Bitwidth Analysis with Application to Silicon Compilation

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Outline

- Why Bitwidth Matters
- Bitwidth Analysis
- SSA Form and Data-Range Propagation
- Example
- Results
- Quiz

The Importance of Bitwidth

For the past couple decades, we haven’t needed to care about bit widths too much due to modern processors.

That’s changing because of:

- Comeback of SIMD architecture for specific applications
- Low power embedded systems that turn off bit slices
- FPGA and ASIC Design

Bitwidth Analysis

Look at static code to find smallest amount of needed bits. Different operations give us hints:

- Array Indexing
- Type casts
- Loop variables
- Bitmask operations
- Boolean operations
- Arithmetic operations
- Bounded Variables

Array Indexing

Can narrow bit width of a variable if it is used to index an array.

Int a; (32 bits)

Int b[2047];

Int c = b[a];

‘a’ only needs to be 11 bits.

Type casts

During a typecast, assume that the casted variable only needs the bitwidth of the type it is casted to.

long a; (32 bits)

char b = (char) a; (8 bits)

‘a’ only needs 8 bits, not 32.

Loop variables

If a variable is used until it reaches a certain value, it only needs to be wide enough for the bounding value

int a;

For (int a = 0; a < 42; a++) {}

‘a’ only needs to store up to 42, so it only needs 6 bits

Boolean operations

If a variable is used like a boolean, we can assume it only needs 1 bit

```
int a;

a = (input() > 420);
```

Arithmetic Operations

Different arithmetic operations allow us to reduce bit widths

short a; (16 bits)
short b = a /16; (12 bits)
short c = b >> 9; (3 bits)

Bounded variables

Sometimes programs will bound the value of a variable, this can be taken advantage of

```
short wins;
if (wins > 8)
  wins = 8;
else if (wins < 0)
  wins = 0
```

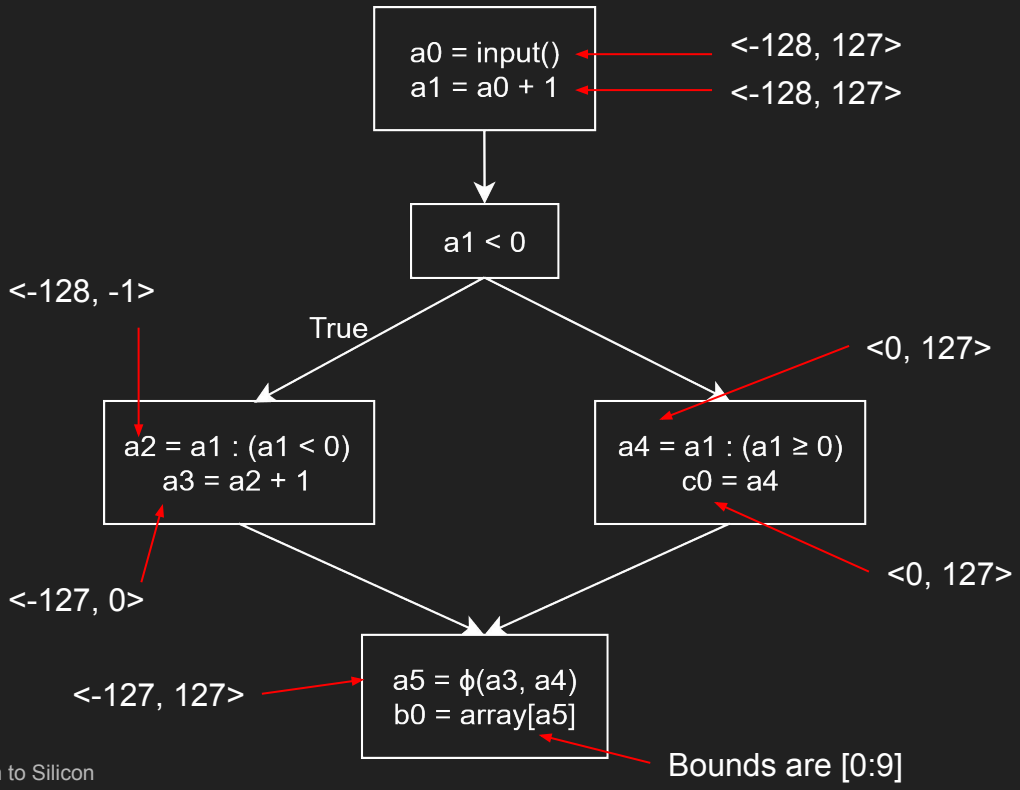
“wins” only needs 4 bits

SSA Form and Data Range Propagation

Propagate data ranges forward and backwards

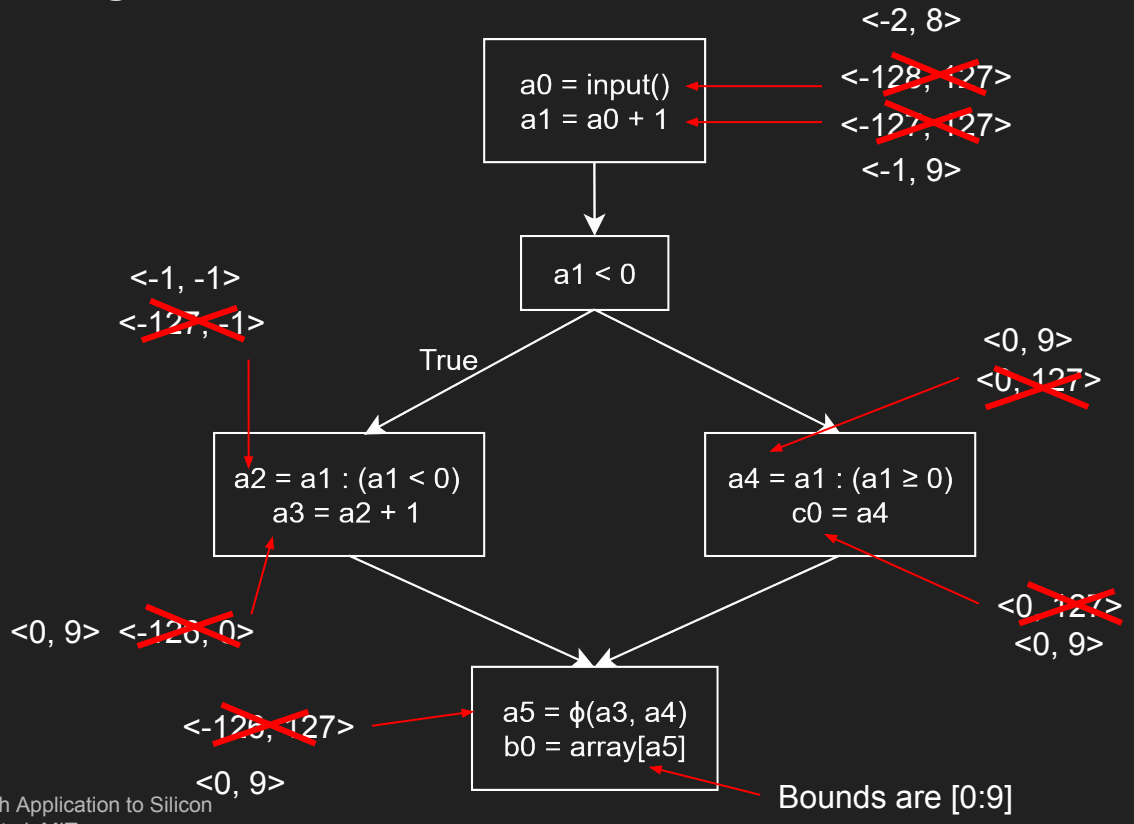
Use SSA form to easily handle information from conditional statements

Data Propagation Example



Example from Bitwidth Analysis with Application to Silicon Compilation by Mark Stephenson et al. MIT

Data Propagation Example



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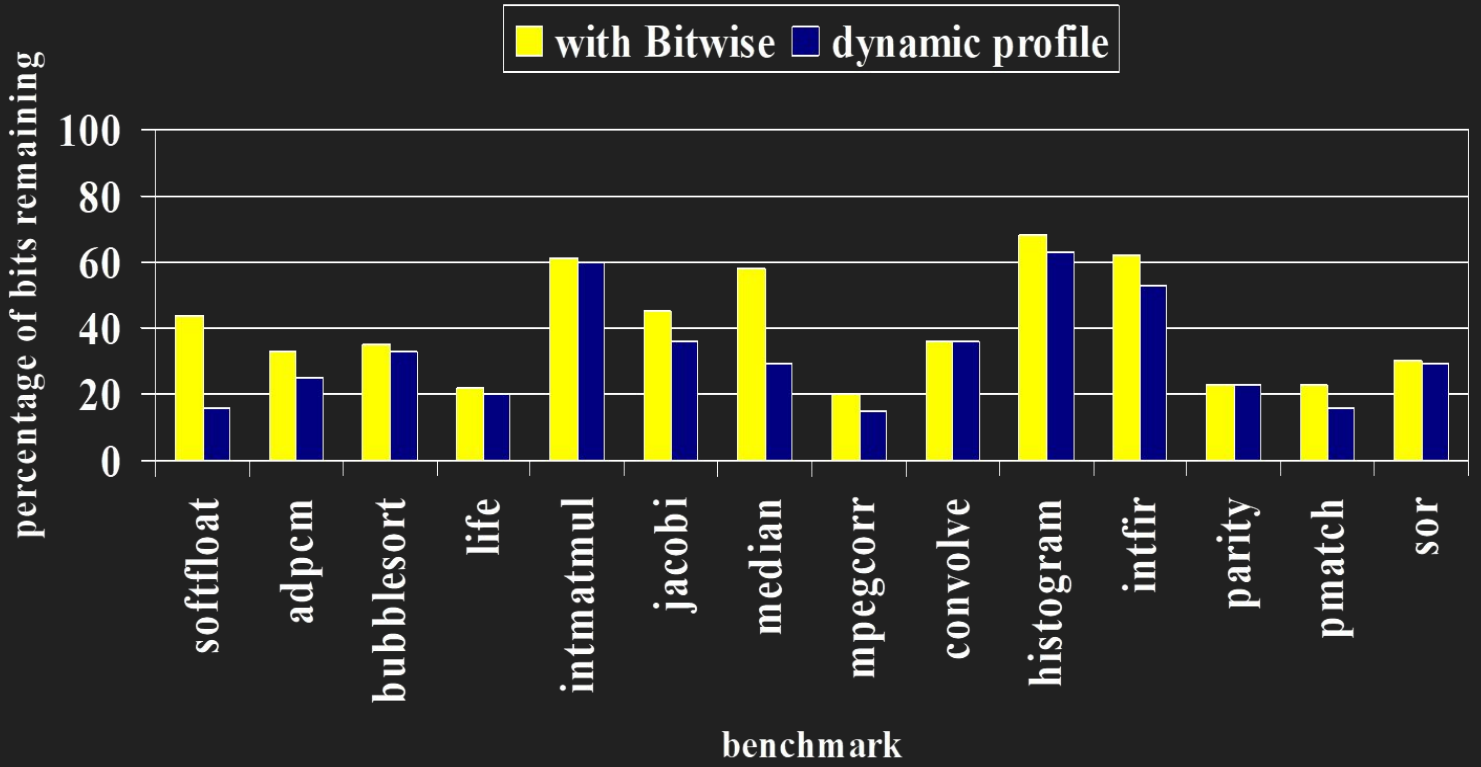
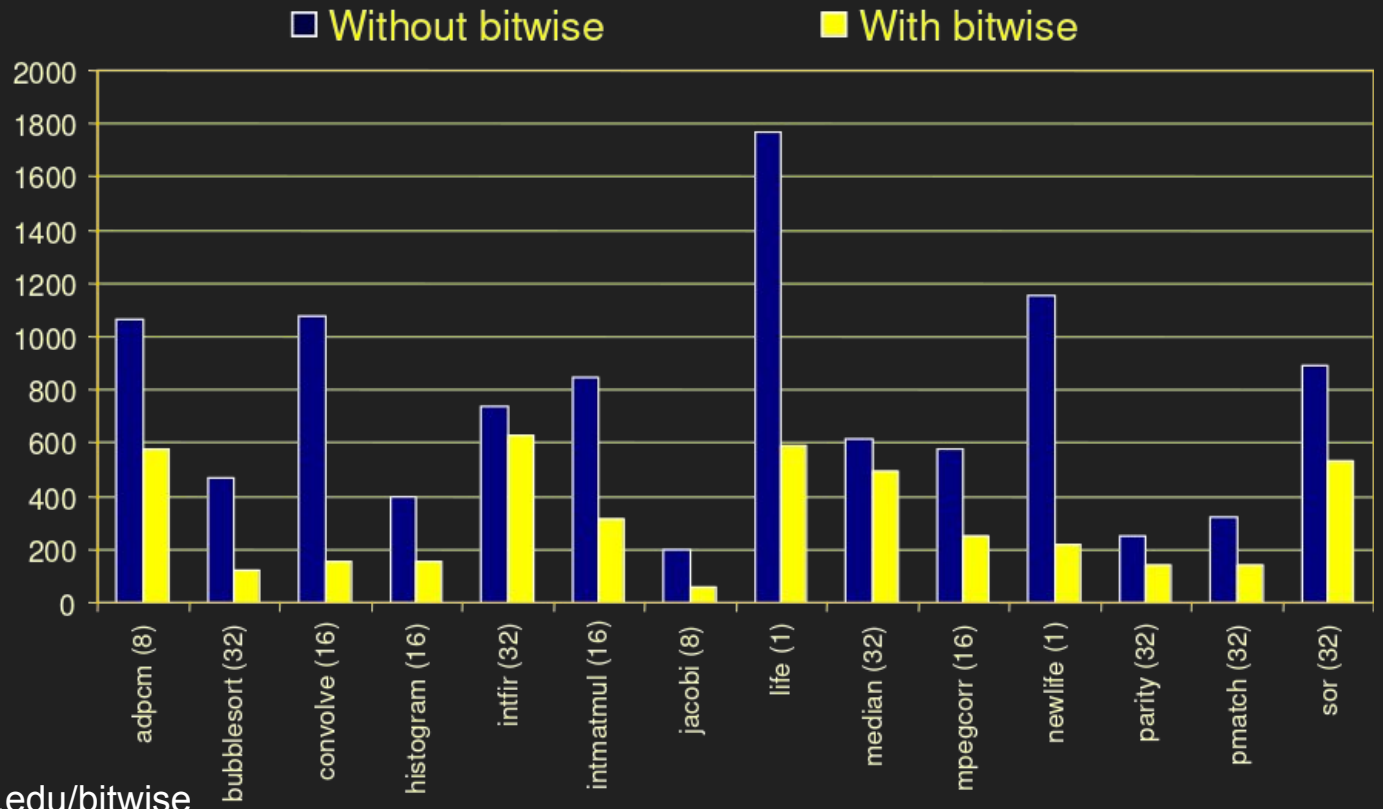
Results: Bit Savings



www.cag.lcs.mit.edu/bitwise

FPGA Area



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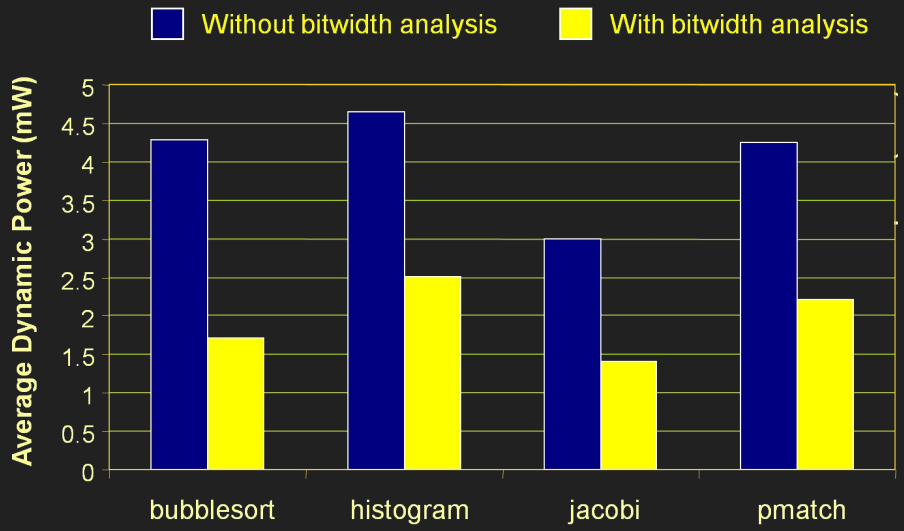
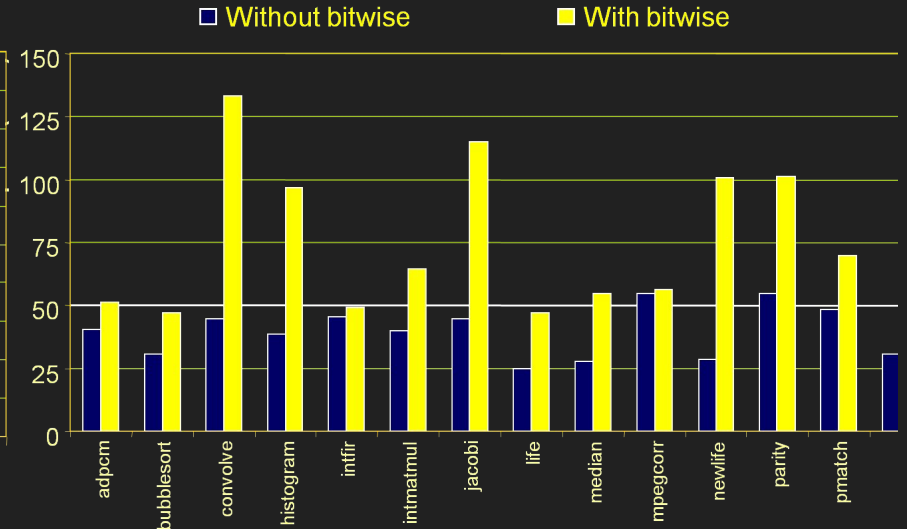
Power Savings



Clock Speed Increase



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QUESTIONS

Quiz time

How many bits does ‘i’ and ‘a’ need?

```
short arr[1337];

int i;

short a = arr[i] / 8;
```