MPI - Derived Data Structures

Based on notes from
Science & Technology Support
High Performance Computing

Ohio Supercomputer Center

Derived Datatypes

- MPI Datatypes
- Procedure
- Datatype Construction
- Contiguous Datatype*
- Vector Datatype*
- Extent of a Datatype
- Structure Datatype*
- Committing a Datatype

*includes sample C and Fortran programs

MPI Datatypes

- Basic types
- Derived types
  - Constructed from existing types (basic and derived)
  - Used in MPI communication routines to transfer high-level, extensive data entities
- Examples:
  - Sub-arrays or “unnatural” array memory striding
  - C structures and Fortran common blocks
  - Large set of general variables
- Alternative to repeated sends of varied basic types
  - Slow, clumsy, and error prone

Procedure

- *Construct* the new datatype using appropriate MPI routines

  `MPI_Type_contiguous, MPI_Type_vector, MPI_Type_struct, MPI_Type_indexed, MPI_Type_hvector, MPI_Type_hindexed`

- *Commit* the new datatype

  `MPI_Type_Commit`

- *Use* the new datatype in sends/receives, etc.

Datatype Construction

- Datatype specified by its *type map*
  - Stencil laid over memory

Basic datatype 0	Displacement of datatype 0
Basic datatype 1	Displacement of datatype 1
...	...
Basic datatype n-1	Displacement of datatype n-1

- Displacements are offsets (in bytes) from the starting memory address of the desired data
  - **`MPI_Type_extent`** function can be used to get size (in bytes) of datatypes

Contiguous Datatype

- The simplest derived datatype consists of a number of contiguous items of the same datatype

C:

```
int MPI_Type_contiguous (int count,
        MPI_Datatype oldtype,MPI_Datatype *newtype)
```

Sample Program #1 - C

```
#include <stdio.h>
#include <mpi.h>
/* Run with four processes */
 void main(int argc, char *argv[]) {
    int rank;
    MPI_Status status;
    struct {
     int x;     int y;     int z;
    } point;
    MPI_Datatype ptype;
    MPI_Init(&argc,&argv);
    MPI_Comm_rank(MPI_COMM_WORLD,&rank);
    MPI_Type_contiguous(3,MPI_INT,&ptype);
    MPI_Type_commit(&ptype);
    if(rank==3){
       point.x=15; point.y=23; point.z=6;
       MPI_Send(&point,1,ptype,1,52,MPI_COMM_WORLD);
    } else if(rank==1) {
       MPI_Recv(&point,1,ptype,3,52,MPI_COMM_WORLD,&status);
       printf("P:%d received coords are (%d,%d,%d)
   \n",rank,point.x,point.y,point.z);
    }
P:1 received coords are (15,23,6)
 }
```


Vector Datatype

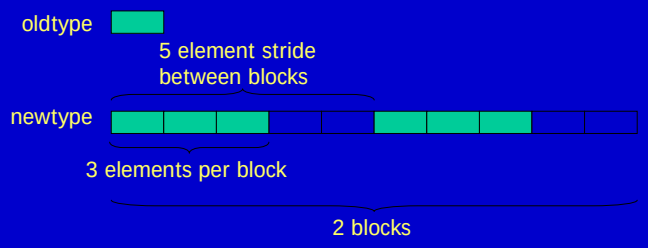
- User completely specifies memory locations defining the **vector**

C:

```
int MPI_Type_vector(int count, int blocklength,
int stride,
    MPI_Datatype oldtype, MPI_Datatype *newtype)
```

- *newtype* has *count* blocks each consisting of *blocklength* copies of *oldtype*
- Displacement between blocks is set by *stride*

Vector Datatype Example



- count = 2
- stride = 5
- blocklength = 3

Sample Program #2 - C

```
#include <mpi.h>
#include <math.h>
#include <stdio.h>

 void main(int argc, char *argv[]) {
    int rank,i,j;
    MPI_Status status;
    double x[4][8];
    MPI_Datatype coltype;
    MPI_Init(&argc, &argv);
    MPI_Comm_rank(MPI_COMM_WORLD,&rank);
    MPI_Type_vector(4,1,8,MPI_DOUBLE,&coltype);
    MPI_Type_commit(&coltype);
    if(rank==3){
      for(i=0;i<4;++i)
       for(j=0;j<8;++j) x[i][j]=pow(10.0,i+1)+j;
      MPI_Send(&x[0][7],1,coltype,1,52,MPI_COMM_WORLD);
    } else if(rank==1) {
       MPI_Recv(&x[0][2],1,coltype,3,52,MPI_COMM_WORLD,&status);
       for(i=0;i<4;++i)printf("P:%d my x[%d][2]=%1f\n",rank,i,x[i][2]);
    }
    MPI_Finalize();
 }
```

```
P:1 my x[0][2]=17.000000
P:1 my x[1][2]=107.000000
P:1 my x[2][2]=1007.000000
P:1 my x[3][2]=10007.000000
```

Committing a Datatype

- Once a datatype has been constructed, it needs to be committed before it is used.
- This is done using `MPI_TYPE_COMMIT`

C:

```
int MPI_Type_commit (MPI_Datatype *datatype)
```


Extent of a Datatype

- Handy utility function for datatype construction
- Extent defined to be the memory span (in bytes) of a datatype

C:

```
MPI_Type_extent (MPI_Datatype datatype, MPI_Aint* extent)
```

Fortran:

```
INTEGER     DATATYPE, EXTENT, IERROR
CALL MPI_TYPE_EXTENT (DATATYPE, EXTENT, IERROR)
```

Additional Material

- Structure Datatype
- Example Programs

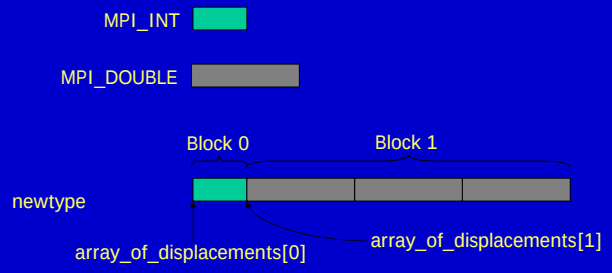
Structure Datatype

- Use for variables comprised of heterogeneous datatypes
  - C structures
  - Fortran common blocks
- This is the most general derived data type

```
int MPI_Type_struct (int count, int
  *array_of_blocklengths,
                     MPI_Aint *array_of_displacements,
                     MPI_Datatype *array_of_types,
                     MPI_Datatype *newtype)
```

- *newtype* consists of count blocks where the i^{th} block is array_of_blocklengths[i] copies of the type array_of_types[i]. The displacement of the i^{th} block (in bytes) is given by **array_of_displacements[i]**.

Struct Datatype Example



- `count = 2`
- `array_of_blocklengths = {1,3}`
- `array_of_types = {MPI_INT, MPI_DOUBLE}`
- `array_of_displacements = {0, extent(MPI_INT)}`

Sample Program #3 - C

```
#include <stdio.h>
#include<mpi.h>
void main(int argc, char *argv[]) {
 int rank,i;
 MPI_Status status;
 struct {
    int num;
    float x;
    double data[4];
  } a;
  int blocklengths[3]={1,1,4};
  MPI_Datatype types[3]={MPI_INT,MPI_FLOAT,MPI_DOUBLE};
  MPI_Aint displacements[3];
  MPI_Datatype restype;
  MPI_Aint intex,floatex;
  MPI_Init(&argc,&argv);
  MPI_Comm_rank(MPI_COMM_WORLD,&rank);

  MPI_Type_extent(MPI_INT,&intex);MPI_Type_extent(MPI_FLOAT,&floatex
  );
  displacements[0]= (MPI_Aint) 0; displacemtnts[1]=intex;
  displacements[2]=intex+floatex;
  MPI_Type_struct(3,blocklengths,displacements,types,&restype);
```

Sample Program #4 - C (cont.)

```
...
   MPI_Type_commit(&restype);
   if (rank==3){
      a.num=6; a.x=3.14; for(i=0;i 4;++i) a.data[i]=(double) i;
      MPI_Send(&a,1,restype,1,52,MPI_COMM_WORLD);
   } else if(rank==1) {
      MPI_Recv(&a,1,restype,3,52,MPI_COMM_WORLD,&status);
      printf("P:%d my a is %d %f %lf %lf %lf %lf\n",
             rank,a.num,a.x,a.data[0],a.data[1],a.data[2],a.data[3]);
    }
    MPI_Finalize();
}
```

```
P:1 my a is 6 3.140000 0.000000 1.000000 2.000000 3.000002
```


Examples of Datatype Use

- Building a derived data type
- Sending Row
- Sending Column
- Pack and Unpack