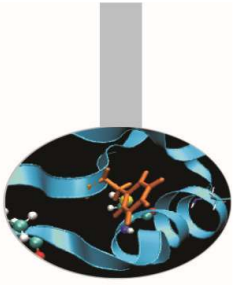
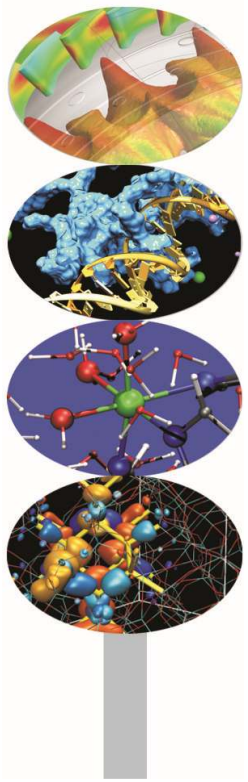
CINECA SCAI
SuperComputing Applications and Innovation



MPI introduction
- *exercises* -



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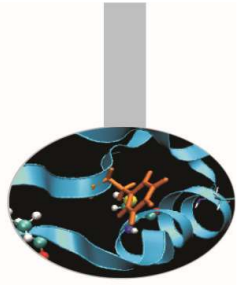
CINECA

Startup notes



To access the server:

```
ssh a08trb??@login.galileo.cineca.it
```

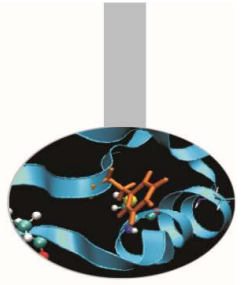
To reserve space on the server:

```
qsub -I -A train_cmpD2017 -l select=1:ncpus=4:mpiprocs=4 \
       -l walltime=3:00:00
```

To configure the MPI environment:

```
module load autoload openmpi
```

Compiling notes



To compile programs that make use of MPI library:

```
mpif90/mpicc/mpiCC -o <executable> <file 1> <file 2> … <file n>
```

Where: `<file n>` - program source files

`<executable>` - executable file

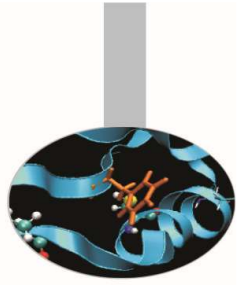
To start parallel execution on one node only:

```
mpirun -np <processor_number> <executable> <exe_params>
```

To start parallel execution on many nodes:

```
mpirun -np <processor_number> -machinefile <node_list_file> \
       <executable> <exe_params>
```

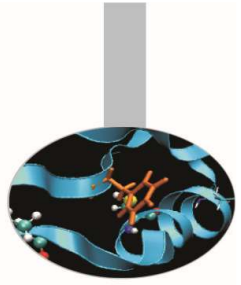
Startup notes



To run a course exercise:

```
#!/bin/bash
#PBS -N myname
#PBS -o job.out
#PBS -e job.err
#PBS -l walltime=00:30:00
#PBS -l select=1:ncpus=4:mpiprocs=4:mem=7GB
#PBS -A train_cmpD2017
#PBS -q R2475696
#PBS -W group_list=train_cmpD2017
#
module load autoload intelmpi  # or openmpi
mpirun <executable>
exit
```

Hello world! (Fortran)

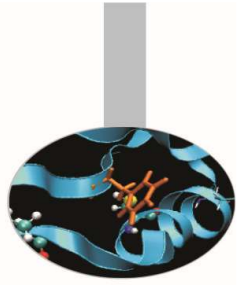


As an ice breaking activity try to compile and run the *Hello* program, either in C or in Fortran.

The most important lines in Fortran code are emphasized:

```
PROGRAM HelloWorld
    INCLUDE 'mpif.h'
    INTEGER my_rank, p
    INTEGER source, dest, tag
    INTEGER ierr, status(MPI_STATUS_SIZE)

    CALL MPI_Init(ierr)
    CALL MPI_Comm_rank(MPI_COMM_WORLD, my_rank, ierr)
    CALL MPI_Comm_size(MPI_COMM_WORLD, p, ierr)

    WRITE(*,FMT="(A,I4)") "Hello world from process ", my_rank

    CALL MPI_Finalize(ierr)
END PROGRAM HelloWorld
```

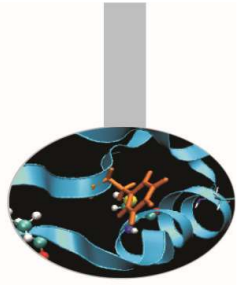
Hello world! (C/C++)



The most important lines in C code are emphasized:

```
#include "mpi.h"

int main( int argc, char *argv[])
{
    int my_rank, numprocs;
    int dest, tag, source;
    MPI_Status status;

    MPI_Init(&argc,&argv);
    MPI_Comm_rank(MPI_COMM_WORLD,&my_rank);
    MPI_Comm_size(MPI_COMM_WORLD,&numprocs);

    printf("Hello world from process %d\n",my_rank);

    MPI_Finalize();
    return 0;
}
```

Hello world! (output)



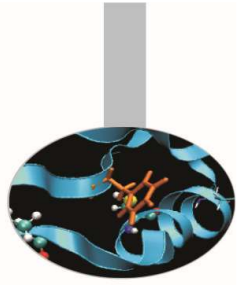
If the program is executed with one process the output is:

```
Hello world from process 0
```

If the program is executed with four processes the output is:

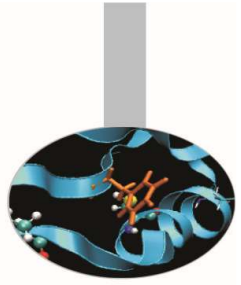
```
Hello world from process 0
Hello world from process 1
Hello world from process 2
Hello world from process 3
```

Send array



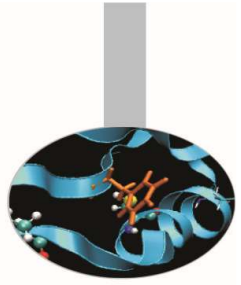
Use point to point communication so that processes send an array of floats containing their rank to the next process. Each process will declare two float arrays, A and B, of a fixed dimension (10000). All of the elements of the array A will be initialized with the rank of the process. Then, A and B will be used as the buffers for SEND and RECEIVE, respectively. The program terminates with each process printing out one element of the array B.

Send array (Fortran)



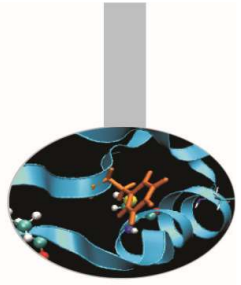
```
PROGRAM SENDARRAY
  USE MPI
  IMPLICIT NONE
  INTEGER IERR, ME, NPROCS, ERRCODE, SNDTO, RCVFROM
  INTEGER STATUS(MPI_STATUS_SIZE)
  INTEGER,PARAMETER :: NDATA = 10000
  REAL              :: A(NDATA)
  REAL              :: B(NDATA)

  CALL MPI_INIT(IERR)
  CALL MPI_COMM_SIZE(MPI_COMM_WORLD, NPROCS, IERR)
  CALL MPI_COMM_RANK(MPI_COMM_WORLD, ME, IERR)

  !$ INITIALIZE DATA
  A = ME

. . .
```

Send array (Fortran)



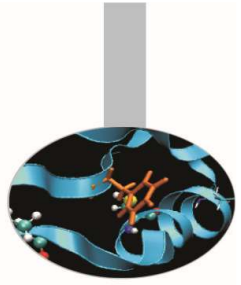
```
. . .
!$ SEND AND RECEIVE DATA
! SNDTO = ??
! RCVFROM = ??
! SENDING/RECEIVING CALLS?

  PRINT *,'I AM PROC ',ME,' AND I HAVE RECEIVED B(1) = ',B(1)
!$ FINALIZE MPI
! FINALIZE CALLS?

END PROGRAM SENDARRAY
```

Send array (C)



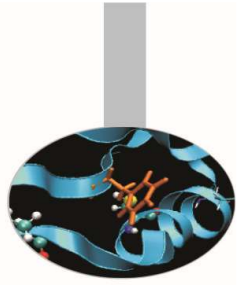
```
#include <stdlib.h>
#include <stdio.h>
#include <mpi.h>
#define NDATA 10000
int main(int argc, char* argv[]){
    int me, nprocs, i = 0, sndto, rcvfrom;
    MPI_Status status;
    float a[NDATA];
    float b[NDATA];
    MPI_Init(&argc, &argv);
    MPI_Comm_size(MPI_COMM_WORLD, &nprocs);
    MPI_Comm_rank(MPI_COMM_WORLD, &me);
. . .
```

Send array (C)



```
. . .
    /* Initialize data */
    for(i=0;i<NDATA;++i)   a[i] = me;
    /* Send and Receive data */
    // sndto = ??; rcvfrom = ??
    // Sending/receiving calls

    printf("\tI am task %d and I have received
b(0) = %1.2f \n", me, b[0]);

// Finalizing calls
    return 0;
}
```

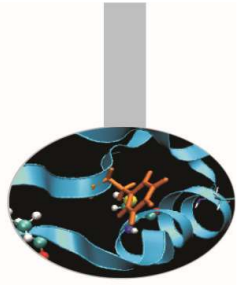
Sendrecv array



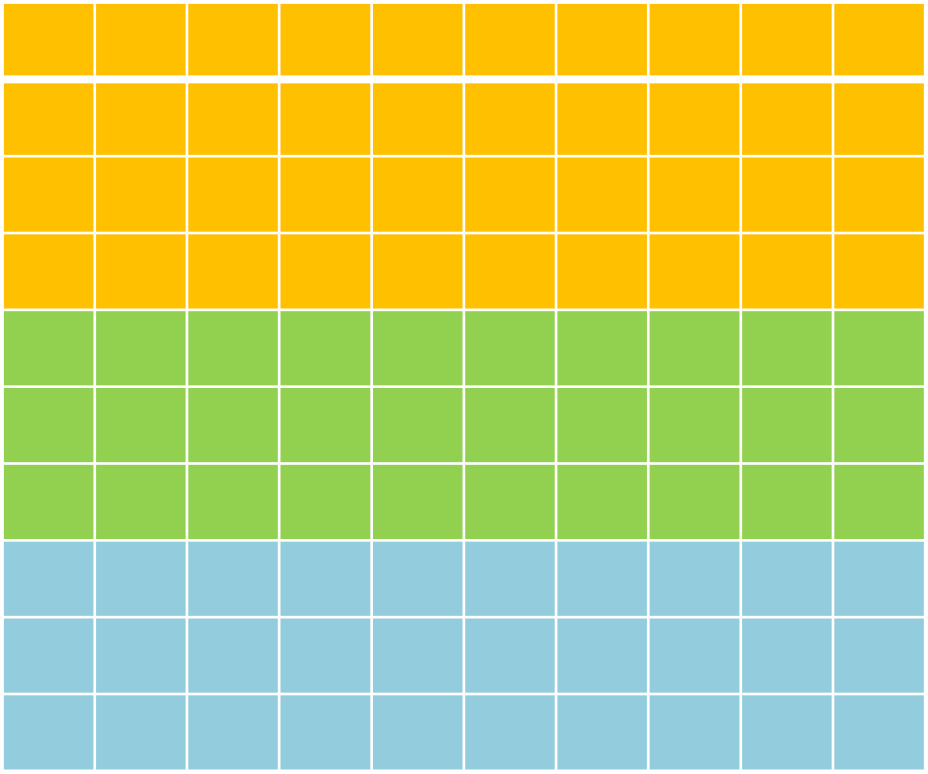
The solution of the last exercise could be simplified by using MPI_Sendrecv function:

```
int MPI_Sendrecv(
        void *sendbuf, int sendcount, MPI_Datatype sendtype,
                int dest, int sendtag,
        void *recvbuf, int recvcount, MPI_Datatype recvtype,
                int source, int recvtag,
        MPI_Comm comm, MPI_Status *status)
```

Ghost cells



Distribute a global square NxN matrix over P processors, so that each task has a local portion of it in its memory. Initialize such portion with the task's rank.

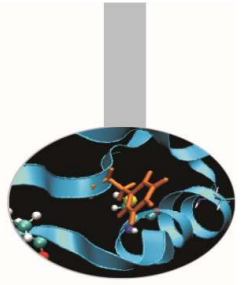


proc 0

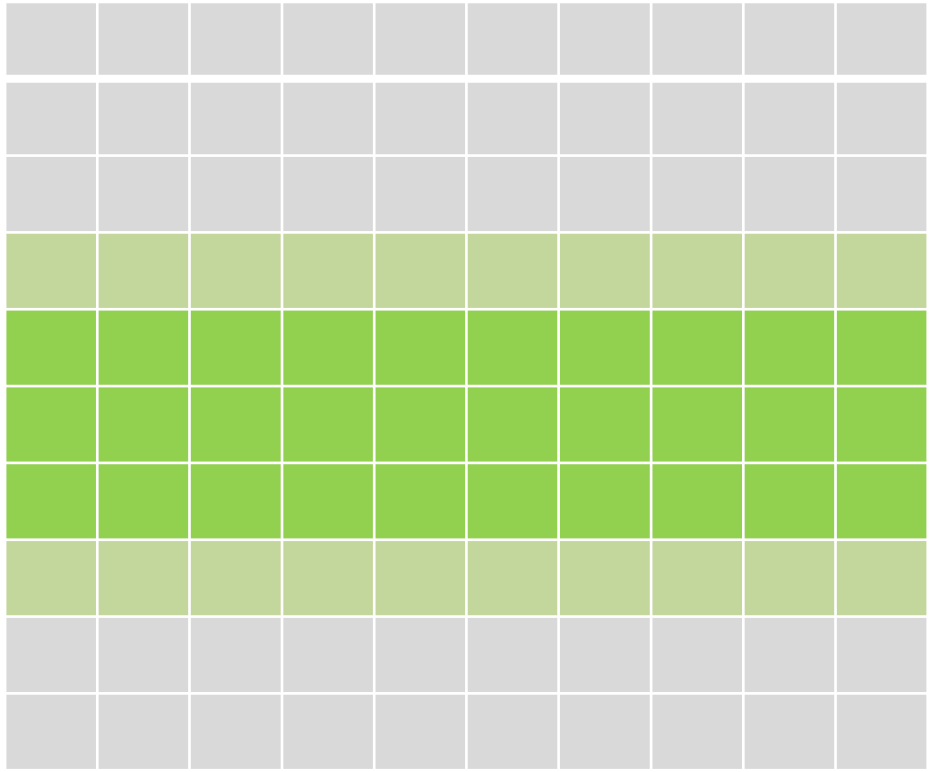
proc 1

proc2

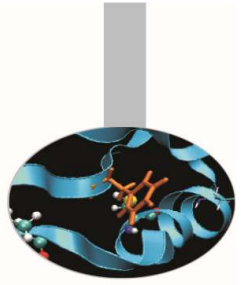
Ghost cells



Each task sends its first and last columns (if Fortran) or rows (if C) to its neighbors (i.e.: the first column/row to the left processor, the last column/row to the right processor). Note that each task has to actually allocate a larger portion of its submatrix (ghost cells), with two extra columns/rows at the extremities to hold the received values.

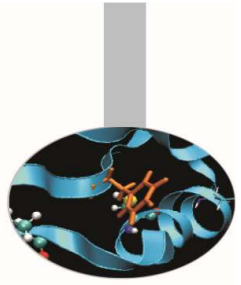


Ghost cells (Fortran)



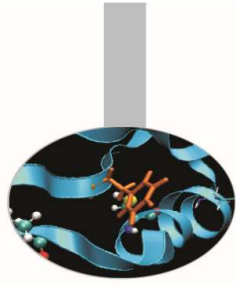
```
program ghost_cells
   use mpi
   implicit none
   integer, parameter :: N=20
         .        .        .
!!       Inizialize MPI

   !  number of columns for each mpi task
!!       Compute local columns (take care of remainder if any)
!!       Allocate and initialize local matrix
```

Ghost cells (Fortran)



```
!!        Compute id of neighbors (proc_right, proc_left)

!!         send receive of the ghost regions
  deallocate(matrix)

!!        Finalize

 end program
```

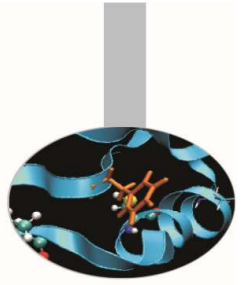
Ghost cells (C)



. . .

```
#define N 20
int main(int argc, char* argv[]){

//        Initialize MPI
   /*  number of rows for each mpi task */
//        Compute local rows (take care of remainder if any)
//        Allocate and initialize local matrix
```

Ghost cells (C)



```
//        Compute id of neighbors (proc_up, proc_down)

//         send receive of the ghost regions


   free(matrix);
//        Finalize
   return 0;
}
```