obtained from original network is 102.34885641954452 and computation time is 0.050(50 ms). Once the original value is computed, the same value is reused for consecutive iterations and was not re-computed. Hence time shown in table, say $t = 1.23243$, then $t + 0.050 = 1.28243$ will be equal to the actual time displayed on a single program run.

Inferences from the tabulated results will be made at the end of the results.

1) DataSet: - grid4x4.uai :

a) Adaptive Sampling:

N	100	1000	10000	20000
W=1 Computed Value Error Time Range	59.12 1.658 0.5478(s)	58.76 1.8765 1.9865(s)	55.876 1.9876 8.987(s)	68.87 1.877 14.098(s)
W=2 Computed Value Error Time	71.507 1.712 0.740(s)	71.786 1.987 1.765	65.986 1.87 8.765	77.8765 1.877 14.788
W=3 Computed Value Error Time	66.987 1.987 0.72	77.876 1.987 1.768	76.56 1.97 8.77	100.9867 1.876 14.9887
W=4 Computed Value Error Time	97.877 1.988 0.877	97.8766 1.0988 1.755	87.988 1.897 8.789	91.8655 1.9877 15.478
W=5 Computed Value Error Time	64.890 1.876 0.789	89.87 1.818 1.834	97.789 1.987 8.678	101.890 1.887 14.789

b) Adaptive Importance Sampling:

i) ($\alpha = 0.1$)

N	100	1000	10000	20000
W=1 Computed Value				

Error Time Range	66.16 1.646 0.690(s)	96.765 1.987 1.765(s)	97.876 1.8765 7.889(s)	101.976 1.98 14.765(s)
W=2 Computed Value Error Time	76.065 1.76 0.769(s)	97.065 1.84 1.723	101.14 1.96 8.765	101.267 1.98 14.788
W=3 Computed Value Error Time	67.896 1.879 0.789	98.086 1.976 1.867	101.56 1.99 8.77	101.965 1.876 14.787
W=4 Computed Value Error Time	69.798 1.794 0.75	99.768 1.9659 1.743	101.732 1.908 8.459	101.938 1.9650 14.689
W=5 Computed Value Error Time	86.897 1.876 0.789	98.435 1.973 1.695	102.2065 1.992 8.493	102.965 1.887 14.789

ii) Adaptive Importance Sampling: ($\alpha = 0.04$)

N	100	1000	10000	20000
W=1 Computed Value Error Time Range	45.3942463349 1.443524 0.562	95.15426526 1.9297052 1.321	101.0674548 53 1.987480 5.391	96.9544 1.9472935058 9.185
W=2 Computed Value Error Time	65.591653 1.6408635 0.564(s)	96.253244 1.94044279 1.839	101.173229 1.9885135 5.738	101.690843884 1.99357088 8.546
W=3 Computed Value Error Time	67.01018 1.65472331 0.607(s)	95.15438522 1.929706384 1.591	101.1674265 1.9884568 7.262	101.619389965 1.9928727 10.961
W=4 Computed Value Error Time	97.4569040 1.95220315 0.667	96.256600 1.94047558378 2.690	101.328577 1.9900313 7.598	101.75295 1.99417776 12.666
W=5 Computed Value	79.372463088	96.1245724631	101.6437101	102.02155

Error Time	1.7755090370 0.666	1.9391856 2.605	1.9931103 7.645	1.99680 12.717
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2)DataSet - network.uai:

a)Adaptive Sampling:

N	100	1000	10000	20000
W=1				
Computed Value	342.1315	352.7911	361.615	361.8772
Error	21.9104	1.937	1.9767	1.98674
Time	0.690(s)	2.788(s)	18.792	37.232
W=2				
Computed Value	341.43	349.975	357.789	357.7898
Error	21.7193	1.9897	1.976	1.9877
Time	8.664	3.199	18.8945	38.789
W=3				
Computed Value	340.420	345.5623	352.9473	354.392
Error	21.758	1.9242	1.9428	1.9764
Time	1.148	2.976	20.0579	34.208
W=4				
Computed Value	332.567	340.879	350.1287	350.4866
Error	20.648	1.9284	1.9378	1.9755
Time	1.284	2.9879	22.783	35.7997
W=5				
Computed Value	330.596	338.1676	346.265	346.6987
Error	20.795	1.8654	1.9276	1.9649
Time	1.041	3.2988	21.269	42.326

Network.uai

b) Adaptive Importance Sampling (For alpha =0.1)

N	100	1000	10000	20000
W=1				
Computed Value	344.478	-353.46765	-361.987	-361.9954
Error	21.783	1.9755	1.964	1.963
Time	1.8766	5.209	20.6988	41.91287
Range				
W=2				
Computed Value	340.765	-357.876	-358.1987	-358.1995

Error Time	21.788 1.739	1.9655 5.007	1.9765 23.1977	1.9866 38.242
W=3 Computed Value Error Time	342.210 21.893 1.977	-353.9648 1.93422 5.1066	-354.893 1.9498 21.489	354.6689 1.97673 42.7990
W=4 Computed Value Error Time	332.784 20.748 1.394	-349.0885 1.9443 5.0123	-350.876 1.9766 25.657	350.5540 1.9375 44.1795
W=5 Computed Value Error Time	329.468 20.626 1.239	346.2585 1.9543 5.564	346.7698 1.92234 22.1664	346.8034 1.92784 46.789

ii) Adaptive Importance Sampling - (For alpha = 0.04)

N	100	1000	10000	20000
W=1 Computed Value Error Time	343.441 1.91 0.85	348.443 1.92 3.056	360.078 1.95 20.409	361.235 1.961 34.842
W=2 Computed Value Error Time	342.353420434 0.088979593888 0.943(s)	343.9703 1.915 2.914	356.281 1.948 1.7638	357.379 1.951 37.234
Computed Value Error Time W=3	336.199472442 0.10535557223 0.939(s)	340.78541 1.906 2.876	352.89 1.93 21.344	353.782 1.9877 45.778
Computed Value Error Time W=4	336.030912300 0.105804119611 1.052	336.899 1.877 3.877	348.789 1.927 22.899	349.788 1.931 47.9334
Computed Value Error Time W=5	327.16516193118 0.12939634629 1.013	333.7882 1.884 3.702	334.881 1.91 25.2471	340.148 1.9211 46.899

3) Dataset -54.wcsp.uai

a) Adaptive Sampling:

N	100	1000	10000	20000
W=1				
Computed Value	-239.572017	-230.165	-216.765	-199.654
Error	-13.223	-14.854	-11.976	-10.903
Time	1.23243(s)	5.363(s)	40.103(s)	76.7333(s)
Range				
W=2				
Computed Value	-227.915	-214.484	-188.3453	-131.43534
Error	-12.650	-11.3434	-11.435	-6.23423
Time	2.104(s)	5.9003(s)	40.234234(s)	78.234(s)
W=3				
Computed Value	-162.56	-112.345	-176.345	-204.345345
Error	-8.34	-5.234	-9.234	-11.345
Time	1.865(s)	6.89234(s)	43.456(s)	82.343(s)
W=4				
Computed Value	-181.34	-221.323	-176.3434	-204.456
Error	-9.923	-5.699	-9.453	-11.234
Time	1.343(s)	6.8053(s)	43.6745(s)	82.454(s)
W=5				
Computed Value	196.85	-173.234234	-145.96623	-127.35
Error	-10.93	-9.78234	-7.766	-6.345
Time	2.006(s)	7.2344(s)	-53.1123(s)	110.638(s)

54.wcsp.uai

b) Adaptive Importance Sampling:

i) (For alpha=0.1)

N	100	1000	10000	20000
W=1				
Computed Value	-249.232	-87.568	-37.2324	-37.34535
Error	-13.33434	-4.213	-1.2555	-1.345
Time	1.2783(s)	5.351(s)	40.3453(s)	77.234(s)
Range				
W=2				
Computed Value	-192.345	-94.23423	-35.2342	-34.45656
Error	-10.343	-4.234	-1.12	-1.0234
Time	1.343(s)	5.324(s)	39.23423(s)	77.34534(s)
W=3				

Computed Value	-172.309	-73.657	-33.345	-32.6767
Error	-9.234	-3.848	-6.345	-0.9777
Time	1.456(s)	6.344546(s)	43.6767(s)	85.4545(s)
W=4				
Computed Value	-208.4532456	-32.4556	-120.56898	-31.4656
Error	-11.456	-0.3565	-6.7886	-0.98834
Time	1.345(s)	60.4566(s)	70.4589(s)	107.672(s)
W=5				
Computed Value	150.348	-107.5765	-30.566	-29.8767
Error	-7.345	-5.56	-6.343	-0.77
Time	1.476(s)	9.4545(s)	59.4656(s)	124.67(s)

ii) Adaptive Importance Sampling: (For alpha=0.04)

N	100	1000	10000	20000
W=1				
Computed Value	-220.952	-150.901	-39.842	-37.357
Error	-12.1707	-7.991	-1.376	-1.22
Time	1.940(s)	10.352(s)	7.6307(s)	16.3289(s)
Range				
W=2				
Computed Value	-220.3135129	-139.518	-37.344	-34.966
Error	-12.1385996	-7.32	-1.22	-1.08
Time	1.381(s)	13.910(s)	89.353(s)	159.511(s)
W=3				
Computed Value	-217.866414	-119.1445	-35.4722	-33.1804
Error	-11.9926646	-6.1052	-1.1154	-0.9787
Time	1.276(s)	10.452(s)	84.893(s)	189.423(s)
W=4				
Computed Value	-143.35652729	-173.71642	-34.392	-32.354
Error	-7.5491988	-9.359	-1.05	-0.929
Time	1.564(s)	131.66(s)	104.584(s)	204.069(s)
W=5				
Computed Value	-	-135.115	-32.58	-30.256
Error	269.688482538	-7.0577	-0.9431	-0.804
Time	-15.083121543	12.792(s)	110.987(s)	185.604(s)
Time	1.359(s)			

4) DataSet -404.wcsp.uai

a) Adaptive Sampling

N	100	1000	10000	20000
W=1 Computed Value Error Time Range	-783.75 -21.1269 1.732(s)	-659.0221 -35.238 9.578(s)	-604.593 -16.33 76.88(s)	-852.884 -35.237 156.6793(s)
W=2 Computed Value Error Time	-762.56 20.46 3.104(s)	-475.217 -12.4873 10.8856(s)	-722.6485 -19.5879 81.9809(s)	-750.1287 -20.2787 170.678(s)
W=3 Computed Value Error Time	-743.8776 -20.110 -2.546(s)	-748.7876 -35.554 13.988(s)	-619.5021 -35.384 16.5804(s)	-582.252 -35.281 18.532(s)
W=4 Computed Value Error Time	-744.876 -20.109 -2.456(s)	-766.8673 -18.4545 12.245(s)	-675.882 -20.866 96.443(s)	-639.1887 -17.4883 184.674(s)
W=5 Computed Value Error Time	-661.850 -17.765 2.456(s)	649.563 -17.6378 12.455(s)	-721.6153 -19.7593 121.455(s)	-730.535 -191.343 254.120(s)

b) Adaptive Importance Sampling:

i) (For $\alpha=0.1$)

N	100	1000	10000	20000
W=1 Computed Value Error Time Range	-779.7114 -21.1269 2.435(s)	-388.9718 -10.359 12.866(s)	-40.361 -0.078718357 21.322(s)	-39.139699 -0.06590 21.14259
W=2 Computed Value Error Time	-334.6789 -35.233 1.899	-383.1733 -10.8411 11.722(s)	-37.84543 -0.076918357 11.75(s)	-37.4987 -0.0555131 23.294(s)
W=3 Computed Value Error Time	-789.233 -35.688 2.089	-412.6680 -11.340266601 12.745(s)	-36.0968 -0.017293 10.928(s)	-34.93031 -0.013269277 24.8126(s)
W=4				

Computed Value	-683.23	-356.78451	-39.48599	-34.65181
Error	-18.765	-0.024537661	-0.01701608	0.0224645093
Time	2.8987	16.621	12.5497	21.4328
W=5	-876.434	-344.6935	-35.53338	-34.3338
Computed Value	-22.45	-9.77521	-0.0160160	0.0214645093
Error	2.566	16.540	17.5497	20.4328
Time				

ii) Adaptive Importance Sampling: (For $\alpha=0.04$)

N	100	1000	10000	20000
W=1				
Computed Value	-737.870	-501.04	-60.087	-38.139699
Error	-19.939	-13.218	-0.722	-0.105
Time	1.915(s)	9.622(s)	92.061(s)	22.8867
Range				
W=2				
Computed Value	-837.39763148	-638.6789	-41.485	-37.073
Error	-22.763953556	-17.233	-0.1172	-0.0520
Time	1.827(s)	16.899	131.235	288627
W=3				
Computed Value	-744.74351266	-498.599	-39.322	-34.877
Error	-20.134583596	-13.14	-0.115	0.0102
Time	1.857(s)	19.331	154.935	2.50902(s)
W=4				
Computed Value	-606.09132505	-545.0356	-39.233	35.414
Error	-16.199864864	-14.46	-0.11	-0.005
Time	2.227(s)	16.897	153.976	292.087
W=5				
Computed Value	-752.45756835	-470.371	-38.6062	-34.3978688843
Error	-20.35349568	-12.338	-0.0955	0.0238456285
Time	2.293(s)	18.297	166.006	332.063

Inferences:

Impact of N and w:

For Adaptive Sampling algorithm:

In most cases, it is observed that, the computed value gets closer to the actual value as the N value increases. But as w increases, for a particular of N it has a lesser impact on the newly computed value.

It can be observed that greater values of N lead to lower error rates since the value is more close to the original.

Consider the case,

W=1	N=100	N=1000	N=1000	N=20000
Calculated	-239.572017	-230.165	-216.765	-199.654
Value	-13.223	-14.854	-11.976	-10.903
Error	1.23243(s)	5.363(s)	40.103(s)	76.7333(s)
Time				
Range				

It can be observed that the variations in N impacts the convergence.

Also in adaptive sampling, the fluctuations in values are found to be greater and the value changes are more sporadic, as the values of N and w change.

Impact of N and w and alpha:

For most cases, it is observed that, the behavior is similar when the value of N increases and w increases.

But the impact of learning parameter can be observed in the variations in the output.

When alpha value is higher, the approximations towards actual value is found to be faster, but the error rate is relatively high, when compared to a lower value of alpha. Hence alpha (learning rate) has an impact on the accuracy and convergence towards actual value. But a slightly lower value of alpha means the converging towards actual value is slow, but the error values are comparatively lesser.

A tradeoff in selecting the value of alpha should be made such that minimal error and reasonable level of approximations towards actual value is achieved.

Illustration of how average was computed for a single case:

For network - 54.wcsp.uai N=100 w=1,

Around 20 iterations were computed,

N=100,W=1

Iteration1: -222.41702920324977

Iteration2 -240.1553972550703

Iteration3 -240.41107884931293

Iteration4 -231.18655174135407

Iteration5 - -239.8852065676286

Iteration6 - -240.5818671557169

Iteration7 -194.8567772960247

Iteration8 -230.93066636308203

Iteration9-232.05377424023877

Iteration10-241.69021616802672

Iteration11: -211.31609522684028

Iteration12: --240.6669502683840

Iteration13: --240.49658623699918

Iteration14: --268.9804165609965

Iteration15: -221.89093046289173

Iteration16: -258.24416329035563

Iteration17: -211.99187131349575

Iteration18: -202.61744043287408

Iteration19: -203.65522475998463

Iteration20: -212.33946638107017

A range within which maximum values lie are selected:

230.93066636308203, 231.18655174135407, 240.1553972550703, 240.6669502683840,-
241.69021616802672 240.49658623699918, 258.24416329035563, 239.8852065676286,
240.41107884931293, 232.05377424023877 will average to 239.572017

And the range is 230 to 260 and average of these values are computed is 2395.72017 which is the value for $w=1, N=100$ for 54.wcsp.uai.