

Supplementary Materials for: ”Causal Feature Selection With Two-Stage Candidate Spouses Pruning”

Overview

This document contains detailed experimental results, including the Average F1-score and CI tests (Conditional Independence tests) for all algorithms across varying sample sizes on Alarm, Child, and Insurance Bayesian networks.

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1 Detailed Results of F1-score

Alarm Networks (Alarm, Alarm3, Alarm5, Alarm10)

Table 1: Average F1-score of each algorithm on the Alarm Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.741	0.858	0.913
BAMB	0.695	0.809	0.873
EEMB	0.697	0.832	0.912
LSMB	0.639	0.796	0.882
CFS-HITONPC	0.676	0.803	0.885
TSP-HITONPC	0.741	0.850	0.925
IPCMB	0.649	0.786	0.933
STMB	0.538	0.742	0.737
CFS-PCsimple	0.640	0.803	0.876
TSP-PCsimple	0.707	0.866	0.931
MMMB	0.740	0.826	0.932
CFS-MMPC	0.699	0.812	0.885
TSP-MMPC	0.741	0.840	0.944
PCMB	0.740	0.826	0.932
CFS-GetPCD	0.671	0.792	0.876
TSP-GetPCD	0.741	0.837	0.944

Table 2: Average F1-score of each algorithm on the Alarm3 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.659	0.819	0.882
BAMB	0.640	0.756	0.825
EEMB	0.635	0.787	0.881
LSMB	0.585	0.714	0.817
CFS-HITONPC	0.620	0.765	0.846
TSP-HITONPC	0.670	0.819	0.891
IPCMB	0.627	0.783	0.877
STMB	0.484	0.593	0.657
CFS-PCsimple	0.628	0.766	0.847
TSP-PCsimple	0.680	0.806	0.900
MMMB	0.649	0.801	0.886
CFS-MMPC	0.638	0.777	0.845
TSP-MMPC	0.666	0.801	0.893
PCMB	0.649	0.801	0.886
CFS-GetPCD	0.615	0.754	0.841
TSP-GetPCD	0.666	0.799	0.893

Table 3: Average F1-score of each algorithm on the Alarm5 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.629	0.791	0.856
BAMB	0.601	0.715	0.792
EEMB	0.602	0.752	0.851
LSMB	0.545	0.673	0.783
CFS-HITONPC	0.590	0.731	0.815
TSP-HITONPC	0.639	0.785	0.865
IPCMB	0.596	0.748	0.849
STMB	0.442	0.548	0.608
CFS-PCsimple	0.597	0.730	0.814
TSP-PCsimple	0.649	0.773	0.872
MMMB	0.617	0.767	0.859
CFS-MMPC	0.605	0.742	0.812
TSP-MMPC	0.635	0.767	0.866
PCMB	0.617	0.767	0.859
CFS-GetPCD	0.582	0.720	0.808
TSP-GetPCD	0.635	0.764	0.866

Table 4: Average F1-score of each algorithm on the Alarm10 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.591	0.756	0.824
BAMB	0.559	0.672	0.750
EEMB	0.563	0.709	0.818
LSMB	0.502	0.631	0.741
CFS-HITONPC	0.548	0.689	0.782
TSP-HITONPC	0.600	0.749	0.832
IPCMB	0.558	0.708	0.816
STMB	0.400	0.501	0.560
CFS-PCsimple	0.559	0.688	0.780
TSP-PCsimple	0.609	0.735	0.839
MMMB	0.578	0.728	0.826
CFS-MMPC	0.565	0.702	0.779
TSP-MMPC	0.595	0.728	0.833
PCMB	0.578	0.728	0.826
CFS-GetPCD	0.543	0.680	0.775
TSP-GetPCD	0.595	0.725	0.833

Child Networks (Child, Child3, Child5, Child10)

Table 5: Average F1-score of each algorithm on the Child Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.786	0.883	1.000
BAMB	0.817	0.886	0.884
EEMB	0.776	0.878	0.933
LSMB	0.691	0.839	0.924
CFS-HITONPC	0.653	0.741	0.897
TSP-HITONPC	0.854	0.901	0.973
IPCMB	0.709	0.810	1.000
STMB	0.616	0.854	0.881
CFS-PCsimple	0.629	0.741	0.902
TSP-PCsimple	0.808	0.901	0.973
MMMB	0.787	0.882	0.997
CFS-MMPC	0.780	0.877	0.906
TSP-MMPC	0.854	0.896	0.973
PCMB	0.796	0.882	0.997
CFS-GetPCD	0.663	0.736	0.902
TSP-GetPCD	0.805	0.896	0.973

Table 6: Average F1-score of each algorithm on the Child3 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.724	0.840	0.941
BAMB	0.737	0.837	0.909
EEMB	0.686	0.829	0.946
LSMB	0.570	0.747	0.881
CFS-HITONPC	0.615	0.697	0.886
TSP-HITONPC	0.775	0.853	0.957
IPCMB	0.692	0.806	0.960
STMB	0.523	0.684	0.752
CFS-PCsimple	0.602	0.704	0.870
TSP-PCsimple	0.766	0.855	0.956
MMMB	0.711	0.828	0.940
CFS-MMPC	0.686	0.797	0.893
TSP-MMPC	0.775	0.846	0.957
PCMB	0.702	0.828	0.940
CFS-GetPCD	0.612	0.692	0.891
TSP-GetPCD	0.741	0.846	0.957

Table 7: Average F1-score of each algorithm on the Child5 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.727	0.859	0.964
BAMB	0.746	0.841	0.920
EEMB	0.705	0.839	0.952
LSMB	0.592	0.738	0.890
CFS-HITONPC	0.614	0.701	0.890
TSP-HITONPC	0.781	0.856	0.973
IPCMB	0.660	0.809	0.986
STMB	0.449	0.626	0.732
CFS-PCsimple	0.608	0.721	0.890
TSP-PCsimple	0.780	0.861	0.978
MMMB	0.712	0.843	0.964
CFS-MMPC	0.687	0.803	0.894
TSP-MMPC	0.776	0.856	0.973
PCMB	0.710	0.843	0.964
CFS-GetPCD	0.607	0.698	0.894
TSP-GetPCD	0.742	0.856	0.973

Table 8: Average F1-score of each algorithm on the Child10 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.670	0.827	0.953
BAMB	0.711	0.814	0.914
EEMB	0.662	0.806	0.952
LSMB	0.521	0.699	0.820
CFS-HITONPC	0.589	0.680	0.884
TSP-HITONPC	0.736	0.832	0.962
IPCMB	0.653	0.795	0.976
STMB	0.321	0.441	0.582
CFS-PCsimple	0.590	0.687	0.882
TSP-PCsimple	0.741	0.828	0.974
MMMB	0.659	0.816	0.954
CFS-MMPC	0.639	0.768	0.889
TSP-MMPC	0.734	0.829	0.963
PCMB	0.660	0.816	0.954
CFS-GetPCD	0.591	0.680	0.887
TSP-GetPCD	0.714	0.829	0.963

Insurance Networks (Insurance, Insurance3, Insurance5, Insurance10)

Table 9: Average F1-score of each algorithm on the Insurance Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.663	0.726	0.813
BAMB	0.641	0.732	0.802
EEMB	0.611	0.718	0.796
LSMB	0.551	0.647	0.792
CFS-HITONPC	0.531	0.643	0.759
TSP-HITONPC	0.662	0.738	0.830
IPCMB	0.604	0.645	0.750
STMB	0.481	0.590	0.726
CFS-PCsimple	0.528	0.623	0.752
TSP-PCsimple	0.619	0.724	0.842
MMMB	0.666	0.706	0.825
CFS-MMPC	0.588	0.683	0.769
TSP-MMPC	0.662	0.730	0.839
PCMB	0.666	0.706	0.822
CFS-GetPCD	0.543	0.632	0.755
TSP-GetPCD	0.662	0.730	0.841

Table 10: Average F1-score of each algorithm on the Insurance3 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.629	0.710	0.827
BAMB	0.654	0.707	0.778
EEMB	0.627	0.704	0.817
LSMB	0.593	0.698	0.759
CFS-HITONPC	0.540	0.631	0.696
TSP-HITONPC	0.678	0.738	0.831
IPCMB	0.591	0.720	0.819
STMB	0.481	0.523	0.564
CFS-PCsimple	0.538	0.643	0.680
TSP-PCsimple	0.671	0.732	0.834
MMMB	0.619	0.697	0.822
CFS-MMPC	0.593	0.646	0.693
TSP-MMPC	0.678	0.734	0.830
PCMB	0.619	0.697	0.822
CFS-GetPCD	0.532	0.623	0.688
TSP-GetPCD	0.678	0.733	0.832

Table 11: Average F1-score of each algorithm on the Insurance5 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.655	0.713	0.817
BAMB	0.658	0.705	0.773
EEMB	0.634	0.703	0.791
LSMB	0.580	0.673	0.746
CFS-HITONPC	0.538	0.634	0.687
TSP-HITONPC	0.677	0.723	0.812
IPCMB	0.641	0.702	0.808
STMB	0.437	0.498	0.511
CFS-PCsimple	0.542	0.635	0.674
TSP-PCsimple	0.678	0.722	0.814
MMMB	0.646	0.707	0.815
CFS-MMPC	0.606	0.665	0.686
TSP-MMPC	0.676	0.720	0.810
PCMB	0.646	0.707	0.813
CFS-GetPCD	0.535	0.633	0.683
TSP-GetPCD	0.676	0.720	0.808

Table 12: Average F1-score of each algorithm on the Insurance10 Bayesian network

Algorithm	Sample size		
	500	1000	5000
HITONMB	0.638	0.700	0.804
BAMB	0.642	0.689	0.777
EEMB	0.615	0.689	0.799
LSMB	0.563	0.679	0.733
CFS-HITONPC	0.532	0.607	0.684
TSP-HITONPC	0.662	0.714	0.813
IPCMB	0.621	0.703	0.793
STMB	0.346	0.386	0.434
CFS-PCsimple	0.527	0.617	0.669
TSP-PCsimple	0.651	0.712	0.816
MMMB	0.632	0.689	0.802
CFS-MMPC	0.585	0.636	0.686
TSP-MMPC	0.661	0.710	0.812
PCMB	0.632	0.689	0.803
CFS-GetPCD	0.530	0.600	0.680
TSP-GetPCD	0.661	0.708	0.812

2 Detailed Results of CI Tests

Alarm Networks (CIIts)

Table 13: Average CIIts of each algorithm on the Alarm Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	375.351	356.351	436.162	456.054
BAMB	326.081	341.514	603.838	798.432
EEMB	375.784	190.649	212.703	217.649
LSMB	1589.297	366.811	482.784	548.054
CFS-HITONPC	258.730	224.676	232.081	228.459
TSP-HITONPC	160.838	167.892	199.784	212.054
IPCMB	413.919	392.027	532.622	579.162
STMB	513.162	234.649	287.730	303.000
CFS-PCsimple	260.703	226.297	250.405	258.027
TSP-PCsimple	177.892	191.135	248.297	270.270
MMMB	372.730	321.162	356.135	371.351
CFS-MMPC	233.270	203.514	206.946	208.243
TSP-MMPC	164.297	167.676	194.000	204.622
PCMB	360.757	331.865	359.351	367.676
CFS-GetPCD	249.703	218.297	211.649	220.649
TSP-GetPCD	161.135	170.838	194.351	204.676

Table 14: Average CIts of each algorithm on the Alarm3 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	564.604	539.631	639.505	1047.784
BAMB	541.216	654.270	1248.568	2765.477
EEMB	498.351	434.225	476.757	859.099
LSMB	761.694	593.234	775.081	2212.081
CFS-HITONPC	458.135	432.631	476.126	710.279
TSP-HITONPC	411.351	403.198	456.333	724.225
IPCMB	562.414	579.162	823.802	1318.802
STMB	531.207	472.829	562.423	1039.847
CFS-PCsimple	445.820	435.532	513.991	740.315
TSP-PCsimple	414.865	423.712	521.811	790.207
MMMB	551.297	504.072	589.928	939.378
CFS-MMPC	441.721	415.802	457.405	693.577
TSP-MMPC	412.396	401.297	451.712	716.396
PCMB	546.982	506.568	611.910	985.928
CFS-GetPCD	449.351	421.261	462.054	698.892
TSP-GetPCD	410.063	400.703	455.297	715.495

Table 15: Average CIts of each algorithm on the Alarm5 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	838.757	801.605	939.897	1622.708
BAMB	865.881	990.108	1748.146	3919.519
EEMB	789.832	709.081	782.362	1488.427
LSMB	1485.622	871.362	1068.773	3920.308
CFS-HITONPC	725.659	688.497	759.205	1197.481
TSP-HITONPC	679.259	659.800	740.708	1222.941
IPCMB	846.422	844.643	1074.605	1891.070
STMB	857.735	735.130	843.362	1809.708
CFS-PCsimple	712.070	687.470	778.643	1152.038
TSP-PCsimple	680.892	677.514	790.297	1211.778
MMMB	823.486	764.703	870.859	1439.476
CFS-MMPC	705.881	671.492	737.995	1151.357
TSP-MMPC	681.135	658.114	734.135	1202.227
PCMB	827.584	769.357	886.276	1485.135
CFS-GetPCD	717.054	677.114	742.432	1169.557
TSP-GetPCD	677.946	658.638	736.265	1206.449

Table 16: Average CIts of each algorithm on the Alarm10 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	1572.930	1479.746	1720.749	2194.557
BAMB	1689.259	1966.965	3465.738	5259.519
EEMB	1559.722	1410.208	1558.641	1949.095
LSMB	2181.603	1545.584	1929.724	2947.605
CFS-HITONPC	1431.295	1348.711	1497.289	1810.514
TSP-HITONPC	1373.254	1313.632	1468.922	1789.276
IPCMB	1534.608	1510.368	1906.857	2509.841
STMB	1584.668	1395.684	1621.789	2252.189
CFS-PCsimple	1380.465	1321.978	1512.489	1789.059
TSP-PCsimple	1347.746	1309.870	1521.951	1820.081
MMMB	1551.668	1423.943	1633.289	2034.116
CFS-MMPC	1407.749	1325.778	1470.527	1761.170
TSP-MMPC	1375.038	1309.551	1460.519	1772.343
PCMB	1546.476	1428.524	1651.149	2086.908
CFS-GetPCD	1419.670	1334.089	1475.665	1772.551
TSP-GetPCD	1370.968	1310.008	1465.441	1779.605

Child Networks (CIts)

Table 17: Average CIts of each algorithm on the Child Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	968.75	571.80	665.65	708.80
BAMB	269.90	238.30	433.75	655.65
EEMB	516.80	271.85	189.90	188.55
LSMB	2880.80	740.10	612.85	624.20
CFS-HITONPC	473.00	329.65	277.90	286.70
TSP-HITONPC	146.80	107.90	138.85	145.10
IPCMB	902.60	613.55	761.30	846.20
STMB	802.70	368.20	197.55	211.30
CFS-PCsimple	481.55	333.10	294.30	311.00
TSP-PCsimple	160.00	125.30	170.90	188.80
MMMB	1064.55	618.20	638.50	663.35
CFS-MMPC	414.50	249.55	263.25	269.50
TSP-MMPC	158.35	115.55	135.45	140.35
PCMB	523.30	588.70	625.85	658.55
CFS-GetPCD	286.55	343.15	263.85	270.70
TSP-GetPCD	118.80	112.95	134.90	141.35

Table 18: Average CIts of each algorithm on the Child3 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	1572.017	1157.367	871.150	1329.133
BAMB	489.117	518.383	724.050	1580.217
EEMB	785.233	510.150	359.967	634.433
LSMB	7842.883	1355.317	833.350	2427.233
CFS-HITONPC	776.200	617.417	439.950	631.383
TSP-HITONPC	326.867	296.617	299.633	459.917
IPCMB	1499.233	1190.833	965.617	1493.950
STMB	1770.950	780.450	482.583	1138.650
CFS-PCsimple	752.100	616.550	457.283	633.150
TSP-PCsimple	323.000	309.950	336.117	480.967
MMMB	1734.600	1244.850	830.417	1285.450
CFS-MMPC	692.850	534.500	423.083	606.700
TSP-MMPC	342.617	306.783	297.067	446.383
PCMB	1196.850	1163.983	834.400	1271.333
CFS-GetPCD	601.067	617.533	425.583	604.950
TSP-GetPCD	301.117	299.800	298.800	442.033

Table 19: Average CIts of each algorithm on the Child5 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	1706.95	1240.66	1028.30	1752.36
BAMB	670.68	624.36	1024.03	2091.40
EEMB	1004.68	626.16	515.06	949.18
LSMB	16831.73	1506.44	1018.77	5301.49
CFS-HITONPC	874.41	742.30	579.96	881.63
TSP-HITONPC	482.86	435.55	440.18	690.48
IPCMB	1532.93	1295.89	1115.78	1624.19
STMB	2143.73	937.96	607.22	1554.47
CFS-PCsimple	846.98	732.97	596.70	765.76
TSP-PCsimple	465.85	441.84	476.45	680.54
MMMB	1873.96	1314.89	989.07	1709.89
CFS-MMPC	800.79	671.06	563.26	833.77
TSP-MMPC	498.00	444.99	437.42	678.39
PCMB	1429.25	1237.14	994.32	1652.66
CFS-GetPCD	775.50	737.55	565.90	843.71
TSP-GetPCD	460.36	437.81	439.43	667.81

Table 20: Average CIts of each algorithm on the Child10 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	1729.985	1649.085	1365.960	2191.030
BAMB	1082.385	1127.545	1667.515	3002.530
EEMB	2054.480	1036.955	897.130	1536.585
LSMB	148989.510	2180.235	1386.185	4821.780
CFS-HITONPC	1172.875	1117.990	947.515	1337.830
TSP-HITONPC	879.305	829.910	815.395	1200.935
IPCMB	1641.825	1663.090	1455.890	1951.665
STMB	3411.600	1622.270	1109.200	2681.550
CFS-PCsimple	1119.820	1093.545	958.175	1176.885
TSP-PCsimple	841.375	823.325	847.915	1124.315
MMMB	1867.420	1730.545	1326.765	2126.960
CFS-MMPC	1128.270	1045.760	930.705	1304.970
TSP-MMPC	891.505	837.450	813.330	1181.945
PCMB	1529.220	1670.600	1332.705	2100.290
CFS-GetPCD	1068.900	1124.695	933.750	1292.520
TSP-GetPCD	833.470	831.975	815.355	1175.490

Insurance Networks (CIIts)

Table 21: Average CIIts of each algorithm on the Insurance Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	353.148	367.296	686.296	950.926
BAMB	293.667	320.333	871.222	1333.741
EEMB	321.519	227.481	259.556	315.926
LSMB	1738.074	605.333	907.778	1135.593
CFS-HITONPC	245.111	217.111	283.889	407.667
TSP-HITONPC	147.111	148.889	216.000	249.630
IPCMB	392.556	433.222	1025.111	1466.111
STMB	382.852	287.815	422.889	495.074
CFS-PCsimple	252.037	228.667	327.148	497.185
TSP-PCsimple	164.556	184.593	307.259	379.630
MMMB	335.111	346.333	687.667	962.815
CFS-MMPC	202.407	191.111	268.593	388.778
TSP-MMPC	149.407	143.667	223.148	254.185
PCMB	333.222	340.778	693.926	982.704
CFS-GetPCD	228.074	207.148	272.370	393.889
TSP-GetPCD	147.074	143.333	216.444	256.778

Table 22: Average CIts of each algorithm on the Insurance3 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	955.309	932.753	1694.123	3374.185
BAMB	786.173	806.074	2214.457	5542.049
EEMB	984.136	641.704	848.580	2098.864
LSMB	5561.926	1830.914	2940.321	15126.988
CFS-HITONPC	665.407	598.580	845.025	1503.136
TSP-HITONPC	475.284	465.333	638.543	1164.691
IPCMB	975.247	1067.346	2416.444	4555.679
STMB	1081.741	862.395	1160.864	3493.778
CFS-PCsimple	652.704	618.704	966.901	1640.716
TSP-PCsimple	479.617	514.346	796.889	1422.037
MMMB	1027.654	991.901	1758.259	3306.099
CFS-MMPC	625.284	587.815	849.654	1508.469
TSP-MMPC	490.247	479.691	651.901	1162.037
PCMB	998.914	986.099	1803.531	3554.259
CFS-GetPCD	664.074	613.580	875.062	1510.210
TSP-GetPCD	480.407	475.704	658.395	1166.889

Table 23: Average CIts of each algorithm on the Insurance5 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	1038.948	1157.556	2079.267	4029.496
BAMB	958.963	1097.489	2794.837	6494.244
EEMB	1045.000	899.326	1194.600	2620.496
LSMB	5801.296	2192.556	3549.030	17680.815
CFS-HITONPC	816.948	829.222	1164.844	1840.452
TSP-HITONPC	689.689	694.015	902.096	1487.126
IPCMB	1028.770	1262.037	2768.326	5188.600
STMB	1210.563	1138.948	1522.044	4674.281
CFS-PCsimple	783.489	821.563	1248.267	2026.474
TSP-PCsimple	674.400	724.978	1064.830	1741.630
MMMB	1083.163	1190.252	2122.030	3829.874
CFS-MMPC	776.859	810.933	1125.741	1878.326
TSP-MMPC	700.141	705.304	907.326	1461.207
PCMB	1061.696	1178.867	2203.978	4284.867
CFS-GetPCD	812.341	831.267	1201.948	1873.444
TSP-GetPCD	690.770	701.481	922.422	1495.170

Table 24: Average CIts of each algorithm on the Insurance10 Bayesian network

Algorithm	Sample size			
	500	1000	2000	5000
HITONMB	1763.870	1762.889	2558.656	4162.837
BAMB	1727.141	1890.452	3755.393	7448.267
EEMB	1881.374	1562.470	1867.489	3375.315
LSMB	11759.678	2964.022	3748.052	16509.630
CFS-HITONPC	1489.767	1430.333	1742.944	2508.041
TSP-HITONPC	1327.878	1297.941	1516.989	2233.730
IPCMB	1682.104	1833.237	3212.689	5075.481
STMB	2088.441	1802.256	2212.367	6866.756
CFS-PCsimple	1399.215	1393.111	1823.567	2575.826
TSP-PCsimple	1266.263	1305.433	1668.511	2399.830
MMMB	1818.789	1800.674	2600.100	4185.396
CFS-MMPC	1448.674	1405.348	1707.067	2508.533
TSP-MMPC	1341.115	1309.578	1523.215	2214.215
PCMB	1795.800	1805.496	2648.426	4430.059
CFS-GetPCD	1488.611	1436.656	1754.619	2522.107
TSP-GetPCD	1331.407	1307.826	1534.033	2237.489