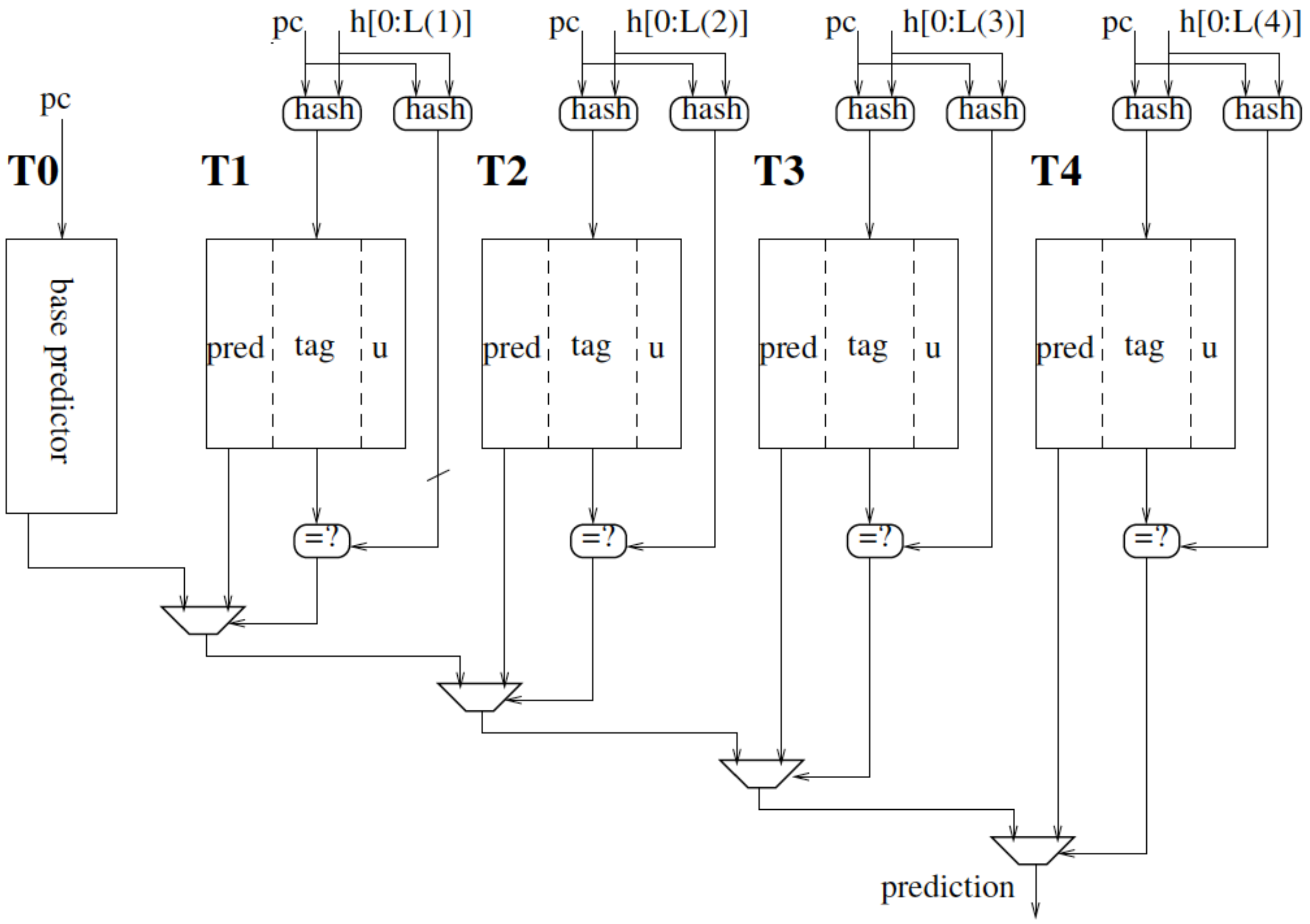
Hybrid TAGE & Perceptron Branch Predictor

Zhenyu Wu

THE OHIO STATE UNIVERSITY

TAGE Predictor



Prediction Computation

- Base predictor T_0
  - PC-indexed 3-bit saturating counter
  - Giving default prediction
- Tagged predictor $T_i (1 \leq i \leq 4)$
  - T_i are indexed using a geometric series of history length $\{L(i) = (int)(\alpha^{i-1} * L(1) + 0.5)\}$
  - 11-bit *tag*, 2-bit unsigned useful counter *u*, 3-bit signed counter *pred*
  - Giving prediction on a tag match
  - Provider component & *altpred*

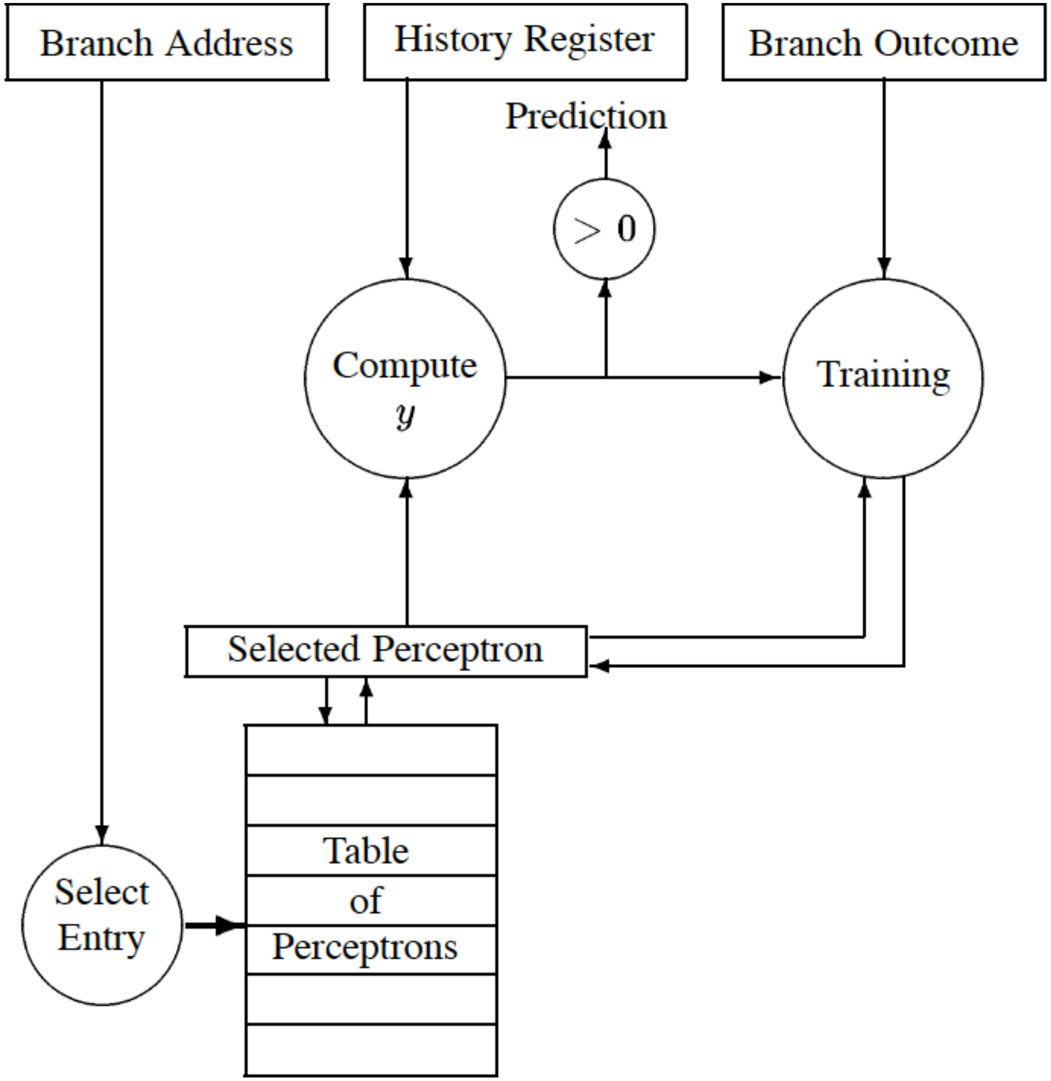
Updating Policy

- Update the useful counter *u*
  - *u* is updated when *altpred* is different from final *pred*
  - Increment if *pred* is correct, decrement otherwise
  - Reset in period of 256K branches
- Update the *pred* counter of the provider component on a correct prediction
- The overall prediction is incorrect
  - Update the *pred* counter of the provider component T_i
  - If $i < M$, allocate an entry on a predictor component $T_k (i < k < M)$
  - Read $M - i - 1$ u_j from $T_j (i < j < M)$

Updating Policy (Cont.)

- Rules for new entry allocation
  - Priority for allocation
    - If exits k, such that $u_k = 0$, then T_k is allocated
    - Else the *u counters from the components* T_j $(i < j < M)$ are all decremented
  - Avoiding ping-phenomenon
    - If T_j & T_k can be allocated, then T_j is chosen with higher probability.
  - Initializing the allocated entry
    - *pred* counter set to *weak correct*
    - *u* useful counter set to *strongly not useful*

Perceptron Predictor

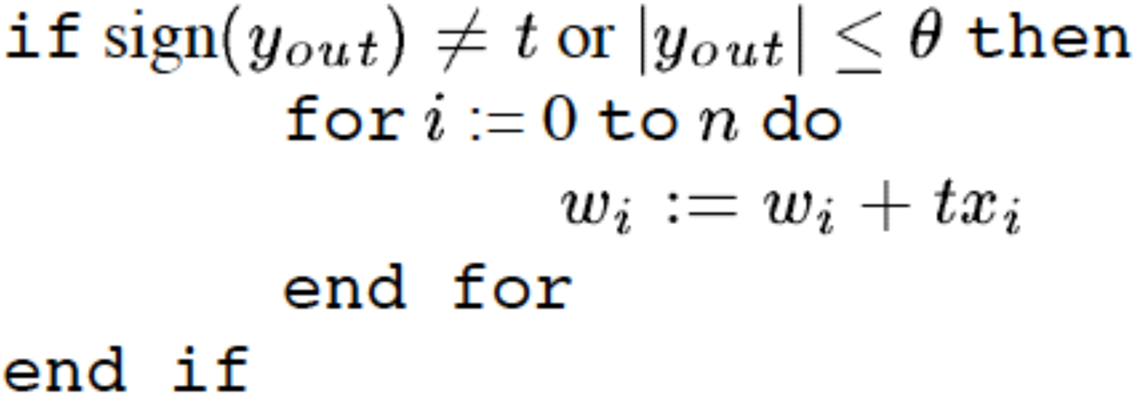


Prediction Computation

- A perceptron is represented by a vector of signed integer weights $(w_{0..n})$
  - w_0 serves as bias
- The input is the global history record $(x_{1..n})$
  - x_0 is always set to 1, providing a bias input
  - x_i is either -1 (NT) or +1 (T)
- The output y of the perceptron is computed as
  - $y = w_0 + \sum_{i=1}^{n} x_i w_i$
  - Predict to take if $y \geq 0$, not to take if $y < 0$

Updating Policy

- Using the following algorithm to train the perceptron
  - θ is the threshold parameter to decide when enough training has been done
  - $\theta = \lfloor 1.93h + 14 \rfloor$



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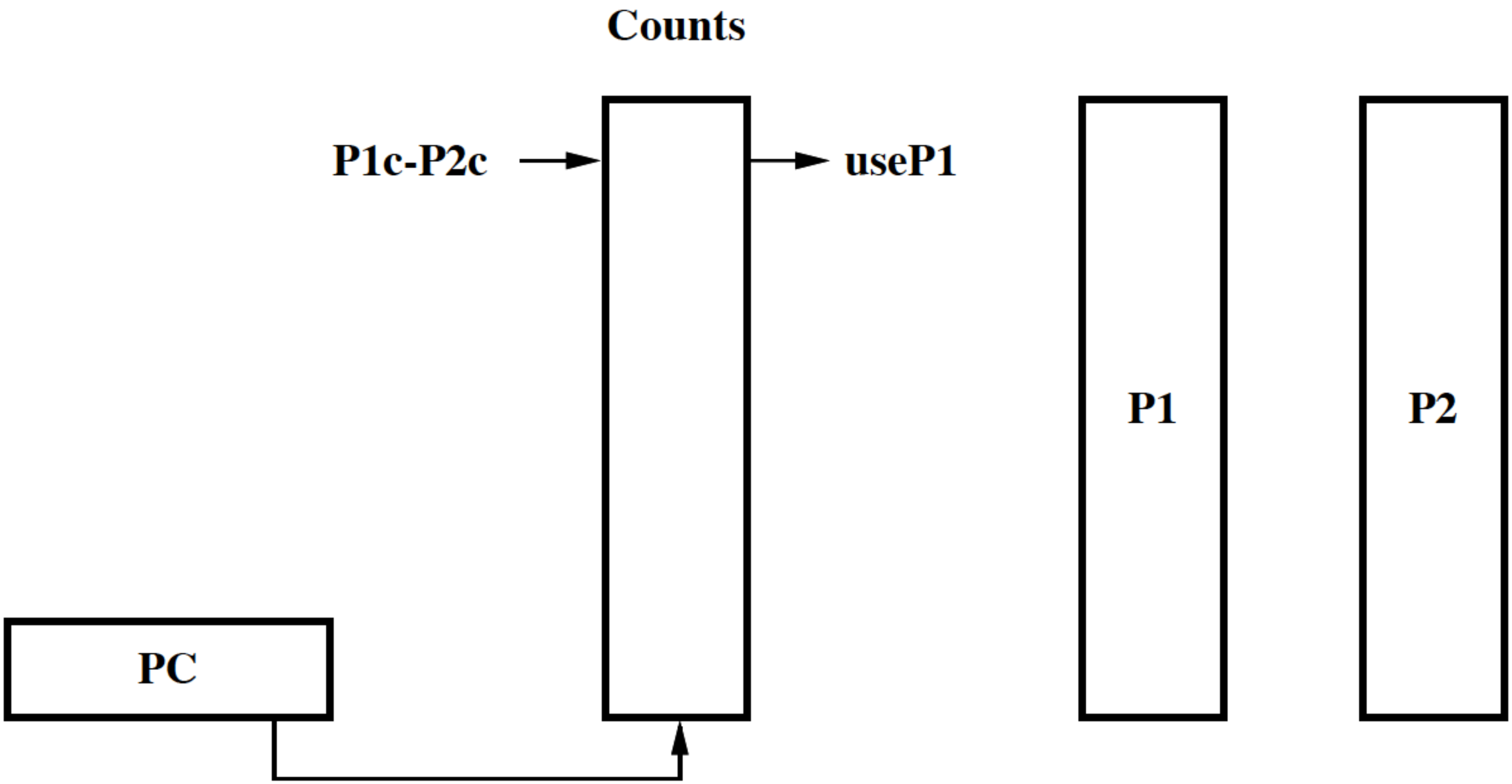
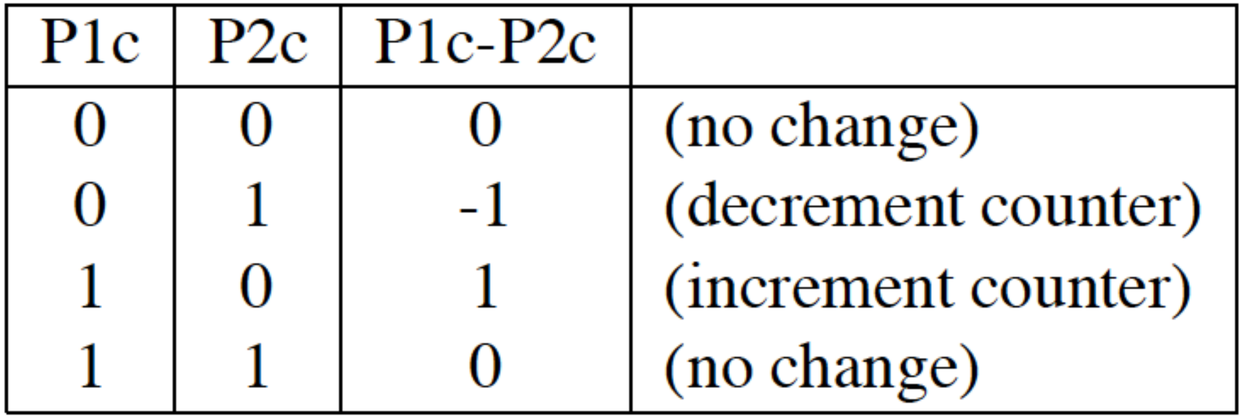
if $\mathrm{sign}(y_{out}) \neq t$ or $|y_{out}| \leq \theta$ then
    for $i := 0$ to $n$ do
        $w_i := w_i + t x_i$
    end for
end if
```

Combining Branch Predictors



How to combine TAGE with Perceptron to make better prediction?

- The combined predictor contains 2 predictors: TAGE & Perceptron
- Using a 2-bit saturating counter to select better predictor
- Each counter keeps track of which predictor is more accurate for the shared branches

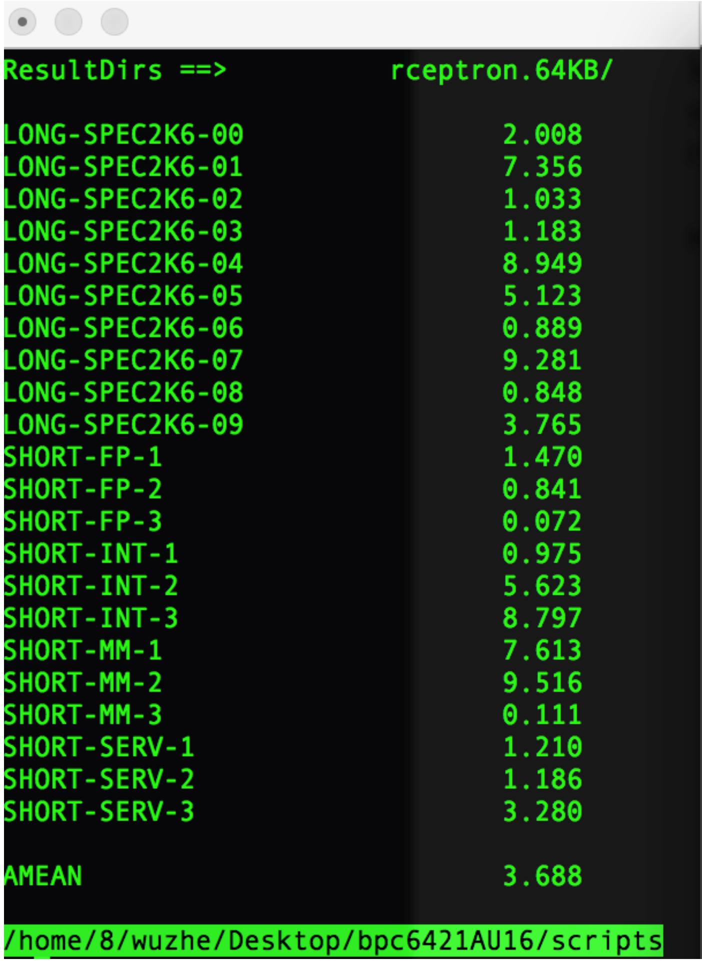


P1c	P2c	P1c-P2c	
0	0	0	(no change)
0	1	-1	(decrement counter)
1	0	1	(increment counter)
1	1	0	(no change)

Storage Computation

- Perceptron
  - 512 perceptron
  - 8-bit unsigned integer weight
  - 64 weights (1 for bias) per perceptron
  - $512 \times 8 \times 64\ bits = 32KB$
- TAGE
  - $T_0: 2^{13} \times 3\ bits = 3\text{KB}$
  - $T_1: 2^{12} \times (5 + 11)\ bits = 8KB$
  - $T_2: 2^{12} \times (5 + 10)\ bits = 7.5KB$
  - $T_3: 2^{12} \times (5 + 9)\ bits = 7KB$
  - $T_3: 2^{12} \times (5 + 8)\ bits = 6.5KB$
  - $3 + 8 + 7.5 + 7 + 6.5 = 32\text{KB}$
- Combining $32 + 32 = 64KB$

Performance

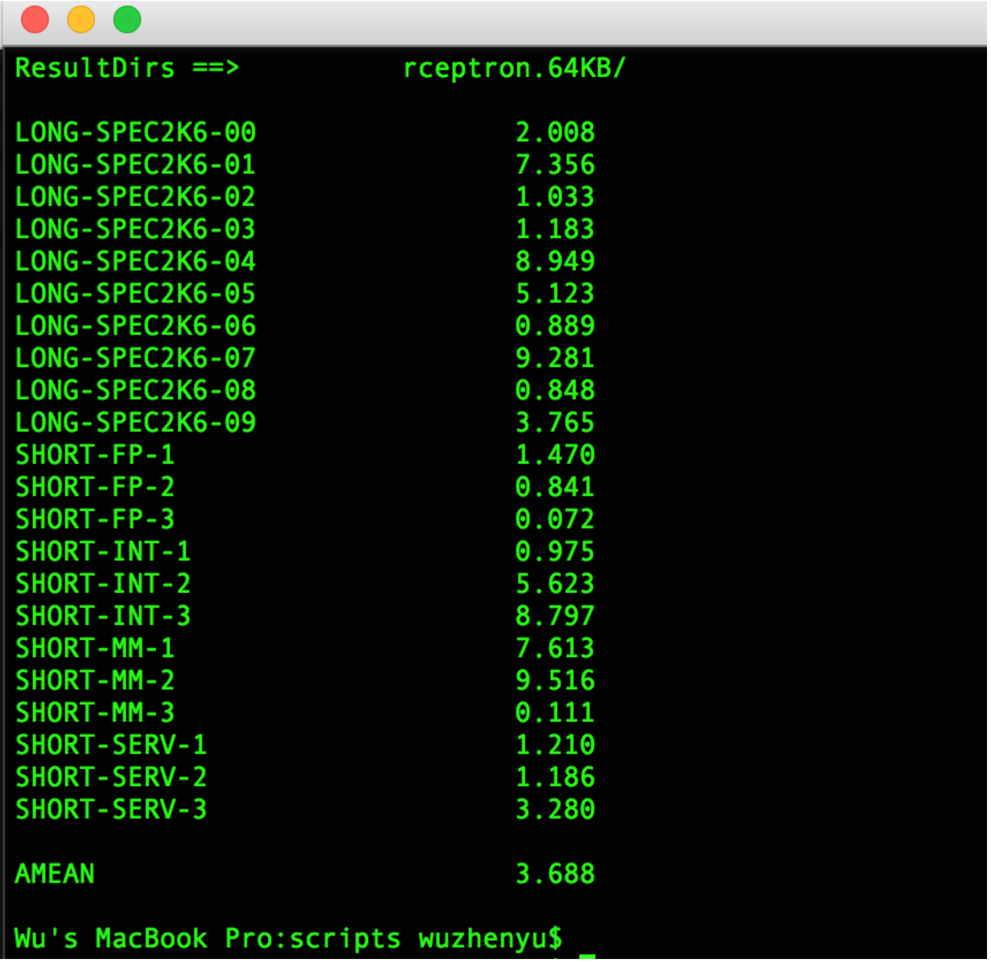


```
ResultDirs ==>            rceptron.64KB/

LONG-SPEC2K6-00                  2.008
LONG-SPEC2K6-01                  7.356
LONG-SPEC2K6-02                  1.033
LONG-SPEC2K6-03                  1.183
LONG-SPEC2K6-04                  8.949
LONG-SPEC2K6-05                  5.123
LONG-SPEC2K6-06                  0.889
LONG-SPEC2K6-07                  9.281
LONG-SPEC2K6-08                  0.848
LONG-SPEC2K6-09                  3.765
SHORT-FP-1                       1.470
SHORT-FP-2                       0.841
SHORT-FP-3                       0.072
SHORT-INT-1                      0.975
SHORT-INT-2                      5.623
SHORT-INT-3                      8.797
SHORT-MM-1                       7.613
SHORT-MM-2                       9.516
SHORT-MM-3                       0.111
SHORT-SERV-1                     1.210
SHORT-SERV-2                     1.186
SHORT-SERV-3                     3.280

AMEAN                            3.688

/home/8/wuzhe/Desktop/bpc6421AU16/scripts
```



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Wu's MacBook Pro:scripts wuzhenyu$ 
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