Parallel Models

Different ways to exploit parallelism

Reusing this material

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THE UNIVERSITY OF EDINBURGH

Outline

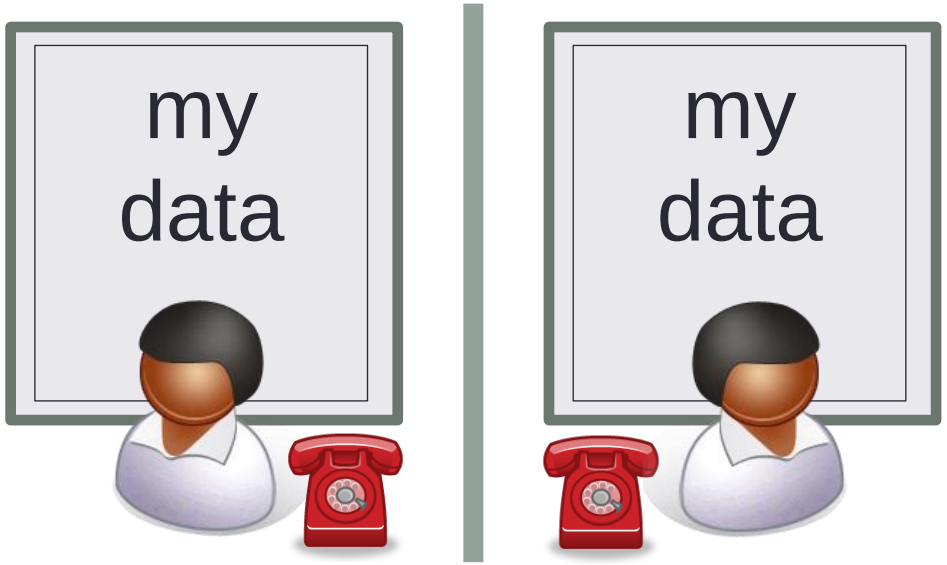
- Message-Passing Parallelism
  - processes
  - distributed-memory architectures
- Shared-Variables Parallelism
  - threads
  - shared-memory architectures
- Practicalities
  - usage on real HPC architectures

Message Passing

Process-based parallelism

Analogy

- Two whiteboards in different single-person offices
  - the distributed memory
- Two people working on the same problem
  - the processes on different nodes attached to the interconnect
- How do they collaborate?
  - to work on single problem
- Explicit communication
  - e.g. by telephone
  - no shared data



Process communication

Program

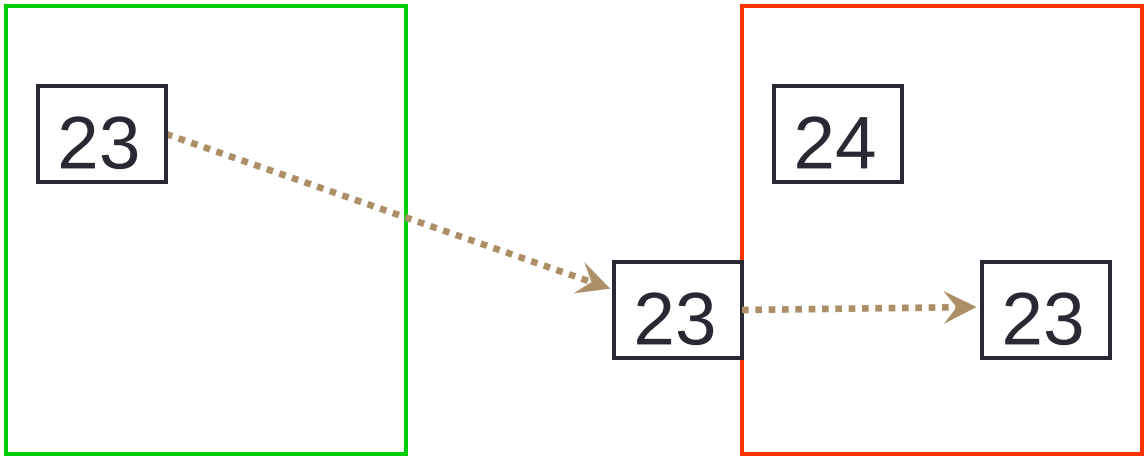
Process 1

```
a=23
Send(2,a)
```

Process 2

```
Recv(1,b)
a=b+1
```

Data



Synchronisation

- Synchronisation is automatic in message-passing
  - the messages do it for you

- Make a phone call …
  - … wait until the receiver picks up
- Receive a phone call
  - … wait until the phone rings

- No danger of corrupting someone else's data
  - no shared blackboard

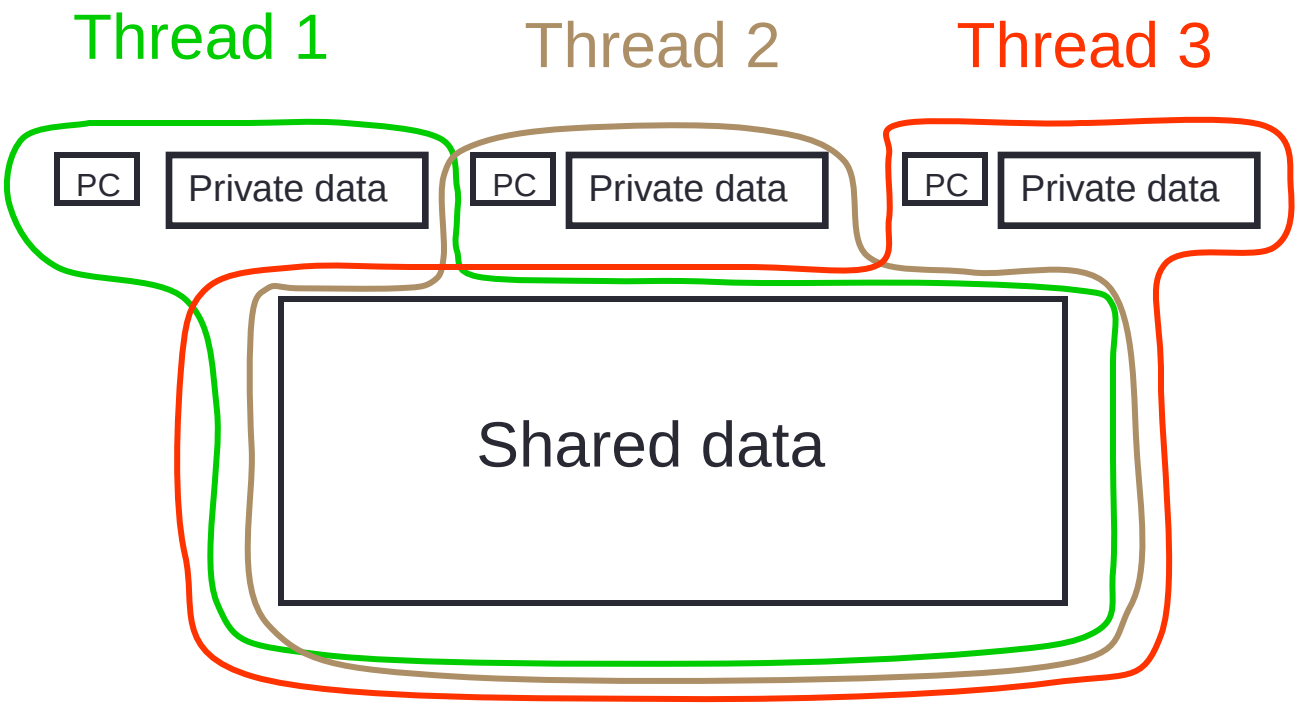
Shared Variables

Threads-based parallelism

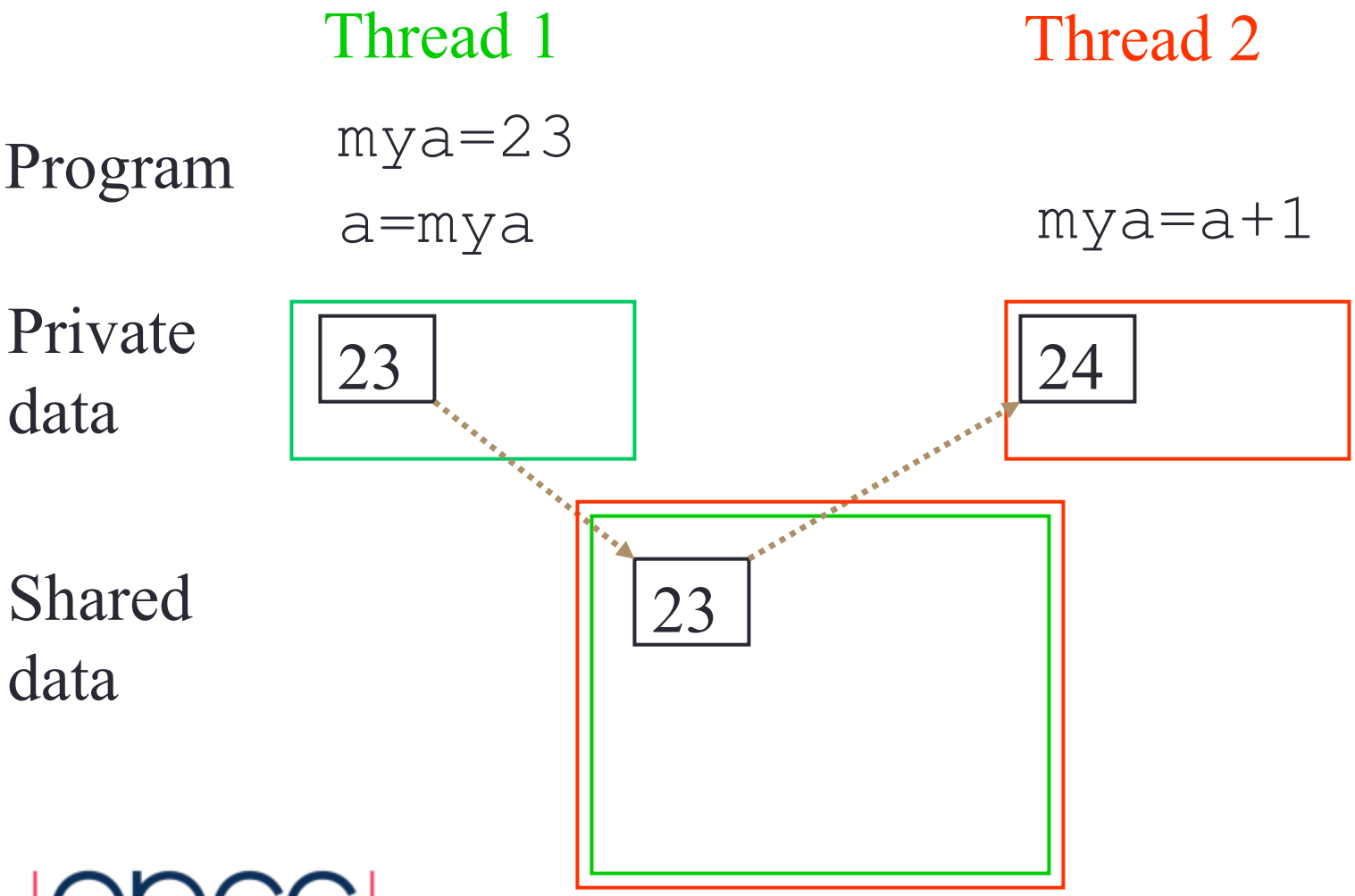
Analogy

- One very large whiteboard in a two-person office
  - the shared memory
- Two people working on the same problem
  - the threads running on different cores attached to the memory
- How do they collaborate?
  - working together
  - but not interfering
- Also need *private* data

Threads


Thread 1
Thread 2
Thread 3
PC
Private data
PC
Private data
PC
Private data
Shared data

Thread Communication



Synchronisation

- Synchronisation crucial for shared variables approach
  - thread 2's code must execute *after* thread 1
- Most commonly use global barrier synchronisation
  - other mechanisms such as locks also available
- Writing parallel codes relatively straightforward
  - access shared data as and when its needed
- Getting correct code can be difficult!

Threads: Summary

- Shared blackboard a good analogy for thread parallelism
- Requires a shared-memory architecture
  - in HPC terms, cannot scale beyond a single node
- Threads operate independently on the shared data
  - need to ensure they don't interfere; synchronisation is crucial
- Threading in HPC usually uses OpenMP directives
  - supports common parallel patterns
  - e.g. loop limits computed by the compiler
  - e.g. summing values across threads done automatically

OpenMP fork / join model

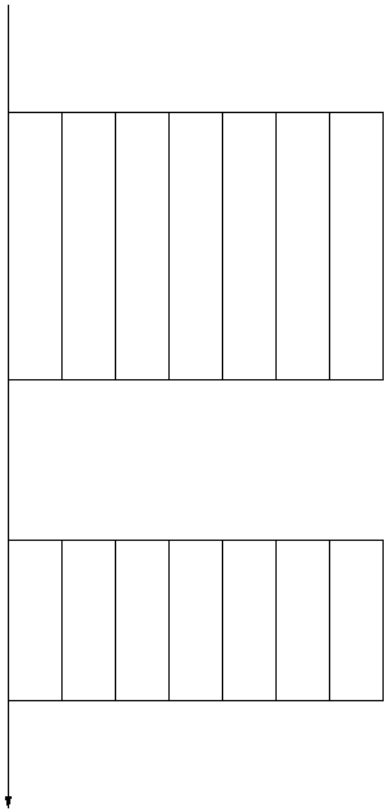
Sequential part

Parallel region

Sequential part

Parallel region

Sequential part



```
      PROGRAM FRED
        .
        .
!$OMP PARALLEL
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!$OMP END PARALLEL
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        .
!$OMP PARALLEL
        .
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        .
!$OMP END PARALLEL
        .
        .
        .
```

```
int main(){
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#pragma omp parallel
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}
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#pragma omp parallel
{
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}
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```
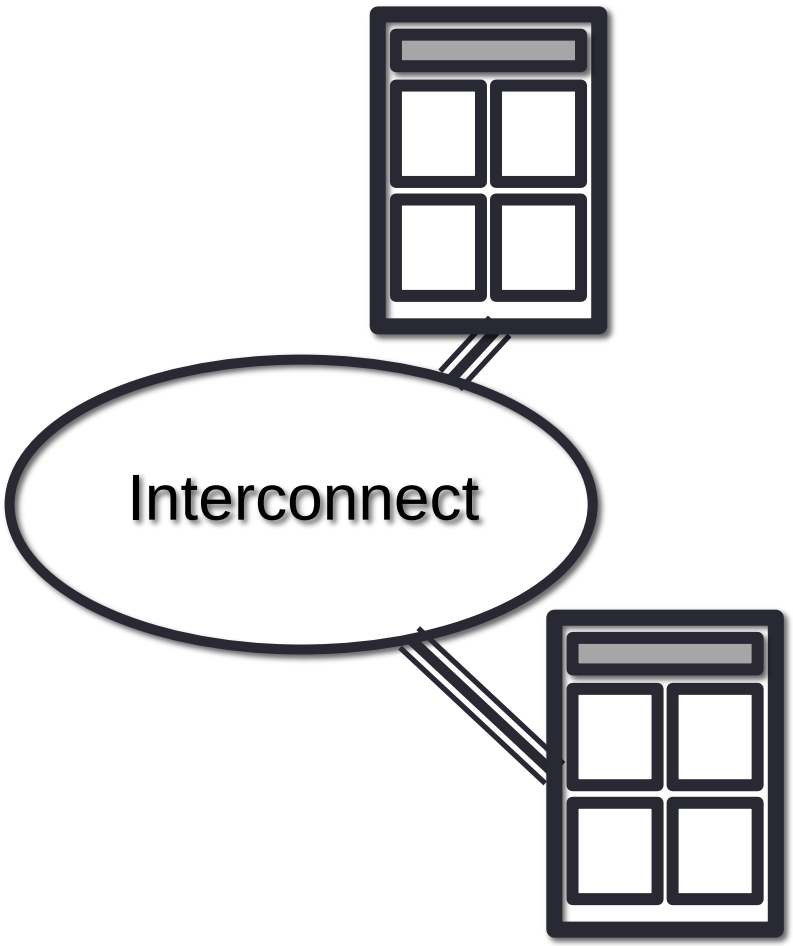

Practicalities

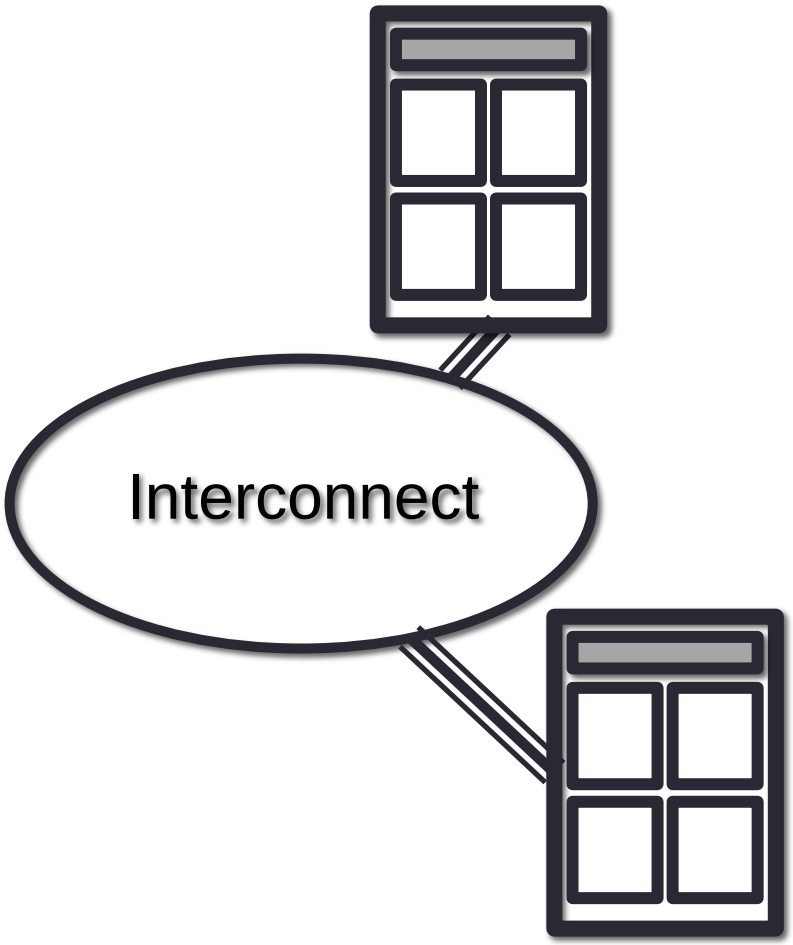
How we use the parallel models

Practicalities



- 8-core machine might only have 2 nodes
  - how do we run MPI on a real HPC machine?
- Mostly ignore architecture
  - pretend we have single-core nodes
  - one MPI process per processor-core
  - e.g. run 8 processes on the 2 nodes
- Messages between processor-cores on the same node are fast
  - but remember they also share access to the network

Hybrid MPI / OpenMP



- Take advantage of architecture
  - one MPI process per node
  - four OpenMP threads per process
    - one for each physical code