



<http://acaps.ulbsibiu.ro/>

ABPS – Advanced Branch Prediction Simulator

Ciprian RADU, Horia CALBOREAN, Adrian CRAPCIU

Lucian VINȚAN, Adrian FLOREA

04/09/07

<http://abps.sourceforge.net>

```
-----Simulation number: 2-----
Detector type: DETECTOR HrG + HrL
Detection for trace: FBUBBLE.TRA
Parameters: Hrl = 4, HrG = 4, Path = not
selected, Unbiased polarization degree = 0.95
PC: 68 , HrG: 0011 , HrL: 0101 , BIAS: 0.657
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.533
PC: 68 , HrG: 0111 , HrL: 1000 , BIAS: 0.647
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.596
PC: 68 , HrG: 0011 , HrL: 0110 , BIAS: 0.842
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.666
PC: 68 , HrG: 1011 , HrL: 0001 , BIAS: 0.571
PC: 68 , HrG: 1000 , HrL: 0101 , BIAS: 0.833
PC: 68 , HrG: 0011 , HrL: 0000 , BIAS: 0.517
PC: 68 , HrG: 1110 , HrL: 1000 , BIAS: 0.712
PC: 68 , HrG: 0110 , HrL: 1000 , BIAS: 0.661
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.517
PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.819
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.602
PC: 68 , HrG: 1110 , HrL: 0000 , BIAS: 0.517
PC: 68 , HrG: 1110 , HrL: 0010 , BIAS: 0.571
PC: 68 , HrG: 1011 , HrL: 0110 , BIAS: 0.735
PC: 68 , HrG: 0110 , HrL: 0000 , BIAS: 0.596
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.603
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.622
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.724
PC: 45 , HrG: 1010 , HrL: 0001 , BIAS: 0.9
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.622
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.607
PC: 68 , HrG: 1011 , HrL: 0111 , BIAS: 0.622
PC: 75 , HrG: 0010 , HrL: 0110 , BIAS: 0.923
PC: 68 , HrG: 1110 , HrL: 0001 , BIAS: 0.652
PC: 68 , HrG: 1011 , HrL: 0010 , BIAS: 0.84
PC: 68 , HrG: 0100 , HrL: 0000 , BIAS: 0.734
PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.588
PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.656
PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.585
PC: 68 , HrG: 1010 , HrL: 1000 , BIAS: 0.529
PC: 68 , HrG: 1101 , HrL: 0101 , BIAS: 0.529
PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.78
```

What is ABPS?

- A trace-driven simulator that allows you to study the problem of branch prediction;
- A detector of difficult to predict branches;
- A predictor of branches;
- An interactive tool;
- An easy to use and highly configurable simulator;
- An OS independent platform.

Why do we need ABPS?

- **Lack of simulators dedicated to branch prediction used in didactical purposes despite of plenty used in research goals;**
- **Most existing simulators (from research) are difficult to use and don't provide a GUI;**
- **Studying processors performance requires simulators;**
- **ABPS permits the migration of some mature actual scientific problems to students' understanding level.**

A trace driven Branch Prediction Simulator

- ABPS currently uses two kind of **integer benchmarks** for simulation purposes:
 - **8 Stanford** benchmarks - very helpful for didactic purposes (**Hennessy**);
 - **17 SPEC 2000** benchmarks (**standardized** and more complex, **1.000.000** dynamic branches - **research**).

A trace driven Branch Prediction Simulator (cont.)

- CBP 2 (Championship of Branch Prediction, second edition) benchmarks were recently integrated with ABPS: 20 benchmarks (integer and Java), having approximately **20.000.000 branch instructions**, allowing the user to perform complex simulations

ABPS is a Detector

- All present branch prediction techniques are limited in their accuracy.
- An important limitation cause is given by the used prediction contexts (*global and local histories, path information*).
- Some branches are unbiased and non-deterministically shuffled, thus unpredictable.
- The percentages of these branches represents a fundamental prediction limitation.

ABPS is a Detector (cont.)

- Detecting difficult to predict branches can be easily done with ABPS, in a highly configurable manner;
- ABPS includes several detection schemes, based on:
 - Local history (**HrL**);
 - Global history (**HrG**);
 - **HrL + HrG**;
 - **HrG + Path**;
 - **HrL + HrG + Path**.

ABPS is a Predictor

- Or, more exactly: a collection of predictors, fully configurable;
- ABPS integrates two level predictors and state of the art (neural) predictors;
- Simulation over different benchmarks, using multiple prediction schemes, allows an easy to perform comparison between different predictors.

ABPS is a Predictor (Cont.)

- Two level predictors:
 - GAg
 - GShare
 - PAg
 - PAp
- Neural Predictors:
 - Simple perceptron
 - Fast Path-based perceptron

```
-----Simulation number: 2-----
Detector type: DETECTOR HrG + HrL
Detection for trace: PUSBN (K)
Parameters: HrG: 4, HrL: 4, Path: 1
selected, Unbiased polarization degree = 0.99
PC: 68 , HrG: 0011 , HrL: 0101 , BIAS: 0.657
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.533
PC: 68 , HrG: 0111 , HrL: 1000 , BIAS: 0.647
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.565
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.565
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.666
PC: 68 , HrG: 1011 , HrL: 0001 , BIAS: 0.571
PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.833
PC: 68 , HrG: 0001 , HrL: 0000 , BIAS: 0.513
PC: 68 , HrG: 1110 , HrL: 1000 , BIAS: 0.712
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.661
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.518
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.809
PC: 68 , HrG: 0111 , HrL: 0111 , BIAS: 0.602
PC: 68 , HrG: 1110 , HrL: 0000 , BIAS: 0.517
PC: 68 , HrG: 1110 , HrL: 0010 , BIAS: 0.571
PC: 68 , HrG: 1111 , HrL: 0110 , BIAS: 0.735
PC: 68 , HrG: 0110 , HrL: 0000 , BIAS: 0.596
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.603
PC: 68 , HrG: 0111 , HrL: 0000 , BIAS: 0.724
PC: 45 , HrG: 1010 , HrL: 0001 , BIAS: 0.9
PC: 68 , HrG: 0111 , HrL: 0001 , BIAS: 0.587
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.697
PC: 68 , HrG: 1011 , HrL: 0111 , BIAS: 0.622
PC: 75 , HrG: 0110 , HrL: 0110 , BIAS: 0.693
PC: 68 , HrG: 1110 , HrL: 0001 , BIAS: 0.632
PC: 68 , HrG: 1011 , HrL: 0010 , BIAS: 0.84
PC: 68 , HrG: 0100 , HrL: 0000 , BIAS: 0.734
PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.588
PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.656
PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.585
PC: 68 , HrG: 1010 , HrL: 1000 , BIAS: 0.656
PC: 68 , HrG: 1101 , HrL: 0101 , BIAS: 0.529
PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.78
```

04/09/07

<http://abps.sourceforge.net>

-----Simulation number: 2-----

Detector type: DETECTOR HrG + HrL
Detection For trace: FEEDBACK
Parameter: HrG = 4, Pch = 0.25
selected, Unbiased polarization degree = 0.25

ABPS is a Detector & Predictor

PC: 68 , HrG: 0011 , HrL: 0101 , BIAS: 0.657
 PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
 PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.533
 PC: 68 , HrG: 0111 , HrL: 1000 , BIAS: 0.647
 PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.842
 PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.665
 PC: 68 , HrG: 1000 , HrL: 0100 , BIAS: 0.833
 PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.661
 PC: 68 , HrG: 1110 , HrL: 1000 , BIAS: 0.712
 PC: 68 , HrG: 0110 , HrL: 1000 , BIAS: 0.661
 PC: 68 , HrG: 1110 , HrL: 0000 , BIAS: 0.518
 PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.809
 PC: 68 , HrG: 0001 , HrL: 0111 , BIAS: 0.622
 PC: 68 , HrG: 1110 , HrL: 0000 , BIAS: 0.517
 PC: 68 , HrG: 1110 , HrL: 0010 , BIAS: 0.571
 PC: 68 , HrG: 0001 , HrL: 0000 , BIAS: 0.586
 PC: 68 , HrG: 0001 , HrL: 0111 , BIAS: 0.708
 PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.724
 PC: 45 , HrG: 1010 , HrL: 0001 , BIAS: 0.9
 PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.622
 PC: 68 , HrG: 0110 , HrL: 0010 , BIAS: 0.923
 PC: 68 , HrG: 0010 , HrL: 0000 , BIAS: 0.652
 PC: 68 , HrG: 1011 , HrL: 0010 , BIAS: 0.84
 PC: 68 , HrG: 0100 , HrL: 0000 , BIAS: 0.734
 PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.588
 PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.656
 PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.585
 PC: 68 , HrG: 1010 , HrL: 1000 , BIAS: 0.529
 PC: 68 , HrG: 1101 , HrL: 0101 , BIAS: 0.529
 PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.76

- The two major core elements of ABPS are linked: a predictor may benefit from the results provided by a detector;
- One can use detection results and try a prediction over unbiased branches only;
- Thus, we can observe how a predictor is able to manage unbiased branches;

=> ABPS provides a lot of simulation possibilities.

```
-----Simulation number: 2-----
Detector type: DETECTOR_HSG+
Detection for wave: FBUSQL.TPA
Parameters: Hrl = 4, HrG = 4, Path = not
selected, Unbiased polarization degree = 0.95
PC: 68 , HrG: 0011 , HrL: 0101 , BIAS: 0.657
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.533
PC: 68 , HrG: 0111 , HrL: 1000 , BIAS: 0.647
PC: 68 , HrG: 0110 , HrL: 1000 , BIAS: 0.661
PC: 68 , HrG: 1010 , HrL: 0001 , BIAS: 0.9
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.602
PC: 68 , HrG: 1011 , HrL: 0111 , BIAS: 0.622
PC: 75 , HrG: 0111 , HrL: 0111 , BIAS: 0.738
PC: 68 , HrG: 1110 , HrL: 0001 , BIAS: 0.632
PC: 68 , HrG: 1011 , HrL: 0010 , BIAS: 0.84
PC: 68 , HrG: 0100 , HrL: 0000 , BIAS: 0.734
PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.588
PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.656
PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.585
PC: 68 , HrG: 1010 , HrL: 1000 , BIAS: 0.529
PC: 68 , HrG: 1101 , HrL: 0101 , BIAS: 0.529
PC: 68 , HrG: 0011 , HrL: 0011 , BIAS: 0.76
```

ABPS gives you what you need: results

- **ABPS** allows simulation results to be persisted. This way, **ABPS** saves you time (e.g. simulation over a single CBP2 benchmark takes ~ 1 hour).
- Saving and using simulation results is configurable. You can choose whether or not to:
 - save results;
 - use the saved results.

How does ABPS look like - detection

ABPS - Advanced Branch Prediction Simulator [v. 1.0 beta]

File Options Help

Benchmarks

Stanford SPEC 2000 CBP2

FBUBBLE.TRA
FMATRIX.TRA
FPERM.TRA
FPUZZLE.TRA
FQUEENS.TRA
FSORT.TRA

+ Add - Remove

✓ Select all ✗ Deselect all

selected: Stanford: 1 SPEC 2000: 0 CBP2: 0

Tools

Detector Predictors

Parameters

Local history 4

Global history 4

Path 4

Unbiased polarization 0,95

Cascade

Results Charts

-----Simulation number: 2-----
Detector type: DETECTOR HrG
Detection for trace: **FPUZZLE.TRA**
Parameters: HrL = not selected, HrG = 16, Path = not selected, Unbiased polarization degree = 0.95
simulation details...
Unbiased contexts: 8.454[%]

-----Simulation number: 3-----
Detector type: DETECTOR HrG
Detection for trace: **FBUBBLE.TRA**
Parameters: HrL = not selected, HrG = 4, Path = not selected, Unbiased polarization degree = 0.95
simulation details...
PC: 68 , HrG: 1101 , BIAS: 0.534
PC: 68 , HrG: 1111 , BIAS: 0.751
PC: 68 , HrG: 1001 , BIAS: 0.666
PC: 68 , HrG: 0101 , BIAS: 0.76
PC: 68 , HrG: 0111 , BIAS: 0.535
Unbiased contexts: 47.326[%]

Clear results Save results

Save your results

Simulate Abort Simulation

04/09/07

<http://abps.sourceforge.net>

How does ABPS look like - prediction

The screenshot displays the ABPS - Advanced Branch Prediction Simulator [v. 1.0 beta] interface. The main window is titled "Results" and shows simulation details for "Simulation number: 1".

Simulation number: 1
Predictor type: PERCEPTRON SIMPLE, only for Unbiased branches, Polarization degree = 0.95

Parameters: Perceptrons = 100, HrG = 32, Threshold = 76, Weight bits = 8
Simulation for trace: **FBUBBLE.TRA**

simulation details...

Accuracy of prediction for all branches (global Ap) = 86.291 [%]
Accuracy of prediction for unbiased branches (Apub) = 72.601 [%]
Ratio of unbiased context instances = 13.203 [%]
Performance loss (relative to an ideal Issue Rate of 4) = 48.478 [%] details...

Computed Issue Rate (real IR) = 2.06 [instructions / clock cycle]
Confidence = 83.872 [%]
Saturation degree = 1.358 [%]
Number of perceptrons used = 25

The interface also shows a "Benchmarks" section with a list of traces including FBUBBLE.TRA, FMATRIX.TRA, FPERM.TRA, FPUZZLE.TRA, FQUEENS.TRA, and FSORT.TRA. The "Tools" section includes a "Predictors" tab with "Perceptron" selected, and a "Parameters" section with settings for Perceptrons (N) = 100, Global history (h) = 32, Threshold = 76, and Weight bits = 8. The "Unbiased polarization" is set to 0.95.

04/09/07

<http://abps.sourceforge.net>

How does ABPS look like - chart



```
-----Simulation number: 2-----
Detector type: DETECTOR HrG + HrL
Detection for trace: FBUBBLE.TRA
Parameters: Nr = 4, HrG = 4, HrL = 4, Path = Spot
selected, Unbiased polarization degree = 0.95
PC: 68 , HrG: 0011 , HrL: 0101 , BIAS: 0.657
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.533
PC: 68 , HrG: 0111 , HrL: 1000 , BIAS: 0.647
PC: 68 , HrG: 0111 , HrL: 0111 , BIAS: 0.596
PC: 68 , HrG: 0111 , HrL: 0111 , BIAS: 0.842
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.666
PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.571
PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.513
PC: 68 , HrG: 0001 , HrL: 0000 , BIAS: 0.513
PC: 68 , HrG: 1110 , HrL: 1000 , BIAS: 0.712
PC: 68 , HrG: 0011 , HrL: 1000 , BIAS: 0.603
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.518
PC: 68 , HrG: 0011 , HrL: 0011 , BIAS: 0.809
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.602
PC: 68 , HrG: 1110 , HrL: 0000 , BIAS: 0.517
PC: 68 , HrG: 1110 , HrL: 0011 , BIAS: 0.571
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
PC: 68 , HrG: 0110 , HrL: 0000 , BIAS: 0.596
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.503
PC: 68 , HrG: 0011 , HrL: 0011 , BIAS: 0.708
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.724
PC: 45 , HrG: 1010 , HrL: 0001 , BIAS: 0.9
PC: 68 , HrG: 0011 , HrL: 0011 , BIAS: 0.64
PC: 68 , HrG: 0111 , HrL: 0000 , BIAS: 0.607
PC: 68 , HrG: 1011 , HrL: 0111 , BIAS: 0.622
PC: 75 , HrG: 0010 , HrL: 0110 , BIAS: 0.923
PC: 68 , HrG: 1110 , HrL: 0001 , BIAS: 0.652
PC: 68 , HrG: 1011 , HrL: 0010 , BIAS: 0.84
PC: 68 , HrG: 0100 , HrL: 0000 , BIAS: 0.734
PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.588
PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.656
PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.585
PC: 68 , HrG: 1010 , HrL: 1000 , BIAS: 0.529
PC: 68 , HrG: 1101 , HrL: 0101 , BIAS: 0.529
PC: 68 , HrG: 0011 , HrL: 0011 , BIAS: 0.76
```

And that's not all... (further work)

- **ABPS** will:
 - be a distributed software application;
 - allow you to import and export simulation data;

The main goal of **ABPS** is to become a **framework** for branch prediction simulation.

And that's not all... (further work) (cont.)

- The first step was made: you can integrate your own benchmarks in ABPS by:
 - instructing ABPS how to read your benchmarks;
 - editing a simple XML file.



<http://acaps.ulbsibiu.ro/>

ABPS – Advanced Branch Prediction Simulator

THANK YOU for your time

```

-----Simulation number: 2-----
Detector type: DETECTOR HrG + HrL
Detection for trace: FBUBBLE.TRA
Parameters: Hrl = 4, HrG = 4, Path = not
selected, Unbiased polarization degree = 0.95
PC: 68 , HrG: 0011 , HrL: 0101 , BIAS: 0.657
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.571
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.533
PC: 68 , HrG: 0111 , HrL: 1000 , BIAS: 0.647
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.596
PC: 68 , HrG: 0011 , HrL: 0110 , BIAS: 0.842
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.666
PC: 68 , HrG: 1011 , HrL: 0011 , BIAS: 0.571
PC: 68 , HrG: 1000 , HrL: 0101 , BIAS: 0.833
PC: 68 , HrG: 0001 , HrL: 0000 , BIAS: 0.513
PC: 68 , HrG: 1110 , HrL: 1000 , BIAS: 0.712
PC: 68 , HrG: 0110 , HrL: 1000 , BIAS: 0.511
PC: 68 , HrG: 1011 , HrL: 0000 , BIAS: 0.518
PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.809
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.602
PC: 68 , HrG: 1110 , HrL: 0000 , BIAS: 0.517
PC: 68 , HrG: 1110 , HrL: 0010 , BIAS: 0.571
PC: 68 , HrG: 1011 , HrL: 0110 , BIAS: 0.735
PC: 68 , HrG: 0110 , HrL: 0011 , BIAS: 0.799
PC: 68 , HrG: 1110 , HrL: 0110 , BIAS: 0.728
PC: 68 , HrG: 0001 , HrL: 0111 , BIAS: 0.708
PC: 68 , HrG: 0111 , HrL: 0011 , BIAS: 0.724
PC: 45 , HrG: 1010 , HrL: 0001 , BIAS: 0.9
PC: 68 , HrG: 0011 , HrL: 0111 , BIAS: 0.647
PC: 68 , HrG: 0111 , HrL: 0110 , BIAS: 0.607
PC: 68 , HrG: 1011 , HrL: 0111 , BIAS: 0.622
PC: 75 , HrG: 0010 , HrL: 0110 , BIAS: 0.923
PC: 68 , HrG: 1110 , HrL: 0001 , BIAS: 0.652
PC: 68 , HrG: 1011 , HrL: 0010 , BIAS: 0.84
PC: 68 , HrG: 0100 , HrL: 0000 , BIAS: 0.734
PC: 68 , HrG: 1001 , HrL: 0101 , BIAS: 0.588
PC: 68 , HrG: 1000 , HrL: 0000 , BIAS: 0.656
PC: 68 , HrG: 1111 , HrL: 0011 , BIAS: 0.585
PC: 68 , HrG: 1010 , HrL: 1000 , BIAS: 0.529
PC: 68 , HrG: 1101 , HrL: 0101 , BIAS: 0.529
PC: 68 , HrG: 0001 , HrL: 0011 , BIAS: 0.78

```

04/09/07

<http://abps.sourceforge.net>