

F. Vogel

General

→ setxkbmap ch -variant de-nodeadkeys

makefile make

CXX = g++

CFLAGS = -Wall -O3 -std=c++11

test: test.cpp

\$(CXX) \$(CFLAGS) -o \$@ \$<

clean:

rm -f test

#PCSE I HS16

Threads

compile g++ -std=c++11 -pthread

import #include <thread>

launch func std::thread t(foo, arg1);

launch λ std::thread [&]() {do something};

mutex:

import #include <mutex>

declare std::mutex mtx;

lock mtx.lock();

;

mtx.unlock();

lock_guard std::lock_guard<std::mutex> l(mtx);

↳ locked when initialized

↳ unlocked when destroyed

unique_lock std::unique_lock<std::mutex> l(mtx, n);

↳ locks work with multiple locks (no deadlock)

l.unlock();, l.lock(); for manual

Example

int nthreads = 4;

int nstep = N/nthreads;

std::vector<std::thread> threads(nthreads);

for (int t = 0; t < nthreads; t++) {

threads[t] = thread([&, t] {

for (int i = t*nstep; i < (t+1)*nstep; i++) {

z[i] = x[i] + y[i];

});

}

for (std::thread& t : threads) {

t.join();

}

MPI

compile mpicc, mpic++

import #include <mpi.h>

run mpicxx -np 4 ./a.out

info MPI_Comm_rank (MPI_COMM_WORLD, &rank);

MPI_Comm_size (MPI_COMM_WORLD, &size);

Example

int main (int argc, char **argv) {

MPI_Init (&argc, &argv);

int num;

MPI_Comm_rank (MPI_COMM_WORLD, &num);

if (num == 0) { //master

MPI_Status status;

char txt[100];

MPI_Recv (txt, 100, MPI_CHAR, 1, 42, MPI_COMM_WORLD, &status);

std::cout << txt << '\n';

} else { //worker

std::string text = "Bla";

MPI_Send (&text, text.size()+1, MPI_CHAR, 0, 42, MPI_COMM_WORLD);

}

MPI_Finalize();

Open MP

compile g++ -fopenmp -std=c++11

import #include <omp.h>

info omp_get_thread_num() → id

omp_get_num_threads() → #threads

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Parallel Scaling

Amdahl's Law:

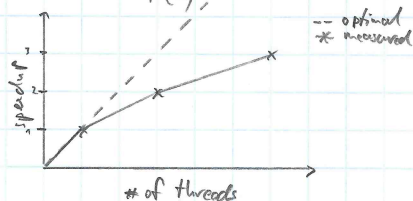
$$S(n) = \frac{1}{(1-p) + \frac{p}{n}}$$

Gustafson's Law:

$$S(n) = 1 - p + n \cdot p \quad (\text{weak scaling})$$

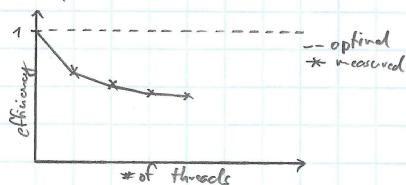
Strong scaling:

$$S(n) = \frac{T(1)}{T(n)} \quad E(n) = \frac{S(n)}{n}$$

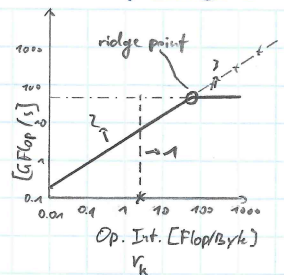


Weak scaling:

$$E(n) = \frac{T(1)}{T(n)} \quad \text{fixed problem size per thread}$$

Note: Problem size for N^2 solver is N^2/n 

Plot



1: Locality

2: Communication

3: Computation

limit by comp. --- $f_{peak} = f(r_k)$
 limit by DRAM --- $r_k \cdot b_{peak} = f(r_k)$

Bugs

- Threads: Pass thread id by value, not by reference
- SIMD: Race condition by interleaving of loads
- SIMD: Undefined behavior by loading not allocated memory
- OMP: implicit barrier @ end of for, all threads have to call it. Fix: schedule(dyn) nowait
- MPI: Don't update asynchronous send buffer
- Threads: Not passing all needed variables
- Threads: Race condition by not locking result double
- Threads: Result reduction before join is called on each thread
- Threads: Master thread: not releasing lock before calling join can result in deadlock
- MPI: Ordering needed to prevent deadlock (replacing with asynchronous works too)

Roofline ModelOperational Intensity [Flop/Byte] r

$$r = \frac{\text{\# of Flops}}{\text{\# of Mem accesses} \cdot \text{\# of Bytes}}$$

→ Example: $RHS_{i,j} = C_n \cdot (\tilde{q}_{i,n,j}^n + \tilde{q}_{i,n,j}^n + \tilde{q}_{i,n,j}^n + \tilde{q}_{i,n,j}^n - 4\tilde{q}_{i,j}^n)$

→ 6 Flops (4 ADD + 2 MUL)

→ Mem Access:

→ No cache: 5 read + 1 write = 6

→ Infinite cache: 1 read + 1 write = 2

→ Op. Int.

→ No cache: $\frac{6 \text{ Flops}}{6 \cdot 4 \text{ B}} = 0.25 \text{ Flop/B}$

→ Infinite cache: $\frac{6 \text{ Flops}}{2 \cdot 4 \text{ B}} = 0.75 \text{ Flop/B}$

Nominal performance

→ $f_{peak} = \text{processor clock/sec} \cdot \text{vector size} \cdot \text{instructions/clock} \cdot \text{\# cores}$

→ $b_{peak} = \text{memory clock/sec} \cdot \text{channel size} \cdot \text{\# channels} / 8 [\text{bit/byte}]$

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