Using OpenACC With CUDA Libraries

John Urbanic
with NVIDIA
Pittsburgh Supercomputing Center

3 Ways to Accelerate Applications

Applications

Libraries	OpenACC Directives	Programming Languages
“Drop-in” Acceleration	Easily Accelerate Applications	Maximum Flexibility

CUDA Libraries are interoperable with OpenACC

3 Ways to Accelerate Applications

Applications

Libraries

OpenACC Directives

Programming Languages

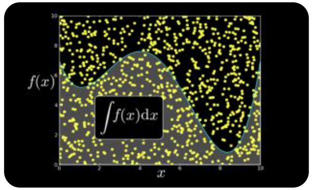
CUDA Languages are interoperable with OpenACC, too!

"Drop-in" Acceleration

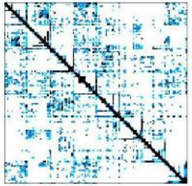
Easily Ac
Applications

imum
Flexibility

NVIDIA cuBLAS



NVIDIA cuRAND



NVIDIA cuSPARSE

NVIDIA NPP

GPU VSIPL

Vector Signal Image Processing

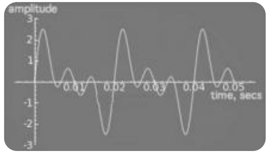
CULA tools

GPU Accelerated Linear Algebra

MAGMA

Matrix Algebra on GPU and Multicore

open source initiative



NVIDIA cuFFT

ROGUE WAVE SOFTWARE

IMSL Library

libjacket

Building-block Algorithms for CUDA

CUSP

Sparse Linear Algebra

open source initiative

Thrust

C++ STL Features for CUDA

open source initiative

GPU Accelerated Libraries

"Drop-in" Acceleration for Your Applications

CUDA data in OpenACC

You have to allocate data memory on the host and device with alloc/cudaMalloc. deviceptr() lets OpenACC know that has happened.

```
float *a;
...
err = cudaMalloc(&a, sizeof(float)*n);
kernel<<<n/32,32>>>(a,...);
...
incr(a,n);

void incr(float* x, int n){
  #pragma acc parallel loop deviceptr(x)
  for (int i = 0; i < n; ++i)
    x[i] += 1.0f;
}
```

deviceptr Data Clause

`deviceptr( list )` Declares that the pointers in *list* refer to device pointers that need not be allocated or moved between the host and device for this pointer.

Example:

C

```
#pragma acc data deviceptr(d_input)
```

Fortran

```
$!acc data deviceptr(d_input)
```

host_data Construct

If the data is on the device - say it has been *create()*ed - then host_data use_device() allows us to grab that device pointer on the host so that we can pass it along to some CUDA routine elsewhere.

```
a = (float*)malloc(sizeof(float)*n);
#pragma acc data create(a[0:n])
{
   #pragma acc host_data use_device(a)
   {
      incr(a,n);
   }
}

----- separate file with CUDA code -----
__global__ inckernel(float* x, int n){ ... }

void incr(float* x, int n){
  inckernel<<<n/32,n>>>(x,n);
}
```

Example: 1D convolution using CUFFT

- Perform convolution in frequency space
  1. Use CUFFT to transform input signal and filter kernel into the frequency domain
  2. Perform point-wise complex multiply and scale on transformed signal
  3. Use CUFFT to transform result back into the time domain

- We will perform step 2 using OpenACC

- Code highlights follow. Code available with exercises in: `Exercises/OpenACC/Cufft-acc`

Source Excerpt

Allocating Data

```
// Allocate host memory for the signal and filter
Complex *h_signal = (Complex *)malloc(sizeof(Complex) * SIGNAL_SIZE);
Complex *h_filter_kernel = (Complex *)malloc(sizeof(Complex) * FILTER_KERNEL_SIZE);
      .
      .
      .

// Allocate device memory for signal
Complex *d_signal;
checkCudaErrors(cudaMalloc((void **)&d_signal, mem_size));
// Copy host memory to device
checkCudaErrors(cudaMemcpy(d_signal, h_padded_signal, mem_size, cudaMemcpyHostToDevice));

// Allocate device memory for filter kernel
Complex *d_filter_kernel;
checkCudaErrors(cudaMalloc((void **)&d_filter_kernel, mem_size));
```

Source Excerpt

Sharing Device Data (d_signal, d_filter_kernel)

```
// Transform signal and kernel
error = cufftExecC2C(plan, (cufftComplex *)d_signal, (cufftComplex *)d_signal, CUFFT_FORWARD);
error = cufftExecC2C(plan, (cufftComplex *)d_filter_kernel, (cufftComplex *)d_filter_kernel, CUFFT_FORWARD);


// Multiply the coefficients together and normalize the result
printf("Performing point-wise complex multiply and scale.\n");
complexPointwiseMulAndScale(new_size,(float *restrict)d_signal,(float *restrict)d_filter_kernel);


// Transform signal back
error = cufftExecC2C(plan, (cufftComplex *)d_signal,(cufftComplex *)d_signal, CUFFT_INVERSE);
```

OpenACC Routine

CUDA Routines

OpenACC Convolution Code

```
void complexPointwiseMulAndScale(int n, float *restrict signal,
                                 float *restrict filter_kernel)
{
// Multiply the coefficients together and normalize the result
#pragma acc data deviceptr(signal, filter_kernel)
    {
#pragma acc kernels loop independent
        for (int i = 0; i < n; i++) {
            float ax = signal[2*i];
            float ay = signal[2*i+1];
            float bx = filter_kernel[2*i];
            float by = filter_kernel[2*i+1];
            float s = 1.0f / n;
            float cx = s * (ax * bx - ay * by);
            float cy = s * (ax * by + ay * bx);
            signal[2*i] = cx;
            signal[2*i+1] = cy;
        }
    }
}
```

Implementation note: We cast the Complex* pointers to float* pointers and use interleaved indexing

Linking CUFFT

- `#include “cufft.h”`
- Compiler command line options:

```
CUDA_PATH = /opt/pgi/13.10.0/linux86-64/2013/cuda/5.0
CCFLAGS = -I$(CUDA_PATH)/include -L$(CUDA_PATH)/lib64
          -lcudart -lcufft
```

Must use PGI-provided CUDA toolkit paths

Must link libcudart and libcufft

Result

```
instr009@nid27635:~/Cufft> aprun -n 1 cufft_acc
Transforming signal cufftExecC2C
Performing point-wise complex multiply and scale.
Transforming signal back cufftExecC2C
Performing Convolution on the host and checking correctness

Signal size: 500000, filter size: 33
Total Device Convolution Time: 6.576960 ms (0.186368 for point-wise convolution)
Test PASSED
```

CUFFT + cudaMemcpy

OpenACC

Summary

- Use deviceptr data clause to pass pre-allocated device data to OpenACC regions and loops
- Use host_data to get device address for pointers inside acc data regions
- The same techniques shown here can be used to share device data between OpenACC loops and
  - Your custom CUDA C/C++/Fortran/etc. device code
  - Any CUDA Library that uses CUDA device pointers