Software-Controlled Operand-Gating

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Outline

1. Introduction
2. Value Range Propagation
3. Value Range Specialization
4. Cooperative Hw-Sw
5. Summary & Conclusions

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Introduction

Increasing miniaturization
- Portable handhelds (PDAs, notebooks, cell phones, etc.)

Increasing computation requirements
- Multimedia processing (audio, video)
  - Speech-recognition
  - Audio and video encoding/decoding
- Wireless communication

Increasing demand for
- Longer battery life
- Smaller heat dissipance

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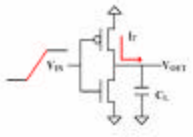
Motivation

Design for low power
- Becoming a critical design constraint
- Types of energy consumption
  - Dynamic (predominant source for current technology)
    - Charging/Discharging capacitors



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Introduction

Design goal:

POWER EFFICIENCY

Metrics used:
- Energy consumption
- Energy-delay ^{2}

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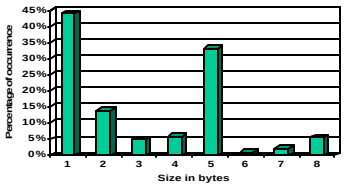
Value Compression

Data size distribution for the Spec Integer 95 benchmarks



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Software Techniques

Value Range Propagation

- Propagate at compile-time operand's range

Value Range Specialization

- Using value profiling information, specialize regions of code to certain value ranges

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Value Range Propagation

Find initial value ranges

- Inst. declared with narrow operands (e.g. add_short)
- Assignments (e.g. Variable=constant)
- "if" condition statements

Forward propagation

- Set the range of the output operands
  - Depending on the input operands' ranges and operation

Backward propagation

- Set the range of the input operands
  - Depending on the ouput operand's range, the input operands' ranges and the operation

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Value Range Propagation

"Useful" Range Propagation

Constrain the range of the values due to their operations

- Logical operations
  - AND R1, 0xFF, R2 (i.e. R2?R1&0xFF)
  - OR R1, 0xFFFFFFFF00000000, R2 (i.e. R2?R1|0xFFFFFFFF00000000)
- Mask operations
- Limited width fields
  - shift amounts

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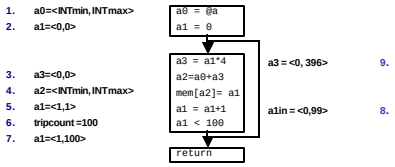
Value Range Propagation

Example of Value Range Propagation



Original C code:

```
for (i=0; i<100; i++) {
        a[i]=i;
}
```

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Value Range Specialization

Profiling based compile-time technique

Three step process:

1. Identification of instructions (candidates) where specialization may be profitable using basic block profiles (i.e. basic block counts)
2. Computation of the ranges of values for the candidates with the support of profiling data
3. Specialization of the candidates that are deemed profitable

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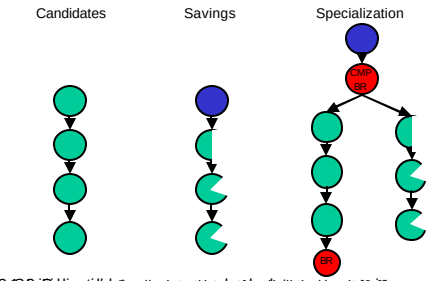
Value Range Specialization



3. Specialization: Insert guards and clone regions accordingly

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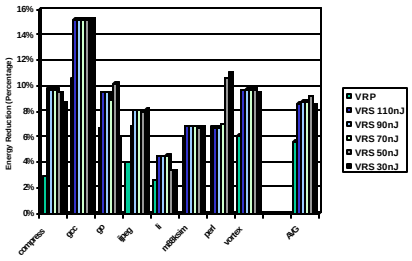
Energy Savings



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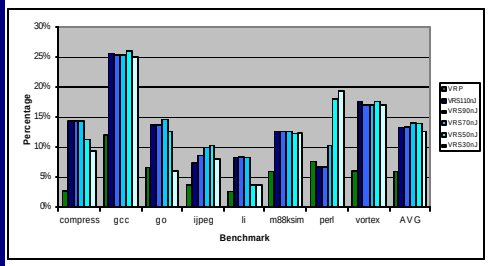
Energy-Delay^2 Savings



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Cooperative Hw-Sw

Advantages Hw

- ISA untouched
- Actual values

Advantages Sw

- Minimal hw complexity
- Wider program scope

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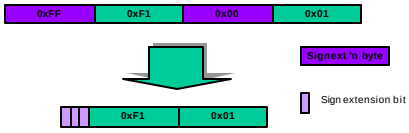
Significance Compression

32-bit value

Significance compression approach



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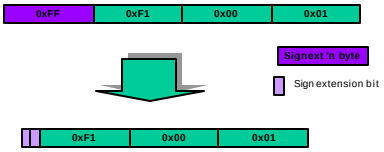
Size Compression

32-bit Value

Size compression approach



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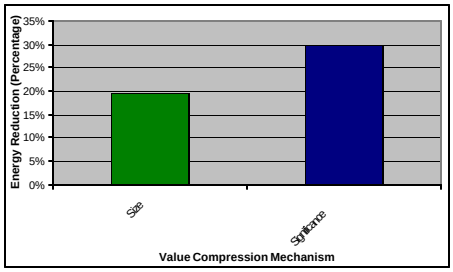
Energy Savings



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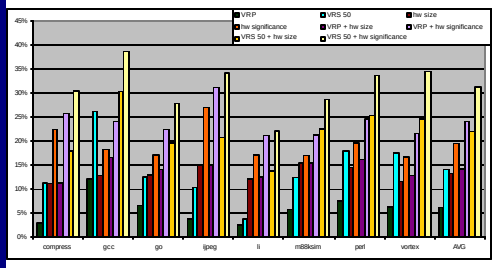
Cooperative Hw-Sw

Energy-Delay² Savings



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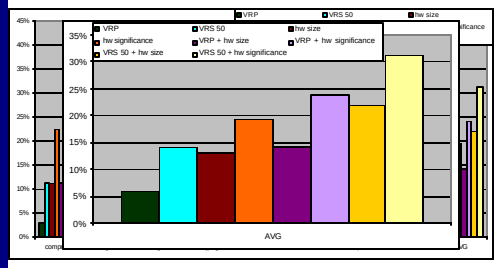
Cooperative Hw-Sw

Energy-Delay² Savings



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Summary

- Value compression is an effective way of reducing power requirements
- Software less effective but less complex
- Cooperative hw-sw for more effectiveness

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