Asynchronous Parallel Methods

Overview

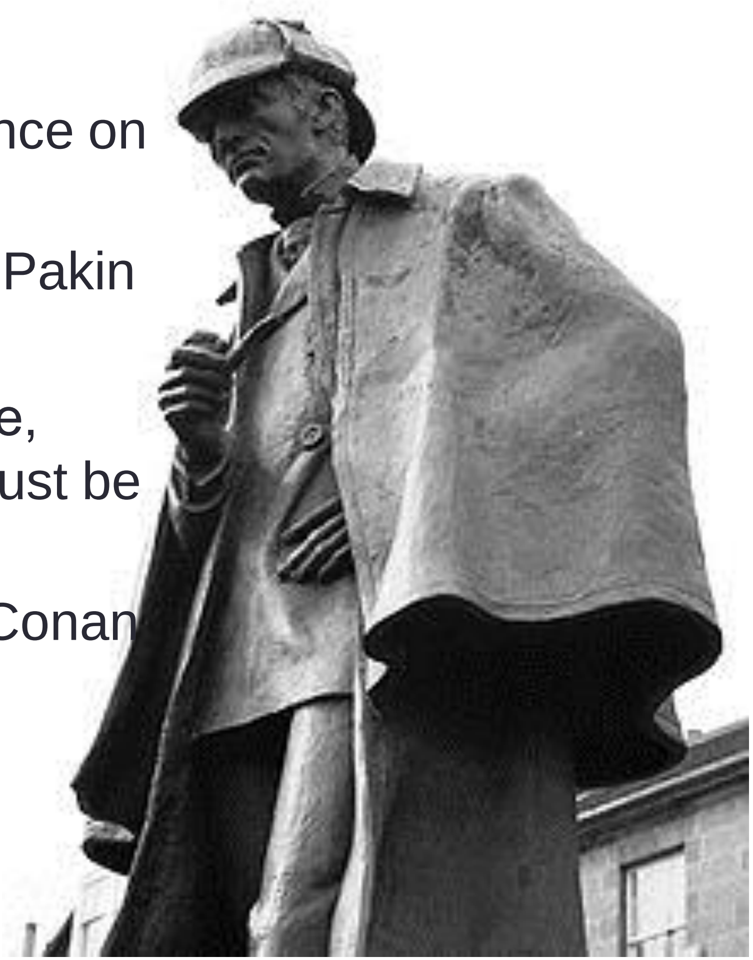
- What's the problem?
- What is an asynchronous method?
- Reducing synchronisation in existing models

The Problem

- Synchronisations often essential for program correctness
  - waiting for an MPI receive to complete before reading from buffer
  - barriers at the end of an OpenMP parallel loop
  - …
- But they cost time
  - and slow down the calculation
- Cost is usually not the synchronisation operation itself
  - it is waiting for other tasks to catch up with each other
  - all calculations have some load imbalance from random fluctuations
  - a real problem as we increase the number of cores
- Try to reduce synchronisation
  - and let things happen in their "natural" order

Reference

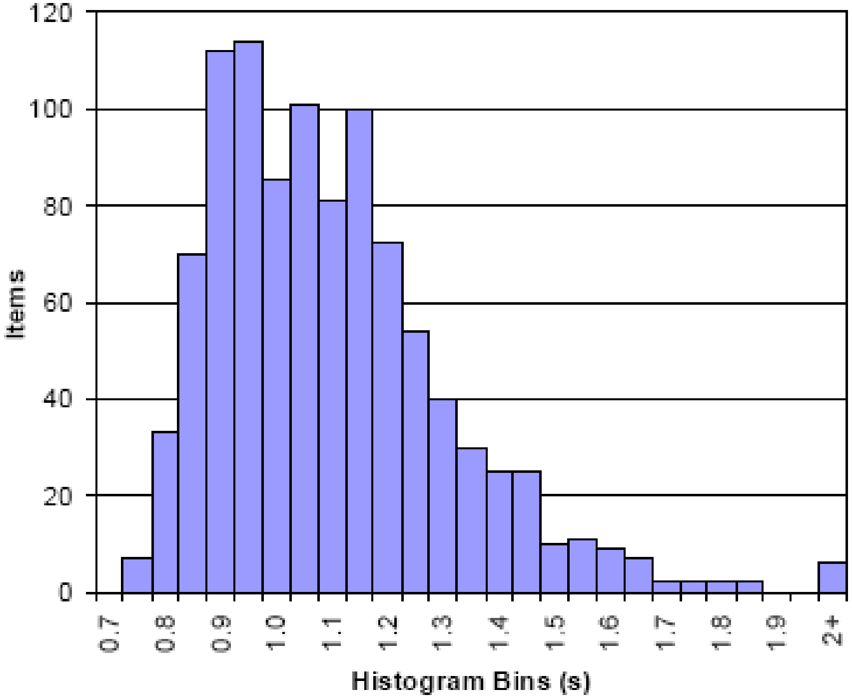
- See:
  - “The Case of the Missing Supercomputer Performance: Achieving Optimal Performance on the 8,192 Processors of ASCI Q”
  - Fabrizio Petrini, Darren J. Kerbyson, Scott Pakin
  - *http://dx.doi.org/10.1145/1048935.1050204*
  - “[W]hen you have eliminated the impossible, whatever remains, however improbable, must be the truth.”
  - Sherlock Holmes, *Sign of Four*, Sir Arthur Conan Doyle



An example

- "Although SAGE [the application] spends half of its time in allreduce (at 4,096 processors), making allreduce seven times faster leads to a negligible performance improvement."

- Collectives an extreme example
  - point-to-point is also an issue



SAGE time per iteration

Collectives

- Reduce frequency of calculation by a factor X
  - e.g. trade more calculation for fewer synchronisations

```
loop over iterations:
  update arrays;
  compute local delta;
  compute global delta
  using allreduce;
  stop if less than
  tolerance value;
end loop
```

```
loop over iterations:
  update arrays;
  every X iterations:
    local delta;
    global delta;
    can we stop?;

end loop
```

- Possible because array updates independent of global values
  - may not be true for, e.g., Conjugate Gradient ; can use different algorithms, e.g. Chebyshev iteration
  - again, more iterations but less synchronisation

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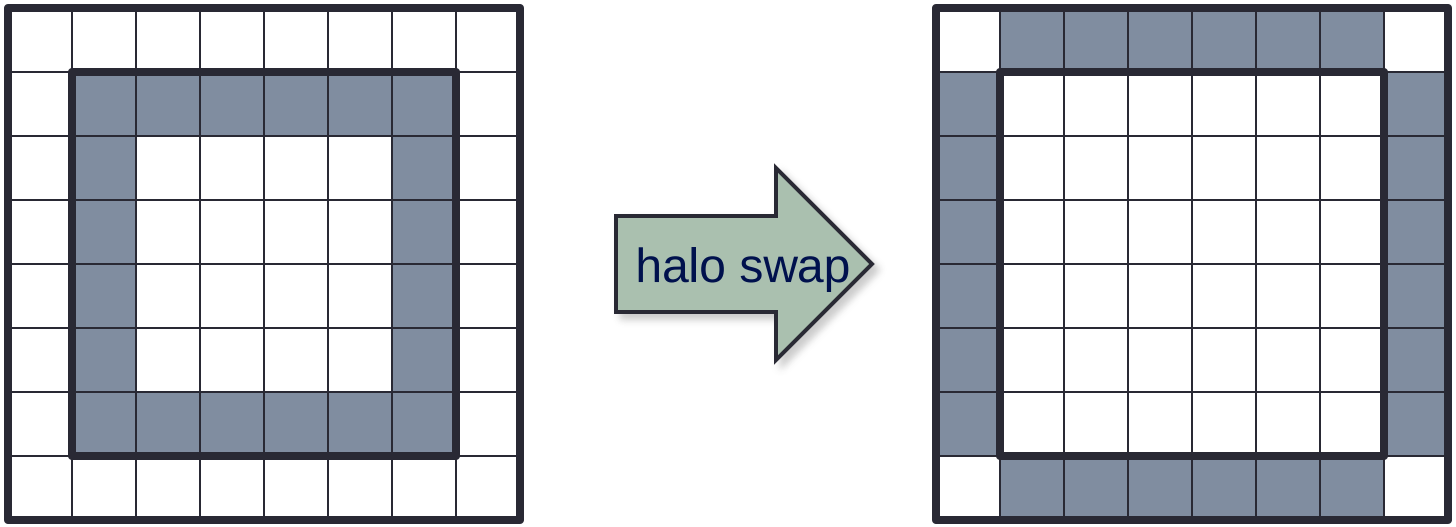
Barriers

- (Almost) never required for MPI program correctness
- Why?
  - because collectives do the appropriate synchronisation
  - because MPI_Recv is synchronous

Normal halo swapping




```
swap data into 4 halos: i=0, i=M+1, j=0, j=M+1
loop i=1:M; j=1:N;
  new(i,j) = 0.25*(    old(i-1,j) + old(i+1,j)
                     + old(i,j-1) + old(i,j+1)
                     - edge(i,j)                  )
```

Point-to-point

- Do not impose unnecessary ordering of messages

```
loop over sources:
  receive value from
  particular source;
end loop
```

```
loop over sources:
  receive value from
  any source;
end loop
```

  - loop now just counts the correct number of messages

- Alternative
  - first issue a separate non-blocking receive for each source
  - then issue a single Waitall

Halo swapping

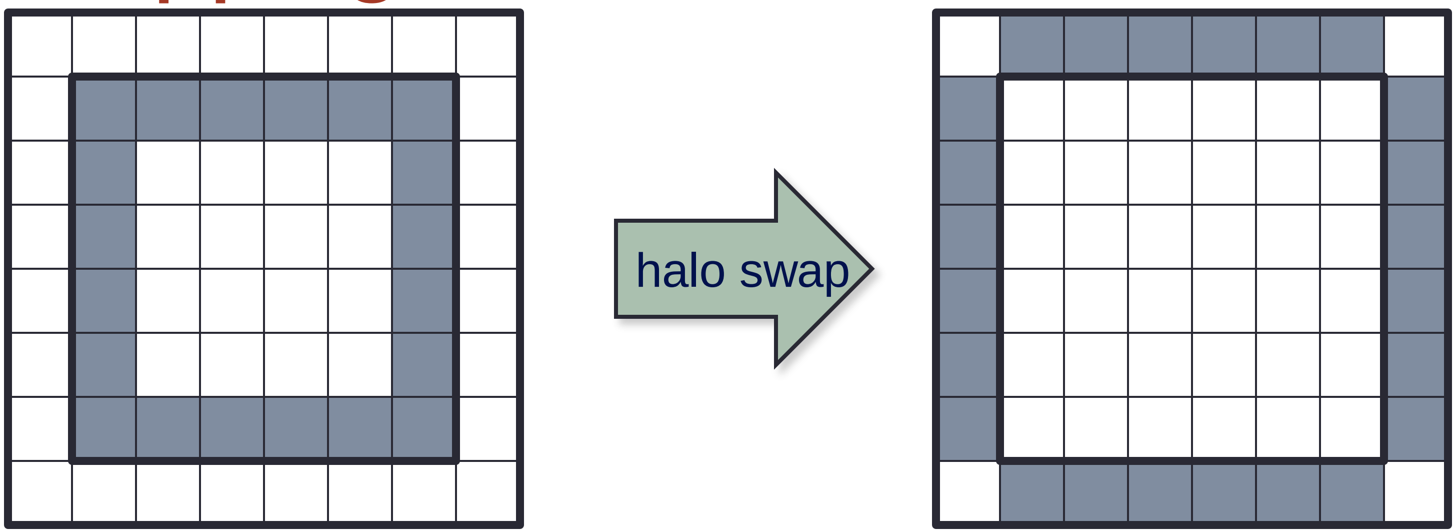
- Do not impose unnecessary ordering of messages

```
loop over directions:
  send up; recv down;
  send down; recv up;
end loop
```

```
loop over directions:
  isend up; irecv down;
  isend down; irecv up;
end loop
wait on all requests;
```

- Extensions
  - can now overlap communications with core calculation
  - only need to wait for receives before non-core calculation
  - wait for sends to complete before starting next core calculation

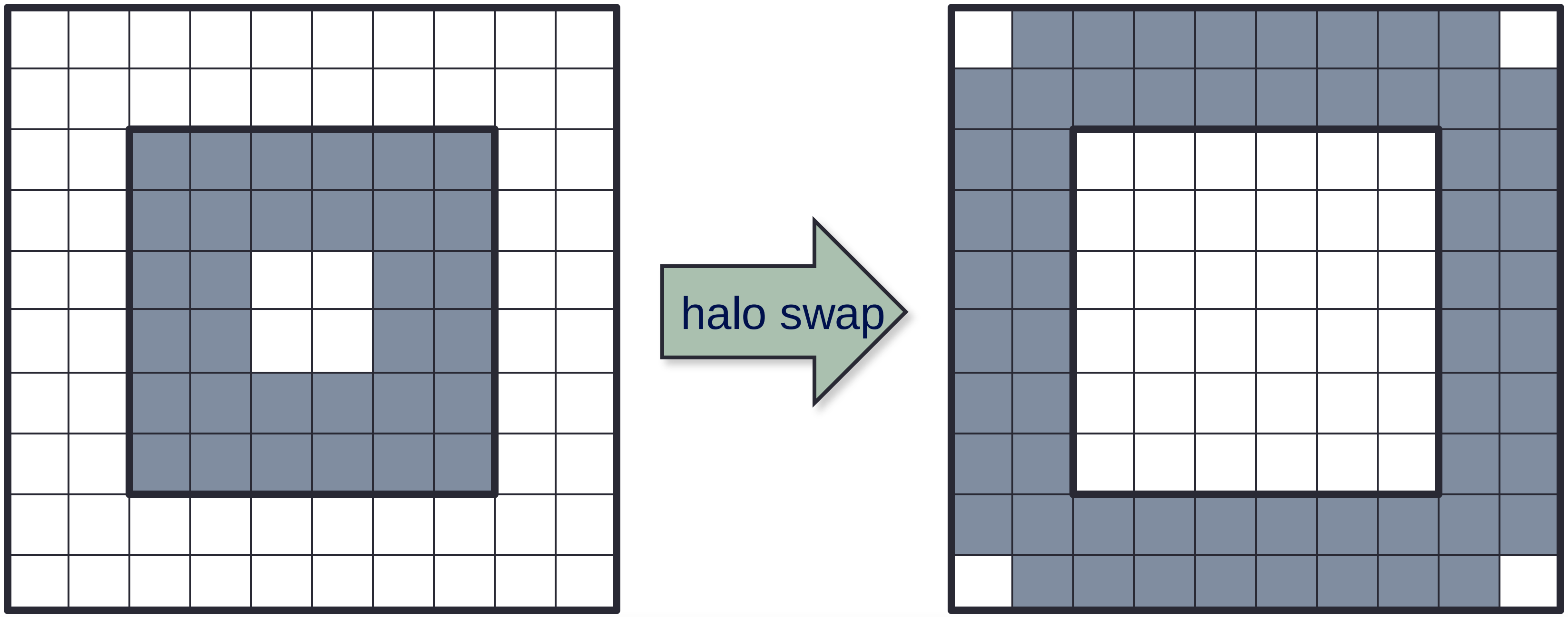
Overlapping




```
start non-blocking sends/recvs
loop i=2:M-1; j=2:N-1;
  new(i,j) = 0.25*(   old(i-1,j) + old(i+1,j)
                    + old(i,j-1) + old(i,j+1)
                    - edge(i,j)                )
wait for completion of non-blocking sends/recvs
complete calculation at the four edges
```

Halos of Depth *D* every *D* iterations

- Smaller number of larger messages; increased computation




```
loop d=D:1:-1
  loop i=2-d:M+d-1; j=2-d:N+d-1;
    new(i,j) = 0.25*(   old(i-1,j) + old(i+1,j)
                      + old(i,j-1) + old(i,j+1)
                      - edge(i,j)                  )
```

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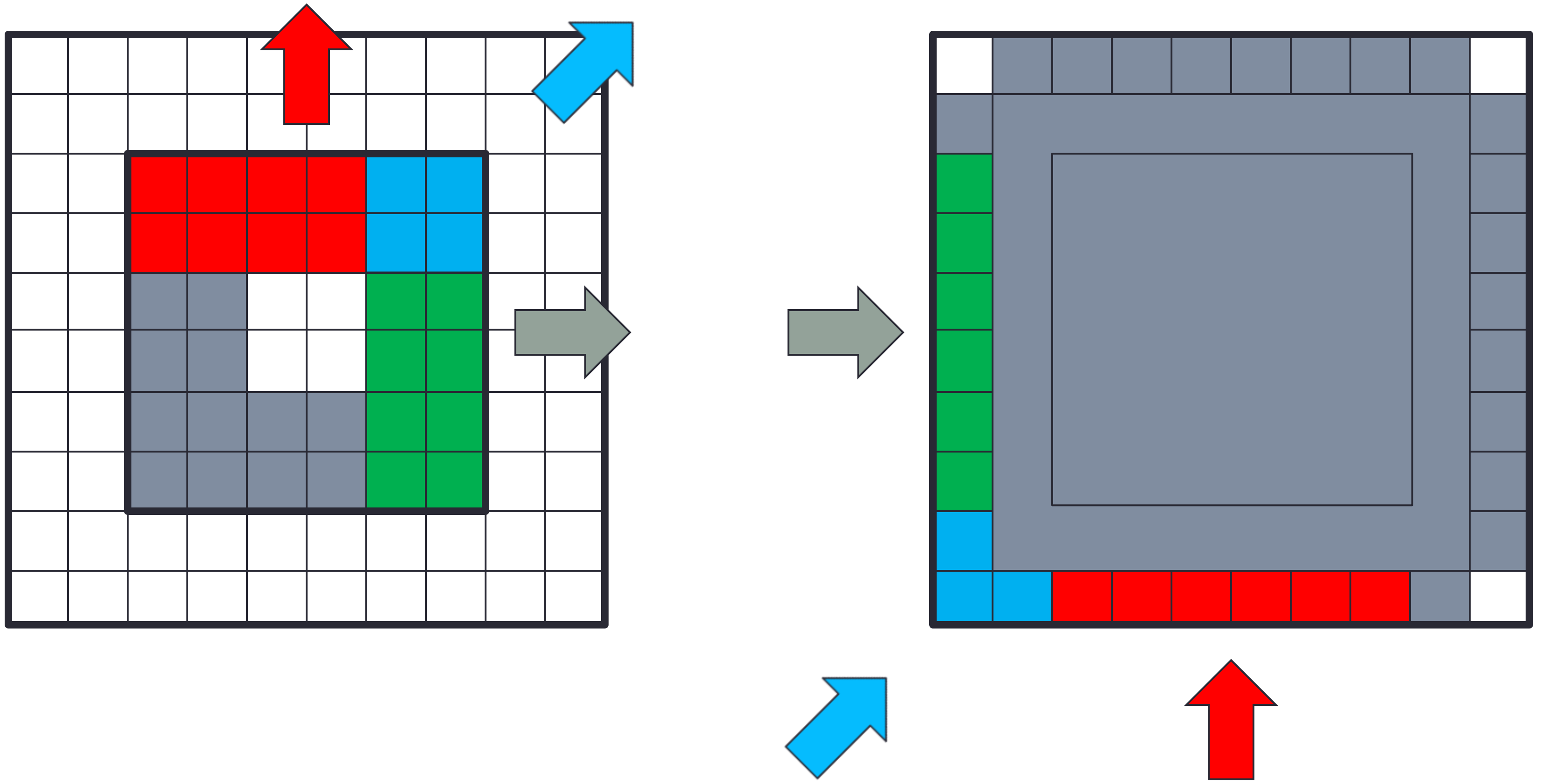
Swap depth *D* every *D* iterations



- Need diagonal communications
  - and a one-off halo swap of depth *D*-1 on the edge array

Implementation

- Do 8 non-blocking sends and 8 non-blocking receives
  - as opposed to only 4 for depth=1
  - ... or 26 vs 6 for three dimensions
  - when we wanted to send fewer messages!

- Can “carry” halos rather than explicit diagonal comms
  - ordered swaps: left/right after up/down …
  - – … but introduces more synchronisation

- Quite hard to implement in practice
  - *D*=1 is (thankfully) special case for 5-point stencil with no diagonals

Persistent communications

- Standard method: run this code every iteration

```
MPI_Irecv(..., procup, ..., &reqs[0]);
MPI_Irecv(..., procdn, ..., &reqs[1]);
MPI_Isend(..., procdn, ..., &reqs[2]);
MPI_Isend(..., procup, ..., &reqs[3]);
MPI_Waitall(4, reqs, statuses);
```

- Persistent comms: setup *once*

```
MPI_Recv_init(..., procup, ..., &reqs[0]);
MPI_Recv_init(..., procdn, ..., &reqs[1]);
MPI_Send_init(..., procdn, .... &reqs[2]);
MPI_Send_init(..., procup, ..., &reqs[3]);
```

- Every iteration:

```
MPI_Startall(4, reqs);
```

- Warning
  - message ordering *not guaranteed to be preserved*