OpenACC 2.0 versus OpenMP 4.0 device constructs

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Contents

- Background or “how to” resources
- High level introduction
- Detailed comparison
- Code example comparisons
- Final thoughts

Background or “how to” resources

- **Videos**
  - www.openacc.org/Videos
  - www.cray.com/About/Videos.aspx
  - http://www.gputechconf.com/gtcnew/on-demand-gtc.php
    - Search by keyword: openacc
  - www.youtube.com
    - Search OpenMP

- **Google search of “OpenMP tutorials” produced 80,000+ hits**
- **Google search of “OpenACC tutorials” produced 19,000+ hits**

High level intro

- **Heritage**
  - OpenMP
    - 15+ years of history
  - OpenACC
    - 2+ years of history
- **Programming model**
  - Directives and function calls
  - Source does not need to change
  - Code still compiles for “host-only” execution
- **Execution model**
  - Host directed
- **Memory model**
  - Weak memory model
  - No synchronization at gang/team level
  - Separate or shared memory
- **Data motion control**
  - present_or_*
  - OpenMP
    - Structured
  - OpenACC
    - Structured
    - Unstructured

OpenACC compared to OpenMP

OpenACC	OpenMP
Parallel (offload) • Parallel (multiple “threads”)	**Target** **Team/Parallel**
Kernels	
Data	**Target Data**
Loop	**Distribute/Do/for/Simd**
Host data	
Cache	
Update	**Target Update**
Wait	
Declare	**Declare target**

OpenACC compared to OpenMP continued

OpenACC

- enter data
- exit data
- data api
- routine
- async wait
- parallel in parallel
- Tile
- Device_type

OpenMP

- declare target
- Parallel in parallel or team

OpenACC compared to OpenMP continued

OpenACC

- atomic
-
-
-
-
-
-
-
-

OpenMP

- Atomic
- Critical sections
- Master
- Single
- Tasks
- barrier
- get_thread_num
- get_num_threads
- …

OpenACC compared to OpenMP

- OpenACC 2.0
  - acc_copy(in|out)(ptr, bytes)
  - acc_create(ptr, bytes)
  - acc_delete(ptr, bytes)
  - acc_is_present(ptr, bytes)
  - acc_update_(device|local)(ptr, bytes)
  - acc_deviceptr(ptr)
  - acc_hostptr(devptr)
  - acc_[un]map_data(devptr, hostptr, bytes)
  - acc_memcpy_(to|from)_device
  - If there is a directive/clause there is likely an API routine
  - All 1.0 environment APIs still present
    - acc_async_test(id) …
- OpenMP
  - Most environment APIs contained in OpenACC 1.0

Code Example Comparisons

Device-specific tuning, multiple devices

OpenACC

```
PROGRAM main
  INTEGER :: a(N),b(N)
  <stuff>
!$acc parallel loop &
&  device_type(nvidia) num_gangs(200) &
&  device_type(host) num_gangs(16)
  DO i = 1,N
   a(i) = a(i) + rhs(i)
  ENDDO
!$acc end parallel loop
<stuff>
END PROGRAM main
```

OpenMP

```
PROGRAM main
  INTEGER :: a(N),b(N)
  <stuff>
!$omp target teams distribute &
&  num_teams( x )
  DO i = 1,N
   a(i) = a(i) + rhs(i)
  ENDDO
!$omp end target parallel do
<stuff>
END PROGRAM main
```

- Device_type(type)
- Similar to an #if def
- Compiler can generate code for all targets from single invocation
- Which clauses are allowed to follow clause are limited
  - No data clauses

Accerator ‘Worksharing’

OpenACC

```
PROGRAM main
  INTEGER :: a(N),b(N)
  <stuff>
!$acc kernels
  a = (/ ( I, I = 1, N ) /)
  a = 2*a +b
!$acc end kernels
  <stuff>
END PROGRAM main
```

OpenMP

```
PROGRAM main
  INTEGER :: a(N),b(N)
  <stuff>
!$omp target
!$omp parallel workshare
  a = (/ ( I, I = 1, N ) /)
  a = 2*a +b
!$omp end parallel workshare
!$omp end target
  <stuff>
END PROGRAM main
```

- These are not equivalent!!!
- OpenMP workshare construct not defined in the same way as kernels
- OpenMP must insert a “barrier” between statements
- For OpenACC Array a(:) possibly unnecessarily moved from and to GPU between kernels
  - "data sloshing"
- Code still compile-able for CPU

Unstructured Data Lifetimes

OpenACC

```
PROGRAM main
  INTEGER :: a(N)
  <stuff>
  call init(a)
!$acc parallel loop
  DO i = 1,N
   a(i) = i
  ENDDO
!$acc end parallel loop
!$acc parallel loop
  DO i = 1,N
   a(i) = 2*a(i)
  ENDDO
!$acc end parallel loop
  call fini(a)
  <stuff>
END PROGRAM main

SUBROUTINE init(b)
  INTEGER :: b(:)
  !$acc enter data pcreate(b)
END SUBROUTINE init

SUBROUTINE fini(b)
  INTEGER :: b(:)
  !$acc exit data copyout(b)
END SUBROUTINE init
```

OpenMP

Subprograms sharing GPU (Error vs Fix-up)

OpenACC

```
PROGRAM main
  INTEGER :: a(N)
  <stuff>
!$acc data copyout(a) if( test )
!$acc parallel loop
  DO i = 1,N
   a(i) = i
  ENDDO
!$acc end parallel loop
  CALL double_array(a)
!$acc end data
  <stuff>
END PROGRAM main
```

```
SUBROUTINE double_array(b)
  INTEGER :: b(N)
!$acc parallel loop present(b)
  DO i = 1,N
   b(i) = double_scalar(b(i))
  ENDDO
!$acc end parallel loop
END SUBROUTINE double_array
```

```
INTEGER FUNCTION double_scalar(c)
  INTEGER :: c
  double_scalar = 2*c
END FUNCTION double_scalar
```

OpenMP

```
PROGRAM main
  INTEGER :: a(N)
  <stuff>
!$omp target data map(out:a) if( test )
!$omp target parallel do
  DO i = 1,N
   a(i) = i
  ENDDO
!$omp end target parallel loop
  CALL double_array(a)
!$omp end target data
  <stuff>
END PROGRAM main
```

```
SUBROUTINE double_array(b)
  INTEGER :: b(N)
!$omp parallel loop map(tofrom:b)
  DO i = 1,N
   b(i) = double_scalar(b(i))
  ENDDO
!$omp end parallel loop
END SUBROUTINE double_array
```

```
INTEGER FUNCTION double_scalar(c)
  INTEGER :: c
  double_scalar = 2*c
END FUNCTION double_scalar
```

Interoperability with CUDA

OpenACC

```
PROGRAM main
  INTEGER :: a(N)
  <stuff>
!$acc data copy(a)
! <Populate a(:) on device
!  as before>
!$acc host_data use_device(a)
  CALL dbl_cuda(a)
!$acc end host_data
!$acc end data
  <stuff>
END PROGRAM main
```

```
__global__ void dbl_knl(int *c) {
  int i = \
        blockIdx.x*blockDim.x+threadIdx.x;
  if (i < N) c[i] *= 2;
}

extern "C" void dbl_cuda_(int *b_d) {
  cudaThreadSynchronize();
  dbl_knl<<<NBLOCKS,BSIZE>>>(b_d);
  cudaThreadSynchronize();
}
```

OpenMP

Tile clause

OpenACC

```
!$acc loop tile(64,4) gang vector
  do i = 1, n
    do j = 1, m
      a(j,i) = (b(j-1,i)+b(j+1,i)+ &
                 b(j,i-1)+b(j,i+1))*0.25
    enddo
  enddo
```

```
!$acc loop collapse(2) gang
  do i = 1, n, 4
    do j = 1, m, 64
!$acc loop collapse(2) vector
      do ii = i, min(n,i+4)
        do jj = j, min(m,j+64)
         a(jj,ii) = (b(jj-1,ii)+ &
                     b(jj+1,ii)+ &
                     b(jj,ii-1)+ &
                     b(jj,ii+1))*0.25
    enddo
  enddo
```

cache clause examples

OpenACC

```
!$acc loop tile( 64, 16, 1 ) gang &
      worker vector
DO k = 1,N
  DO j = 1,N
    DO i = 1,N
!$acc cache( A(i,j,k), &
!$acc        B(i-1:i+1,j-1:j+1,k) )

      A(i,j,k) = B(i,  j,  k) - &
                 ( B(i-1,j-1,k) &
                 + B(i-1,j+1,k) &
                 + B(i+1,j-1,k) &
                 + B(i+1,j+1,k) ) / 5
    ENDDO
  ENDDO
ENDDO
!$acc end parallel
```

OpenACC Loop selection

OpenACC

```
PROGRAM main
  INTEGER :: a(N)
!$acc routine( foo ) worker
  <stuff>
!$acc parallel loop
  DO i = 1,N
   CALL foo(a)
  ENDDO
!$acc end parallel loop
<stuff>
END PROGRAM main
```

```
PROGRAM main
  INTEGER :: a(N)
!$acc routine( foo ) seq
  <stuff>
!$acc parallel loop
  DO i = 1,N
   CALL foo(a)
  ENDDO
!$acc end parallel loop
<stuff>
END PROGRAM main
```

OpenMP

```
PROGRAM main
  INTEGER :: a(N)
!$omp delcare target ( foo )
  <stuff>
!$omp target parallel do
  DO i = 1,N
   CALL foo(a)
  ENDDO
!$omp end target parallel do
  <stuff>
!$omp target teams distribute
  DO i = 1,N
   CALL foo(a)
  ENDDO
!$omp end target teams distribute
  <stuff>
END PROGRAM main
```

Declare Create vs Declare Link

```
float a[100000];
#pragma acc declare create( a )
...
#pragma acc routine gang
void foo() {
#pragma acc loop
for(…)
a[..] = …
}
...
void bar() {
#pragma acc update device( a )
#pragma acc parallel
foo();
#pragma acc update self( a )
}
```

```
float a[100000];
#pragma acc declare link(a)
...
#pragma acc routine gang
void foo() {
#pragma acc loop
for(…)
a[..] = …
}
...
void bar() {
!! #pragma acc update device( a ) ERROR!!!
#pragma acc parallel copy( a )
foo();
!! #pragma acc update self( a ) ERROR!!!
}
```

- Both OpenACC and OpenMP support the declare create concept
- Only OpenACC contains the link concept at this time

OpenACC bind clause examples

File 1

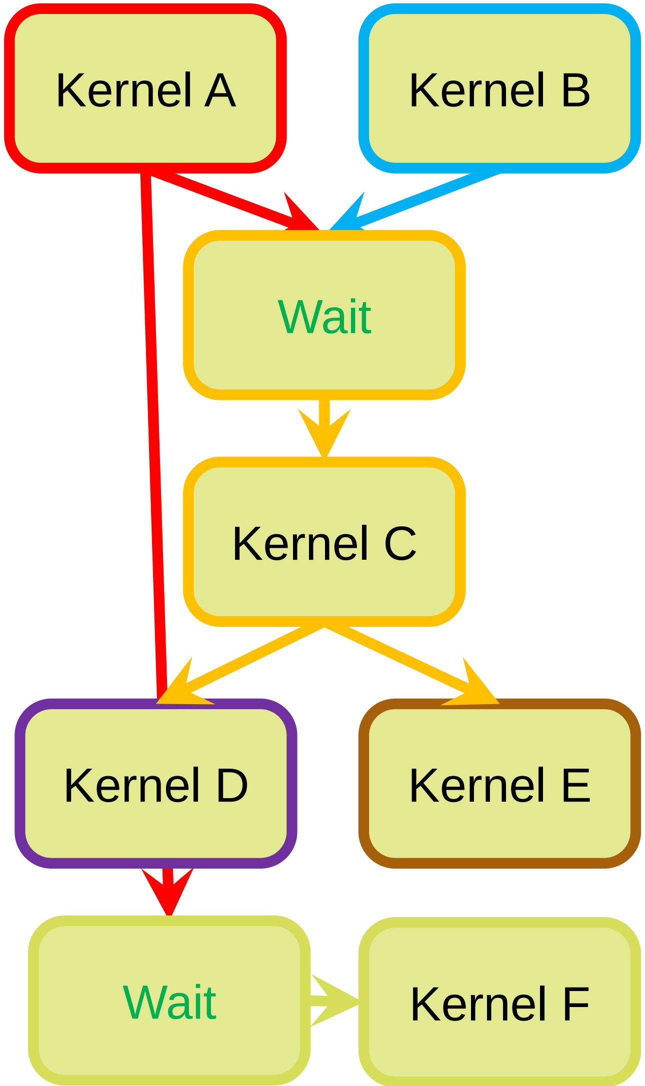
```
#pragma acc declare create(a)
extern int a[];
#pragma acc routine(foo) bind(foo_nvidia) gang
extern void foo(int i);
#pragma acc parallel loop gang copy(a)
for(i…)
  foo(i);
```

File 2

```
#pragma acc routine bind(“foo_worker”) worker
void foo( int i) {
#pragma acc loop worker vector
for(…)
a[..] = …
}
```

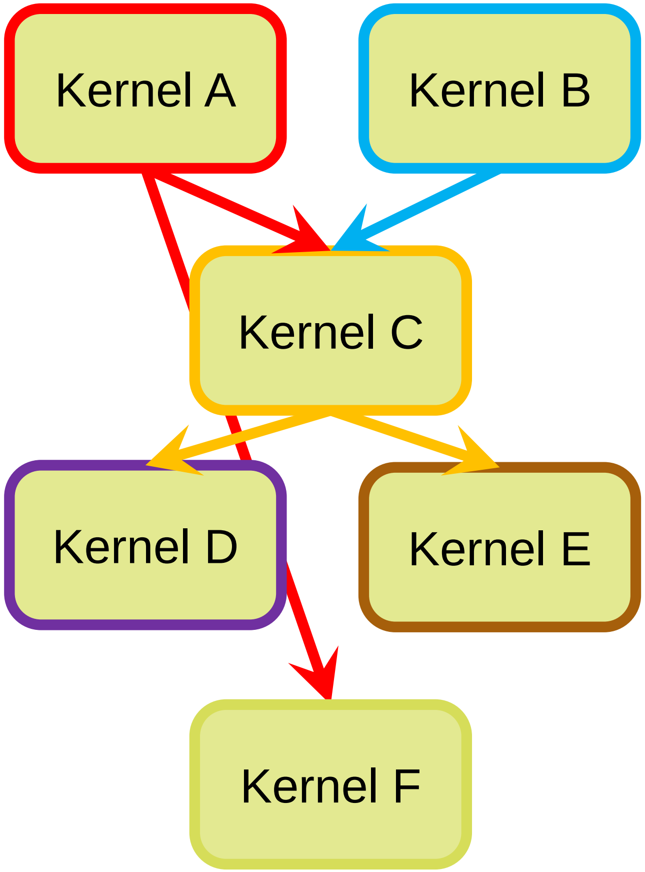
OpenACC High-level async example

```
!$acc parallel loop async(1)
<Kernel A>
!$acc parallel loop async(2)
<Kernel B>

!$acc wait( 1, 2 ) async( 3 )

!$acc parallel loop async(3)
!! wait( 1, 2 )
<Kernel C>

!$acc parallel loop async(4) &
!$acc      wait(3)
<Kernel D>

!$acc parallel loop async(5) &
!$acc      wait(3)
<Kernel E>

!$acc wait( 1 )

<Kernel F>
```



OpenMPHigh-level async example

```
!$omp task depend(inout:a)
!$omp target parallel do
<Kernel A>
!$omp task depend(inout:b)
!$omp target parallel do
<Kernel B>
!$omp task depend(inout:c)
depend(in:a,b)
!$omp target parallel do
<Kernel C>
!$omp task depend(inout:d) depend(in:c)
!$omp target parallel do
<Kernel D>
!$omp task depend(inout:e) depend(in:c)
!$omp target parallel do
<Kernel E>

!$omp task depend(in:a)
<Kernel F>
```



Nested Parallelism

- OpenACC 2.0
  - Actually simply a deletion of two restrictions
    - OpenACC parallel regions may not contain other parallel regions or kernels regions.
    - OpenACC kernels regions may not contain other parallel regions or kernels regions.
  - Other changes were mainly cosmetic
  - Has significant impact on where objects can be placed in memory.
- OpenMP
  - Target constructs not allowed inside of target constructs.
  - Teams constructs not allowed inside of teams constructs
  - …
  - Only parallel inside of target/teams/parallel
  - May come in next release

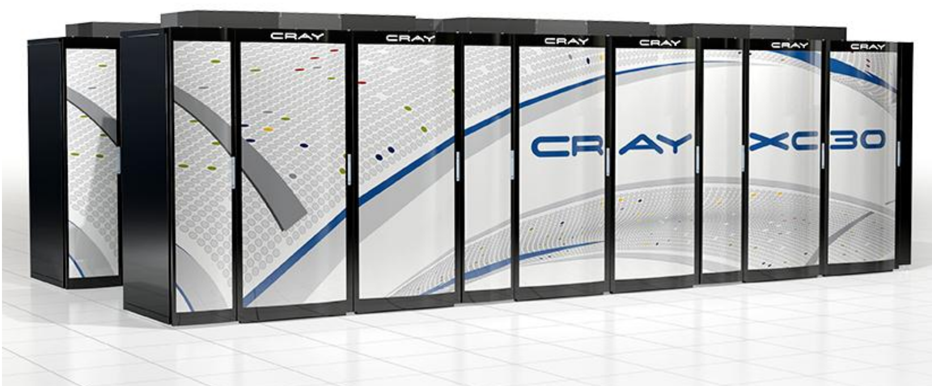
Manual deep-copy

```
struct A_t
  int n;
  int *x;      // dynamic size n
};
...
struct A_t *A; // dynamic size 2
/* shallow copyin A[0:2] to device_A[0:2] */
struct A_t *dA = acc_copyin( A, 2*sizeof(struct A_t) );
     int i = 0 ; i < 2 ; i++) {
  /* shallow copyin A[i].x[0:A[i].n] to "orphaned" object */
  int *dx = acc_copyin( A[i].x, A[i].n*sizeof(int) );
  /* fix acc pointer device_A[i].x */
  acc_memcpy_to_device( &dA[i].x, &dx, sizeof(int*);
}
```

- Currently works for C/C++
- Portable in OpenACC 2.0, but not usually practical
- Not in OpenMP

Final thoughts

- **OpenMP is …**
  - Easier to write codes that will not compile for some devices
  - All historic OpenMP constructs allowed inside of parallel regions on the device
- **OpenACC is**
  - Harder to write codes that will not compile for some device
  - OpenMP NOT allowed inside of construct by most vendors
- **…**



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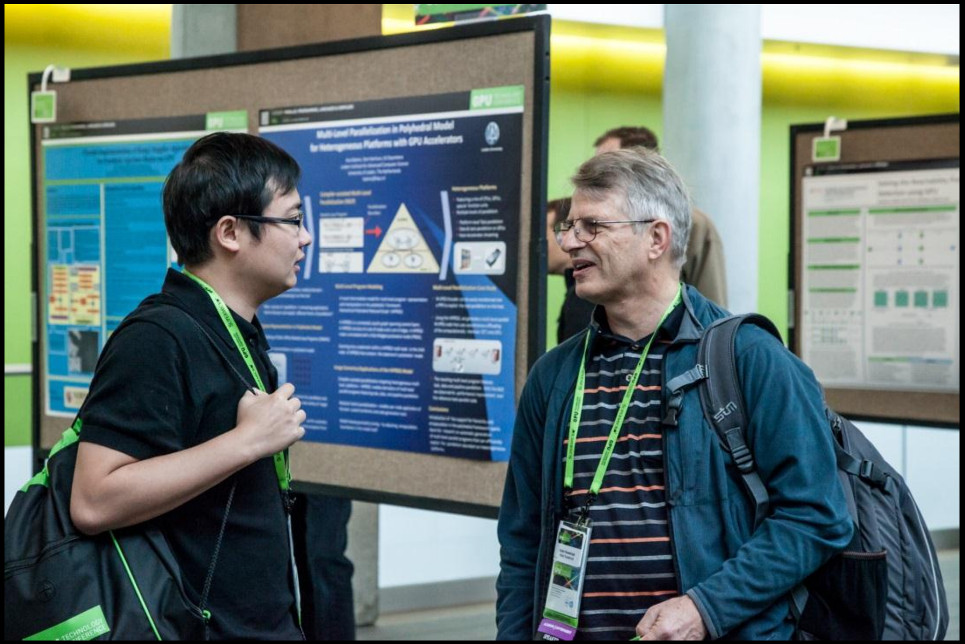

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