

Derived Datatypes

- ▶ Basic types
- ▶ Derived types
 - vectors
 - structs
 - others

```

int x[10];
INTEGER:: x(10);

// send all 10 values
MPI_Send(x, 10, MPI_INT, ...);
MPI_SEND(x, 10, MPI_INTEGER, ...)

// send first 4 values
MPI_Send(&x[0], 4, ...);
MPI_SEND(x(1), 4, ...)

// send 5th, 6th, 7th, 8th
MPI_Send(&x[4], 4, ...);
MPI_SEND(x(5), 4, ...)

// ??
struct mystruct x[10];
type(mytype) :: x(10)
    
```



- ▶ Send / Recv calls need a datatype argument
 - pre-defined values exist for pre-defined language types
 - eg `real` \leftrightarrow `MPI_REAL`; `int` \leftrightarrow `MPI_INT`
- ▶ What about types defined by a program?
 - eg structures (in C) or user-defined types (Fortran)
- ▶ Send / Recv calls take a count parameter
 - what about data that isn't contiguous in memory?
 - eg subsections of 2D arrays

- ▶ Can define new types in MPI
 - user calls setup routines to describe new datatype to MPI
 - remember, MPI is a library and NOT a compiler!
 - MPI returns a new datatype handle
 - store this value in a variable, eg MPI_MY_NEWTYPE

- ▶ Derived types have same status as pre-defined
 - can use in any message-passing call

- ▶ Some care needed for reduction operations
 - user must also define a new MPI_Op appropriate to the new datatype to tell MPI how to combine them

- ▶ All derived types stored by MPI as a list of basic types and displacements (in bytes)
 - for a structure, types may be different
 - for an array subsection, types will be the same
- ▶ User can define new derived types in terms of both basic types and other derived types

basic datatype 0	displacement of datatype 0
basic datatype 1	displacement of datatype 1
...	...
basic datatype n-1	displacement of datatype n-1

- ▶ 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)
```

- ▶ Fortran:

```
MPI_TYPE_CONTIGUOUS(COUNT, OLDTYPE,  
                    NEWTYPE, IERROR)
```

```
INTEGER COUNT, OLDTYPE, NEWTYPE, IERROR
```

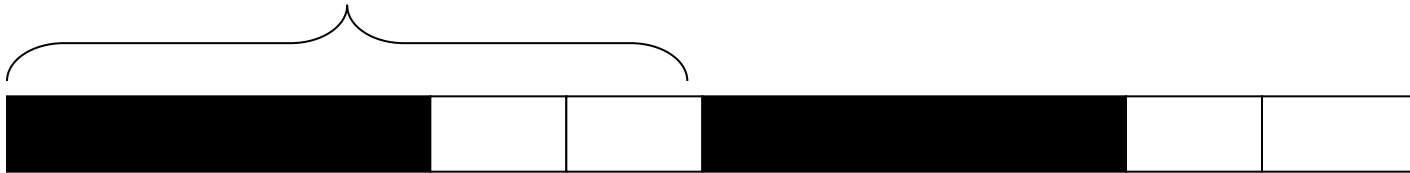

- ▶ May make program clearer to read
- ▶ Imagine sending a block of 4 integers
 - use `MPI_Ssend` with `MPI_INT / MPI_INTEGER` and `count = 4`
- ▶ Or ...
 - define a new contiguous type of 4 integers called `BLOCK4`
 - use `MPI_Ssend` with `type=BLOCK4` and `count = 1`
- ▶ May also be useful intermediate stage in building more complicated types
 - ie later used in definition of another derived type

Oldtype



**5 element stride
between blocks**

Newtype



3 elements per block

2 blocks

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

- ▶ Why is a pattern with blocks and gaps useful?

A vector type corresponds to a subsection of a 2D array

- ▶ Think about how arrays are stored in memory
 - unfortunately, different conventions for C and Fortran!
 - must use statically allocated arrays in C because dynamically allocated arrays (using malloc) have no defined storage format
 - In Fortran, can use either static or allocatable arrays

epcc Coordinate System (how I draw arrays)

$x[i][j]$

j



i

$x(i, j)$

$x[0][3]$	$x[1][3]$	$x[2][3]$	$x[3][3]$
$x[0][2]$	$x[1][2]$	$x[2][2]$	$x[3][2]$
$x[0][1]$	$x[1][1]$	$x[2][1]$	$x[3][1]$
$x[0][0]$	$x[1][0]$	$x[2][0]$	$x[3][0]$

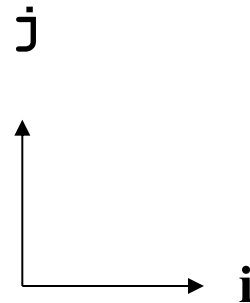
$x(1, 4)$	$x(2, 4)$	$x(3, 4)$	$x(4, 4)$
$x(1, 3)$	$x(2, 3)$	$x(3, 3)$	$x(4, 3)$
$x(1, 2)$	$x(2, 2)$	$x(3, 2)$	$x(4, 2)$
$x(1, 1)$	$x(2, 1)$	$x(3, 1)$	$x(4, 1)$

C: $\mathbf{x}[16]$ F: $\mathbf{x}(16)$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----

C: $\mathbf{x}[4][4]$ F: $\mathbf{x}(4, 4)$

4	8	12	16
3	7	11	15
2	6	10	14
1	5	9	13

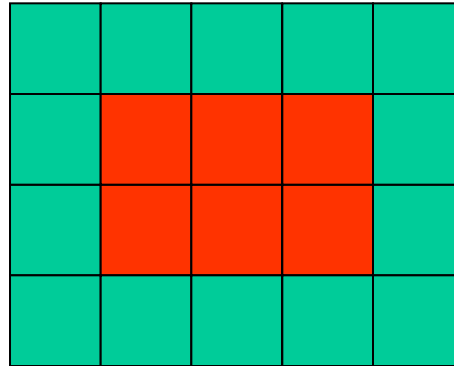


13	14	15	16
9	10	11	12
5	6	7	8
1	2	3	4

▶ Data is contiguous in memory

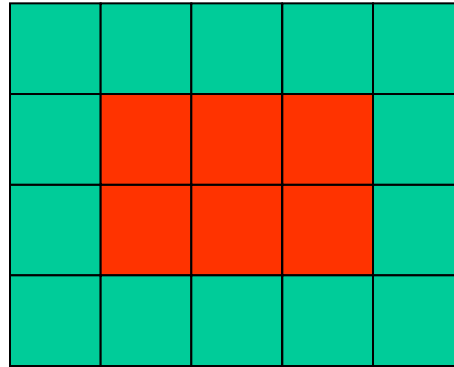
– different conventions for mapping 2D to 1D arrays in C and Fortran

C: `x[5][4]`

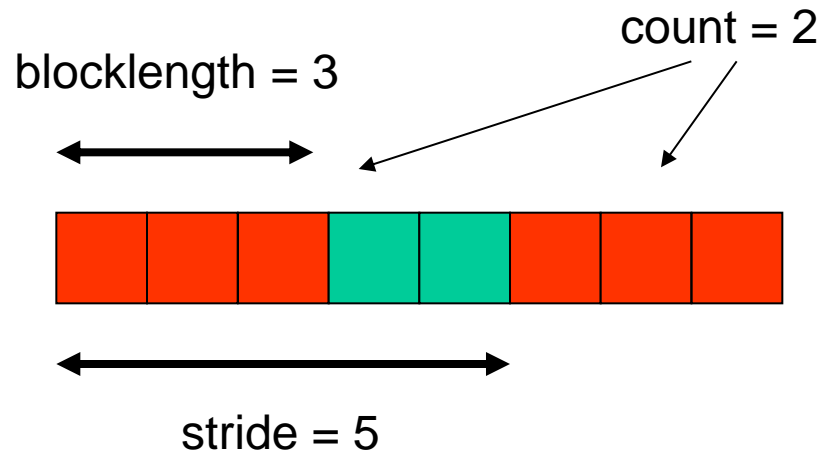
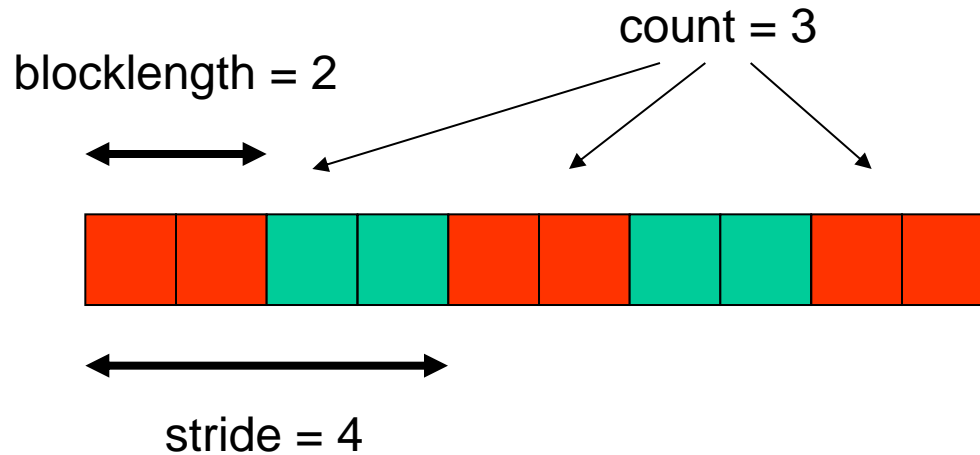


- ▶ A 3 x 2 subsection of a 5 x 4 array
 - three blocks of two elements separated by gaps of two

F: $x(5, 4)$



- ▶ A 3 x 2 subsection of a 5 x 4 array
 - two blocks of three elements separated by gaps of two



▶ C:

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

▶ Fortran:

```
MPI_TYPE_VECTOR (COUNT, BLOCKLENGTH,  
                STRIDE, OLDTYPE, NEWTYPE, IERROR)
```

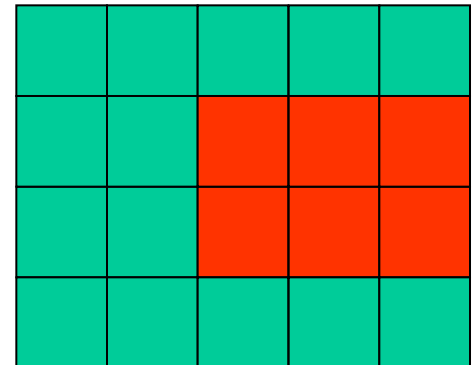
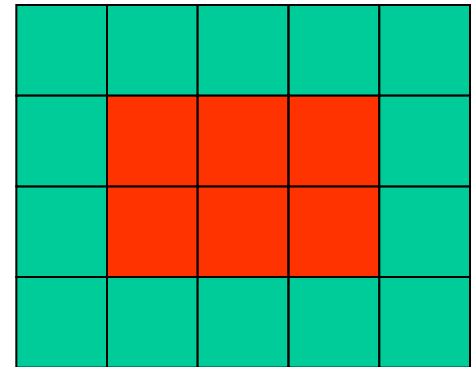
- ▶ Have defined a 3x2 subsection of a 5x4 array
 - but not defined WHICH subsection
 - is it the bottom left-hand corner? top-right?
- ▶ Data that is sent depends on what buffer you pass to the send routines
 - pass the address of the first element that should be sent

```
MPI_Ssend(&x[1][1], 1, vector3x2, ...);
```

```
MPI_SSEND(x(2,2), 1, vector3x2, ...)
```

```
MPI_Ssend(&x[2][1], 1, vector3x2, ...);
```

```
MPI_SSEND(x(3,2), 1, vector3x2, ...)
```



- ▶ May be useful to find out how big a derived type is
 - extent is distance from start of first to end of last data entry
 - can use these routines to compute extents of basic types too
 - answer is returned in bytes

- ▶ C:

```
int MPI_Type_get_extent (MPI_Datatype datatype,  
                        MPI_Aint *extent)
```

- ▶ Fortran:

```
MPI_TYPE_GET_EXTENT( DATATYPE, EXTENT, IERROR)  
INTEGER DATATYPE, EXTENT, IERROR
```

- ▶ Can define compound objects in C and Fortran

```
struct compound          type compound
{
    int    ival;          integer          :: ival
    double dval[3];      double precision :: dval(3)
};

                        end type compound
```

- ▶ Storage format NOT defined by the language
 - different compilers do different things
 - eg insert arbitrary padding between successive elements
 - need to tell MPI the byte displacements of every element

▶ C:

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

▶ Fortran:

```
MPI_TYPE_CREATE_STRUCT (COUNT,  
    ARRAY_OF_BLOCKLENGTHS,  
    ARRAY_OF_DISPLACEMENTS,  
    ARRAY_OF_TYPES, NEWTYPE, IERROR)
```

- ▶ `count = 2`
- ▶ `array_of_blocklengths[0] = 1`
- ▶ `array_of_types[0] = MPI_INT`
- ▶ `array_of_blocklengths[1] = 3`
- ▶ `array_of_types[1] = MPI_DOUBLE`

- ▶ But how do we compute the displacements?
 - need to create a compound variable in our program
 - explicitly compute memory addresses of every member
 - subtract addresses to get displacements from origin

▶ C:

```
int MPI_Get_address (void *location,  
                    MPI_Aint *address)
```

▶ Fortran:

```
MPI_GET_ADDRESS (LOCATION, ADDRESS, IERROR)
```

```
<type> LOCATION (*)
```

```
INTEGER (KIND=MPI_ADDRESS_KIND) ADDRESS
```

```
INTEGER IERROR
```


- ▶ Once a datatype has been constructed, it needs to be committed before it is used in a message-passing call
- ▶ This is done using `MPI_TYPE_COMMIT`

- ▶ C:

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

- ▶ Fortran:

```
MPI_TYPE_COMMIT (DATATYPE, IERROR)  
INTEGER DATATYPE, IERROR
```

Derived Datatypes

- ▶ See Exercise 7.1 on the sheet
- ▶ Modify the passing-around-a-ring exercise.
- ▶ Calculate two separate sums:
 - rank integer sum, as before
 - rank floating point sum
- ▶ Use a struct datatype for this.
- ▶ If you are a Fortran programmer unfamiliar with Fortran derived types then jump to exercise 7.2
 - illustrates the use of `MPI_Type_vector`