The Inner Most Loop Iteration counter

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Projeto 3
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Article

Artigo: [MICRO48] The Inner Most Loop Iteration counter: a new dimension in branch history - Andre Seznec (INRIA/IRISA), Joshua San Miguel (University of Toronto), Jorge Albericio (University of Toronto)

Estado da Arte - Branch Predictor

Derived from 2 families:

- Neural-inspired predictors
- TAGE-based predictors

Both works using a neural component, a large global history component and a small local history component

Branch Correlation

“(...) in many cases, the outcome of a branch is correlated with the outcome of a single past branch or the outcomes of a few past branches.”

“(...) in some cases, the outcome of a branch encapsulated in the inner most loop of a multidimensional loop is correlated with the outcomes of the same branch in neighbor iterations of the inner loop but within the previous outer loop iteration.”

```
for (N=0;i <Nmax;N++)
        for (M=0; M <Mmax; M++){
                if (A[M+N] >0) { ..}            // Branch B1
                if (B[N][M]-B[N-1][M])>0{..}  // Branch B2
                if (C[M]>0)                     // Branch B3
                        if(D[M] >0) {..}        // Branch B4
        }
```

Inner Most Loop Iteration (IMLI)

For a dynamic branch: IMLI counter = iteration # of the loop encapsulating the branch

Two IMLI-based components:

- IMLI-SIC (Same Iteration Correlation)
  - IMLI-SIC prediction table indexed with the IMLI counter and the PC
- IMLI-OH (Outer History)
  - Same correlation as WH predictor
  - Prediction table
  - IMLI-OH table indexed with the PC and IMLI counter

IMLI Components

IMLI Counter:

IMLI count it's the number of times that the last encountered backward conditional branch has been consecutively taken

```
if (backward) {
    if (taken) IMLIcount++;
    else IMLIcount = 0;
}
```

IMLI Components

IMLI-SIC:

Add a single table (IMLI-SIC table) to the statistical corrector of TAGE-GSC.
IMLI-SIC is indexed with a hash of the IMLI counter and the PC.

IMLI Components

<u>IMLI-OH:</u>

It consists of the IMLI-OH predictor table, which is incorporated in the SC part of the TAGE-GSC predictor.. It also consists of two structures to store and retrieve the history of the previous outer loop iteration: the IMLI history table and the PIPE vector, described below.

The outcome of branches are stored in the IMLI history table. The outcome of a branch at address B is stored at address (B*64) + IMLIcount. This allows us to recover Out[N-1][M] when predicting Out[N][M]. However, when predicting the next iteration (i.e., Out[N][M+1]), Out[N-1][M] would have already been overwritten with Out[N][M]. Therefore, the PIPE (Previous Inner iteration in Previous External iteration) vector is used to intermediately store Out[N-1][M].

Results - expected

Figure 8: IMLI-induced MPKI reduction on the 80 benchmarks; TAGE-GSC predictor

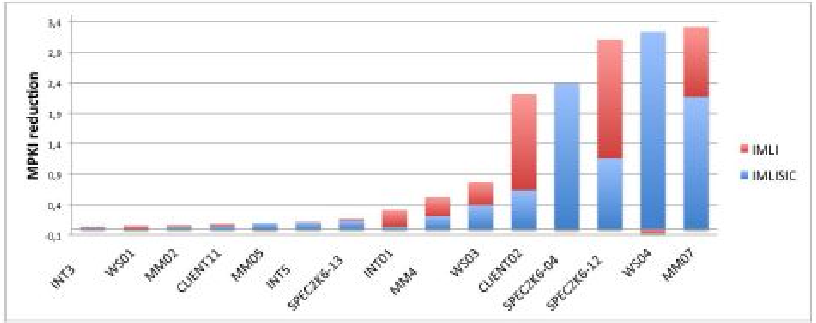
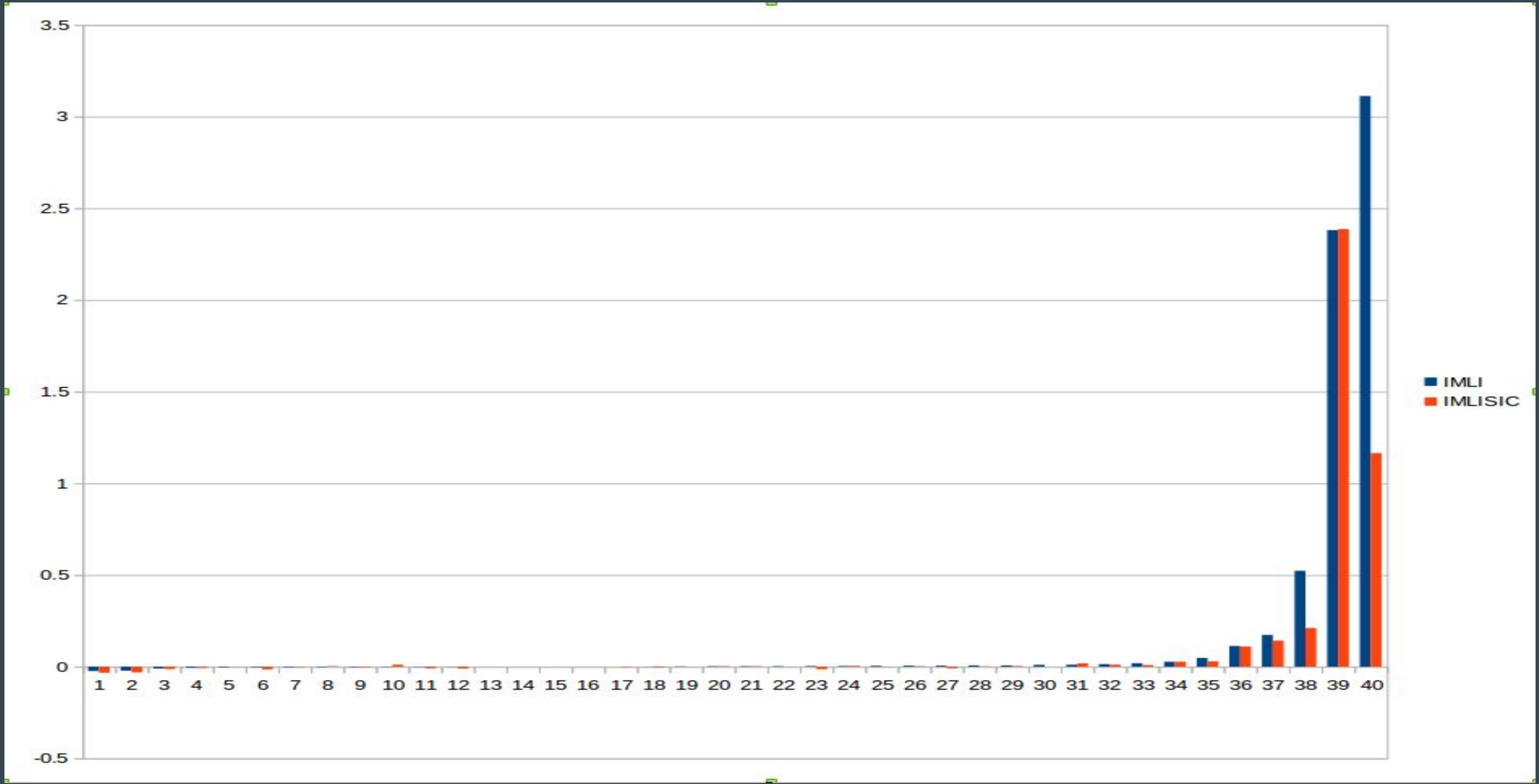


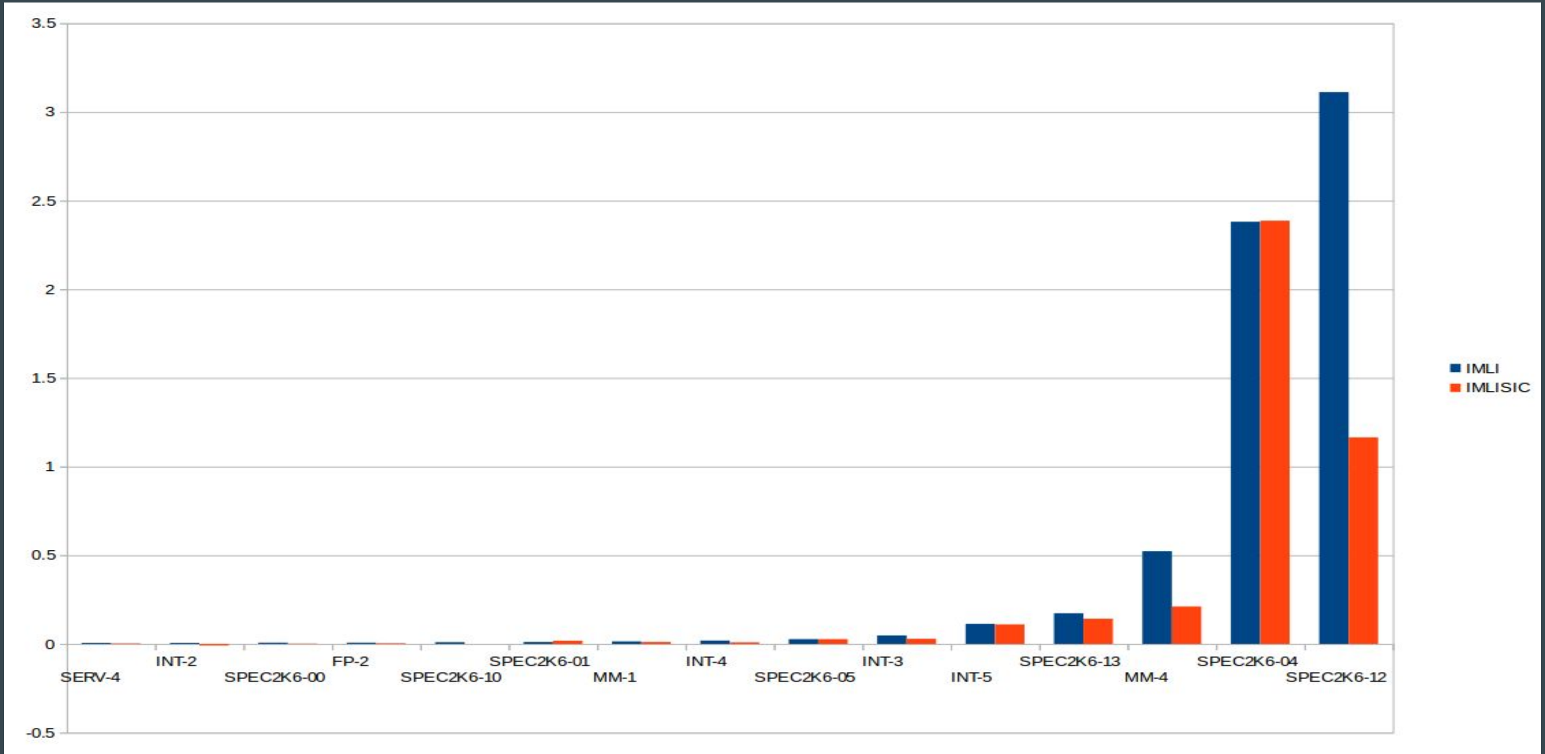
Figure 9: IMLI-induced MPKI reduction on the 15 most benefitting benchmarks; TAGE-GSC predictor

For TAGE-GSC, the misprediction rate is improved by 6.8 % from 2.473 MPKI to 2.313 MPKI on CBP4 traces

Results - 40 traces



Results - 15 best



Results - traces

ResultDirs ==>	ect03/TAGE-GSC
LONG-SPEC2K6-00	1.409
LONG-SPEC2K6-01	6.715
LONG-SPEC2K6-02	0.434
LONG-SPEC2K6-03	0.624
LONG-SPEC2K6-04	8.198
LONG-SPEC2K6-05	4.796
LONG-SPEC2K6-06	0.575
LONG-SPEC2K6-07	7.479
LONG-SPEC2K6-08	0.649
LONG-SPEC2K6-09	3.363
LONG-SPEC2K6-10	0.646
LONG-SPEC2K6-11	0.450
LONG-SPEC2K6-12	11.176
LONG-SPEC2K6-13	4.934
LONG-SPEC2K6-14	0.001
LONG-SPEC2K6-15	0.319
LONG-SPEC2K6-16	2.894
LONG-SPEC2K6-17	2.439
LONG-SPEC2K6-18	0.018
LONG-SPEC2K6-19	1.002
SHORT-FP-1	1.161
SHORT-FP-2	0.463
SHORT-FP-3	0.015
SHORT-FP-4	0.015
SHORT-FP-5	0.027
SHORT-INT-1	0.153
SHORT-INT-2	4.089
SHORT-INT-3	6.868
SHORT-INT-4	0.542
SHORT-INT-5	0.215
SHORT-MM-1	6.855
SHORT-MM-2	8.567
SHORT-MM-3	0.060
SHORT-MM-4	1.036
SHORT-MM-5	3.284
SHORT-SERV-1	0.781
SHORT-SERV-2	0.758
SHORT-SERV-3	2.589
SHORT-SERV-4	1.796
SHORT-SERV-5	1.533
AMEAN	2.473

ResultDirs ==>	ect03/IMLISIC/
LONG-SPEC2K6-00	1.407
LONG-SPEC2K6-01	6.697
LONG-SPEC2K6-02	0.433
LONG-SPEC2K6-03	0.621
LONG-SPEC2K6-04	5.811
LONG-SPEC2K6-05	4.769
LONG-SPEC2K6-06	0.584
LONG-SPEC2K6-07	7.510
LONG-SPEC2K6-08	0.648
LONG-SPEC2K6-09	3.378
LONG-SPEC2K6-10	0.646
LONG-SPEC2K6-11	0.454
LONG-SPEC2K6-12	10.011
LONG-SPEC2K6-13	4.792
LONG-SPEC2K6-14	0.001
LONG-SPEC2K6-15	0.320
LONG-SPEC2K6-16	2.897
LONG-SPEC2K6-17	2.449
LONG-SPEC2K6-18	0.015
LONG-SPEC2K6-19	0.999
SHORT-FP-1	1.175
SHORT-FP-2	0.459
SHORT-FP-3	0.015
SHORT-FP-4	0.015
SHORT-FP-5	0.027
SHORT-INT-1	0.152
SHORT-INT-2	4.098
SHORT-INT-3	6.839
SHORT-INT-4	0.533
SHORT-INT-5	0.105
SHORT-MM-1	6.844
SHORT-MM-2	8.556
SHORT-MM-3	0.063
SHORT-MM-4	0.825
SHORT-MM-5	3.297
SHORT-SERV-1	0.786
SHORT-SERV-2	0.753
SHORT-SERV-3	2.622
SHORT-SERV-4	1.793
SHORT-SERV-5	1.540
AMEAN	2.373

ResultDirs ==>	project03/IMLI
LONG-SPEC2K6-00	1.402
LONG-SPEC2K6-01	6.704
LONG-SPEC2K6-02	0.432
LONG-SPEC2K6-03	0.627
LONG-SPEC2K6-04	5.817
LONG-SPEC2K6-05	4.769
LONG-SPEC2K6-06	0.577
LONG-SPEC2K6-07	7.501
LONG-SPEC2K6-08	0.653
LONG-SPEC2K6-09	3.367
LONG-SPEC2K6-10	0.636
LONG-SPEC2K6-11	0.453
LONG-SPEC2K6-12	8.064
LONG-SPEC2K6-13	4.761
LONG-SPEC2K6-14	0.001
LONG-SPEC2K6-15	0.314
LONG-SPEC2K6-16	2.898
LONG-SPEC2K6-17	2.440
LONG-SPEC2K6-18	0.015
LONG-SPEC2K6-19	0.999
SHORT-FP-1	1.157
SHORT-FP-2	0.456
SHORT-FP-3	0.015
SHORT-FP-4	0.015
SHORT-FP-5	0.027
SHORT-INT-1	0.150
SHORT-INT-2	4.083
SHORT-INT-3	6.820
SHORT-INT-4	0.523
SHORT-INT-5	0.102
SHORT-MM-1	6.841
SHORT-MM-2	8.569
SHORT-MM-3	0.060
SHORT-MM-4	0.513
SHORT-MM-5	3.294
SHORT-SERV-1	0.780
SHORT-SERV-2	0.754
SHORT-SERV-3	2.613
SHORT-SERV-4	1.790
SHORT-SERV-5	1.539
AMEAN	2.313

Bibliography

[MICRO48] The Inner Most Loop Iteration counter: a new dimension in branch history - Andre Seznec (INRIA/IRISA), Joshua San Miguel (University of Toronto), Jorge Albericio (University of Toronto) - http://dx.doi.org/10.1145/2830772.2830831