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Programming assignment #2
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Part 1

I used sig servers to finish this assignment. Both sig servers and independent environment have advantages. For example, when we use sig servers, we do not need to build the complex Linux environment, which saves a considerable of time. However, services may sometimes busy, and it may not as effective as independent environment when there are too much users.

During the period of building gem5, errors occurred because of the server run out of resources. After I changed the server from sig1 to sig2, the problem solved.

Part 2

I used the command line option to finish this part. The result of my config.ini file that shows the BiModeBP is shown below.

```
[rwu@sigint m5out]$ vim config.ini

[system.cpu.branchPred]
type=BiModeBP
BTBEntries=4096
BTBTagSize=16
RASSize=16
choiceCtrBits=2
choicePredictorSize=8192
eventq_index=0
globalCtrBits=2
globalPredictorSize=8192
indirectBranchPred=Null
instShiftAmt=2
numThreads=1
```

Part 3

BTBMissPct = (1 - (BTBHits/BTBLookups)) * 100

BTB Hits -> total number of BTB Hits

BTBLookups -> total number of BTB References

BranchMispredPercent = (numBranchMispred / numBranches) * 100

numBranchMispred -> total number of mispredicted Branches

numBranches -> total number of branches fetched

From part 2, the parameters that can define BTB miss rate and Branch miss prediction are show as below.

```
system.cpu.branchPred.BTBHits                 107       # Number of BTB hits
system.cpu.branchPred.BTBLookups              190       # Number of BTB lookups
system.cpu.BranchMispred                      612       # Number of branch mispredictions
system.cpu.Branches                          1317       # Number of branches fetched
```

BTBMissPct=43.69

BranchMispredPercent=46.47

Part 4

BTB MR refers to BTB miss rate, and Branch MPR refers to Branch misprediction rate.

1) Changing the Number of BTB entries from 512 to 8192:

Default Predictor is BiModeBP. As Number of BTB entries change, the size of predictors remain the same, so we can observe the trend.

	401.bzip2		429.mcf		456.hmmer		458.sjeng		470.lbm	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.6545	10.3748	1.4856	6.1955	1.4653	9.5379	9.0214	14.0734	0.0027	15.1698
1024	0.0423	10.1003	0.7440	5.8250	0.0354	8.4681	4.8271	11.3370	0.0024	15.1697
2048	0.0275	10.0935	0.3705	5.6381	0.0229	8.4590	2.1223	9.6035	0.0024	15.1697
4096	0.0007	10.0775	0.0011	5.4534	0.0177	8.4554	0.8970	8.8279	0.0023	15.1697
8192	0.0007	10.0775	0.0011	5.4534	0.0153	8.4536	0.4712	8.5782	0.0023	15.1697

As the number of BTB entries increases, BTB miss rate and Branch misprediction rate would decrease. However, from 4096 to 8192, the decrease is not significant, so 4096 BTB entries is cost effective in this case.

2)Selecting BimodeBP and changing its parameters

a) Changing the Size of global predictor From 512 to 8192

Default number of BTB entries is 4096, and the default size of choice predictor is 8192.

	401.bzip2		429.mcf		456.hmmer		458.sjeng		470.lbm	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.0021	10.4806	0.0416	6.1421	0.0523	9.8341	1.1649	11.0168	0.0028	0.8091
1024	0.0013	10.3789	0.0252	5.8280	0.0373	9.0882	1.0913	10.0206	0.0025	8.2169
2048	0.0010	10.1701	0.0019	5.6135	0.0311	8.8767	1.0199	8.9680	0.0026	15.6248
4096	0.0009	10.1364	0.0014	5.5313	0.0249	8.7142	0.9416	9.4110	0.0024	15.6250
8192	0.0007	10.0775	0.0011	5.4534	0.0177	8.4554	0.8970	8.8279	0.0023	15.1697

Considering BimodeBP, as the size of global predictor increases, BTB miss rate and Branch misprediction rate would decrease. Than we could assume that the predictor has the best performance

when the size of global predictor of BimodeBP is 8192. However, when we set size of global predictor as 512 and 1024, the results of Branch misprediction rate of benchmark 470.lbm are unexpected, and this probably errors occur.

b)Changing the Size of choice predictor From 512 to 8192

Default number of BTB entries is 4096, and the default size of global predictor is 8192.

	401.bzip2		**429.mcf**		**456.hmmer**		**458.sjeng**		**470.lbm**	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.0009	10.0502	0.0056	5.4537	0.0196	8.4678	1.1024	10.5689	0.0023	15.1695
1024	0.0008	10.0773	0.0014	5.4534	0.0181	8.4522	1.0222	10.4079	0.0023	15.1696
2048	0.0008	10.0773	0.0014	5.4534	0.0179	8.4536	0.9687	10.2337	0.0023	15.1696
4096	0.0008	10.0776	0.0012	5.4533	0.0178	8.4553	0.9148	8.8535	0.0023	15.1697
8192	0.0007	10.0775	0.0011	5.4534	0.0153	8.4536	0.4712	8.5782	0.0023	15.1697

Considering BimodeBP, as the size of choice predictor increases, BTB miss rate and Branch misprediction rate would decrease, but the decreasing trend is not significant for some benchmark.

2) Selecting LocalBP and changing its parameters

Default number of BTB entries is 4096.

	401.bzip2		429.mcf		456.hmmer		458.sjeng		470.lbm	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.0041	9.3694	2.8366	10.9703	0.7510	14.4613	2.2615	14.8642	0.0054	8.0019
1024	0.0015	9.6199	0.8735	10.4861	0.0301	14.2884	1.9137	13.5650	0.0038	8.0020
2048	0.0012	12.3578	0.6732	9.7530	0.0174	14.2794	1.5549	12.6317	0.0028	8.0021
4096	0.0009	12.6867	0.0128	9.1954	0.0132	14.2717	1.3057	12.0502	0.0023	8.0021
8192	0.0008	12.6851	0.0126	9.0753	0.0117	14.2693	1.1772	11.8307	0.0020	8.0021

When we changed parameters of LocalBP, as the size of choice predictor increases, BTB miss rate and Branch misprediction rate would decrease, but for some benchmarks, the decreasing trend is not obvious and some even keep stable.

3）Choosing TournamentBP and changing its parameters

a)Changing the Size of local predictor From 512 to 8192

Default number of BTB entries is 4096.Default size of global predictor is 8192, and the default size of choice predictor is 8192.

	401.bzip2		429.mcf		456.hmmer		458.sjeng		470.lbm	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.0042	5.9733	0.0089	4.8610	0.0220	8.8010	1.2130	10.0425	0.0043	0.3486
1024	0.0041	6.0049	0.0082	4.7693	0.0200	7.7551	1.1879	9.5487	0.0043	0.3484
2048	0.0041	5.9800	0.0078	4.7363	0.0196	6.6287	1.1781	9.3182	0.0052	7.7562
4096	0.0040	5.9668	0.0074	4.7088	0.0192	6.5353	1.1670	9.0953	0.0052	7.7567
8192	0.0038	5.9842	0.0070	4.6866	0.0190	6.4648	1.1394	7.5811	0.0052	7.7572

Considering TournamentBP, as the size of global predictor increases, BTB miss rate and Branch misprediction rate present decreasing trend. Unexpected results occur again for 470.lbm.

b)Changing the Size of global predictor From 512 to 8192

Default size of local predictor is 2048, and the default size of choice predictor is 8192.

	401.bzip2		**429.mcf**		**456.hmmer**		**458.sjeng**		**470.lbm**	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.0047	6.0636	0.0074	5.0590	0.0204	7.9767	1.2598	8.5561	0.0052	7.7651
1024	0.0044	5.8619	0.0120	4.9889	0.0213	7.2178	1.2542	8.4004	0.0052	7.7651
2048	0.0041	5.8707	0.0074	4.8616	0.0211	6.6866	1.2358	8.2095	0.0052	7.7652
4096	0.0041	5.8793	0.0077	4.7905	0.0201	6.5097	1.1860	8.0276	0.0052	7.7652
8192	0.0041	5.9800	0.0078	4.7363	0.0196	6.6287	1.1781	9.3182	0.0052	7.7562

Also for the size of global predictor, the bigger size, the smaller of BTB miss rate and Branch misprediction rate. The size of 8192 has the best performance.

c) Changing the Size of choice predictor From 512 to 8192

Default size of local predictor is 2048, and the default size of global predictor is 8192.

	401.bzip2		**429.mcf**		**456.hmmer**		**458.sjeng**		**470.lbm**	
	BTB MR	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**	**BTB MR**	**Branch MPR**
512	0.0053	6.1601	0.0112	4.9320	0.0329	7.0461	1.2860	10.0361	0.0050	7.7577
1024	0.0045	6.1045	0.0098	4.8824	0.0283	6.9045	1.2427	8.4797	0.0051	7.7577
2048	0.0042	6.0511	0.0089	4.8313	0.0276	6.8009	1.2111	8.3140	0.0051	7.7577
4096	0.0042	6.0176	0.0080	4.7795	0.0261	6.6996	1.1781	8.1243	0.0051	7.7577
8192	0.0041	5.9800	0.0078	4.7363	0.0196	6.6287	1.1781	9.3182	0.0052	7.7562

Considering the choice predictor size of TournamentBP, bigger size predictor has lower BTB miss rate and Branch misprediction rate. Therefore, aiming at the performance, 8192 can be the best choice.

In brief, BTB miss rate and Branch misprediction rate would decrease when the size of predictors is enlarged. CPI is directly related to Branch misprediction rate. Higher Branch misprediction rate means there are more stall cycles. According to the results I got in above. Except from the benchmark 470.lbm, Branch misprediction rate would decrease as we increase predictors size or BTB entry number. Therefore, CPI would decrease as number of BTB entries and the size of predictors grow.