Transferring User Defined Types in OpenACC

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Topics

- What is this “transferring user define types thing”
- Existing solutions
- Deep copy capabilities
- Directive based solutions
- Complications and future work
Disjoint data-structure challenges

- Non-contiguous transfers
- Pointer translation

```c
struct {
    int *x; // dynamic size 2
} *A; // dynamic size 2
#pragma acc data copy( A[0:2] )
```

![Diagram showing host and device memory with shallow copy]
Disjoint data-structure challenges

- Non-contiguous transfers
- Pointer translation

```c
struct {
    int *x;  // dynamic size 2
} *A;      // dynamic size 2
#pragma acc data copy(A[0:2])
```

Host Memory:

```
```

Device Memory:

```
```

Deep Copy
Transferring user defined types

- **MPI**
  - MPI_Type_contiguous()
  - MPI_Type_vector()
  - MPI_Type_indexed()

- **Object serialization**
  - Write structures to storage and reload later
  - Supported in many languages

- **OpenACC**
  - API
  - Directives

- **“Deep copy”**
  - -h[no_]deep_copy
  - Limitations
    - Fortran only
    - No aliases
    - CRI pointer
    - C_ptr

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Base type for future slides

```c
struct Deep {
    int size;
    double scalar;
    double* A; /* A[0:size] */
    double* B; /* B[0:size] */
};
```
Manual deep copy example

```c
void deep_copy( struct Deep* P, int n ) {
    int i,j;
    struct Deep *dP;
    double *dA, *dB;
    /* enter copyin( P[0:n] ) */
    dP = acc_copyin( P, sizeof( struct Deep)*n );
    for ( i=0; i < n; ++i ) {
        dA = acc_copyin( P[i].A, P[i].size*sizeof( double ) );
        acc_memcpy_to_device( &dP[i].A, &dA, sizeof( double ) );
        dB = acc_copyin( P[i].B, P[i].size*sizeof( double ) );
        acc_memcpy_to_device( &dP[i].B, &dB, sizeof( double ) );
    }
    /* P is available for use on device */
    ...
    /* exit copyout( P[0:n] ) */
    for ( i=0; i<n; ++i ) {
        acc_update_self( &P[i].scalar, sizeof(double) );
        acc_copyout( P[i].A, P[i].size*sizeof( double ) );
        acc_copyout( P[i].B, P[i].size*sizeof( double ) );
    }
    acc_delete( P, sizeof( struct Deep )*n );
}
```

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Language complications

● **Fortran allocatable and pointer members**
  ● Self-describing
  ● Compiler can calculate their shape at runtime
  ● Opaque types
    ● Difficult to use manual deep copy, pointer hidden

● **C/C++ pointers**
  ● Compiler has no way to calculate their shape
  ● User can easily manipulate since it’s a basic type

● **Solution**
  ● Allow user to provide shaping information for C/C++ pointer members
  ● Directives allow compiler to manage dope vectors during transfer
Full deep-copy

(a) Host memory

(b) Device memory
Selective member deep-copy

(a) Host memory

(b) Device memory
Selective direction deep-copy

- **This is an optimization**
  - Users can transfer everything in and out

- **This is a convenience**
  - Users can do this with deep create and selective update
Mutable deep-copy

Top down:

(a) Selective deep-copy

(b) Attach to parent

(c) Detach from parent

Bottom up:

(a) Copy sub-objects

(b) Attach to children

(c) Attach to children
struct Deep {
    int size;
    double scalar;
    double* A; /* A[0:size] */
    double* B; /* B[0:size] */
}*p;

// copy n elements of p and size elements of A and B for each p
#pragma acc data copy( p[0:n]:: { copy( A[0:size], B[0:size] ) } )
// copyin p and B, copyout A
#pragma acc data copyin( p[0:n] ):: { copyout( A[0:size] ),
                                      copyin ( B[0:size] ) }

// copy p, copy A, leave B as shallow copy
#pragma acc data copy( p[0:n] ):: { copy( A[0:size] ) }
// verify presence of p, copy and attach B, leave A unchanged
#pragma acc data present( p[0:n] ):: { copy( B[0:size] ) }
Global Policies

```c
struct Deep {
    ...
    // same as last slide
    #pragma acc policy( shape ) shape( A[0:size], B[0:size] )
    #pragma acc policy("deep") inherit(*)
    #pragma acc policy("sel_dir") copyout( A[*] ) copyin( B[*] )
    #pragma acc policy("sel_mem") copy( A[*] )
    #pragma acc policy("mut_copy") copy( B[*] )
};
// Use deep policy to copy p, copy A and B
#pragma acc data copy( deep : p[0:n] )
// Use sel_dir policy to copyin p, copyout A and copyin B
#pragma acc data copyin( sel_dir : p[0:n] )
// Use sel_mem policy to copyin p, copy A
#pragma acc data copyin( sel_mem : p[0:n] )
// Use mut_copy policy to attach B to existing p
#pragma acc data present( mut_copy : p[0:n] )
```
Implicit policies, template

template<typename T>
class my_vector {
private:
  T* _begin;
  T* _end_data;
  T* _end_storage;
public:
...

// Shape _begin to size of active elements, others are aliases
#pragma acc policy( shape )
  shape( _begin[0:(((end_data - _begin)/sizeof(T)) - 1)])

// Create implicit data policy using _begin shape policy
#pragma acc policy( data ) inherit( _begin[*] )
  present( _end_data[@_begin] )
  present( _end_storage[@_begin] )

// Create implicit update policy using _begin shape policy
#pragma acc policy(update) update( _begin[*] )
  maintain( _end_data, _end_storage )
};
Implicit policies, use template

```cpp
class Data {
private:
    my_vector<double> A;
    my_vector<double> B;
    my_vector<int> C;
    my_vector<int> Other;
    // Crate shape policy using shape from template
    // for A, B and C, other is forced shallow
    #pragma acc policy( shape ) shallow( Other )
    // Create data policy using template data policy and shape
    #pragma acc policy( data ) inherit(*)
    // Create update policy using template update policy
    #pragma acc policy( update ) update(*)
};
```
Implicit policies, use template and class

// Example 1

my_vector<double> vec1, vec2;
// implicit policies let my_vector be treated
// like a simple variable
#pragma acc data copyin( vec1 ) copy( vec2 )
#pragma acc update self( vec1 )

// Example 2

Data dat1;
// equivalent to copy( dat1 )::{ copy(A,B,C) }
#pragma acc data copy( dat1 )
// override policy when you need to,
// copyin(B) don't copy A, copy(C)
#pragma acc data copyin( dat1 )::{ shallow(A) copy(C) }
Complications and future work

- Modifying pointers in data regions
- Allocation/deallocation on the device
- Polymorphic objects
- Function pointers
- C++ “this->” shallow or deep?
- C++ templates
- etc.
Missing syntax?
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