Performance of mathematical software

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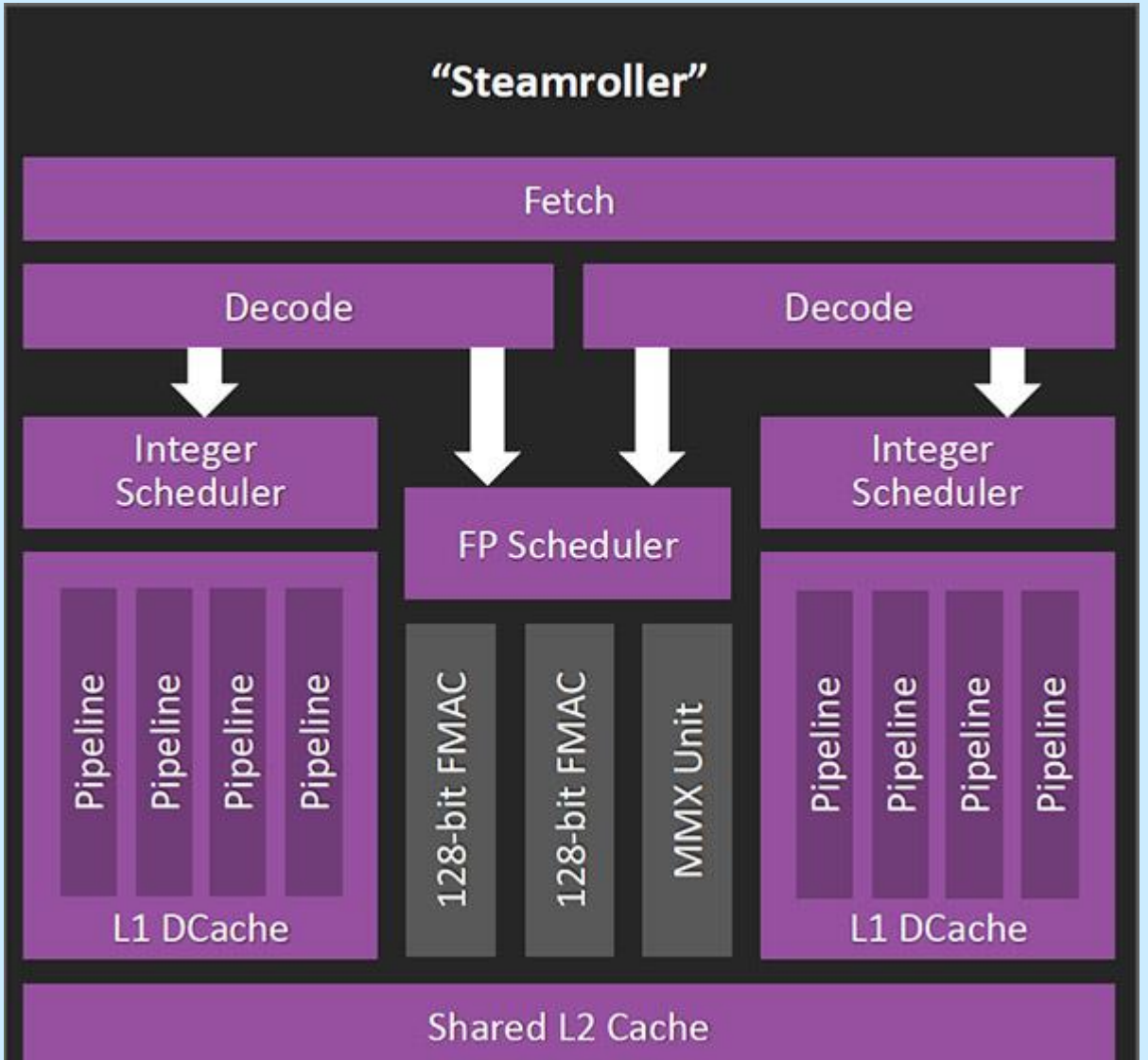
Agenda

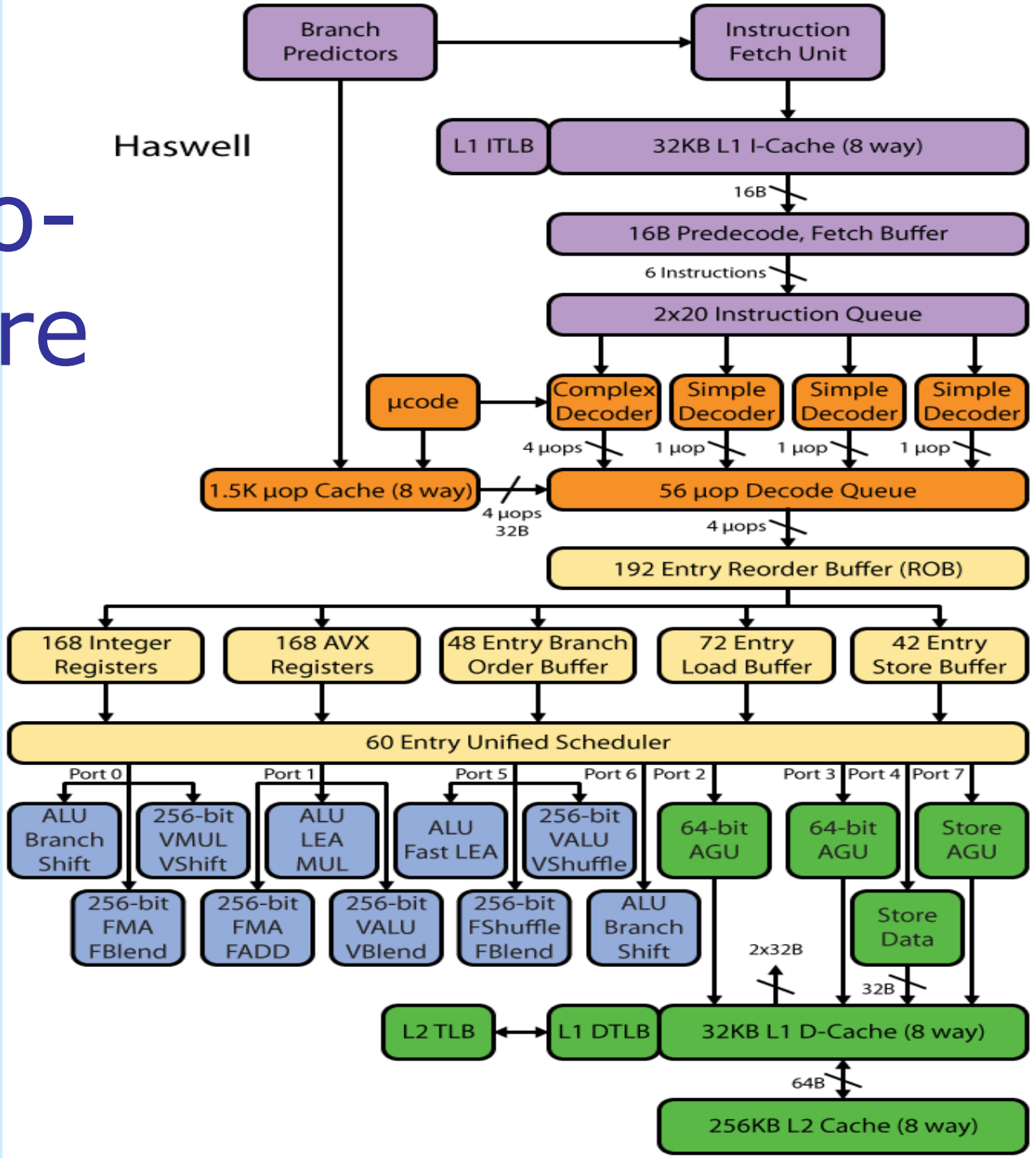
- Intel and AMD microarchitecture
- Performance bottlenecks
- Parallelization
- C++ vector classes, example
- Instruction set dispatching
- Performance measuring
- Hands-on examples

AMD Microarchitecture

- 2 threads per CPU unit
- 4 instructions per clock
- Out-of-order execution

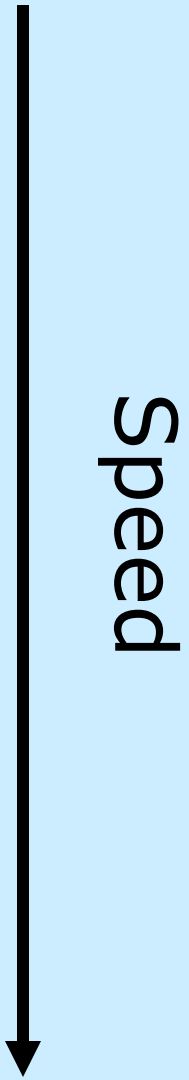


Intel Micro-architecture



Typical bottlenecks

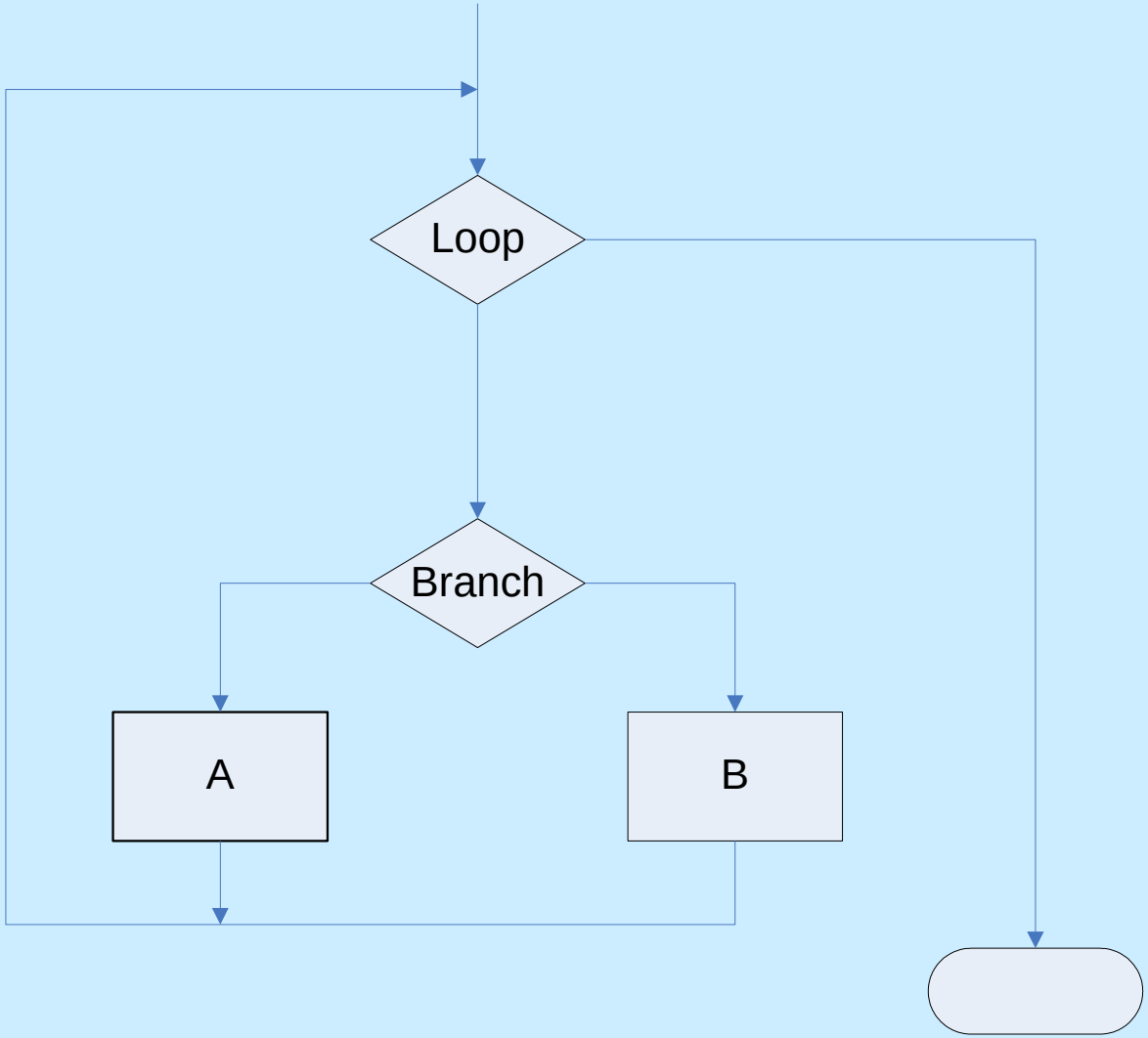
- Installation of program
- Program start, load framework and libraries
- System database
- Network
- File input / output
- Graphics
- RAM access, cache utilization
- Algorithm
- Dependency chains
- CPU pipeline
- CPU execution units



Efficient cache use

- Store data in contiguous blocks
- Avoid advanced data containers such as resizable data structures, linked lists, etc.
- Store local data inside the function they are used in

Branch prediction



Out-Of-Order Execution

```
x = a / b;
y = c * d;
z = x + y;
```

Dependency chains

```
x = a + b + c + d;
```

```
x = (a + b) + (c + d);
```

Loop-carried dependency chain

```
for (i = 0;  i < n;  i++) {
   sum += x[i]; }

for (i = 0;  i < n;  i += 2) {
   sum1 += x[i];
   sum2 += x[i+1]; }
sum = sum1 + sum2;
```

Levels of parallelization

- Multiple threads running in different CPU units
- Out-of-order execution
- SIMD instructions

SIMD programming methods

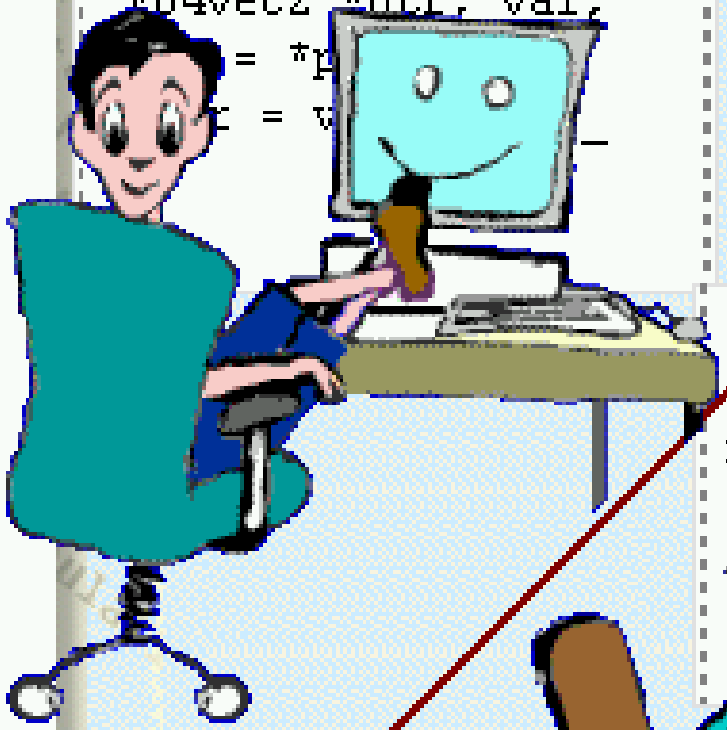
- Assembly language
- Intrinsic functions
- Vector classes
- Automatic vectorization by compiler

Vector Class vs. Assembly

F64vec2 *ptr, val; val = *ptr; *ptr = val * val;

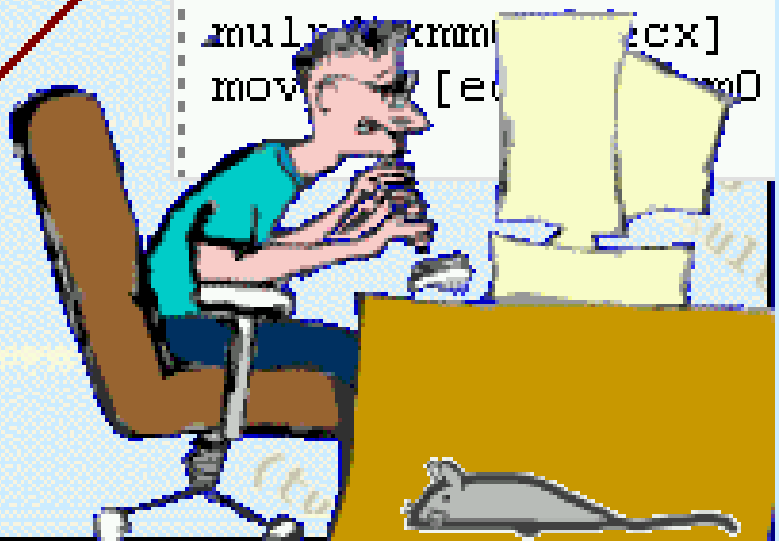
Vector Class

```
F64vec2 *ptr, val;
```



Assembly

```
...
mov ecx, ptr
movapd xmm0, [ecx]
```



Obstacles to automatic vectorization

- Pointer aliasing
- Array alignment
- Array size
- Algebraic reduction
- Branches
- Table lookup

Vector math libraries

Short vectors

- Intel SVML
- AMD libm
- Agner's VCL

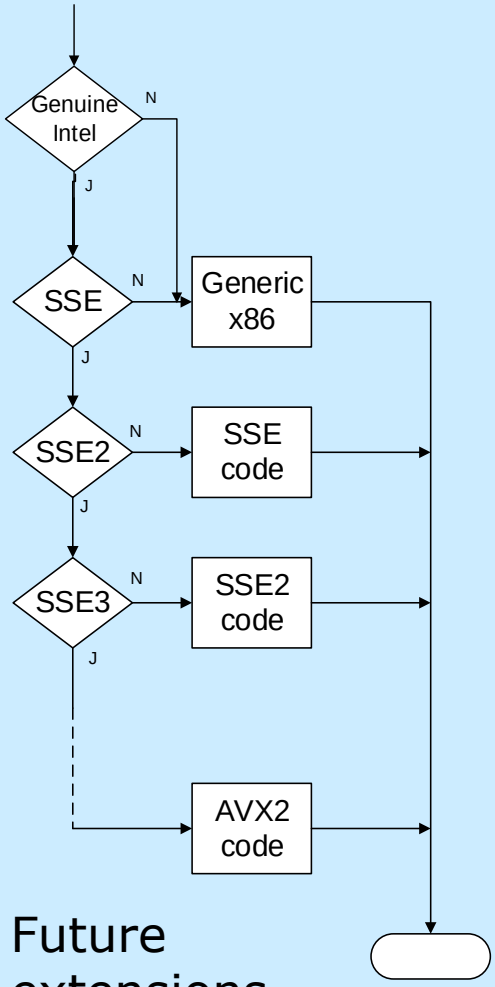
Long vectors

- Intel VML
- Intel IPP
- Yeppp

Example

Exponential function
in vector classes

Instruction set dispatching



Performance measurement

- Profiler
- Insert measuring instruments into code
- Performance monitor counters

When timing results are unstable

- Stop other running programs
- Warm up CPU with heavy work
- Disable power saving features in BIOS setup
- Disable hyperthreading
- Use “core clock cycles” counter (Intel only)

Example

Measuring latency and throughput of machine instruction

Hands-on example

Compare performance of different mathematical function libraries

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