HPC2N, UmU

Parallel programming
Shared and distributed Memory

Joachim Hein
LUNARC & Centre of Mathematical Sciences
Lund University

Pedro Ojeda May
HPC2N
Umeå University

Lund University

1

INTRODUCTION TO PARALLEL COMPUTING

Lund University

2

Why parallel programming?

- Improve computational speed
  - Get faster time to solution
  - Larger, hopefully more realistic problem
- Divide problem into subtasks
  - Assign subtasks to different CPUs → parallel computing
- Parallel computing is presently the **only** game in town to get more performance
  - CPUs do not get faster (stuck around 3 GHz for years)

Example

- Calculate large sum:

$$\sum_{n=1}^{40000} a_n$$

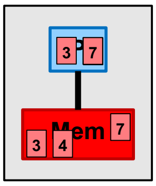
- Split into four sums, use a different processor for each:

$$\sum_{n=1}^{10000} a_n \quad \sum_{n=10001}^{20000} a_n \quad \sum_{n=20001}^{30000} a_n \quad \sum_{n=30001}^{40000} a_n$$

- In the end: four partial results and need to make into one!

Serial programming

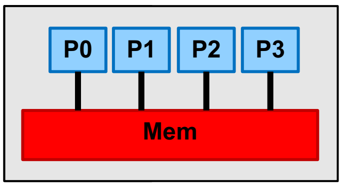
- We want to do a long calculation
- Pencil & Paper to slow ☹
- Take a computer
  - Write a program in C, Fortran, ...
  - Run the program
- What happens when the program runs?
  - Processor reads data from memory
  - Processes these data
  - Writes result back to memory
  - Write final result to disk
- What can we do if that is still too slow ???



5

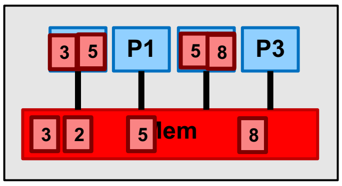
Parallel programming

- Take more than one processor
- Partition the entire calculation into independent parts
- Assign one or more of these parts to each processor
- Should be faster now!
- But normally the parts are **not** fully independent
- Dealing with these data dependencies is a key challenge in parallel computing



6

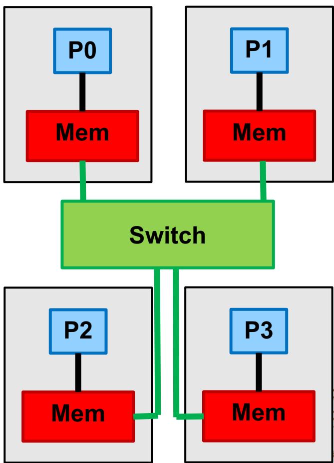
Shared Memory Architecture



- Several processing elements manipulate the same, shared memory space
- Easy to move data between processors
  - Write result to shared memory
  - Read on different processor
- Care is needed regarding order:
  - P0 needs to write before P2 can read
- Read/write to shared memory has typically higher cost than manipulating registers/cache

Distributed memory machine

- Several independent computers (typically referred to as: nodes)
- With interconnect network
- Separate program, called *task*, on each processor
- Each has its private data
- Typically explicit message passing
- Not suitable for shared memory programming (e.g. OpenMP)



Discussion

MESSAGE PASSING VS SHARED MEMORY

Shared memory programming

- Typically less demanding on the programmer
- Possible to work “incremental”
- Allows for more algorithms to be implemented
  - Replicated data situations
  - Unstructured data distributions
- Requires shared memory architecture
  - e.g.: Multicore, SMP, CC-Numa
- Limited in core count
- Typical problems encountered:
  - Data races ➔ wrong results, often non-deterministic
  - Memory locality problems ➔ bad performance

A simple performance model

AMDAHLS LAW
OF PARALLEL COMPUTING

Parallel speed-up and efficiency

- Faster time to solution is the key aim of parallel computing
  - t_1 : time to solution using 1 processor
  - t_N : time to solution using N processors
- Parallel speed-up: $$S(N) = \frac{t_1}{t_N}$$
- Parallel efficiency: $$E(N) = \frac{t_1}{N \cdot t_N}$$
- Naïve performance expectation: *E(N)* = 100%

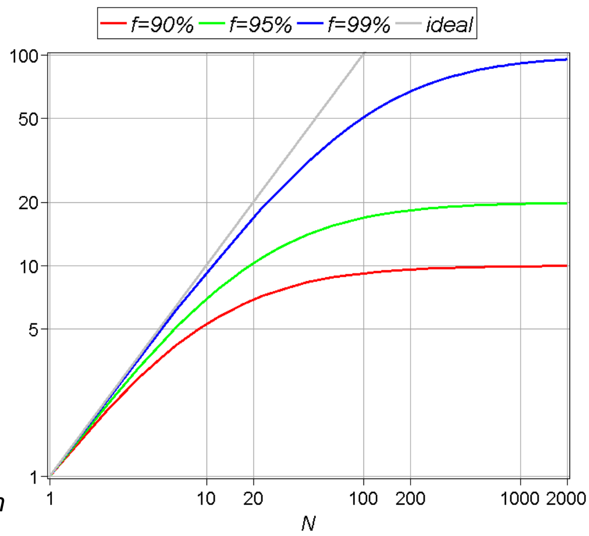
Simple performance model: Amdahl's law for parallel programs

- Consider a program takes time t_1 in serial (on 1 processor)
- A fraction $f < 1$ can be parallelised efficiently on N processors
  - Time spend on the parallel part: $f\, t_1 /N$
  - Time spend on the serial, remaining part: $(1\text{-}f)\, t_1$
  - Total time on parallel code: $t_N=(1-f + f/N)t_1$
- Speed up:

$$\frac{t_1}{t_N} = \frac{1}{1-f\left(1-\frac{1}{N}\right)}$$

Amdahl's law

- Speed-up limited to: $1/(1 - f\,)$
- 50% of max speed-up: $N_{50} \approx 1/(1 - f\,)$
- Not much point in running beyond $\approx\boldsymbol{2N_{50}}$
- ***Fall-out:*** *Serial parts in computational kernel can not be tolerated*



Summary

- Parallel computing offers faster time to solution
- Basic ideas behind
  - Shared memory programming
  - Message passing programming
  - Hybrid programming
- Discussed the impact of remaining serial parts

Lund University

18