High-Performance Scientific Computing
Lecture 9: Parallel Performance

MATH-GA 2011 / CSCI-GA 2945 · October 24, 2012

Today

Tool of the day: Shell scripting

Single-thread performance

Multi-thread performance

Bits and pieces

- Don't have a project? Let's fix that *very soon*
- HW5: soon
- HW6: due today
- Dec 5: Last day of regular class
- Dec 12: Legislative Day
- Dec 17/18/**19**: Project presentations
- Don't have grade reports for HW1…4? Talk to me

Outline

Tool of the day: Shell scripting

Single-thread performance

Multi-thread performance

Shell scripting

Demo time

Shell scripting

All you ever wanted to know about scripting:

- `http://tldp.org/LDP/abs/html/`
- `man bash`

Outline

Tool of the day: Shell scripting

Single-thread performance

- How about actually doing work?
- Compilers and what they do to your code

Multi-thread performance

Recap

Single-thread performance recap:

- CPU bits
  - Bus, Register File, ALU, Memory Interface, Machine language
- Memory hierarchy
  - Latency, bandwidth
  - Caches: lines, associativity
  - Locality, working set
- Pipelines
  - Dependencies
  - Branch predictor
  - Software pipelining, loop unrolling

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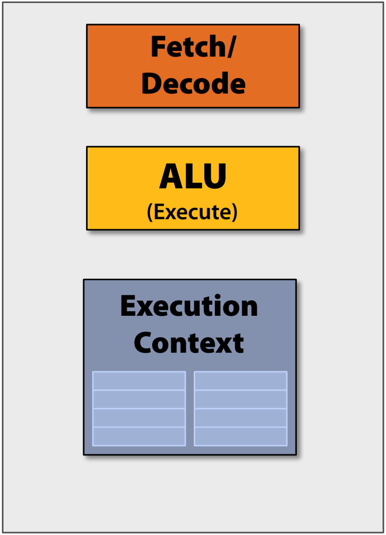
Multi-thread performance

Remember SIMD?



Credit: Kayvon Fatahalian (Stanford)

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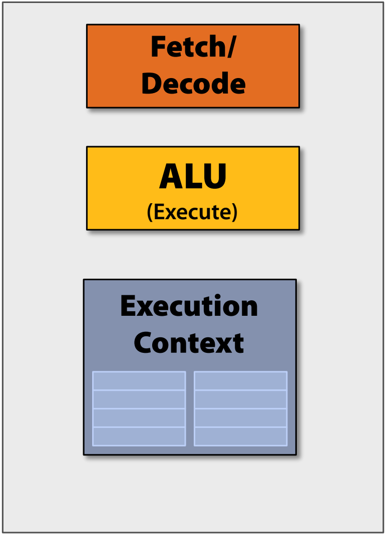

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GPU Idea #2

Amortize cost/complexity of managing an instruction stream across many ALUs

→ **SIMD**

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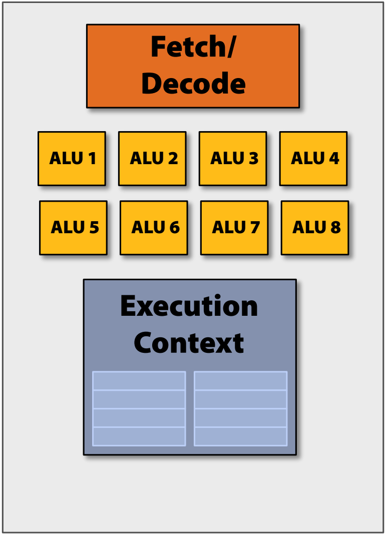

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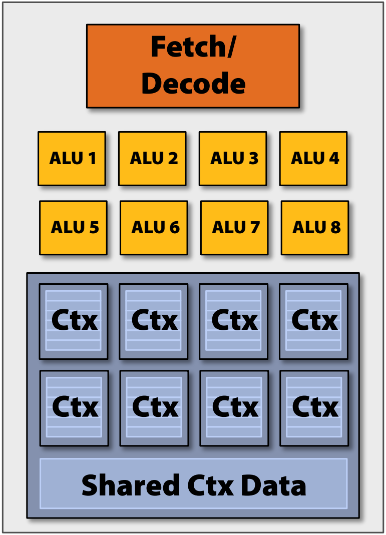

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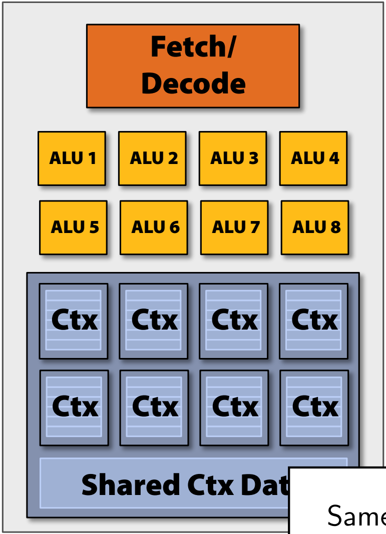

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GPU Idea #2

Amortize cost/complexity of managing an instruction stream across many ALUs

→ **SIMD**

Same principle works well on CPUs, too!

Talking to SIMD

Ways of expressing SIMD:

- Not at all (`-ftree-vectorizer-verbose=2`, pray)
- "Implicit" (OpenCL workgroups)
- "Explicit" (many ways)

OpenCL is also one of the saner ways of expressing *explicit* vectorization.
(even on the CPU)

Other ways:

- "Intrinsics": `_mm256_hadd_ps`
- GCC extensions
- ispc

Floating point

CL vector demo

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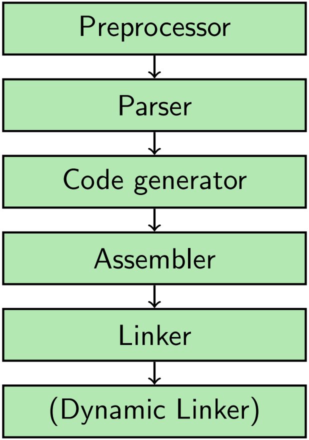
Inside a compiler



Preprocessor

Parser

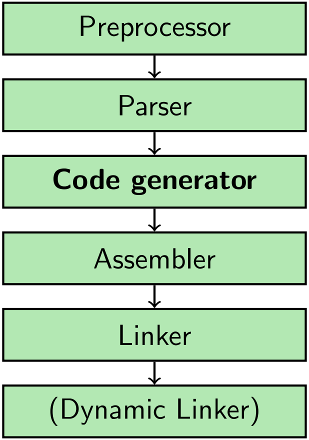
Code generator

Assembler

Linker

(Dynamic Linker)

Inside a compiler



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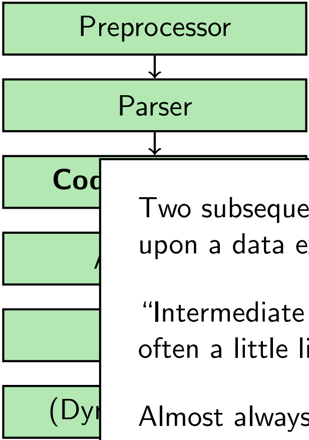

Two subsequent stages agree upon a data exchange format

“Intermediate Representation”– often a little like assembly

Almost always more complicated:
“Passes” include optimizers, . . .
`http://llvm.org/demo/`

Compilers and the register file

Register allocator:

- Important
- Complicated

Failure: ‘Register Spill’

Not dramatic on the CPU (L1 is fast)

Very dramatic on the GPU

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Demo

Registers most effective when data can be reused many times

Pointer aliasing

Pointer aliasing demo

Pointer aliasing

Pointer aliasing demo

Not the only thing to go wrong with pointers...

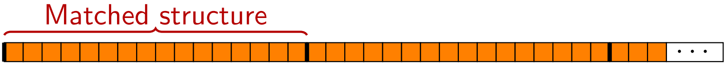
Alignment

Match base address of:

- Single word: `double`, `float`
- SIMD vector
- Larger structure

To:

- Natural word size
- Vector size
- Cache line



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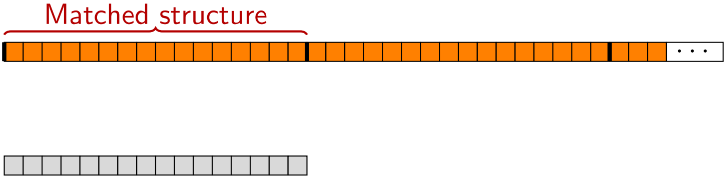

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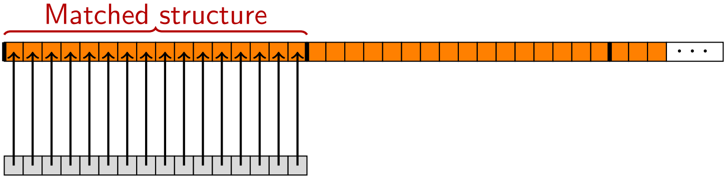

OK

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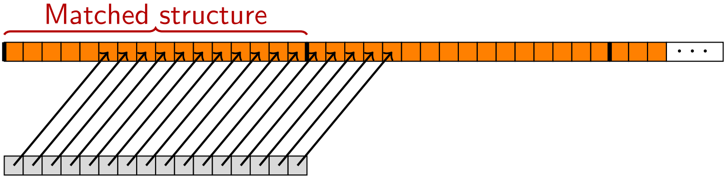

"Bad"

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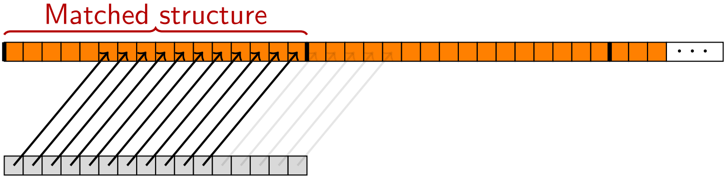

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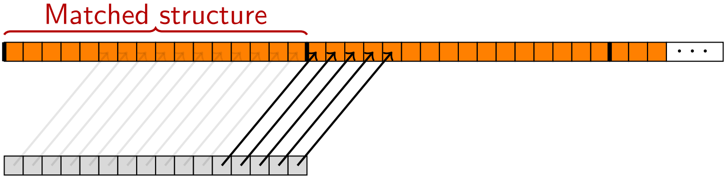

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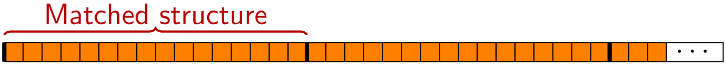

Comes in two flavors:

- Actual alignment
  `malloc` → `posix_memalign`
- Compiler-known alignment
  `float __attribute__ ((aligned (64))) *a`

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More difference on other machines
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Brief demo

Other compiler optimizations

More techniques:

- Inlining (see HW6)
- Unrolling
- Vectorization

Many of these need tunable parameters. From where?

- `-march=native -mtune=native`
- Profile-Guided Optimization

From the horses' mouth

- AMD Optimization Manual
  - Good source-level C part at the beginning
- Intel Optimization Manual
  - Dual audience: Compiler writers, users

Grab bag of good practices:

- Use indices rather than pointers (easier to reason about)
- Extract common subexpressions
- Make functions static
- Use `const`
- Avoid store-to-load dependencies

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Multi-thread performance

- Memory-related

Multi-thread performance

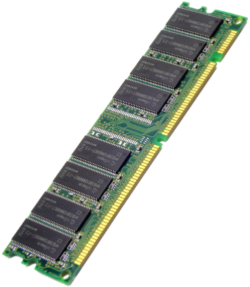
Difference to single-thread?

Multi-thread performance

Difference to single-thread?

Memory System is (about) the only shared resource.

All ‘interesting’ performance behavior of multiple threads has to do with that.



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Multiple threads

Threads v. caches demo

Questions?

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Image Credits

- Pebbles: sxc.hu/topfer