CSCS
Centro Svizzero di Calcolo Scientifico
Swiss National Supercomputing Centre

ETH zürich

Message Passing Interface (MPI)

Summer School 2015 - Effective High Performance Computing

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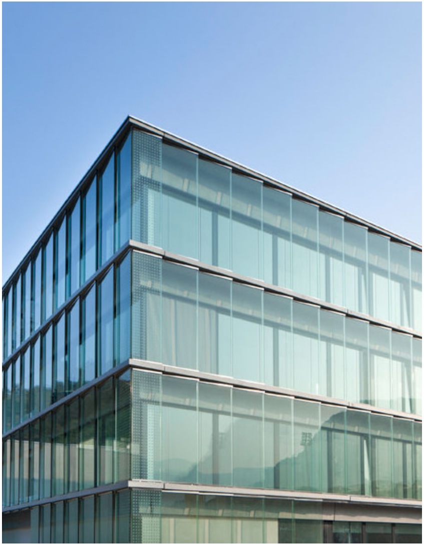
Previous course summary

- Point-to-point communication, blocking and non-blocking
- Collective operations
- Communicators and groups
- Cartesian and Graph topology

Course Objectives

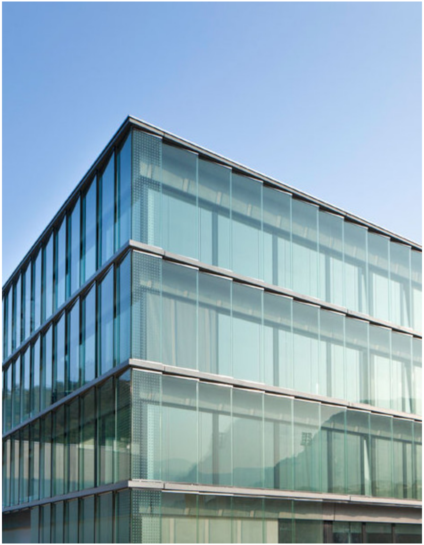
- Construct and use MPI derived datatypes

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
- Collective communications
- Topology
- Datatypes
  - Construct datatype
  - Contiguous datatype
  - Indexed datatype
  - Struct datatype
  - Sub-array datatype

MPI derived datatypes

Using MPI derived datatypes

MPI derived datatypes (differently from C or Fortran) are created (and destroyed) at run-time through calls to MPI library routines.

Implementation steps:

1. Construct the datatype;
2. Allocate the datatype;
3. Use the datatype;
4. Deallocate the datatype.

Construct a datatype

- `MPI_Type_contiguous`
  Produces a new datatype by making count copies of an existing data type.
- `MPI_Type_vector, MPI_Type_hvector`
  Similar to contiguous, but allows for regular gaps (stride) in the displacements. `MPI_Type_hvector` is identical to `MPI_Type_vector` except that stride is specified in bytes.
- `MPI_Type_indexed, MPI_Type_hindexed`
  An array of displacements of the input data type is provided as the map for the new data type. `MPI_Type_hindexed` is identical to `MPI_Type_indexed` except that offsets are specified in bytes.
- `MPI_Type_struct`
  The most general of all derived datatypes. The new data type is formed according to completely defined map of the component data types.

Allocate and destroy the Datatype

A constructed datatype must be committed to the system before it can be used in a communication.

C/C++

```
int MPI_Type_commit(MPI_datatype *datatype)
int MPI_Type_free(MPI_datatype *datatype)
```

Fortran

```
MPI_TYPE_COMMIT(DATATYPE, IERR)
MPI_TYPE_FREE(DATATYPE, IERR)
```

Contiguous Datatype

`MPI_TYPE_CONTIGOUS` constructs a typemap consisting of the replication of a datatype into contiguous locations.

Fortran
```
MPI_TYPE_CONTIGUOUS(count, oldtype, newtype, ierr)
```

count	number of BLOCKs to be added
oldtype	oldtype Datatype of each element
newtype	new derived datatype

REMEMBER: BLOCK = contiguous elements of the same type.

Contiguous Datatype: example

array $a[][]=$

0.0	0.1	0.2	0.3
0.4	0.5	0.6	0.7
0.8	0.9	0.10	0.11
0.12	0.13	0.14	0.15

Create a new type of 4 floats representing a row in *a*.

```
MPI_Type_contiguous(4, MPI_FLOAT, &MyRowType)
```

Use the new type to send one row:

```
MPI_Send(&a[2][0], 1, MyRowType, dest, tag, comm)
```

Data sent is:

0.8	0.9	0.10	0.11

Contiguous Datatype with stride

`MPI_TYPE_CONTIGOUS` constructs a typemap consisting of the replication of a datatype into contiguous locations.

Fortran
```
MPI_TYPE_VECTOR(count, blocklength, stride, oldtype, newtype
    , ierr)
```

count	number of BLOCKs to be added
blocklength	Number of elements in block
stride	Number of elements (NOT bytes) between start of each block
oldtype	oldtype Datatype of each element
newtype	new derived datatype

The Vector constructor is similar to contiguous, but allows for regular gaps or overlaps (stride) in the displacements.

Contiguous Datatype with stride: example

array $a[][]$=

0.0	0.1	0.2	0.3
0.4	0.5	0.6	0.7
0.8	0.9	0.10	0.11
0.12	0.13	0.14	0.15

Create a new type of 4 floats representing a col in *a*.

C/C++
```
count = 4; blocklength=1; stride = 4;
MPI_Type_contiguous(count, blocklength, stride, MPI_FLOAT, &
    MyColType)
```

Use the new type to send one row:

C/C++
```
MPI_Send(&a[0][2], 1, MyColType, dest, tag, comm)
```

Data sent is:

0.2	0.6	0.10	0.14

Indexed Datatype

`MPI_TYPE_INDEXED` constructs a typemap consisting of the replication of a datatype from locations defined by an array of block lengths and an array of displacements.

C/C++
```
MPI_TYPE_INDEXED(count, array_blocklengths,
    array_displacements, oldtype, newtype, ierr)
```

count	number of BLOCKs to be added and number of elements in the following arrays
array_blocklengths	number of instances of oldtype in each block
array_displacements	displacement of each block in units of extent (oldtype)
oldtype	oldtype Datatype of each element
newtype	new derived datatype

Indexed Datatype: example

count = 3;

oldtype = `MPI_INT`

array_blocklengths=

2	3	1

array_displacements=

0	3	9

Selected blocks are:

0	1	2	3	4	5	6	7	8	9	10

Struct Datatype

`MPI_TYPE_STRUCT` constructs a typemap consisting of different datatype from locations defined by an array of block lengths and an array of displacements. Displacements are expressed in bytes (since the type can change!!!).

C/C++

```
MPI_TYPE_STRUCT(count, array_blocklengths,
    array_displacements,
                array_oldtype, newtype, ierr)
```

count	number of BLOCKs to be added and number of elements in the following arrays
array_blocklengths	number of instances of oldtype in each block
array_displacements	displacement in BYTES of each block
array_oldtype	oldtype Datatype of each element
newtype	new derived datatype

Struct Datatype: example

count = 3;

oldtype = `MPI_INT`

array_blocklengths=

2	2	1

array_displacements (in bytes)=

0	12	36

array_oldtypes=

`MPI_INT`	`MPI_DOUBLE`	`MPI_FLOAT`

A block is 4 Bytes long.

Selected blocks are:

0	1	2	3	4	5	6	7	8	9	10

Sub-array Datatype

The subarray type constructor creates an MPI datatype describing an n-dimensional subarray of an n-dimensional array. The subarray may be placed anywhere within the full array.

C/C++

```
MPI_TYPE_CREATE_SUBARRAY(ndims, array_sizes, array_subsizes,
    array_starts, order, oldtype, newtype)
```

ndims	number of array dimensions
array_sizes	number of elements of type oldtype in each dimension of the full array
array_subsizes	number of elements of type oldtype in each dimension of the subarray
order	array storage order flag
array_starts	starting coordinates of the subarray in each dimension
oldtype	oldtype Datatype of each element
newtype	new derived datatype

Sub-array Datatype: example

A 100x100 2D array of double precision floating point numbers distributed among 4 processes such that each process has a block of 25 columns.

C/C++

```c
double subarray[100][25];
MPI_Datatype filetype;
int sizes[2], subsizes[2], starts[2];
int rank;

MPI_Comm_rank(MPI_COMM_WORLD, &rank);

sizes[0]=100; sizes[1]=100;
subsizes[0]=100; subsizes[1]=25;
starts[0]=0; starts[1]=rank*25;

MPI_Type_create_subarray(2, sizes, subsizes, starts,
    MPI_ORDER_C, MPI_DOUBLE, &filetype);
```

Other functions

- Manage types:

  `MPI_Comm_extent, MPI_Type_dup` ...
- Getter for types:

  `MPI_Type_size, MPI_Type_get_contents` ...

Practicals

Exercise: 05.MPI_Type

1. Create a derived datatype based on a struct

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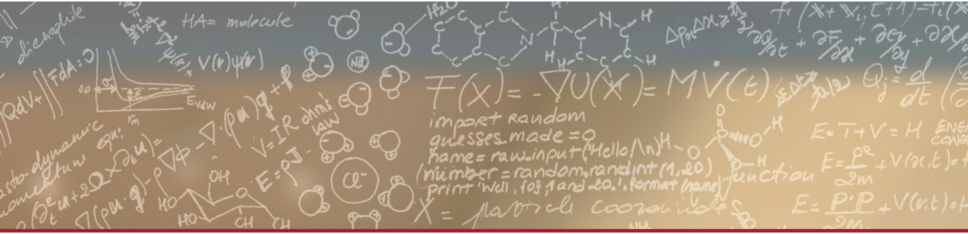

Thank you for your attention.