Transferring User Defined Types in OpenACC

James Beyer, David Oehmke, Jeff Sandoval
(Cray Inc.)

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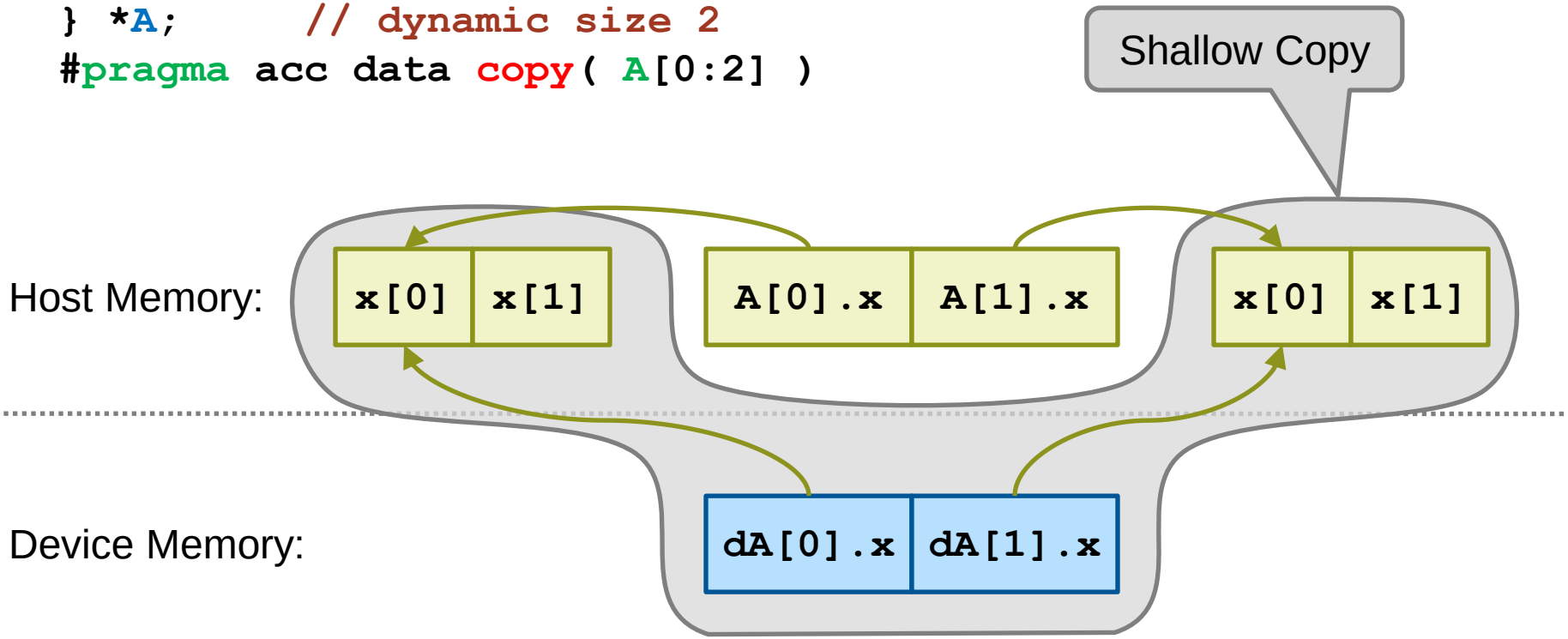
Topics

- 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

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



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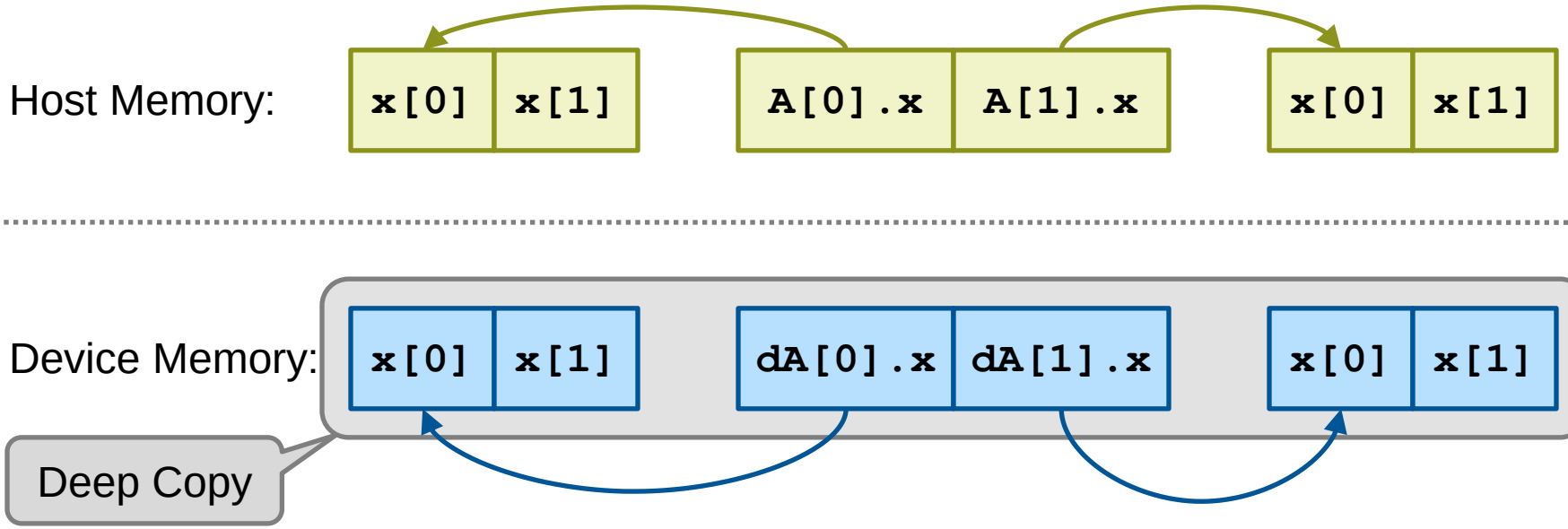


Transferring user defined types

- **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”**

```
struct Deep {
  int size;
  double scalar;
  double* A; /* A[0:size] */
  double* B; /* B[0:size] */
};
```

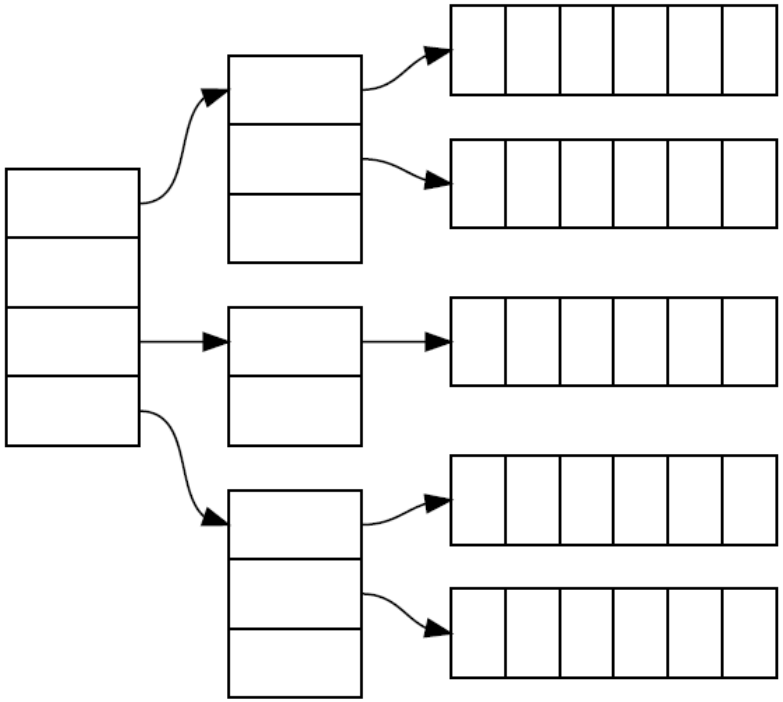
Manual deep copy example

```
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 );
}
```

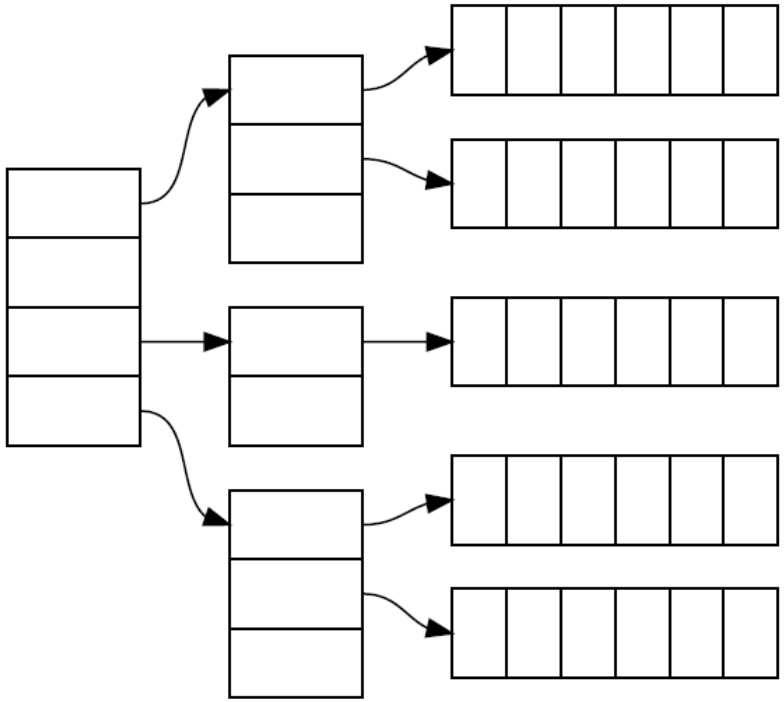
Language complications

- **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

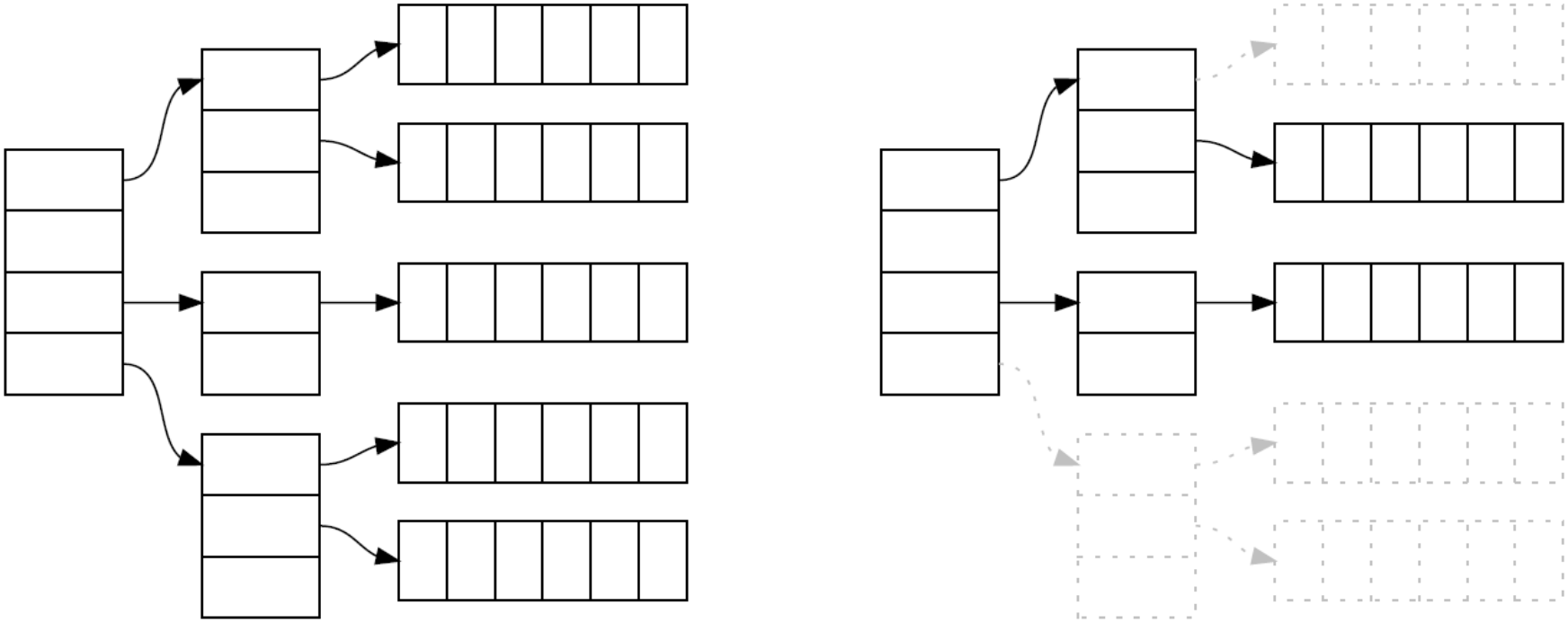


(a) Host memory



(b) Device memory

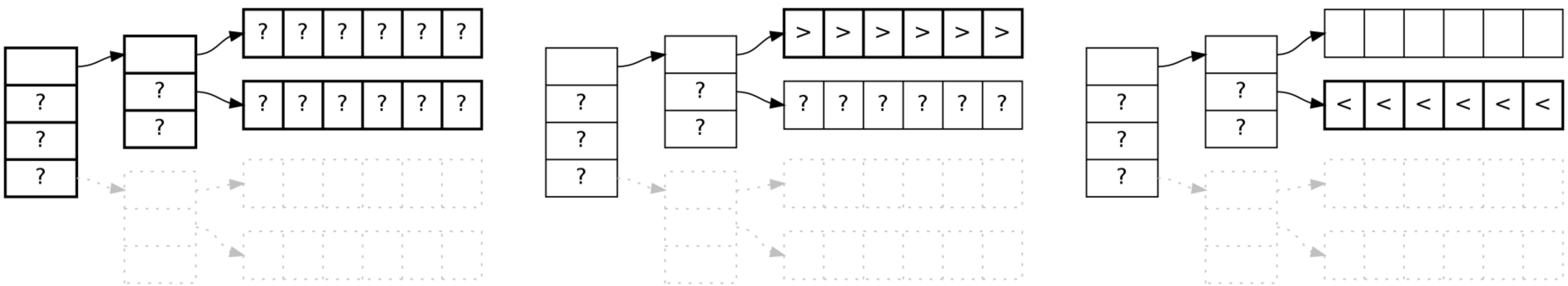
Selective member deep-copy



(a) Host memory

(b) Device memory

Selective direction deep-copy

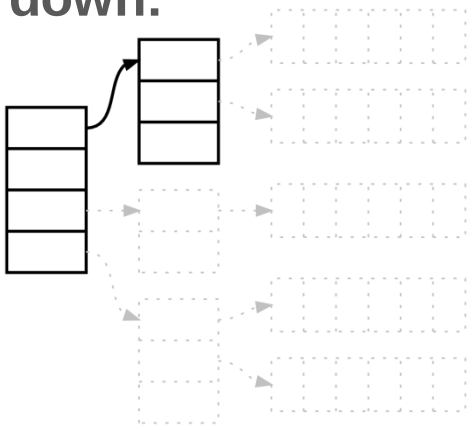


(a) Deep `create` (b) Selective `copyin` (c) Selective `copyout`

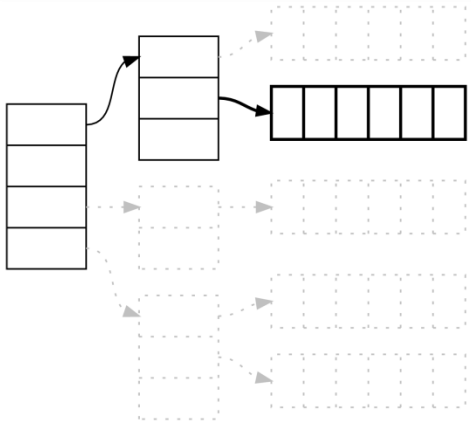
- **This is an optimization**
  - Users can transfer everything in and out
- **This is a convenience**
  - Users can do this with deep create and selective update

Mutable deep-copy

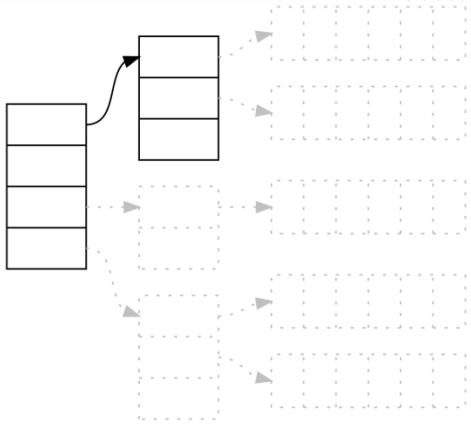
Top down:



(a) Selective deep-copy

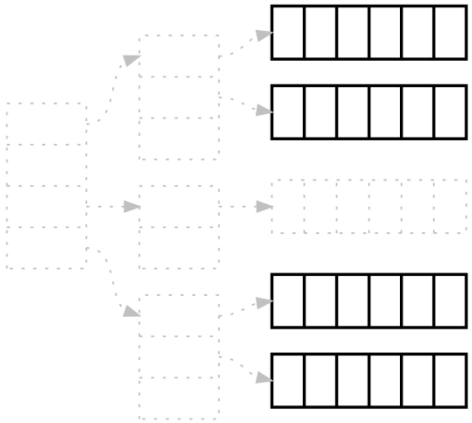


(b) Attach to parent

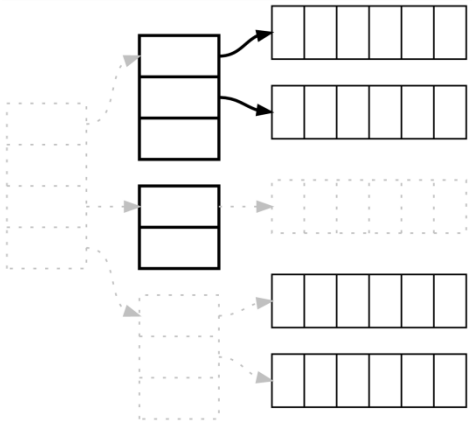


(c) Detach from parent

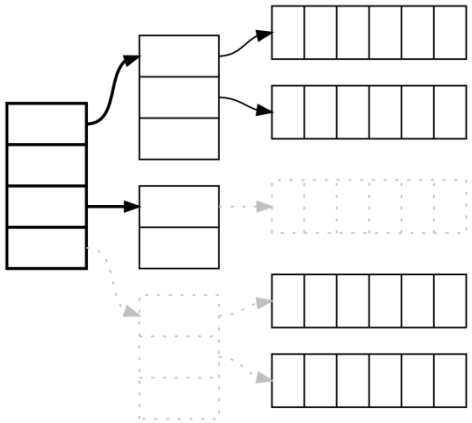
Bottom up:



(a) Copy sub-objects



(b) Attach to children



(c) Attach to children

Local Directive

```
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

```
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

```
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.

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