An Analysis of Correlation and Predictability: What makes 2-level branch predictors work

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Why Analyze Branch Behavior?

- Several areas in predictor design are complex
- Analysis enables further improvements
- Analysis simplifies implementation decisions

Why Analyze Predictor Interaction?

- The most accurate predictors are hybrid predictors
- It is not reasonable to simulate all configurations
- Analysis may aid in selecting configurations

Outline

- The nature of branch correlation
- The nature of self correlation
- Interaction between predictors
- Conclusions

Branch Correlation
Example 1a: Direction

branch Y: if (cond1) a = 2;
...
branch X: if (a == 0)

Branch Correlation
Example 1b: Direction

```
branch Y: if (cond1)
...
branch X: if (cond1 AND cond2)
```

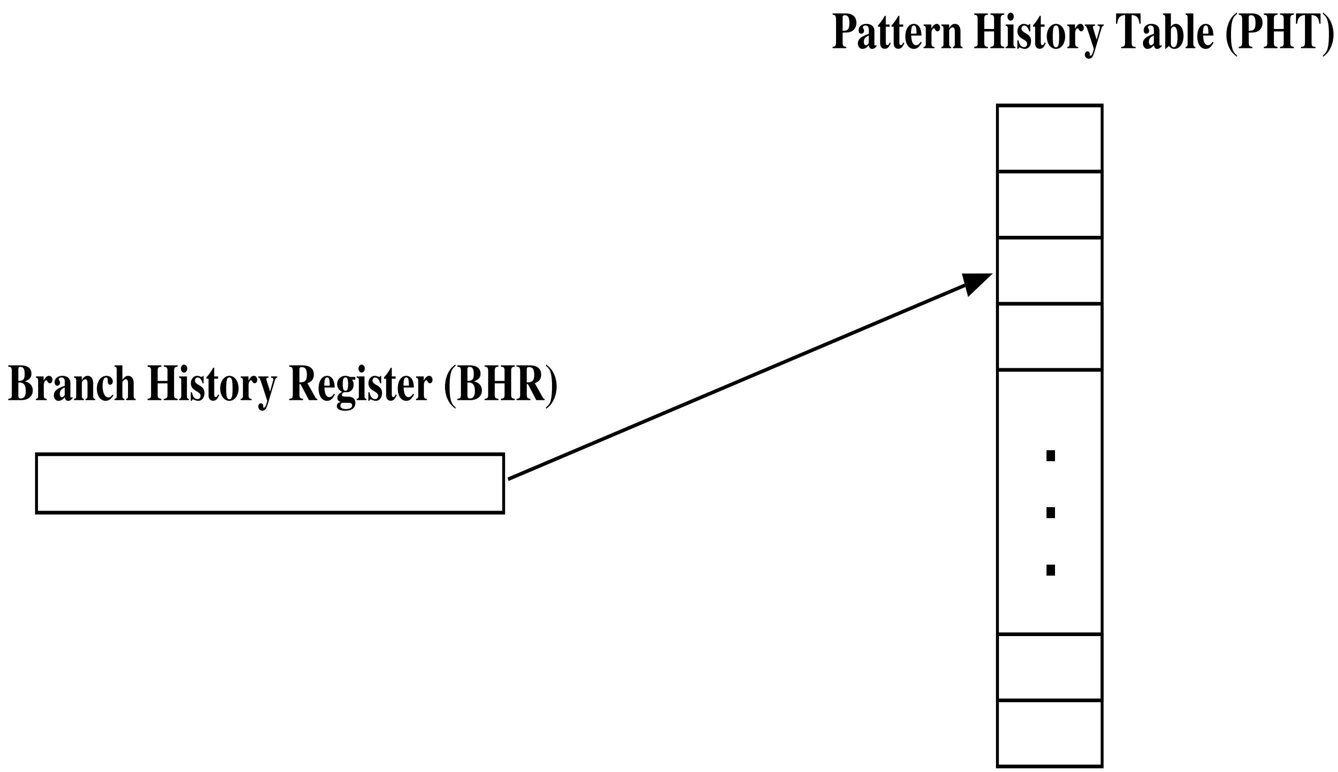
Branch Correlation
Example 1c: Direction

```
branch Y: if (cond1)
...
branch Z: if (cond2)
...
branch X: if (cond1 AND cond2)
```

Branch Correlation
Example 2: In Path

```
branch Y: if (NOT(cond1)) ...
branch Z: else if (NOT(cond2)) ...
branch V: else if (cond3) ...
...
branch X: if (cond1 AND cond2)
```

Two-Level Prediction (GAg)
Yeh and Patt '92

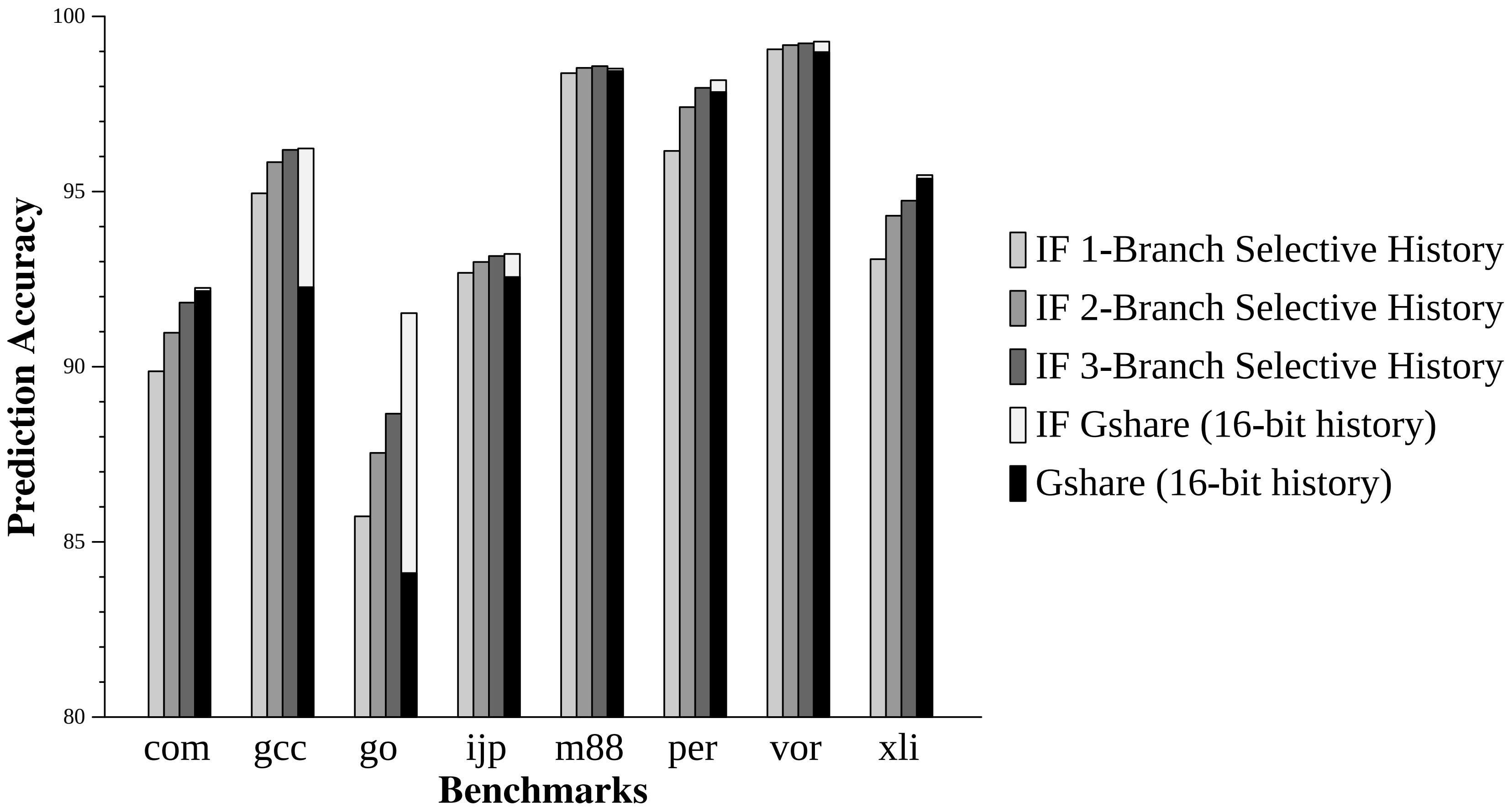


Correlation Using Selective History

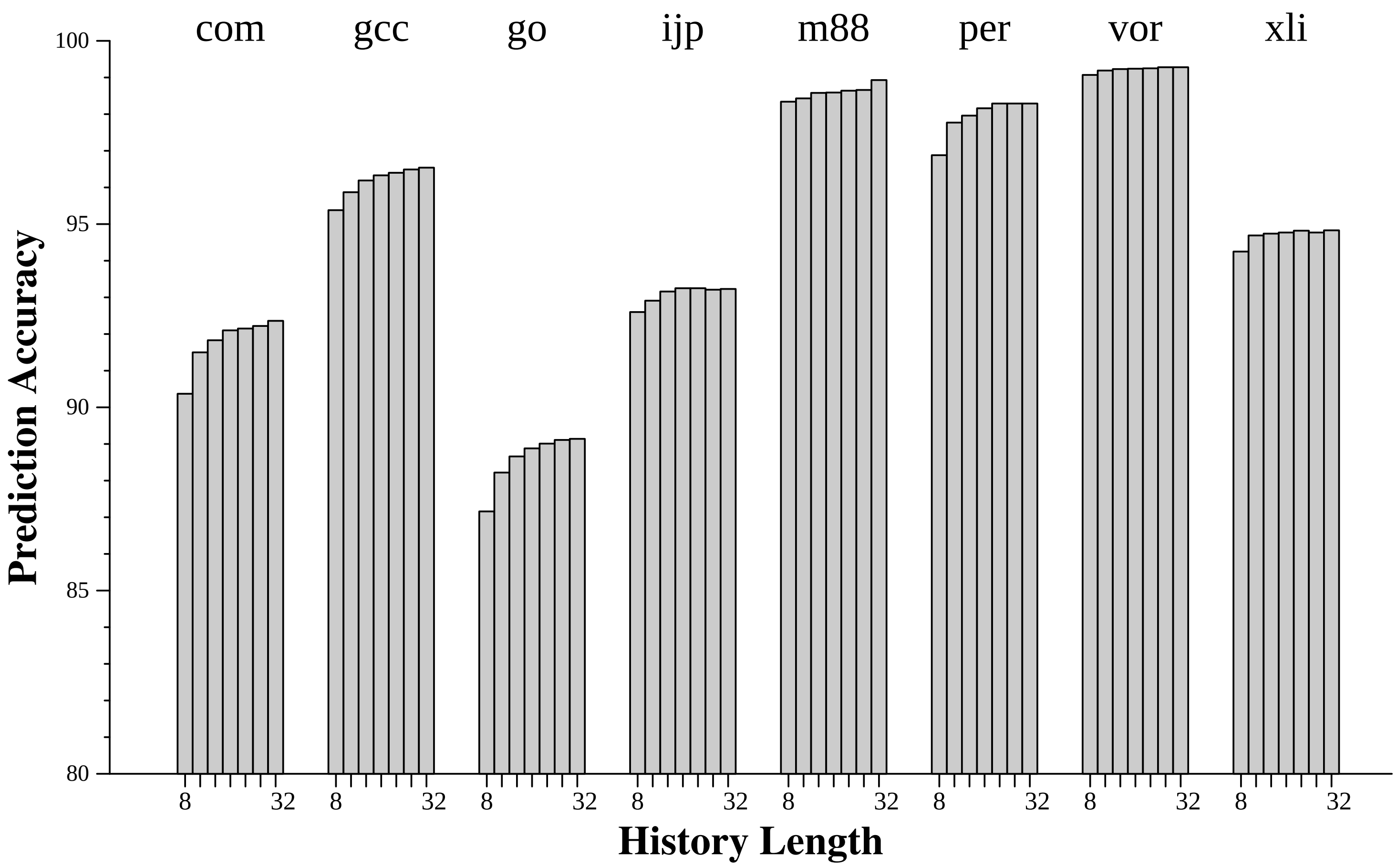
How many of the branches in the history matter?

- History formed using only the best set of 1, 2, or 3 prior branches
- Best set for each branch determined by oracle

Correlation Using Selective History



Distance to Correlated Branches



Outline

- The nature of branch correlation
- **The nature of self correlation**
- Interaction between predictors
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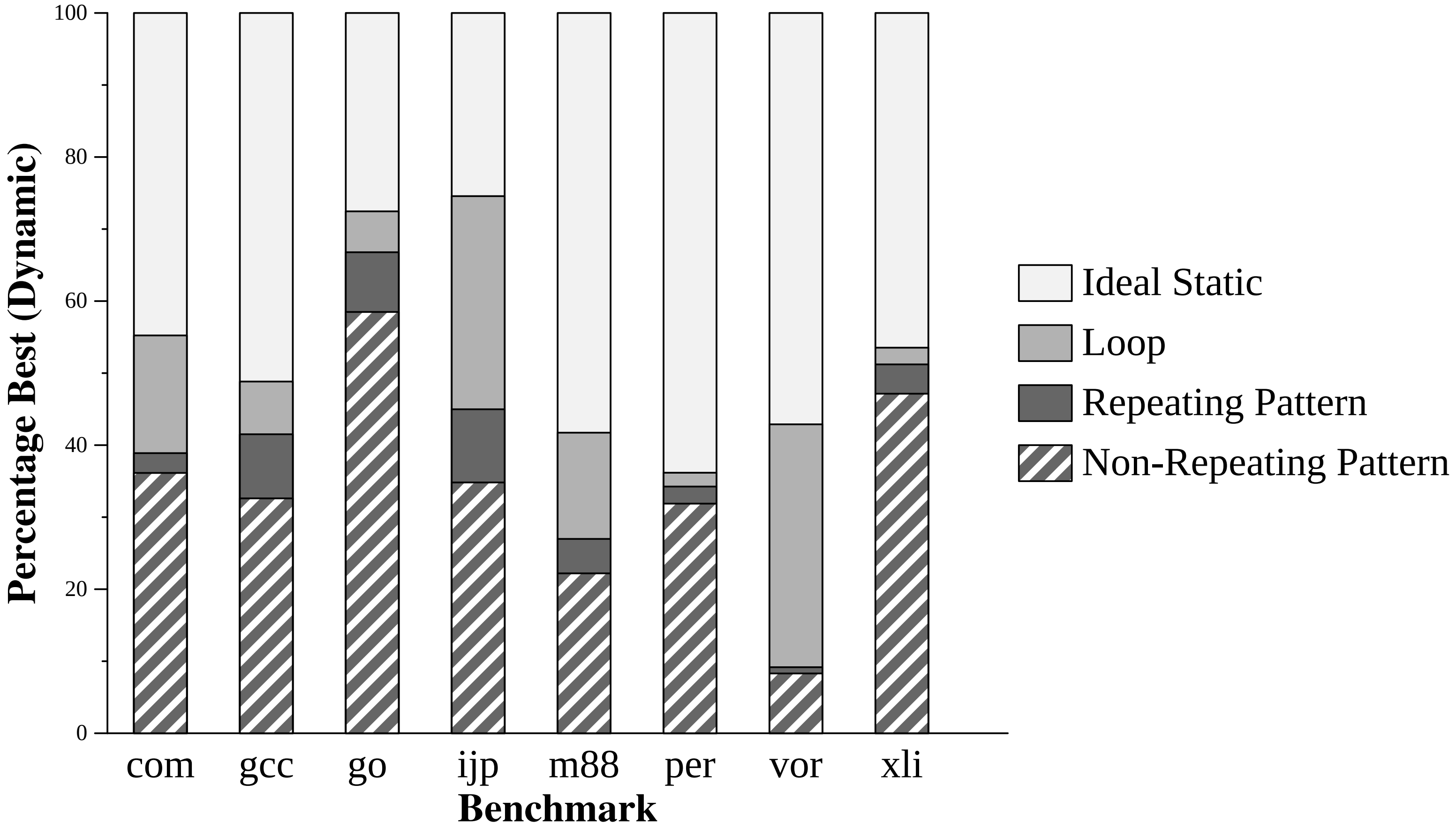
Self Correlation
Example

```
        mov 5,r1
loop:
        ...
        dec r1
        bne r1,loop
```

Self Correlation

- Loops: 11101110 or 00010001
- Repeating patterns: 11001100
- Non-Repeating patterns

Self Correlation
Dynamic Breakdown of Classes



Self Correlation
What PAs is Missing

Benchmark	PAs	PAs w/ Loop	IF PAs	IF PAs w/ Loop
compress	93.46	93.49	94.41	94.42
gcc	92.08	92.91	91.86	93.20
go	82.16	83.53	84.81	85.84
ijpeg	94.87	95.50	95.86	96.28
m88ksim	98.58	99.14	99.09	99.35
perl	96.83	96.96	97.79	97.87
vortex	98.86	99.14	99.03	99.23
xlisp	95.46	95.54	96.70	96.73

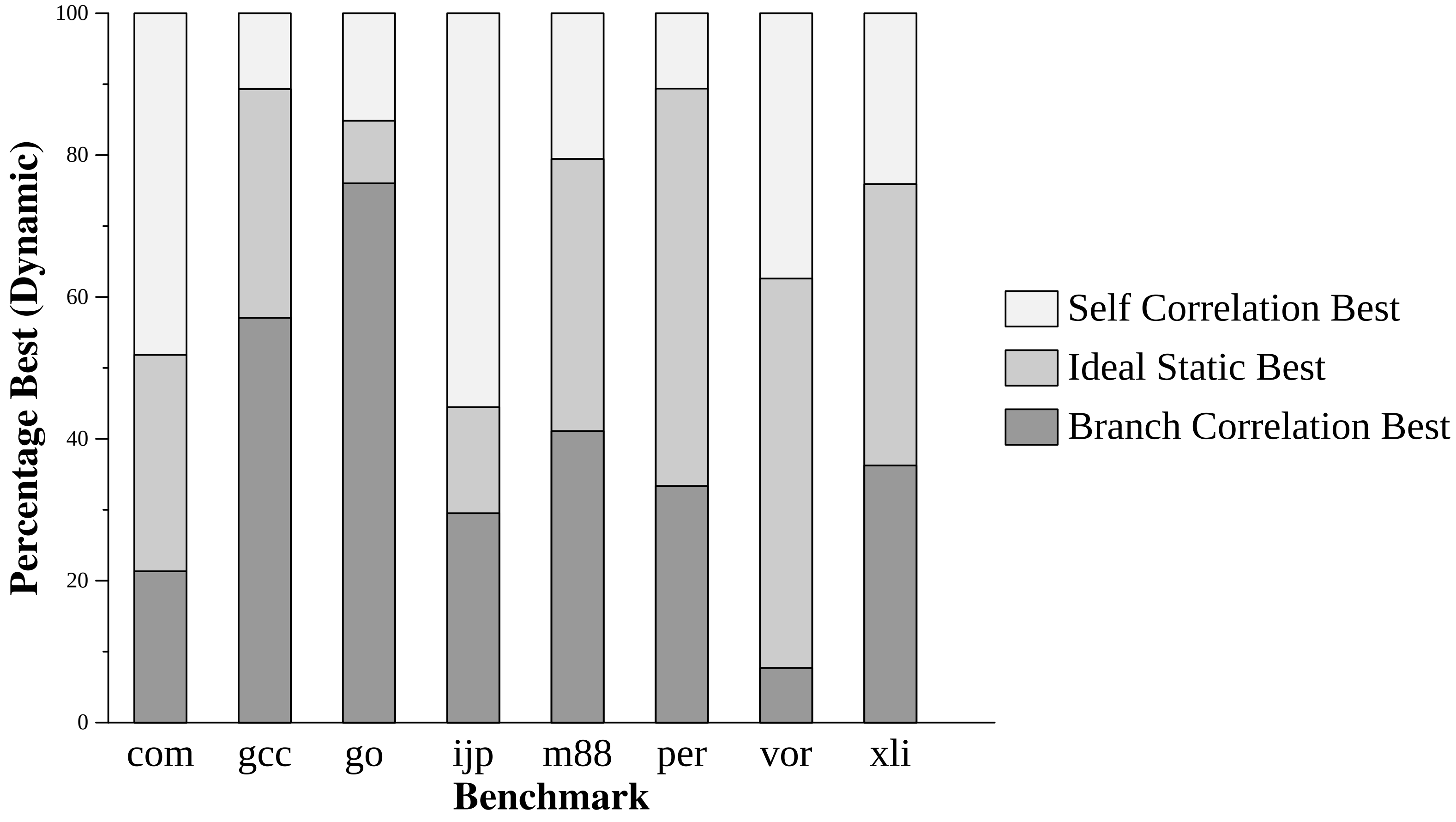
Outline

- The nature of branch correlation
- The nature of self correlation
- **Interaction between predictors**
- Conclusions

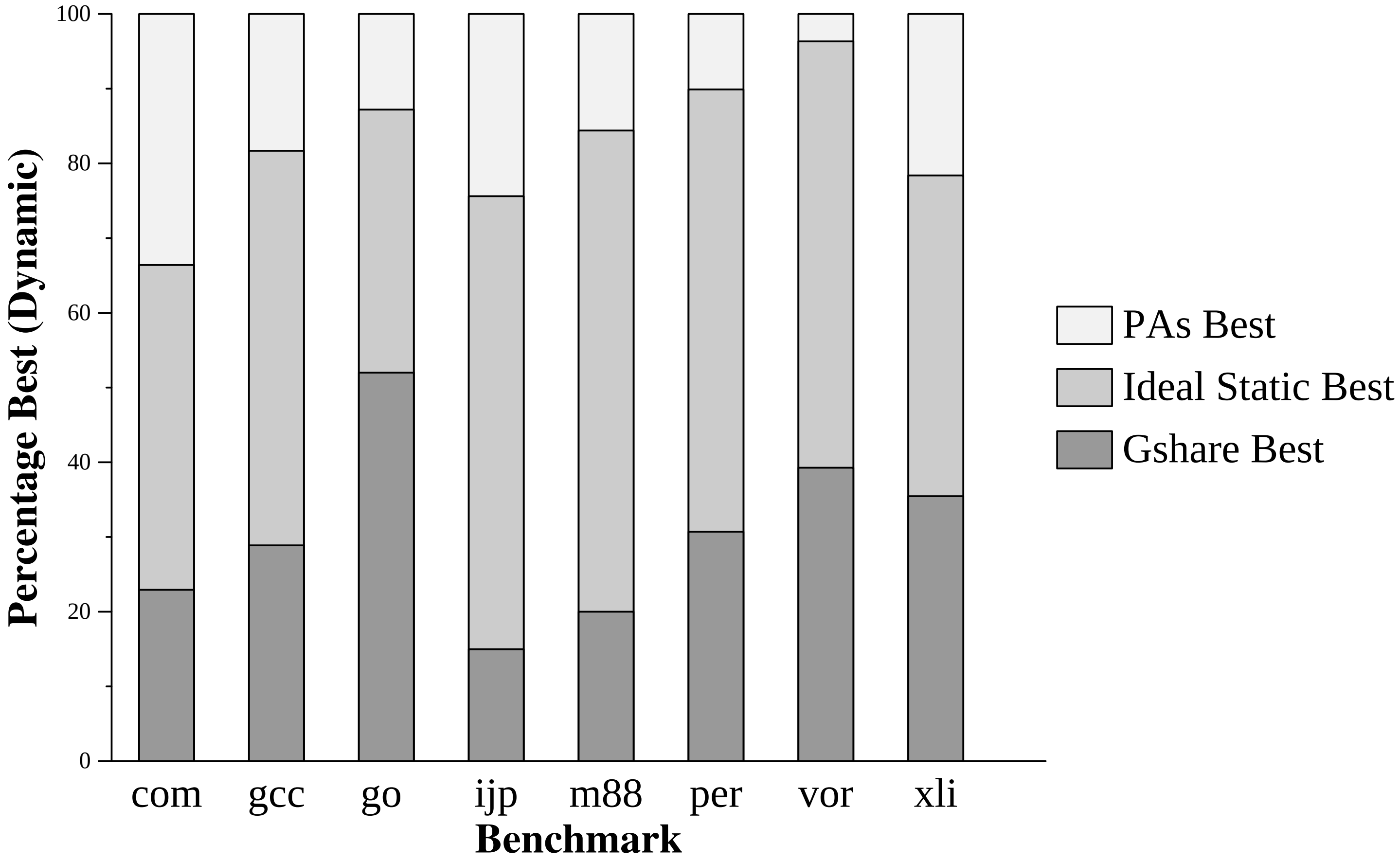
Interaction Between Predictors

- Self Correlation
- Branch Correlation
- Ideal Static Predictor

Interaction Between Predictors
Self Correlation vs. Branch Correlation



Interaction Between Predictors
PAs vs. Gshare



Interaction Between Predictors
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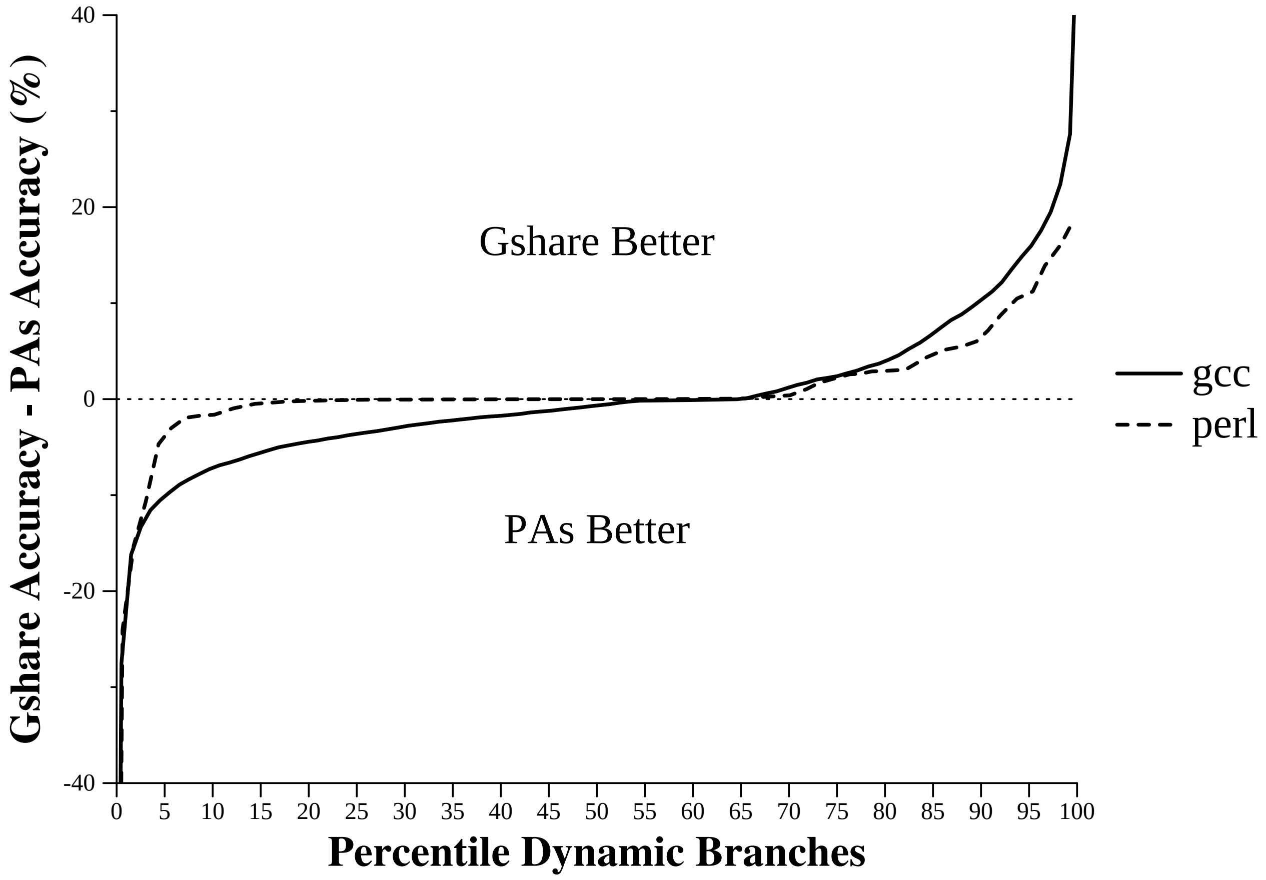

Conclusions

- Only a few branches needed in global history
- PAs accuracy for loop branches is too low
- Both correlation and self history is important