Performance Analysis of different Branch Predictor Configurations in the SPEC2017 Benchmark

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I. Benchmarks used

1) **perlbench:** Made up of three Perl scripts. They are SpamAssasin(a spam checker), MHonArc(email generator and converter), and specdiff(text difference checker)
2) **gcc:** Based on the GCC Version 4.5.0 compiler, generating code for an IA32 processor. It includes modified inlining heuristics for extensive code analysis and memory usage, favoring large C source files like GCC itself to optimize performance.
3) **bwaves:** A solver that uses the Bi-CGstab algorithm to solve the compressible Navier-Stokes equations. This is used to simulate blast waves in a three-dimensional bound.
4) **mcf:** Solves a single-depot vehicle scheduling(Multiple vehicles leaving from one depot) problem primarily using integer arithmetic. Tries to find a minimum-cost path using network algorithms.
5) **cactuBSSN:** Used solve the Einstein equations(relativity) for different astronomical bodies in a vacuum.
6) **lbm:** Simulates incompressible fluids in three dimensions using the uses the Lattice Boltzmann Method (LBM).
7) **omnetpp:** Event based simulation of communication networks based on the OMNeT++ system.
8) **wrf:** A weather forecasting model that takes multiple three dimensional times series as inputs.
9) **xalancbmk:** A parser that converts XML files to other types based on a stylesheet
10) **x264:** Library used to convert videos to H.264 format.
11) **cam4:** The Community Atmosphere Model (CAM) is a numerical model used for simulating atmospheric processes and climate systems.
12) **pop2:**The Parallel Ocean Program (POP) is a numerical model used for simulating ocean circulation and dynamics.
13) **deepsjeng:** Deep Sjeng is a chess engine that participated in the World Computer Chess Championship in 2008.
14) **imagick:** Open-source software suite used for creating, editing, converting, and processing bitmap images.
15) **leela:**Leela is a Go engine that combines Monte Carlo-based position estimation with selective tree search using Upper Confidence Bounds (UCB) and move valuation based on Elo ratings.
16) **nab:** Nucleic Acid Builder (NAB) is a software tool designed for modeling, simulating, and analyzing nucleic acids (DNA & RNA).
17) **exchange2:** Generates 9x9 sudoku puzzles.
18) **fotonik3d:**Fotonik3D solves the Maxwell's equations for photonic waveguides using the Finite-Difference Time-Domain (FDTD) method.
19) **roms:**Regional Ocean Modeling System (ROMS) is a numerical ocean model designed for high-resolution simulations of ocean dynamics.
20) **xz:** XZ Utils, developed by Lasse Collin, is a set of free software command-line lossless data compressors.

II. Results & Analysis

Note : The exact values of all the results are in the Appendix

Across the board, gshare predictors perform the best in terms of both IPC and MPKI, while the perceptron predictors lag slightly behind but at the cost of much higher complexity. This overall trend is underscored by the fact that MPKI shows wide swings between configurations that do not translate to similar variations in IPC. Looking at individual configurations, bimodal1 outperforms bimodal2—likely due to its larger table size—whereas bimodal3 is much worse because its 1-bit counter is heavily affected by branches with alternating directions. Among perceptron predictors, perceptron1 is superior to perceptron2, albeit requiring more perceptrons, while perceptron3 performs significantly worse, suggesting that the number of perceptron bits has a considerable impact. Within the gshare class, gshare1 emerges as the best predictor overall, although gshare2 and gshare3 trade off performance across different benchmarks, potentially reflecting biases in the benchmarks related to aliasing from a smaller table versus a shorter history aliasing

Table 1 Predictor configurations simulated

bimodal1	Table size : 16384 & Counter size : 2 bits
bimodal2	Table size : 8192 & Counter size : 2 bits
bimodal3	Table size : 16384 & Counter size : 1 bit
perceptron1	Perceptron history: 24, Number of perceptrons: 163, Perceptron Bits: 8
perceptron2	Perceptron history: 24, Number of perceptrons: 81, Perceptron Bits: 8
perceptron3	Perceptron history: 24, Number of perceptrons: 163, Perceptron Bits: 4
gshare1	Global History Length: 14, History Table Size: 16384
gshare2	Global History Length: 14, History Table Size: 8192
gshare3	Global History Length: 7, History Table Size: 16384

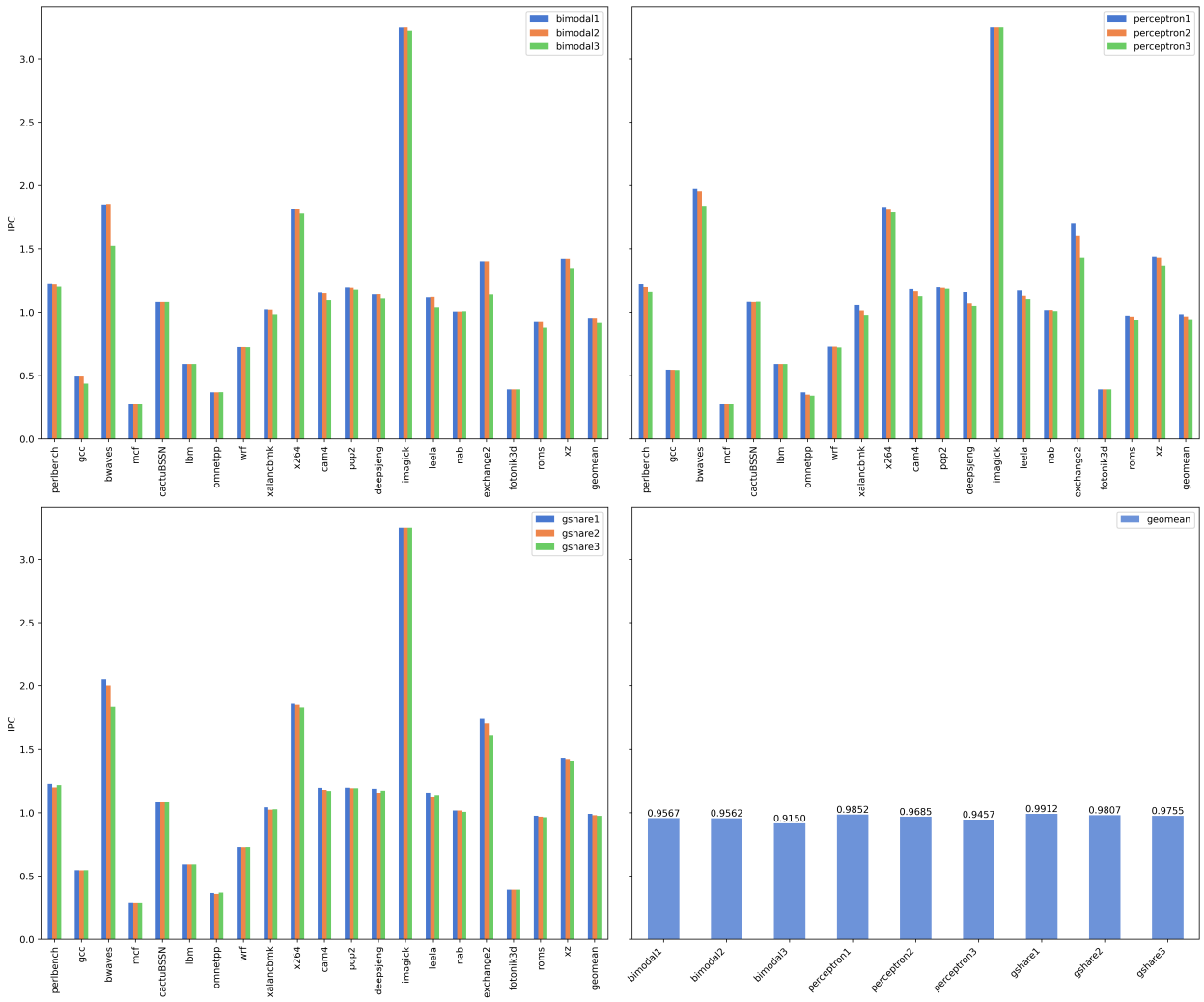

Fig. 1 IPC across different predictors

multiple execution paths.

Appendix

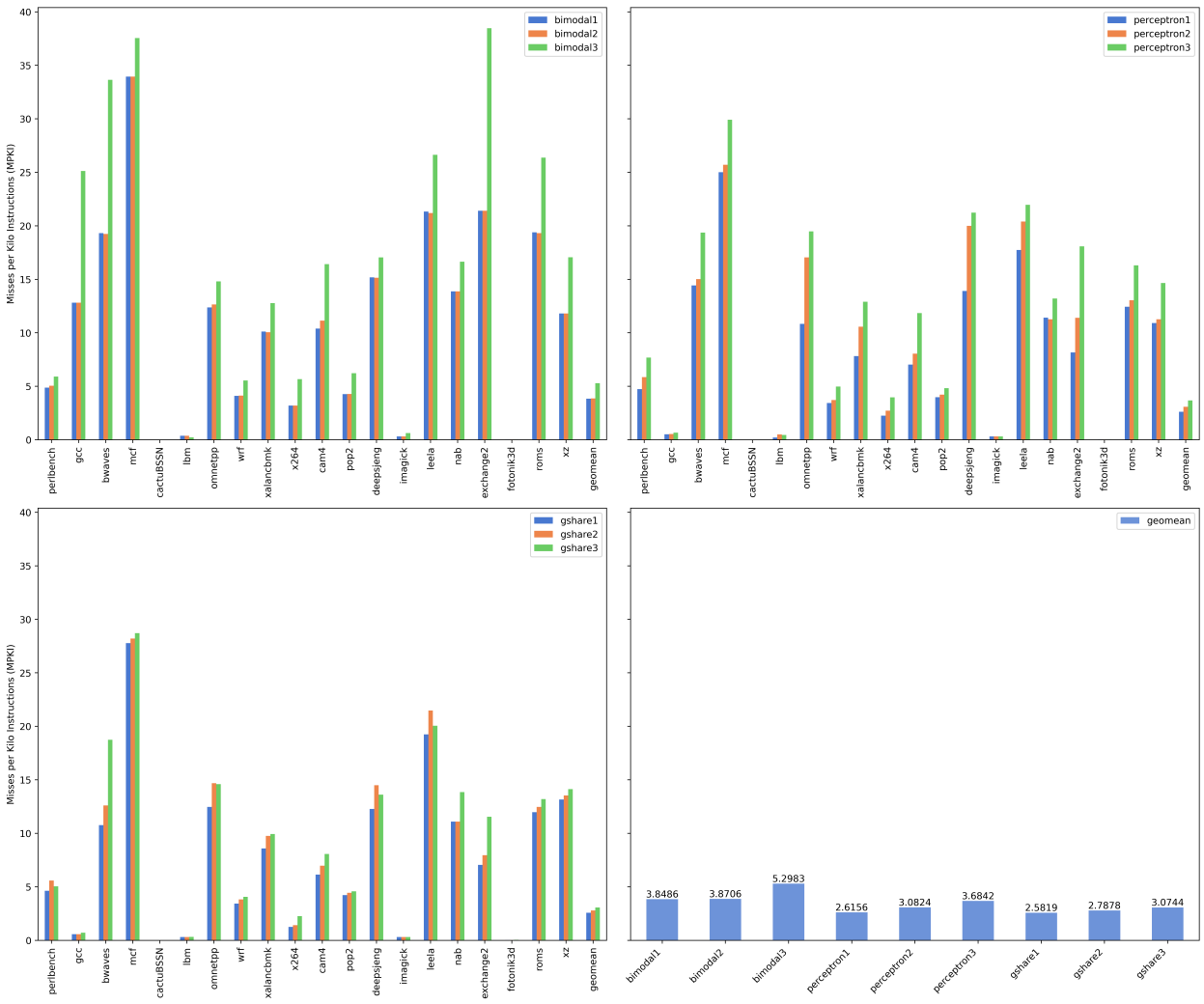

Fig. 2 MPKI across different predictors

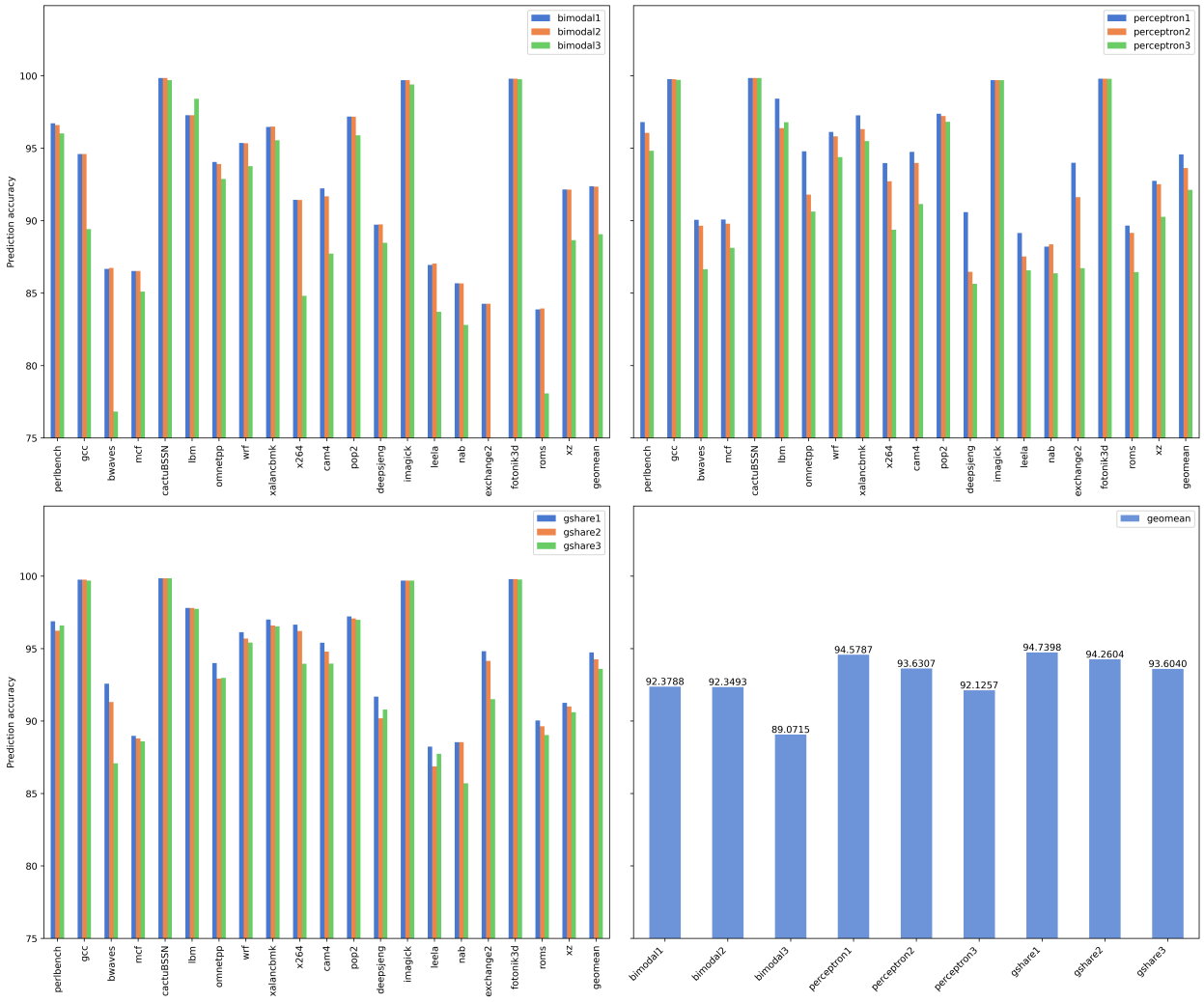

Fig. 3 Prediction accuracy across different predictors

Table 2 IPC across all predictors

	bimodal1	bimodal2	bimodal3	perceptron1	perceptron2	perceptron3	gshare1	gshare2	gshare3
perlbench	1.227	1.223	1.205	1.224	1.202	1.165	1.228	1.201	1.219
gcc	0.493	0.493	0.436	0.546	0.546	0.545	0.546	0.546	0.546
bwaves	1.851	1.855	1.523	1.974	1.954	1.840	2.056	2.001	1.839
mcf	0.276	0.276	0.275	0.279	0.279	0.275	0.292	0.291	0.291
cactuBSSN	1.081	1.081	1.081	1.082	1.081	1.083	1.082	1.082	1.082
lbm	0.592	0.592	0.592	0.592	0.592	0.592	0.592	0.592	0.592
omnetpp	0.370	0.369	0.370	0.369	0.351	0.342	0.367	0.359	0.370
wrf	0.730	0.730	0.729	0.733	0.733	0.727	0.731	0.730	0.732
xalancbmk	1.023	1.021	0.985	1.057	1.015	0.980	1.043	1.024	1.027
x264	1.817	1.815	1.779	1.832	1.810	1.788	1.863	1.855	1.834
cam4	1.153	1.148	1.095	1.187	1.170	1.124	1.197	1.181	1.173
pop2	1.199	1.197	1.182	1.201	1.197	1.189	1.198	1.194	1.194
deepsjeng	1.139	1.140	1.107	1.158	1.070	1.050	1.190	1.153	1.175
imagick	3.249	3.250	3.224	3.250	3.250	3.250	3.249	3.249	3.249
leela	1.116	1.119	1.039	1.177	1.128	1.102	1.159	1.121	1.134
nab	1.006	1.006	1.009	1.017	1.018	1.010	1.018	1.018	1.007
exchange2	1.404	1.404	1.138	1.702	1.608	1.433	1.741	1.705	1.613
fotonik3d	0.392	0.391	0.391	0.391	0.391	0.391	0.392	0.392	0.392
roms	0.922	0.922	0.877	0.975	0.968	0.940	0.976	0.969	0.965
xz	1.425	1.425	1.344	1.441	1.433	1.364	1.433	1.423	1.410
geomean	0.957	0.956	0.915	0.985	0.968	0.946	0.991	0.981	0.976

Table 3 MPKI across all predictors

	bimodal1	bimodal2	bimodal3	perceptron1	perceptron2	perceptron3	gshare1	gshare2	gshare3
perlbench	4.872	5.051	5.904	4.737	5.863	7.683	4.626	5.594	5.050
gcc	12.820	12.820	25.130	0.514	0.540	0.673	0.571	0.575	0.714
bwaves	19.320	19.240	33.640	14.430	15.020	19.370	10.770	12.610	18.740
mcf	33.940	33.940	37.550	25.010	25.710	29.910	27.780	28.210	28.710
cactuBSSN	0.002	0.002	0.004	0.002	0.002	0.002	0.002	0.002	0.002
lbm	0.380	0.380	0.221	0.219	0.504	0.448	0.307	0.307	0.316
omnetpp	12.370	12.650	14.800	10.840	17.050	19.480	12.470	14.690	14.600
wrf	4.113	4.136	5.540	3.441	3.717	4.982	3.436	3.820	4.070
xalancbmk	10.120	10.050	12.780	7.830	10.570	12.900	8.588	9.757	9.941
x264	3.200	3.205	5.674	2.252	2.721	3.973	1.253	1.413	2.259
cam4	10.400	11.140	16.420	7.025	8.047	11.840	6.142	6.976	8.067
pop2	4.277	4.289	6.231	3.983	4.218	4.828	4.223	4.444	4.580
deepsjeng	15.180	15.150	17.050	13.910	20.000	21.230	12.280	14.500	13.610
imagick	0.313	0.313	0.625	0.313	0.313	0.315	0.313	0.313	0.313
leela	21.330	21.190	26.640	17.740	20.400	21.960	19.250	21.480	20.050
nab	13.870	13.870	16.650	11.410	11.260	13.200	11.090	11.090	13.850
exchange2	21.410	21.410	38.470	8.166	11.400	18.080	7.045	7.961	11.550
fotonik3d	0.036	0.036	0.041	0.036	0.037	0.037	0.037	0.037	0.041
roms	19.390	19.320	26.370	12.440	13.040	16.300	11.980	12.470	13.200
xz	11.810	11.810	17.060	10.910	11.260	14.650	13.160	13.540	14.130
geomean	3.849	3.871	5.298	2.616	3.082	3.684	2.582	2.788	3.074

Table 4 Prediction accuracy(%) across all predictors

	bimodal1	bimodal2	bimodal3	perceptron1	perceptron2	perceptron3	gshare1	gshare2	gshare3
perlbench	96.72	96.60	96.03	96.81	96.06	94.83	96.89	96.24	96.60
gcc	94.60	94.60	89.42	99.78	99.77	99.72	99.76	99.76	99.70
bwaves	86.68	86.74	76.82	90.06	89.65	86.65	92.58	91.31	87.08
mcf	86.53	86.53	85.10	90.08	89.79	88.13	88.98	88.80	88.60
cactuBSSN	99.85	99.85	99.70	99.85	99.85	99.85	99.85	99.85	99.85
lbm	97.28	97.28	98.42	98.43	96.39	96.80	97.81	97.81	97.74
omnetpp	94.05	93.91	92.88	94.79	91.80	90.63	94.00	92.93	92.98
wrf	95.37	95.35	93.77	96.13	95.82	94.39	96.13	95.70	95.42
xalancbmk	96.47	96.50	95.55	97.27	96.32	95.50	97.01	96.60	96.53
x264	91.44	91.43	84.82	93.98	92.72	89.37	96.65	96.22	93.96
cam4	92.23	91.68	87.73	94.75	93.99	91.15	95.41	94.79	93.97
pop2	97.19	97.18	95.90	97.38	97.23	96.83	97.22	97.08	96.99
deepsjeng	89.73	89.75	88.47	90.59	86.47	85.64	91.69	90.19	90.79
imagick	99.70	99.70	99.40	99.70	99.70	99.70	99.70	99.70	99.70
leela	86.95	87.04	83.71	89.15	87.53	86.57	88.23	86.87	87.74
nab	85.68	85.67	82.81	88.21	88.37	86.37	88.54	88.54	85.70
exchange2	84.27	84.27	71.74	94.00	91.63	86.72	94.82	94.15	91.51
fotonik3d	99.80	99.80	99.77	99.80	99.80	99.79	99.80	99.80	99.77
roms	83.88	83.94	78.08	89.66	89.16	86.45	90.04	89.64	89.03
xz	92.16	92.15	88.66	92.75	92.52	90.27	91.26	91.01	90.61
geomean	92.38	92.35	89.07	94.58	93.63	92.13	94.74	94.26	93.60