

CS422A: Computer Architecture

Homework 2

Submitted By

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On Tuesday, 10 October 2023

About the Analysis

Flow is such that a call is inserted **before conditional jumps** and before **indirect calls**. These instructions are only present at the **tail of basic block**. These calls are placed with a check fast forward if clause. Terminate check and increase ins count is placed at basic block level to speed up analysis.

The basic block level of ins counts incur a cost of less than 10 extra instructions in 1 Billion instructions.

Used macro and classes for fewer errors in repeated codes

All fractions presented as percentages.

Note: Results of 403.gcc is deviating a lot

Machine used: `image1.cse.iitk.ac.in`

Usage

```
# Build the tool
```

```
make TARGET=ia32 obj-ia32/HW2.so
```

```
# Run the tool on a benchmark
```

```
cd /path/to/spec_2006/400.perlbench/
```

```
pin -t /path/to/obj-ia32/HW2.so -f <FAST_FORWARD_VAL> -o executable..out -- ./executable exec_args
```

- `-f`` flag is used to specify the fast-forward instruction count in billions.
- `-o`` flag is used to specify the output file.
- `-t`` flag is used to specify the pin tool to be used.
- `--`` is used to separate the pin tool arguments from the application arguments.

Pseudo instrumentation code

```
for BBL bbl in trace
```

```
    INS ins = BBL_InsTail(bbl);
```

```
    if (INS_Category(ins) == XED_CATEGORY_COND_BR)
```

```
        INS_InsertIfCall(ins, IPOINT_BEFORE, (AFUNPTR)CheckFastForward, IARG_END);
```

```
        INS_InsertThenCall(ins, IPOINT_BEFORE, AnalyzeUncondBranch, IARG_INST_PTR, ...);
```

```
    if (INS_IsIndirectControlFlow(ins))
```

```
        INS_InsertIfCall(ins, IPOINT_BEFORE, (AFUNPTR)CheckFastForward, IARG_END);
```

```
        INS_InsertThenCall(ins, IPOINT_BEFORE, AnalyzeIndirectControlFlow, ...);
```

```
BBL_InsertIfCall(bbl, IPOINT_BEFORE, (AFUNPTR)CheckTerminate, IARG_END);
```

```
BBL_InsertThenCall(bbl, IPOINT_BEFORE, (AFUNPTR)Terminate, IARG_END);
```

```
BBL_InsertCall(bbl, IPOINT_BEFORE, DoInsCount, IARG_UINT32, BBL_NumIns(bbl));
```

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Key Observations

- Highest degree of misprediction is in FNBT as this is the most primitive and stateless predictor.
- Bimodal predictor predicts based on previous states of the particular branch. This captures the branch's history. Aliasing of several PCs is present. Since the predictor trains itself the accuracy is always several times (3-6 times) better than FNBT.
- SAg predictor works on GHR and prediction on a given history. This caters to the history of a particular PC and the behavior of program on such history. This predictor is always better than bimodal as this also accounts for the correlation of the branches. There's one case where the performance depreciates by 0.5% for forward branches; this is a marginal deviation, and the overall performance is still better.
- GAg does not cater to the branch PC and hence, is totally dependent on the GHR. This results in worse performance than SAg. This is somewhat comparable to Bimodal, which fails to capture GHR and is totally dependent on PC. This, however, is not strictly true as programs like Soplex and mcf GAg perform better than SAg.
- gShare is indexed with both GHR and PC but has only one layer of counters, unlike SAg. This index is computed by the XOR of these two values. By pigeonhole principle, it implies that there will be more aliasing and fewer states with respect to SAg and hence, will be less accurate than SAg. This is also observed in the output. But no clear comparison between Bimodal, GAg, and gshare can be drawn. This indicates the independent behavior of these predictors.
- Hybrid predictor of SAg and GAg. As observed earlier the performance of SAg is *mostly* better than GAg but this does not always hold true depending on the program or program region the branches may depend more on one of the other factors driving the two predictors. The overhead of the tournament meta-predictor ensures the proper selection between two factors and hence this *always* performs better than both the predictors individually.
- Hybrid predictor of SAg, GAg, and gshare. We have already observed the independent behavior of these three predictors. But when we take the majority vote among the three we see improvement in a few and some minor downgrades in programs like perlbench, omnetpp, xalanck. This is due to the aliasing of the three predictors and this can be taken care of by having a bimodal tournament. In that case, the performance is always better than the individual three predictors.

- Forward branch mispredictions are generally more than backward branch mispredictions. This indicates that backward branches are more deterministic with respect to a forward branch which was also premise of FNBT.
- We see more BTB misses in case of indexing with PC+GHR since the same tags are distributed in several sets. This miss rate has increased in the order of 10-100 times.
- We see less BTB misprediction in the case of PC+GHR as the history in which branch trace is also considered instead of the branch. The magnitude of misprediction is far more than misses. There are significant improvements between the two BTB logic in some programs and marginal benefits in other programs. But the performance always increases.

Note: The performance of a predictor is the accuracy of the predictor.

Analysis of 400.perlbench diffmail.pl

=====

HW2 analysis results from perlbench.diffmail.out

Number of instructions: 208000000001

Fast forward at: 207000000000

Number of instructions after fast forward: 1000000001

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward
Overall			
Total number of Unconditional branches:	104112248	25945913	130058161
A. Static FNBT: (41.39%)	39244947 (37.69%)	14592365 (56.24%)	53837312
B. Bimodal predictor: 9.36%)	10071755 (9.67%)	2106085 (8.12%)	12177840 (
C. SAg: 3.49%)	3698499 (3.55%)	846581 (3.26%)	4545080 (
D. GAg: (11.73%)	12926998 (12.42%)	2323887 (8.96%)	15250885
E. gshare: (10.08%)	10624602 (10.20%)	2480040 (9.56%)	13104642

F. Hybrid of SAg and GAg: 2.84%)	3018798 (2.90%)	673600 (2.60%)	3692398 (
G. Hybrid of SAg, GAg, and gshare (majority): 4.84%)	5083102 (4.88%)	1206361 (4.65%)	6289463 (
G. Hybrid of SAg, GAg, and gshare (tournament): 2.50%)	2677945 (2.57%)	578900 (2.23%)	3256845 (

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 28121004

	Misprediction	Miss
BTB PC count:	9805043 (34.87%)	3338 (0.01%)
BTB PC+GHR count:	2467144 (8.77%)	386673 (1.38%)

=====

Time elapsed: 8.41 minutes

Analysis of 401.bzip2 input.source

=====

HW2 analysis results from bzip2.source.out

Number of instructions: 302000000003

Fast forward at: 301000000000

Number of instructions after fast forward: 1000000003

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward	
Overall				
Total number of Unconditional branches:	63177343	66745809	129923152	
A. Static FNBT: (46.89%)	19578181 (30.99%)	41345366 (61.94%)	60923547	
B. Bimodal predictor: (10.00%)	6860732 (10.86%)	6137243 (9.19%)	12997975	
C. SAg: 9.93%)	7063471 (11.18%)	5841630 (8.75%)	12905101 (
D. GAg: (12.49%)	9305143 (14.73%)	6922182 (10.37%)	16227325	
E. gshare: (11.30%)	7649415 (12.11%)	7030582 (10.53%)	14679997	

F. Hybrid of SAg and GAg: 9.32%)	6619302 (10.48%)	5493610 (8.23%)	12112912 (
G. Hybrid of SAg, GAg, and gshare (majority): 9.23%)	6420994 (10.16%)	5571959 (8.35%)	11992953 (
G. Hybrid of SAg, GAg, and gshare (tournament): 8.93%)	6196099 (9.81%)	5405046 (8.10%)	11601145 (

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 791934

	Misprediction	Miss
BTB PC count:	382394 (48.29%)	59 (0.01%)
BTB PC+GHR count:	376140 (47.50%)	214 (0.03%)

=====

Time elapsed: 9.15 minutes

Analysis of 403.gcc cp-decl.i

RUN 1

=====

HW2 analysis results from gcc.cp-decl.out

Number of instructions: 108000000000

Fast forward at: 107000000000

Number of instructions after fast forward: 1000000000

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward
Overall			
Total number of Unconditional branches:	28545036	104756532	133301568
A. Static FNBT: (10.38%)	9099302 (31.88%)	4731542 (4.52%)	13830844
B. Bimodal predictor: 4.14%)	3515356 (12.32%)	2001190 (1.91%)	5516546 (
C. SAg: 2.61%)	2127013 (7.45%)	1347437 (1.29%)	3474450 (
D. GAg: 4.01%)	3427978 (12.01%)	1921202 (1.83%)	5349180 (

E. gshare:	3415961 (11.97%)	1757063 (1.68%)	5173024 (3.88%)
F. Hybrid of SAg and GAg:	1575760 (5.52%)	1019398 (0.97%)	2595158 (1.95%)
G. Hybrid of SAg, GAg, and gshare (majority):	1985865 (6.96%)	1259218 (1.20%)	3245083 (2.43%)
G. Hybrid of SAg, GAg, and gshare (tournament):	1407982 (4.93%)	937539 (0.89%)	2345521 (1.76%)

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 6920903

	Misprediction	Miss
BTB PC count:	2451799 (35.43%)	470 (0.01%)
BTB PC+GHR count:	779945 (11.27%)	54016 (0.78%)

=====

Time elapsed: 5.27 minutes

RUN 2

=====

HW2 analysis results from gcc.cp-decl.out

Number of instructions: 108000000001

Fast forward at: 107000000000

Number of instructions after fast forward: 1000000001

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward
Overall			
Total number of Unconditional branches:	114532159	31251631	145783790
A. Static FNBT: (36.59%)	36427959 (31.81%)	16909826 (54.11%)	53337785
B. Bimodal predictor: (13.26%)	17346531 (15.15%)	1981727 (6.34%)	19328258
C. SAg: 4.98%)	5991377 (5.23%)	1264021 (4.04%)	7255398 (
D. GAg: (15.39%)	18507344 (16.16%)	3933578 (12.59%)	22440922
E. gshare: 9.73%)	10501649 (9.17%)	3677093 (11.77%)	14178742 (
F. Hybrid of SAg and GAg: 4.03%)	4939499 (4.31%)	933127 (2.99%)	5872626 (

G. Hybrid of SAg, GAg, and gshare (majority):	6013444 (5.25%)	1715411 (5.49%)	7728855 (5.30%)
G. Hybrid of SAg, GAg, and gshare (tournament):	3270853 (2.86%)	906350 (2.90%)	4177203 (2.87%)

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PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 34754610

	Misprediction	Miss
BTB PC count:	24536028 (70.60%)	37 (0.00%)
BTB PC+GHR count:	11009643 (31.68%)	13495 (0.04%)

Analysis of 429.mcf

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HW2 analysis results from mcf.out

Number of instructions: 378000000000

Fast forward at: 377000000000

Number of instructions after fast forward: 1000000000

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward	
Overall				
Total number of Unconditional branches:	89124420	89118944	178243364	
A. Static FNBT: (31.95%)	31825913 (35.71%)	25122474 (28.19%)	56948387	
B. Bimodal predictor: (17.75%)	14188093 (15.92%)	17450330 (19.58%)	31638423	
C. SAg: (12.60%)	13038185 (14.63%)	9415904 (10.57%)	22454089	
D. GAg: 9.26%)	8231591 (9.24%)	8273531 (9.28%)	16505122 (
E. gshare: (10.19%)	9271651 (10.40%)	8884776 (9.97%)	18156427	

F. Hybrid of SAg and GAg: 8.68%)	7940222 (8.91%)	7524417 (8.44%)	15464639 (
G. Hybrid of SAg, GAg, and gshare (majority): 8.64%)	7840138 (8.80%)	7564236 (8.49%)	15404374 (
G. Hybrid of SAg, GAg, and gshare (tournament): 8.25%)	7498613 (8.41%)	7210100 (8.09%)	14708713 (

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 12555925

	Misprediction	Miss
BTB PC count:	77021 (0.61%)	9 (0.00%)
BTB PC+GHR count:	51365 (0.41%)	105 (0.00%)

=====

Time elapsed: 15.93 minutes

Analysis of 450.soplex.ref.mps

=====

HW2 analysis results from soplex.ref.out

Number of instructions: 365000000000

Fast forward at: 364000000000

Number of instructions after fast forward: 1000000000

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward	
Overall				
Total number of Unconditional branches:	33953201	69183951	103137152	
A. Static FNBT: (17.15%)	6805080 (20.04%)	10880395 (15.73%)	17685475	
B. Bimodal predictor: 4.91%)	349376 (1.03%)	4718997 (6.82%)	5068373 (
C. SAg: 4.06%)	257709 (0.76%)	3932124 (5.68%)	4189833 (
D. GAg: 3.90%)	333611 (0.98%)	3685869 (5.33%)	4019480 (
E. gshare: 4.07%)	491204 (1.45%)	3709181 (5.36%)	4200385 (

F. Hybrid of SAg and GAg: 3.66%)	250678 (0.74%)	3522638 (5.09%)	3773316 (
G. Hybrid of SAg, GAg, and gshare (majority): 3.86%)	312564 (0.92%)	3670066 (5.30%)	3982630 (
G. Hybrid of SAg, GAg, and gshare (tournament): 3.63%)	253974 (0.75%)	3494631 (5.05%)	3748605 (

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 6333802

	Misprediction	Miss
BTB PC count:	1451 (0.02%)	120 (0.00%)
BTB PC+GHR count:	1540 (0.02%)	516 (0.01%)

=====

Time elapsed: 9.18 minutes

Analysis of 456.hmm nph3.hmm

=====

HW2 analysis results from hmmmer.nph3.out

Number of instructions: 265000000000

Fast forward at: 264000000000

Number of instructions after fast forward: 1000000000

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward
Overall			
Total number of Unconditional branches:	120193487	24167808	144361295
A. Static FNBT: (63.91%)	92105272 (76.63%)	161858 (0.67%)	92267130
B. Bimodal predictor: 8.26%)	11835294 (9.85%)	85482 (0.35%)	11920776 (
C. SAg: 8.80%)	12619089 (10.50%)	88904 (0.37%)	12707993 (
D. GAg: (11.87%)	16528977 (13.75%)	601929 (2.49%)	17130906
E. gshare: (10.29%)	14222474 (11.83%)	638215 (2.64%)	14860689

F. Hybrid of SAg and GAg: 8.47%)	12078925 (10.05%)	151796 (0.63%)	12230721 (
G. Hybrid of SAg, GAg, and gshare (majority): 8.75%)	12488156 (10.39%)	140024 (0.58%)	12628180 (
G. Hybrid of SAg, GAg, and gshare (tournament): 8.29%)	11868115 (9.87%)	103298 (0.43%)	11971413 (

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 201471

	Misprediction	Miss
BTB PC count:	12746 (6.33%)	64 (0.03%)
BTB PC+GHR count:	4472 (2.22%)	685 (0.34%)

=====

Time elapsed: 8.18 minutes

Analysis of 471.omnetpp

=====

HW2 analysis results from omnetpp.out

Number of instructions: 44000000006

Fast forward at: 43000000000

Number of instructions after fast forward: 1000000006

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward	
Overall				
Total number of Unconditional branches:	98389387	18944981	117334368	
A. Static FNBT: (34.12%)	33181690 (33.72%)	6855039 (36.18%)	40036729	
B. Bimodal predictor: (10.22%)	9520613 (9.68%)	2465527 (13.01%)	11986140	
C. SAg: 5.02%)	4313218 (4.38%)	1577291 (8.33%)	5890509 (
D. GAg: (12.27%)	11679187 (11.87%)	2712857 (14.32%)	14392044	
E. gshare: (10.90%)	10292345 (10.46%)	2502768 (13.21%)	12795113	

F. Hybrid of SAg and GAg: 4.08%)	3491049 (3.55%)	1295674 (6.84%)	4786723 (
G. Hybrid of SAg, GAg, and gshare (majority): 5.48%)	4697331 (4.77%)	1736493 (9.17%)	6433824 (
G. Hybrid of SAg, GAg, and gshare (tournament): 3.88%)	3306844 (3.36%)	1245985 (6.58%)	4552829 (

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PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 30294875

	Misprediction	Miss
BTB PC count:	8889426 (29.34%)	5630 (0.02%)
BTB PC+GHR count:	3261040 (10.76%)	273971 (0.90%)

=====

Time elapsed: 2.83 minutes

Analysis of 483.xalancbmk

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HW2 analysis results from xalancbmk.out

Number of instructions: 1332000000000

Fast forward at: 1331000000000

Number of instructions after fast forward: 1000000000

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PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward
Overall			
Total number of Unconditional branches:	140828994	46442339	187271333
A. Static FNBT: 7.16%)	11232326 (7.98%)	2167799 (4.67%)	13400125 (7.16%)
B. Bimodal predictor: 3.23%)	5151750 (3.66%)	895089 (1.93%)	6046839 (3.23%)
C. SAg: 1.71%)	2704853 (1.92%)	489530 (1.05%)	3194383 (1.71%)
D. GAg: 4.12%)	6364390 (4.52%)	1346107 (2.90%)	7710497 (4.12%)
E. gshare: 3.66%)	5576746 (3.96%)	1279347 (2.75%)	6856093 (3.66%)

F. Hybrid of SAg and GAg: 1.26%)	1941124 (1.38%)	422547 (0.91%)	2363671 (
G. Hybrid of SAg, GAg, and gshare (majority): 1.93%)	2936477 (2.09%)	681480 (1.47%)	3617957 (
G. Hybrid of SAg, GAg, and gshare (tournament): 1.15%)	1775834 (1.26%)	373292 (0.80%)	2149126 (

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PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 31521920

	Misprediction	Miss
BTB PC count:	7714839 (24.47%)	613046 (1.94%)
BTB PC+GHR count:	3843076 (12.19%)	4379303 (13.89%)

=====

Time elapsed: 62.44 minutes

Optional Analysis of 436.cactusADM

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HW2 analysis results from cactusADM.out

Number of instructions: 585000000050

Fast forward at: 584000000000

Number of instructions after fast forward: 1000000050

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type		Forward	Backward
Overall			
Total number of Unconditional branches:	2153267	2152350	4305617
A. Static FNBT: (12.69%)	9893 (0.46%)	536542 (24.93%)	546435
B. Bimodal predictor: (12.48%)	3029 (0.14%)	534120 (24.82%)	537149
C. SAg: 0.29%)	2004 (0.09%)	10358 (0.48%)	12362 (
D. GAg: 0.36%)	4240 (0.20%)	11252 (0.52%)	15492 (
E. gshare: (12.26%)	3746 (0.17%)	523976 (24.34%)	527722

F. Hybrid of SAg and GAg: 0.28%)	2035 (0.09%)	10174 (0.47%)	12209 (
G. Hybrid of SAg, GAg, and gshare (majority): 0.30%)	2361 (0.11%)	10730 (0.50%)	13091 (
G. Hybrid of SAg, GAg, and gshare (tournament): 0.29%)	2148 (0.10%)	10232 (0.48%)	12380 (

=====

PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 531992

	Misprediction	Miss
BTB PC count:	1889 (0.36%)	116 (0.02%)
BTB PC+GHR count:	1093 (0.21%)	252 (0.05%)

=====

Time elapsed: 7.92 minutes

Optional Analysis of 437.leslie3d

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HW2 analysis results from leslie3d.out

Number of instructions: 2347000000030

Fast forward at: 2346000000000

Number of instructions after fast forward: 10000000030

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type		Forward	Backward
Overall			
Total number of Unconditional branches:	464563	41084736	41549299
A. Static FNBT: 0.88%)	17778 (3.83%)	349836 (0.85%)	367614 (0.88%)
B. Bimodal predictor: 0.88%)	15873 (3.42%)	349701 (0.85%)	365574 (0.88%)
C. SAg: 0.83%)	2379 (0.51%)	340534 (0.83%)	342913 (0.83%)
D. GAg: 1.14%)	101914 (21.94%)	372788 (0.91%)	474702 (1.14%)
E. gshare: 0.92%)	30958 (6.66%)	350222 (0.85%)	381180 (0.92%)

F. Hybrid of SAg and GAg: 0.83%)	2250 (0.48%)	340774 (0.83%)	343024 (
G. Hybrid of SAg, GAg, and gshare (majority): 0.88%)	23231 (5.00%)	340883 (0.83%)	364114 (
G. Hybrid of SAg, GAg, and gshare (tournament): 0.83%)	2404 (0.52%)	340877 (0.83%)	343281 (

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PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 978

	Misprediction	Miss
BTB PC count:	276 (28.22%)	113 (11.55%)
BTB PC+GHR count:	215 (21.98%)	186 (19.02%)

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Time elapsed: 25.41 minutes

Optional Analysis of 462.libquantum

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HW2 analysis results from libquantum.out

Number of instructions: 3606000000008

Fast forward at: 3605000000000

Number of instructions after fast forward: 1000000008

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type	Forward		Backward
Overall			
Total number of Unconditional branches:	100961333	56456007	157417340
A. Static FNBT: (55.65%)	87053290 (86.22%)	556590 (0.99%)	87609880
B. Bimodal predictor: 7.67%)	11790038 (11.68%)	278307 (0.49%)	12068345 (
C. SAg: 0.97%)	1251087 (1.24%)	278370 (0.49%)	1529457 (
D. GAg: 6.04%)	9236285 (9.15%)	278474 (0.49%)	9514759 (
E. gshare: 5.95%)	9092403 (9.01%)	278505 (0.49%)	9370908 (

F. Hybrid of SAg and GAg: 0.93%)	1177908 (1.17%)	278416 (0.49%)	1456324 (
G. Hybrid of SAg, GAg, and gshare (majority): 5.32%)	8099516 (8.02%)	278437 (0.49%)	8377953 (
G. Hybrid of SAg, GAg, and gshare (tournament): 0.93%)	1178024 (1.17%)	278461 (0.49%)	1456485 (

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PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 556667

	Misprediction	Miss
BTB PC count:	60 (0.01%)	9 (0.00%)
BTB PC+GHR count:	52 (0.01%)	25 (0.00%)

=====

Time elapsed: 113.13 minutes

Optional Analysis of 470.lbm

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HW2 analysis results from lbm.out

Number of instructions: 831000000045

Fast forward at: 830000000000

Number of instructions after fast forward: 1000000045

=====

PART A: DIRECTION PREDICTORS FOR CONDITIONAL BRANCHES

Type		Forward	Backward
Overall			
Total number of Unconditional branches:	5135098	2652381	7787479
A. Static FNBT: (62.02%)	2427185 (47.27%)	2402438 (90.58%)	4829623
B. Bimodal predictor: 1.20%)	1947 (0.04%)	91290 (3.44%)	93237 (
C. SAg: 0.46%)	806 (0.02%)	34840 (1.31%)	35646 (
D. GAg: 0.46%)	1087 (0.02%)	34487 (1.30%)	35574 (
E. gshare: 0.58%)	10386 (0.20%)	34495 (1.30%)	44881 (

F. Hybrid of SAg and GAg: 0.45%)	960 (0.02%)	34437 (1.30%)	35397 (
G. Hybrid of SAg, GAg, and gshare (majority): 0.46%)	1028 (0.02%)	34463 (1.30%)	35491 (
G. Hybrid of SAg, GAg, and gshare (tournament): 0.46%)	1042 (0.02%)	34453 (1.30%)	35495 (

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PART B: TARGET PREDICTORS FOR INDIRECT CONTROL FLOW INSTRUCTIONS

BTB lookup count: 210

	Misprediction	Miss
BTB PC count:	47 (22.38%)	34 (16.19%)
BTB PC+GHR count:	14 (6.67%)	74 (35.24%)

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Time elapsed: 6.30 minutes