CSCS
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Message Passing Interface (MPI)

Summer School 2017 – Effective High Performance Computing

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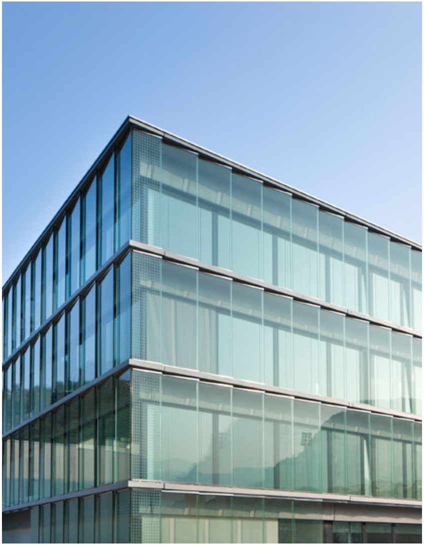
Previous course summary

- MPI, message passing paradigm
- Distributed memory (but also shared memory)
- Write a simple program, no communication

Course Objectives

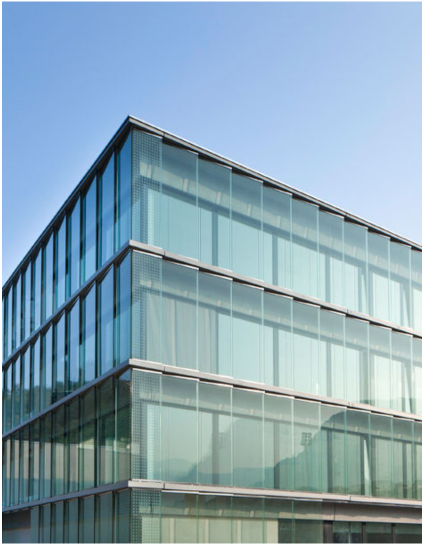
- The understanding of a point-to-point communications
- The understanding of their different flavours
- The importance of buffer availability and scope

General Course Structure



- An introduction to MPI
- Point-to-point communications
- Collective communications
- Topology
- Datatypes

General Course Structure



- An introduction to MPI
- Point-to-point communications
  - Communication
  - Message
  - Data types
  - Standard Send/Recv
  - Communication status
  - Wildcards
  - Synchronization
  - Blocking and non-blocking
  - Transfer modes
  - Summary
- Collective communications
- Topology
- Datatypes

Point-to-point communications

Point-to-Point communication

It is the fundamental communication facility provided by a MPI library.

Communication between 2 processes:

- It is conceptually simple: source process A sends a message to destination process B, B receives the message from A.
- Communication takes place within a communicator
- Source and Destination are identified by their rank in the communicator

Message

Data is exchanged in the buffer, an array of count elements of some particular MPI data type

- One argument that must be given to MPI routines is the type of the data being passed
- This allows MPI programs to run automatically in heterogeneous environments

Messages are identified by their envelopes. A message could be exchanged only if the sender and receiver specify the correct envelope.

body			envelope			
buffer	count	datatype	source	destination	communicator	tag

Message ordering

Each process has a FIFO receipt (queue), incoming messages never overtake each other.

If process A does multiple sends to process B those messages arrive in the same order.

Data types

MPI provides its own data type for send and recv buffers.

- Handle type conversion in a heterogeneous collection of machines

General rule

MPI datatype must match datatypes among pairs of send and recv

MPI defines ”handles” to allow programmers to refer to data types.

Some - MPI Intrinsic Datatypes

MPI Data type	Fortran/C Data type
MPI_INTEGER	INTEGER
MPI_REAL	REAL
MPI_DOUBLE_PRECISION	DOUBLE PRECISION
MPI_COMPLEX	COMPLEX
MPI_LOGICAL	LOGICAL
MPI_CHARACTER	CHARACTER(1)
MPI_CHAR	signed char
MPI_INT	signed int
MPI_LONG	signed long int
MPI_UNSIGNED_LONG	unsigned long int
MPI_FLOAT	float
MPI_DOUBLE	double

Basic Send/Recv

Pseudo-code

```
MPI_SEND(buf, count, type, dest, tag, comm)
MPI_RECV(buf, count, type, source, tag, comm, status)
```

buf	array of type type see table
count	number of elements to be sent
type	MPI type of buf
dest	rank of the destination process
source	rank of the source process
tag	number identifying the message
comm	communicator of the sender and receiver
status	array containing communication status

Basic Send/Recv

```
Pseudo-code
MPI_SEND(buf, count, type, dest, tag, comm)
MPI_RECV(buf, count, type, source, tag, comm, status)
```

buf **count** **type**	BODY
source/dest **tag** **comm** **status**	ENVELOPE

MPI Status and tag

`MPI_Status` structures are used by the message receiving functions to return data about a message. It is an `INTEGER` array of `MPI_STATUS_SIZE` elements in Fortran. The array contains the following info:

- `MPI_SOURCE` - id of processor sending the message
- `MPI_TAG` - the message tag
- `MPI_ERROR` - error status

There may also be other fields in the structure, but these are reserved for the implementation.

A tag is a user-defined identity for a message.

Wildcards

Both in Fortran and C, `MPI_Recv` accepts wildcards:

- To receive from any source: `MPI_ANY_SOURCE`
- To receive with any tag: `MPI_ANY_TAG`
- Actual source and tag are returned in the receiver's status parameter

Synchronization

- In a perfect world, every send operation would be perfectly synchronized with its matching receive. This is actually never the case. A send resp. a receive can be triggered before or after its corresponding receive resp. send.
- Is the receiving rank prepared to receive the data?...

Common MPI protocol

Internal to MPI not expose to the user, not defined by the standard

Pseudo-code Pseudo-code

```
if (size_to_send < CST ) {
  /* EAGER protocol:
  post a send request using a buffer
  expecting the receive to store it */
} else {
  /* RENDEZ-VOUS protocol:
  post an envelope to ask the receive to be prepared
  wait for the receive to acknowledge it
  then the receive is able to store the data
  post a send request using a buffer */
}
```

Practicals

Exercise: 02.MPI_pt2pt

1. Standard Send/Recv communication
2. Ping-pong
3. Measuring bandwidth

Blocking and non-blocking ?

Without non-blocking communications there is potential deadlocks

Process 0		Process 1
send(data,1) →	????	← **send(data,0)**
receive(data,1)		**receive(data,0)**

Also non-blocking communication are useful to overlap communication and computation

Blocking and non-blocking communications

A blocking communication means...

That the buffer can be re-used after the function is returned.

A non-blocking communication means...

That the buffer can only be re-used after a wait function is returned.
Until then, the buffer must not be overwritten (and even read).

Blocking and non-blocking do not mean...

That the communication is completed after the function as returned.

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Blocking and non-blocking do not mean...

That the communication is completed after the function as returned.

$\Rightarrow$ **It is all about buffer availability!**

Blocking and non-blocking examples

Blocking example:

Pseudo-code
```
int  buf[120];
MPI_Send(buf,5,MPI_INT,...);
// after the function returns
// the buffer can be re-used
buf[3]=5
```

Non-blocking example:

Pseudo-code
```
int  buf[120];
MPI_Isend(buf,5,MPI_INT,...);
// after the function returns
// the communication is not done
// do not overwrite buf
// buf[3]=5 illegal
MPI_Wait(...);
// here communication is done
buf[3]=5
```

The `I` in `MPI_Isend` means immediate, the function returns ”immediately” after its call.

Non-blocking MPI_Isend and MPI_Irecv

Pseudo-code

```
MPI_Isend(buf,count,type,dest,tag,comm, MPI_Request req)
MPI_Irecv(buf,count,type,source,tag,comm, MPI_Request req)
```

buf	array of type type see table
count	number of element of buf to be sent
type	MPI type of buf
dest	rank of the destination process
source	rank of the source process
tag	number identifying the message
comm	communicator of the sender and receiver
req	identifier of the communications handle

Waiting for completion

Pseudo-code
```
MPI_Wait(MPI_Request req, status)
MPI_Waitall(count, MPI_Request requests[], status[])
```

req	identifier of the communications handle
status	array containing communication status
count	number of element of in arrays

Testing for completion

Pseudo-code

```
MPI_Test(req, flag, status)
MPI_Testall(count, requests[], flag, status[])
```

req	identifier of the communications handle
flag	true if req has completed false otherwise
status	array containing communication status
count	number of element of in arrays

Transfer modes

Four different communication modes are supported for the Send:

- Standard Mode
- Synchronous Mode
- Buffered Mode
- Ready Mode

All of them can be Blocking or Non-Blocking.

Transfer modes: Standard Mode

- A send operation can be started whether or not a matching receive has started
- Can be buffered or synchronous. It is up to the implementation (and not MPI standard) to decide whether outgoing messages will be buffered
- May complete before a matching receive is posted

Transfer modes: Synchronous Mode

- A send operation can be started whether or not a matching receive has started
- The send will complete successfully only if a matching receive was posted and the receive operation has reached a certain point in its execution
- The completion of a synchronous send not only indicates that the send buffer can be reused but also indicates that the receiver has reached a certain point in its execution (usually it has received all data)

Transfer modes: Buffered Mode

- A send operation can be started whether or not a matching receive has been posted
- It completes whether or not a matching receive has been posted (independent from the receive)
- The original buffer can be read and overwritten, it has been copied to user-supplied buffer
- Buffer space is allocated on demand `MPI_Buffer_Attach`

Transfer modes: Ready Mode

- A send operation may be started only if the matching receive is already started (error otherwise)
- The completion of the send operation does not depend on the status of a matching receive and merely indicates the send buffer can be reused
- Used for performance reasons

Transfer modes overview

Mode	Completion Condition	Blocking	Non-blocking
Standard send	Message sent (receive state unknown)	`MPI_Send`	`MPI_Isend`
Receive	Completes when a matching message has arrived	`MPI_Recv`	`MPI_Irecv`
Synchronous send	Only completes after a matching recv() is posted and the receive operation is at some stages.	`MPI_Ssend`	`MPI_Issend`
Buffered send	Always completes, irrespective of receiver. Guarantees the message to be buffered.	`MPI_Bsend`	`MPI_Ibsend`
Ready send	Always completes, irrespective of whether the receive has completed.	`MPI_Rsend`	`MPI_Irsend`

Communication - summary

Blocking send and recv

- Does not mean that the process is stopped during communication.
- It means that, at return, it is safe to use the variables involved in communication.

Non Blocking send and recv

- Cannot use variables involved in communication until ”wait” completion functions are called.

Transfer modes

- Define the behaviour of the various function for point to point communication. The behaviour can be implementation dependent.

Combined Send and Recv in one function

The send-receive operations combine in one call the sending of a message to one destination and the receiving of another message, from another process. The source and destination are possibly the same. A send-receive operation is very useful for executing a shift operation across a chain of processes. Will block until the sending application buffer is free for reuse and until the receiving application buffer contains the received message.

Pseudo-code
```
MPI_Sendrecv(sndbuf, snd_size, snd_type, rcvid, tag,
             rcvbuf, rcv_size, rcv_type, sndid, tag,
             comm, status)
```

Other functions

- Check for incoming message without actually receiving it:

  `MPI_Probe, MPI_Iprobe`

- Buffer management:

  `MPI_Buffer_attach, MPI_Buffer_detach`

- Wait functions:

  `MPI_Waitany, MPI_Waitsome`

- Test functions:

  `MPI_Testany, MPI_Testsome`

- Cancel a request:

  `MPI_Cancel`

Practicals

Exercise: 02.MPI_pt2pt

4. Parallel sum using a ring:

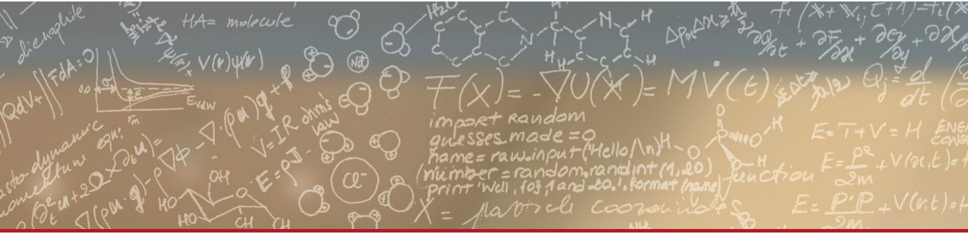
   without using `if (rank == 0)... else ...`

	Rank 0	Rank 1	Rank 2
Send	0	1	2
Recv	2	0	1
Send	2	0	1
Recv	1	2	0
Send	1	2	0
Recv	0	1	2

   All ranks obtain the sum.

5. Send and Recv neighbor ghost cells:

   Top to bottom for C and right to left for Fortran



Thank you for your attention.