Instruction Fetch Characteristics of Media Processing

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Overview

- **Architectures for Media Processing**
- **Workload-Dependent Characteristics**
  - branch characteristics
  - instruction memory characteristics
  - loop characteristics
- **Architecture-Dependent Characteristics**
  - fetch architectures
  - dynamic branch prediction
  - pre-execution pipeline length
- **Conclusions**

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Programmable Architectures for Media Processing

- **General-purpose processors (GPPs) w/ multimedia extensions**
  - good programmability at little added cost
  - some speedup with subword parallelism
  - optimized for general-purpose processing
- **High-performance DSPs (aka Media Processors)**
  - good performance
    - specialized hardware
    - subword parallelism
    - ILP
  - good programmability (w/ special programming libraries)
  - moderate frequency
- **GPPs and DSPs continually evolving towards media processing**
  - computing workloads becoming increasingly dominated by media applications

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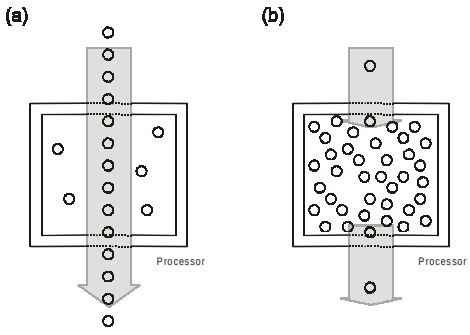
Media Processing vs. General-Purpose Processing

- **General-purpose processing:**
  - streaming instructions
  - static data
- **Media processing:**
  - streaming data
  - static instructions



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Workload-Dependent Characteristics

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Evaluation Environment

- **MediaBench benchmarks**
  - Developed at UCLA
  - Augmented w/ MPEG-4 and H.263
  - Variety of media applications, including video, audio, graphics, image, security, and speech

- **IMPACT compilation & simulation environment**
  - Aggressive ILP research compiler
  - Cycle-accurate simulation
  - Large, generic RISC instruction set
  - Three levels of optimizations
    - Classical - classical optimizations only
    - Superscalar - adds loop unrolling and superblock formation (speculation)
    - Hyperblock - adds hyperblock optimization (predication)

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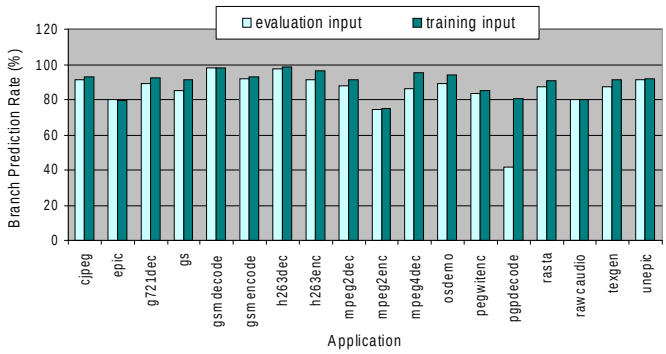
Static Branch Prediction

- **5.5 dynamic operations per basic block**
  - similar to general-purpose applications
- **89.5% prediction rate on training input**
- **85.9% prediction rate on evaluation input**



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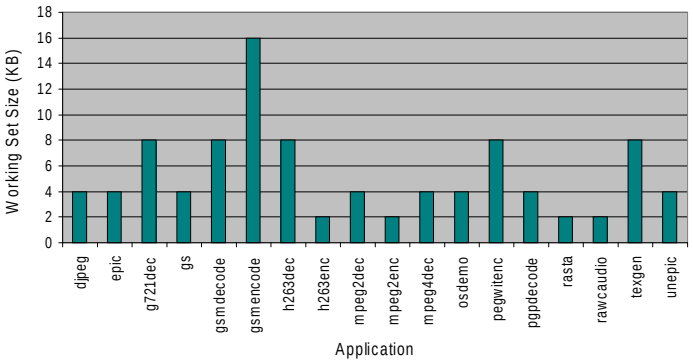
Instruction Working Set Size

- **Cache Regression**
  - cache sizes: 1K to 4MB
  - assumed line size of 64 bytes
  - 8 KB working set size



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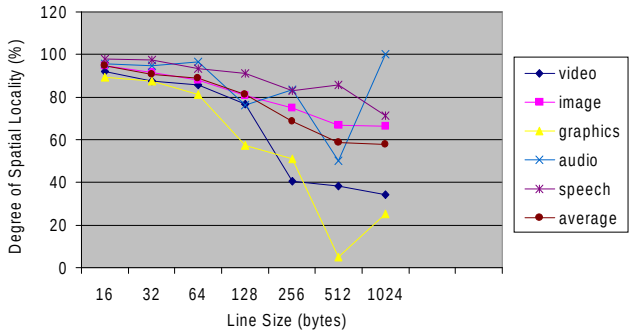
Instruction Spatial Locality

- **Cache Regression**
  - line sizes: 8 to 1024 bytes
  - assumed cache size of 64 KB
  - 84.8% spatial locality (up to 256 bytes)

$$spatial\ locality = \frac{(A-B)}{\left(\frac{A}{l_a / l_b}\right)}$$



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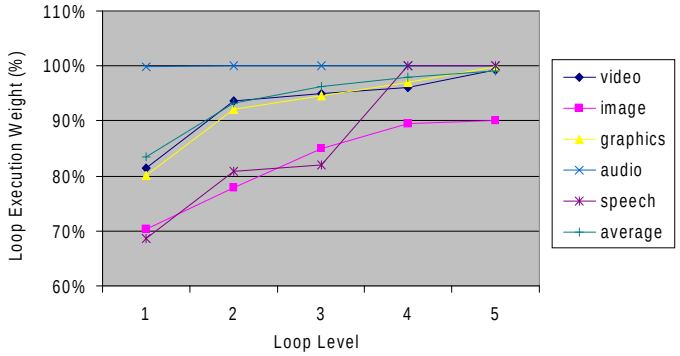
Looping Characteristics

- **Highly Loop Centric**
  - nearly 95% of execution time spent within two innermost loop levels



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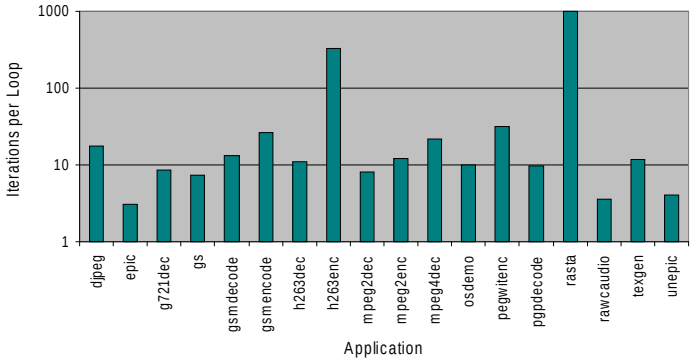
Iterations per Loop

- **Large Number of Iterations**
  - average of 10 iterations per loop
  - significant processing regularity



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Architecture-Dependent Characteristics

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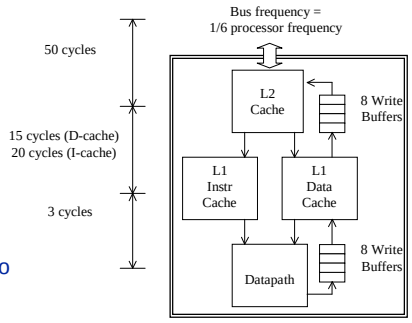
Base Architecture Model

- **Architecture model**
  - 8-issue media processor
  - operation latencies targeting 800 MHz to 1.2 GHz
  - 64 integer and floating-point registers
- **L1 Cache**
  - 16 KB direct-mapped L1 instruction cache w/ 256 byte lines
  - 32 KB direct-mapped L1 data cache w/ 64 byte lines
- **On-Chip L2 Cache**
  - 256 KB 4-way set associate w/ 64 byte lines
- **External Memory**
  - 6:1 Processor to bus frequency ratio



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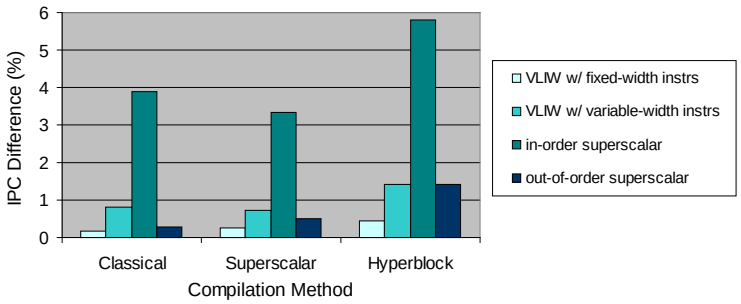
Aggressive vs. Conservative Fetch

- **Aggressive Fetch**
  - decoupled fetch-execute pipeline
  - 12-entry instruction buffer
- **Conservative Fetch**
  - lock-step pipeline



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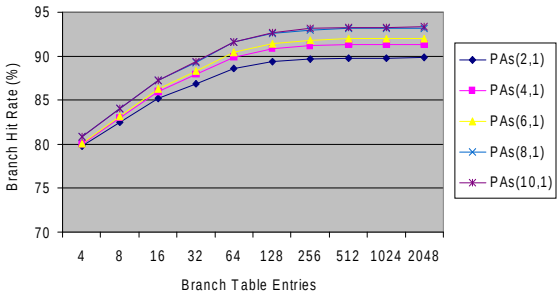
History-Based Dynamic Branch Prediction

- **PAs(k,p)**
  - k - # of history bits
  - p - # of history tables
- **Good performance with small predictors**
  - 128-256 entries
  - 4-8 history bits
  - 1 history table



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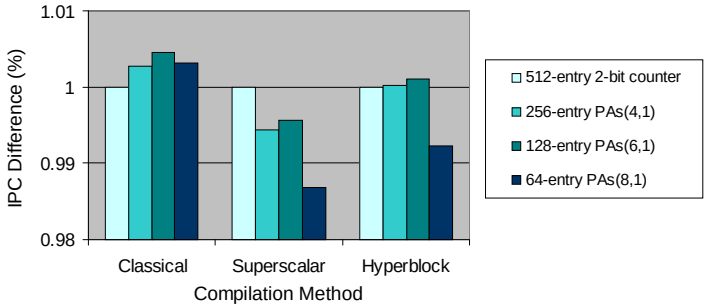
Performance vs. Size for Dynamic Branch Predictors

- **Comparison of four 1 Kb dynamic branch predictors**
  - k - # of history bits
  - p - # of history tables

$$size\_PAs(k,p) = bk + 2^{k+1}p$$

- **Minor variation between 1 Kb predictors**
  - large predictors only provide 2-3% better performance



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Conclusions

- **Instruction fetch characteristics of Media Processing are Idealistic**
- **Workload-Dependent Characteristics**
  - 5.5 operations per basic block
  - 85-90% static branch prediction
  - 8 KB working set size
  - 84.8% spatial locality (up to 256 bytes)
  - 95% of execution in 2 innermost loops
  - 10+ iterations per loop
- **Architecture-Dependent Characteristics**
  - aggressive fetch provides little benefit
  - small dynamic branch predictors sufficient
    - 1K predictors reduce miss rate by 2x
  - 2% performance reduction for each extra pre-execution pipeline stage

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