Reducing Code Size with Run-time Decompression

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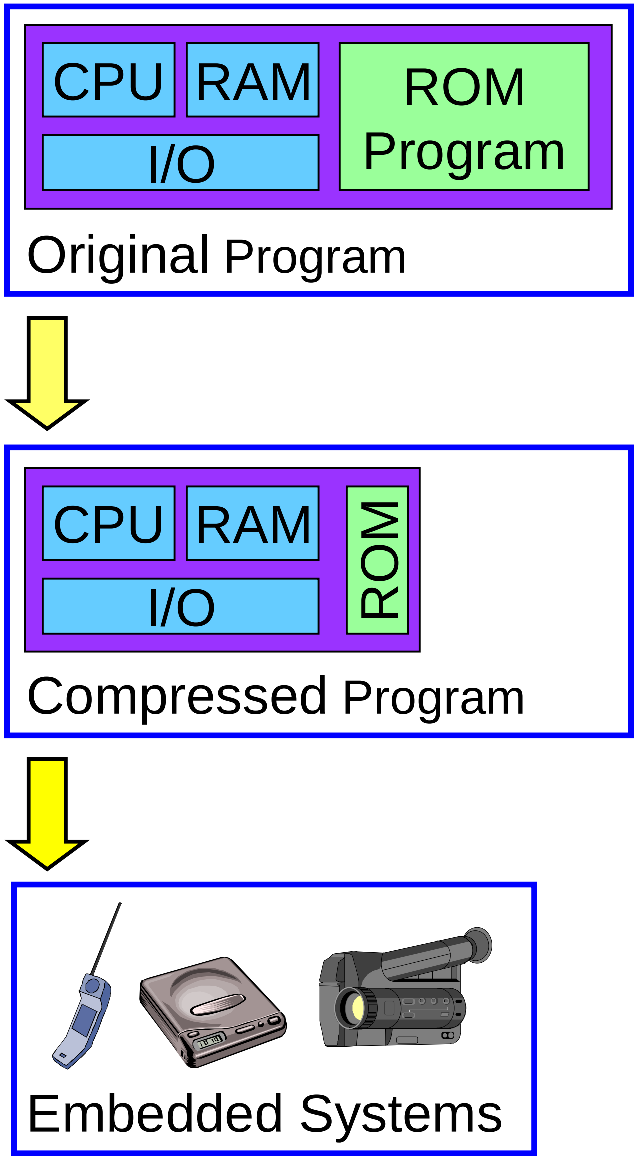
Motivation

- **Problem: embedded code size**
  - Constraints: cost, area, and power
  - Fit program in on-chip memory
  - Compilers vs. hand-coded assembly
    - **Portability**
    - **Development costs**
  - Code bloat
- **Solution: code compression**
  - Reduce compiled code size
  - Take advantage of instruction repetition
- **Implementation**
  - Hardware or software?
  - Code size?
  - Execution speed?

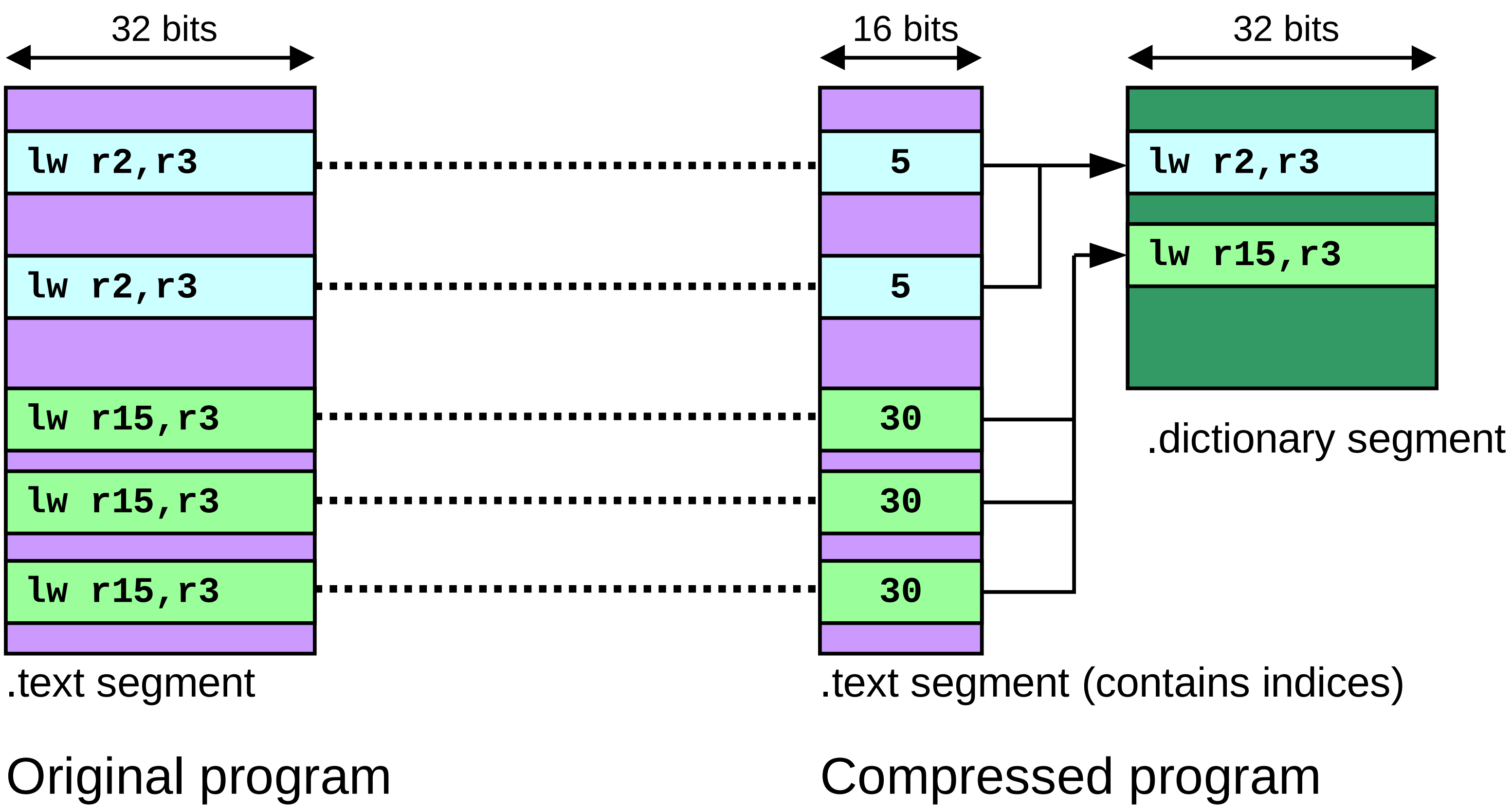


Software decompression

- **Previous work**
  - Decompression unit: whole program [Tauton91]
    - No memory savings
  - Decompression unit: procedures [Kirovski97][Ernst97]
    - Requires large decompression memory
    - Fragmentation of decompression memory
    - Slow
- **Our work**
  - Decompression unit: 1 or 2 cache-lines
  - High performance focus
  - New profiling method

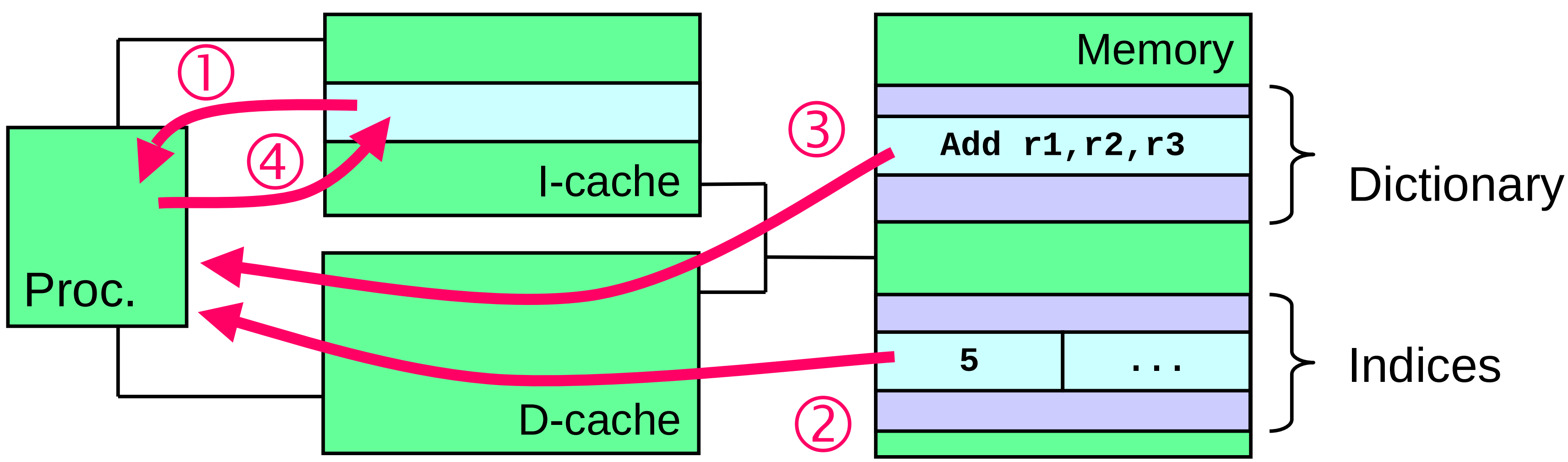
Dictionary compression algorithm

- **Goal: fast decompression**
- **Dictionary contains unique instructions**
- **Replace program instructions with short index**



Decompression

- **Algorithm**
  1. I-cache miss invokes decompressor (exception handler)
  2. Fetch index
  3. Fetch dictionary word
  4. Place instruction in I-cache (special instruction)
- **Write directly into I-cache**
- **Decompressed instructions only exist in I-cache**



CodePack

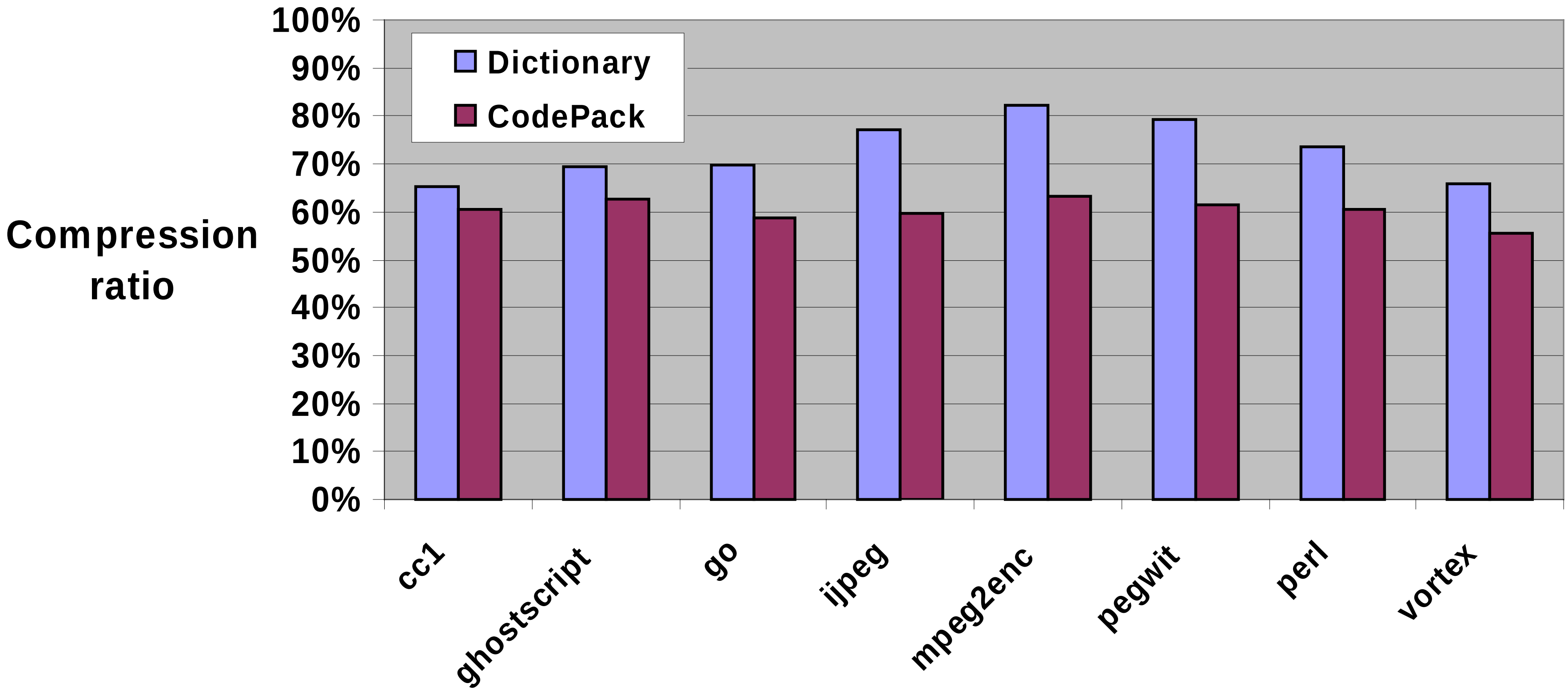
- **Overview**
  - IBM
  - PowerPC
  - First system with instruction stream compression
  - Decompress during I-cache miss

- **Software CodePack**

	Dictionary	**CodePack**
Codewords (indices)	Fixed-length	Variable-length
Decompress granularity	1 cache line	2 cache lines
Decompression overhead	75 instructions	1120 instructions

Compression ratio

- $$\textit{compression ratio} = \frac{\textit{compressed size}}{\textit{original size}}$$
  - CodePack: 55% - 63%
  - Dictionary: 65% - 82%



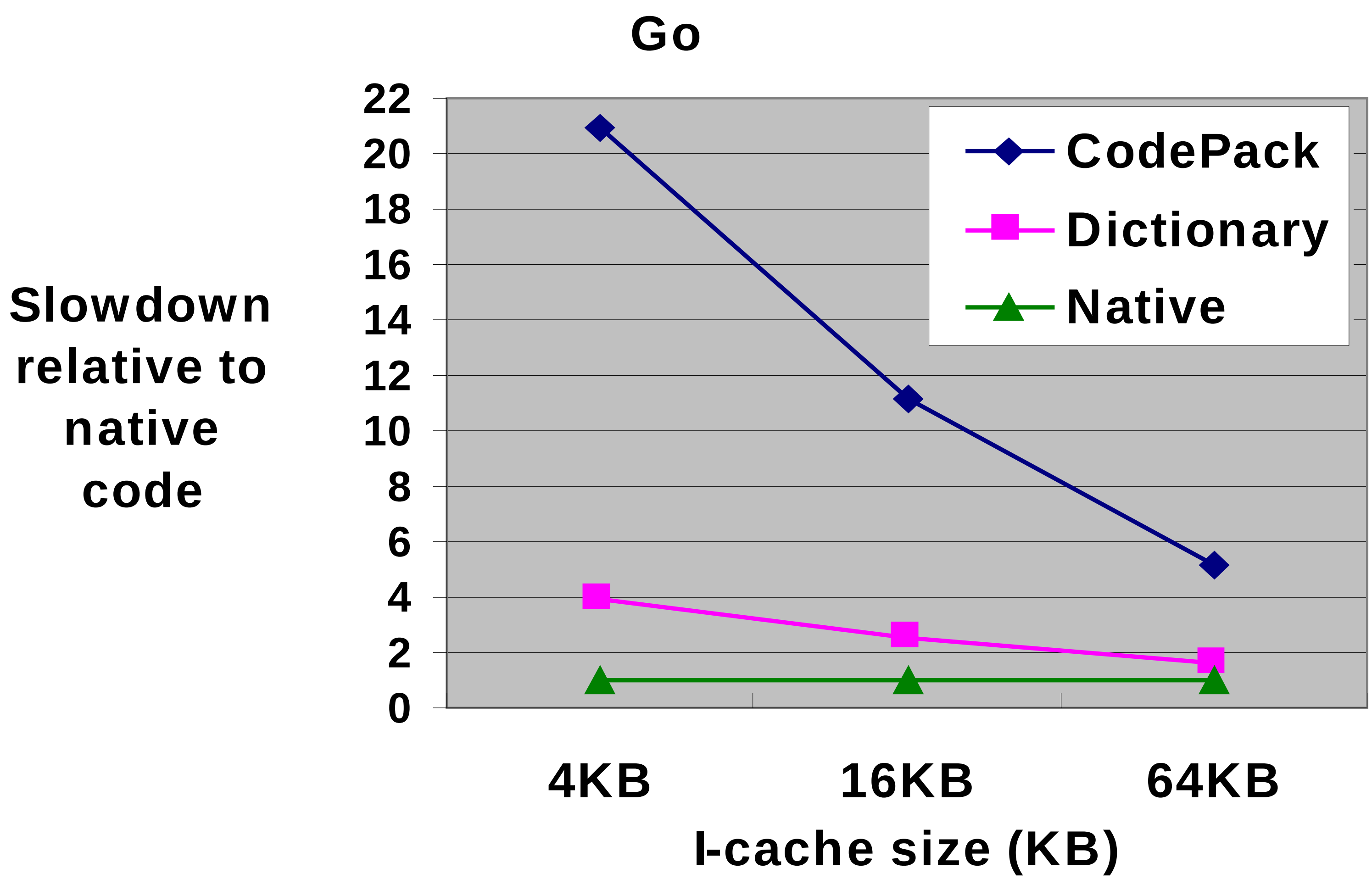
Simulation environment

- **SimpleScalar**

- **Pipeline:** 5 stage, in-order
- **I-cache:** 16KB, 32B lines, 2-way
- **D-cache:** 8KB, 16B lines, 2-way
- **Memory:** 10 cycle latency, 2 cycle rate

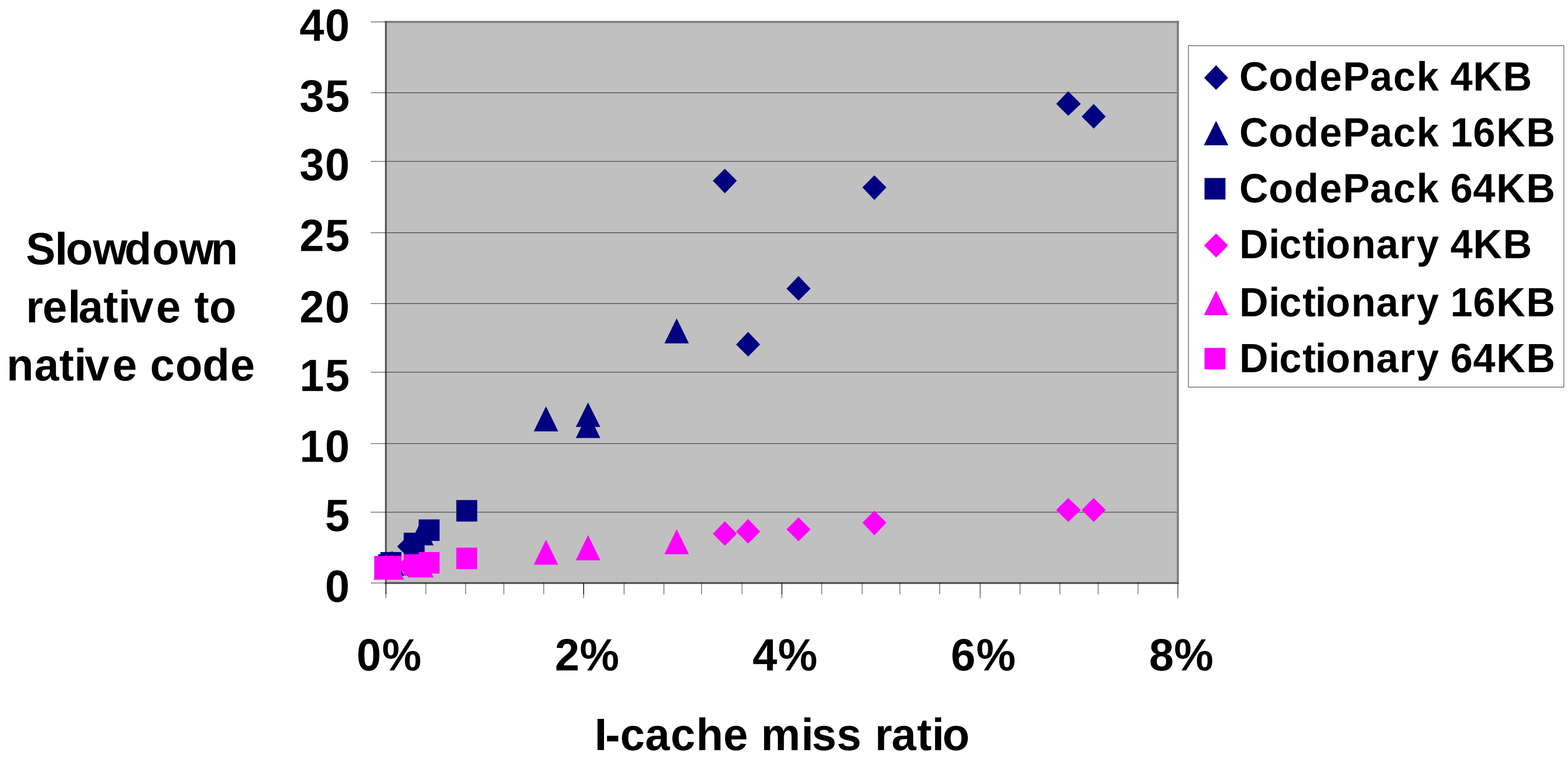
Performance

- **CodePack: very high overhead**
- **Reduce overhead by reducing cache misses**



Cache miss

- **Control slowdown by optimizing I-cache miss ratio**



Selective compression

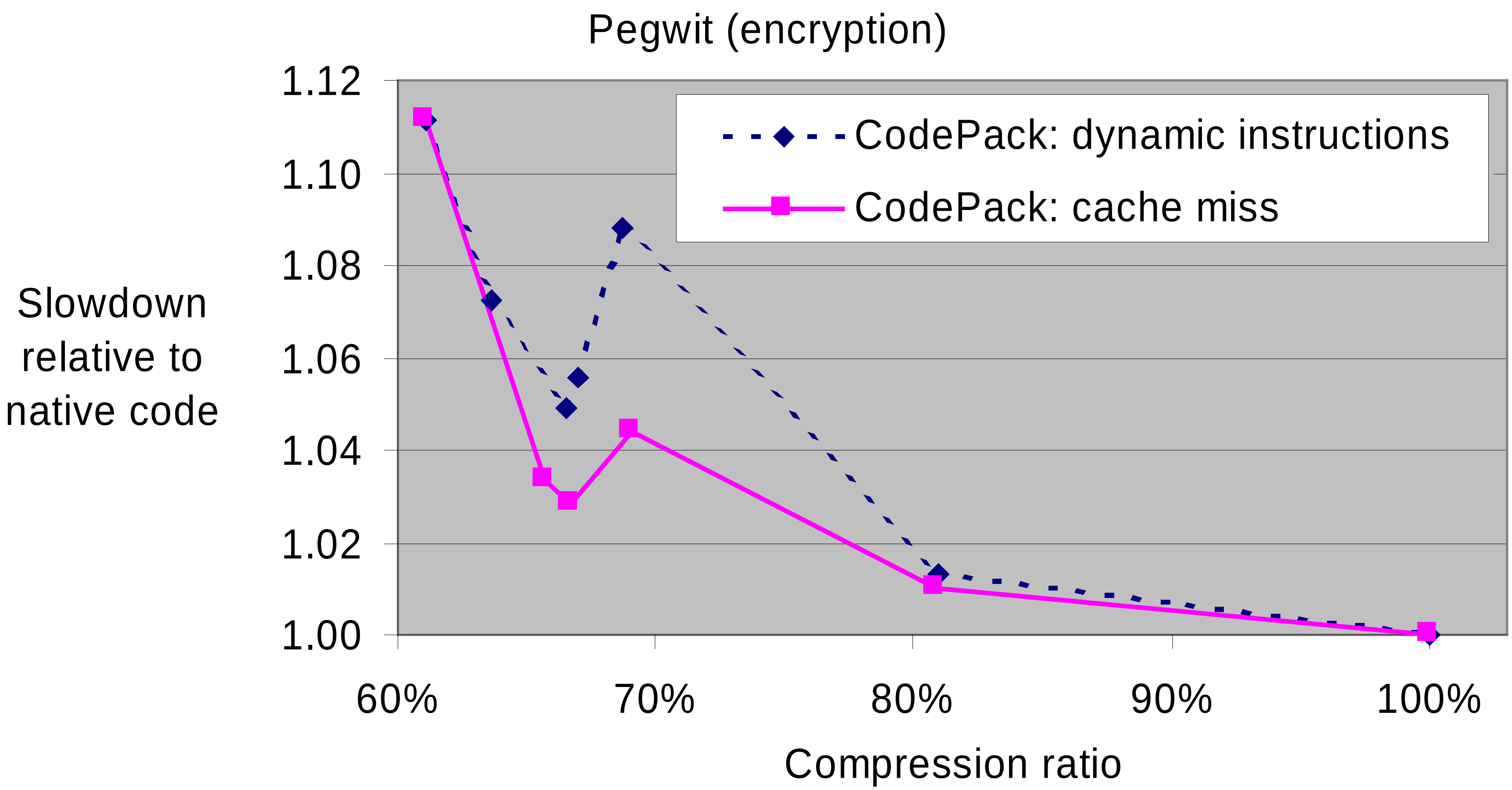
- **Hybrid programs**
  - Only compress some procedures
  - Trade size for speed
  - Avoid decompression overhead

- **Profile methods**
  - Count dynamic instructions
    - Example: Thumb
    - Use when compressed code has more instructions
    - Reduce number of executed instructions

  - Count cache misses New!
    - Example: CodePack
    - Use when compressed code has longer cache miss latency
    - Reduce cache miss latency

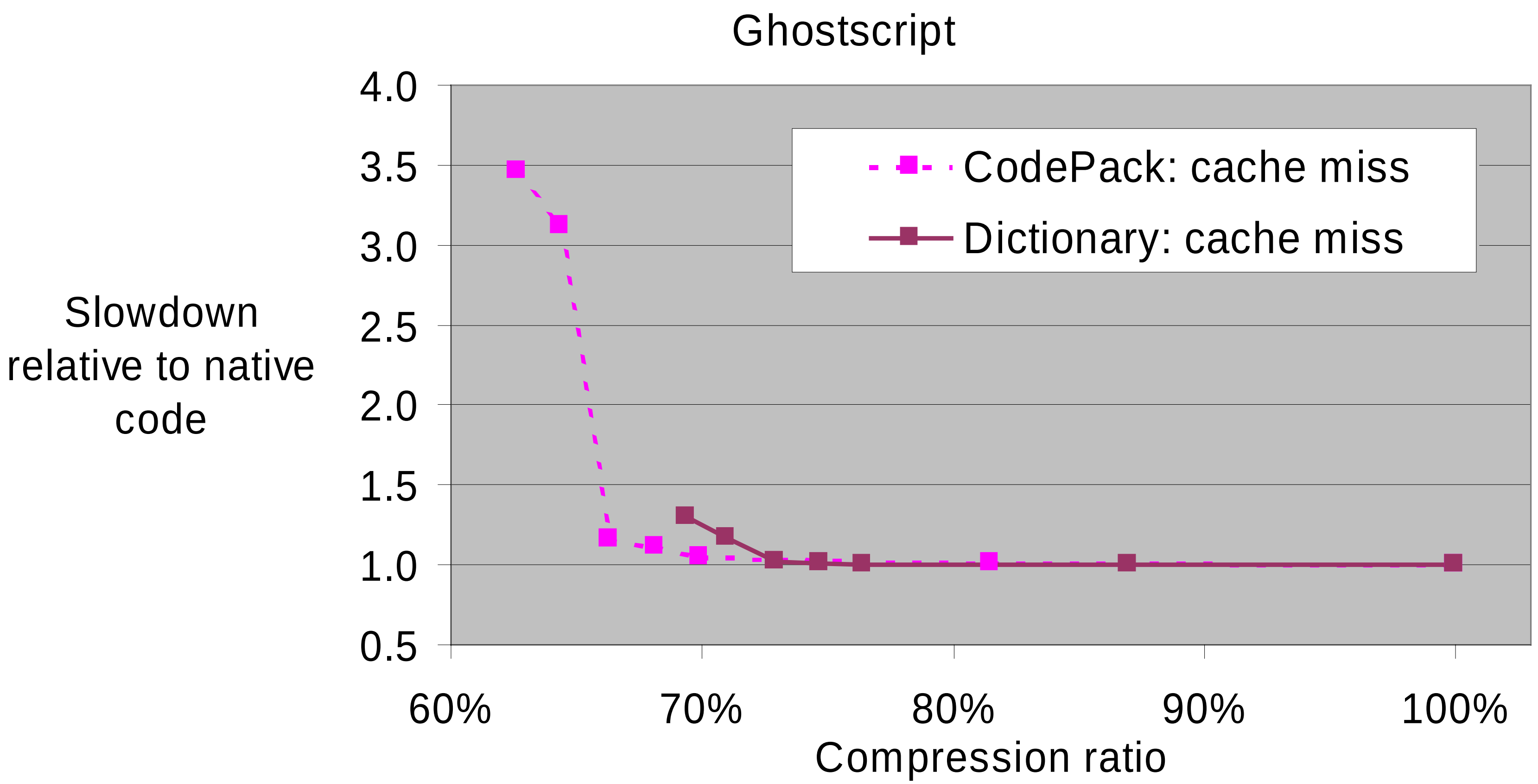
Cache miss profiling

- **Cache miss profile reduces overhead 50%**
- **Loop-oriented benchmarks benefit most**
  - Approach performance of native code



CodePack vs. Dictionary

- **More compression may have better performance**
  - CodePack has smaller size than Dictionary compression
  - Even with some native code, CodePack is smaller
  - CodePack is faster due to using more native code



Conclusions

- **High-performance SW decompression possible**
  - Dictionary faster than CodePack, but 5-25% compression ratio difference
  - Hardware support
    - I-cache miss exception
    - Store-instruction instruction
- **Tune performance by reducing cache misses**
  - Cache size
  - Code placement
- **Selective compression**
  - Use cache miss profile for loop-oriented benchmarks
- **Code placement affects decompression overhead**
  - Future: unify code placement and compression

Web page

`http://www.eecs.umich.edu/compress`