Point-to-Point Communication with MPI

Part I: Blocking Communication

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Outline

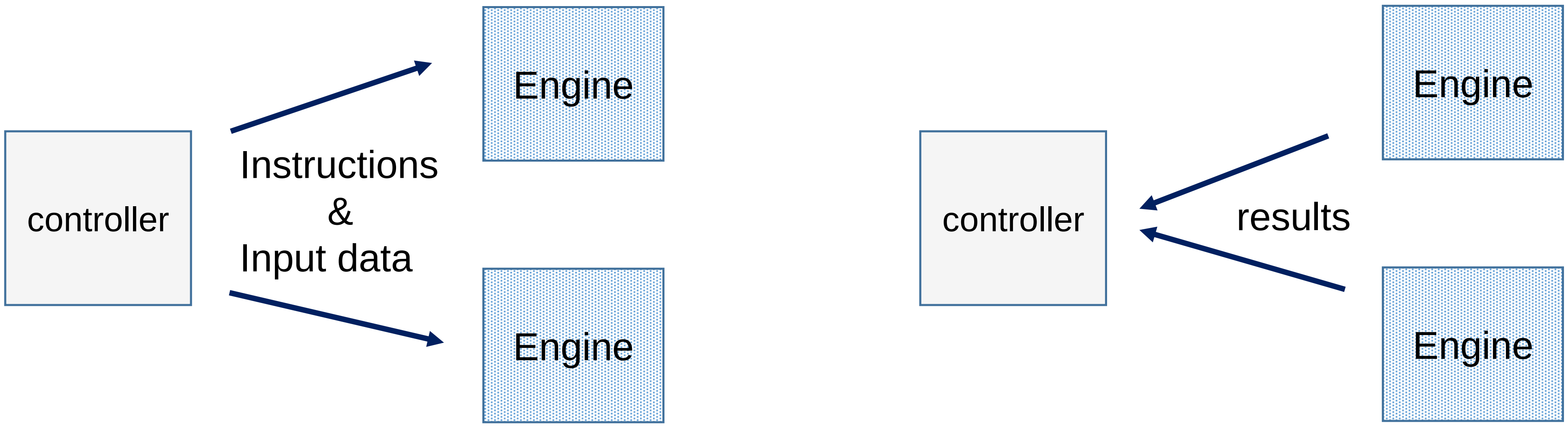
- The message-passing paradigm
- Blocking communication
- Send/Receive Syntax
- Sample program
- Deadlock
- Exercises

Useful MPI References

- General MPI (C++/Fortran):
  https://www.mpich.org/documentation/guides/
- Mpi4py (Python):
  http://mpi4py.scipy.org/docs/usrman/index.html
- pdbMPI (R):
  https://cran.r-project.org/web/packages/pbdMPI/index.html

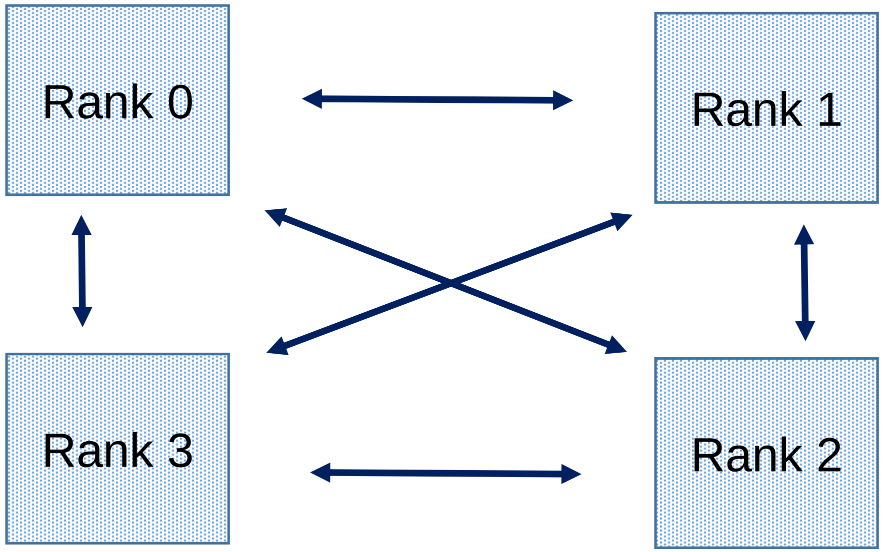
Engine/Controller Paradigm

- Similar to what you've seen so far
- Master process controls workflow
- Well-suited to collective operations



Message-Passing Paradigm

- No one is really in control.
- Everyone can communicate with each other
- **Nearly Entire code** runs on each process
- Processes referred to as MPI ranks



Message passing

- Most natural and efficient paradigm for distributed-memory systems

- Two-sided, send and receive communication between processes

- Efficiently portable to shared-memory or almost any other parallel architecture:

  "assembly language of parallel computing" due to universality and detailed, low-level control of parallelism

More on message passing

- Provides natural synchronization among processes (through blocking receives, for example), so explicit synchronization of memory access is unnecessary

- Sometimes deemed tedious and low-level, but thinking about locality promotes
  - good performance,
  - scalability,
  - Portability

- Dominant paradigm for developing portable and scalable applications for massively parallel systems

Sending and Receiving: Questions

- Which process is sending the message?
- Where is the data on the sending process?
- What kind of data is being sent?
- How much data is there?
- Which process is going to receive the message?
- Where should the data be stored on the receiving process?
- What amount of data is the receiving process prepared to accept?
- Failing to specify these consistently between sender and receiver leads to problems!

Blocking Send (General Syntax)

- call MPI_SEND(

message,	e.g., my_partial_sum,
count,	number of values in messaeg
data_type,	e.g, MPI_DOUBLE_PRECISION,
destination,	e.g., myid + 1
tag,	some info about msg, e.g., store it
communicator,	e.g., MPI_COMM_WORLD,
ierr	error tag (return value)

)

All arguments are inputs (except ierr).

Fortran MPI Data Types

MPI_CHARACTER
MPI_COMPLEX, MPI_COMPLEX8, also 16 and 32
MPI_DOUBLE_COMPLEX
MPI_DOUBLE_PRECISION
MPI_INTEGER
MPI_INTEGER1, MPI_INTEGER2, also 4 and 8
MPI_LOGICAL
MPI_LOGICAL1, MPI_LOGICAL2, also 4 and 8
MPI_REAL
MPI_REAL4, MPI_REAL8, MPI_REAL16

Numbers = numbers of bytes
Somewhat different in C/C++ (next slide)

C MPI Datatypes

MPI_CHAR	8-bit character
MPI_DOUBLE	64-bit floating point
MPI_FLOAT	32-bit floating point
MPI_INT	32-bit integer
MPI_LONG	32-bit integer
MPI_LONG_DOUBLE	64-bit floating point
MPI_LONG_LONG	64-bit integer
MPI_LONG_LONG_INT	64-bit integer
MPI_SHORT	16-bit integer
MPI_SIGNED_CHAR	8-bit signed character
MPI_UNSIGNED	32-bit unsigned integer
MPI_UNSIGNED_CHAR	8-bit unsigned character
MPI_UNSIGNED_LONG	32-bit unsigned integer
MPI_UNSIGNED_LONG_LONG	64-bit unsigned integer
MPI_UNSIGNED_SHORT	16-bit unsigned integer
MPI_WCHAR	Wide (16-bit) unsigned character

Python and R Data Types

- Abstracted away from user (less tedium!)

- Auto-detected when calling Send/Receive

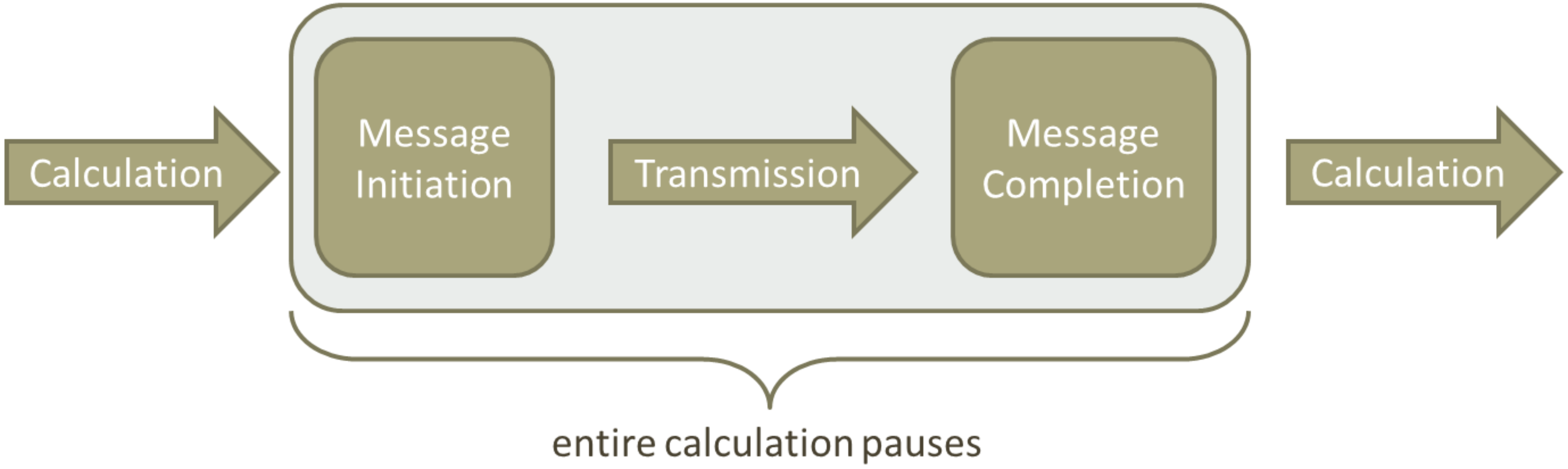
- In Python, best to work with Numpy Arrays (‘int32’, ‘float32’, ‘float64’, ‘i’, ‘d’, etc.)

Blocking?

- MPI_send
  - Does not return until the message data and envelope have been buffered in matching receive buffer or temporary system buffer.
  - Can complete as soon as the message was buffered, even if no matching receive has been executed by the receiver.
  - MPI buffers or not, depending on availability of space
  - **Take-Away 1:** small message sends *may not block…*
  - **Take-Away 2:** successful completion of the send operation *may* depend on the occurrence of a matching receive.

Blocking Communication: Program Flow

- Programs written using blocking sends & receives possess portions similar to schematic below:



Blocking receive

- Process must wait until message is received to return from call.

- Unlike Send, Recv *always* blocks.

- Stalls progress of program BUT
  - blocking sends and receives enforce process synchronization
  - so enforce consistency of data

Blocking Receive (General Syntax)

- call MPI_RECV(

message,	e.g., my_partial_sum,
count,	number of values in msg
data_type,	e.g, MPI_DOUBLE_PRECISION,
source,	e.g., myid - 1
tag,	some info about msg, e.g., store it
communicator,	e.g., MPI_COMM_WORLD,
status,	info on size of message received
ierr	

)

The arguments

- outputs: message, status

- count*size of data_type determines size of receive buffer:
  -- too large message received gives error,
  -- too small message is ok (maybe…won't crash)

- status must be decoded if needed
  - MPI_Get_Count(status, datatype, ierror)
  - status(MPI_SOURCE) status.MPI_SOURCE
  - status(MPI_TAG) status.MPI_TAG
  - status(MPI_ERROR) status.MPI_ERROR

Wildcards

- MPI_ANY_SOURCE
- MPI_ANY_TAG

- Send must send to specific receiver
- Receive can receive from arbitrary sender

Example Program

- Simple example of point-to-point communication:

  …/Point_to_Point/mpi_messages.{f90,cpp,py,R}

- Let's examine the source code

- Building the Code (C++/Fortran):
  - module load intel/psxe-2018u1
  - mpi{f90,cc} mpi_messages.{f90,cpp} –o mpi_messages.out

Python Considerations

In Python, there are two types of Send/Recv calls:

- Send/Recv (capital S and R):
  - Appropriate for Numpy arrays
- send/recv (lower-case s and r)
  - Can be used for any Python object (but is slow)

Running the Program

- For Fortran/C++:
  - srun --mpi=pmi2 –n 2 ./mpi_messages.out
- For Python:
  - srun --mpi=pmi2 –n 2 python mpi_messages.py
- For R:
  - srun --mpi=pmi2 -n 2 Rscript mpi_messages.R

- Uncomment the appropriate lines in job.sh and submit the code: sbatch job.sh

Deadlock

Good Code

```
If (my_rank == 0):
        send( to rank N)
        receive( from rank N)
If (my_rank == N):
        receive( from rank 0)
        send( to rank 0)
```

Bad Code

Communication hangs

```
If (my_rank == 0):
        send( to rank N)
        receive( from rank N-1)
If (my_rank == N):
        send( to rank 0)
        receive( from rank 0)
```

Common source of error and frustration
Many possible sources…

Deadlock

Quick Exercise:
Induce a deadlock in mpi_message by swapping the order of one send/receive pair.

```
If (my_rank == 0):
        send( to rank N)
        receive( from rank N)
If (my_rank == N):
        receive( from rank 0)
        send( to rank 0)
```

```
If (my_rank == 0):
        send( to rank N)
        receive( from rank N-1)
If (my_rank == N):
        send( to rank 0)
        receive( from rank 0)
```

Next Up: Hands-on Exercises

- Exercises 1-3: Clearing deadlocks
- Exercise 5: Write your own parallel routine