Lecture 13

OpenCL

GPU computing with GLSL

OpenGL Compute shaders

Lecture questions

1) What kind of devices will OpenCL run on?

2) What does an OpenCL work group correspond to in CUDA?

3) What geometry is typically used for shader-based GPU computing?

4) What are the main advantages of using OpenGL Compute Shaders?

Introduction to OpenCL

Open Compute Language

- Motivation
- Overview
- Examples
- Performance comparison

Origins of OpenCL

Initiated by Apple

Managed by Khronos group

Many supporting parties

Many providers

KHRONOS
GROUP
Over 100 companies creating
authoring and acceleration standards
Board of Promoters
AMD
ARM
intel
IBM
SONY
SAMSUNG
Imagination Technologies
ERICSSON
freescale
MOTOROLA
NOKIA
NVIDIA
Sun
Texas Instruments
ABB
Acrodea
Activision
Blizzard
Adobe
Analog Devices
Artix
ARC
ArcSoft
Arditee
austriamicrosystems
Autodesk
BEATNIK
BitFlash
BROADCOM
codeplay
CONEXANT
CREATIVE
DAIMLER
DELL
digia
DOLBY
EA
FhG
FUJITSU
FUTUREMARK
GE
GiQuila
Google
graphicREMEDY
Hantro
HISILICON
HUONE
inoras
ideaworks3D
imec
SK
LG
matrox
MARVELL
Mentor Graphics
Micron
MITSUBISHI ELECTRIC
Monotype
MOVIAL
NDS
NEC
Nexus Chips
NXP
Panasonic
QNX
QUALCOMM
RAPIDMIND
RENESAS
S3
sasken
Seaweed Systems
SIEMENS
SiRF
SK telecom
SmithMicro Software
SoftBank
Sony Ericsson
ST
SUNPLUS
symbian
TAKUMI
tat
TES
TOSHIBA
Tungsten Graphics
VIVANTE
YAMAHA
Yumetech

Why?

- The market could not let CUDA rule the world
- Support for other platforms
- Open standard
- Similarity with OpenGL

For programming ”all” parallel architectures

Supported architectures

GPU

Intel compatible CPUs

ARM

FPGA

CELL

Who decides? Any company making its own OpenCL implementation!

”Open”?

Means *open specification*

Like OpenGL

Many providers making their own implementation

There is not *one* OpenCL library.

No free lunch

Model does not fit all architectures

One size fits all - platform dependent optimizations hard to do

OpenCL for GPU Computing

Mostly similar to CUDA both in architecture and performance!

Messy setup- but you get used to it

Kernels similar to CUDA

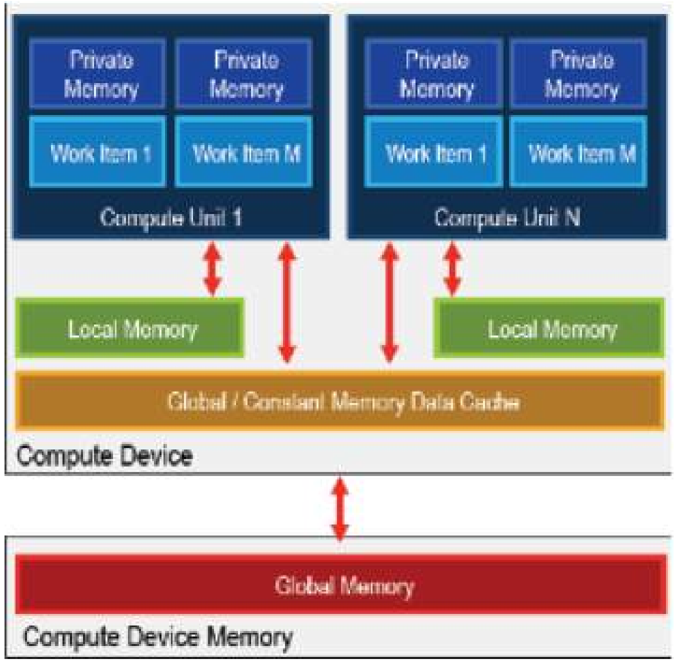
Easier for NVidia to be first with new features

OpenCL vs CUDA terminology

OpenCL	CUDA
compute unit	multiprocessor (SM)
work item	thread
work group	block
local memory	shared memory
private memory	registers

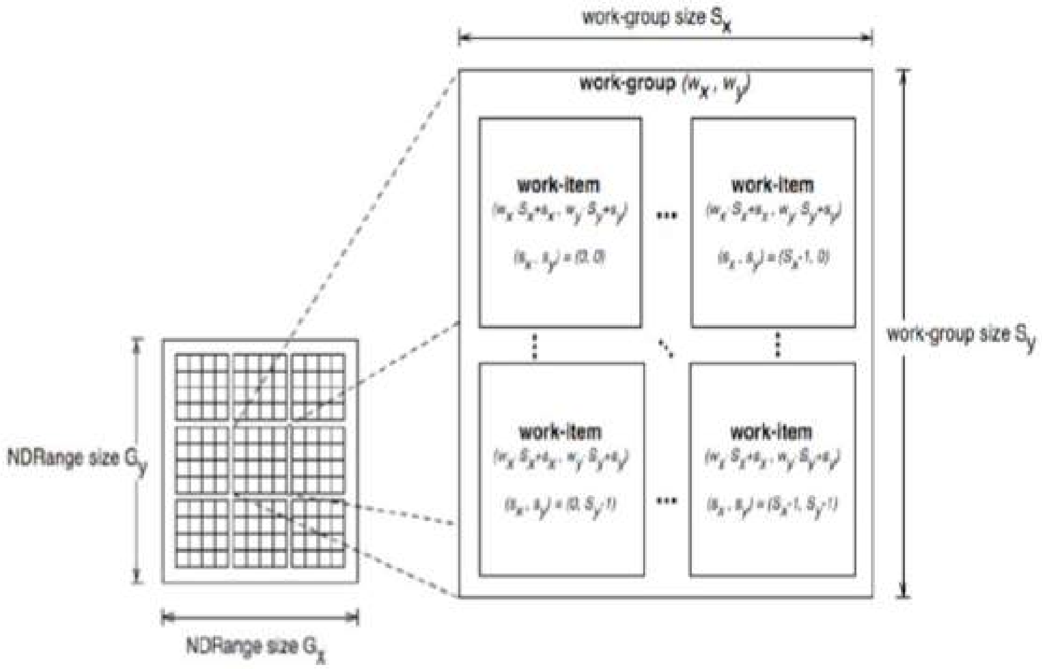
And CUDA local memory =?
OpenCL local memory (= CUDA shared memory)

OpenCL memory model



Been there, done that...

OpenCL execution model


work-group size S_x
work-group (w_x, w_y)
work-item
$(w_x \cdot S_x + s_x, w_y \cdot S_y + s_y)$
$(s_x, s_y) = (0, 0)$
work-item
$(w_x \cdot S_x + s_x, w_y \cdot S_y + s_y)$
$(s_x, s_y) = (S_x - 1, 0)$
work-group size S_y
NDRange size G_y
work-item
$(w_x \cdot S_x + s_x, w_y \cdot S_y + s_y)$
$(s_x, s_y) = (0, S_y - 1)$
work-item
$(w_x \cdot S_x + s_x, w_y \cdot S_y + s_y)$
$(s_x, s_y) = (S_x - 1, S_y - 1)$
NDRange size G_x

Anyone who see ”blocks” and ”threads”?

Synchronization

Kernels can synchronize within a work group:

```
barrier(CLK_LOCAL_MEM_FENCE)
```

No synchronization between work groups.

Synchronizes memory access. You choose which kind of memory access to synchronize (global, local).

Synchronization

The host (CPU) can synchronize on global level:

Available for:
tasks (e.g. clEnqueueNDRangeKernel)
Memory(e.g.clEnqueueReadBuffer)
events (e.g. clWaitforEvents)

Heterogenous

Some differences from CUDA: Designed for heterogenous systems!

Several devices may be active at once

You can specify which device to launch a task to

Query devices and device characteristics

Some overhead compared to CUDA, and the reward is flexibility!

Language

Based on C99, but:

- ❐ No function pointers
- ❐ No pointers to pointers in function calls
  (=> no multi-dimensional arrays)
- ❐ No recursion
- ❐ No arrays with dynamical length
- ❐ No bitfields
- ❐ Also, no possibility to call a kernel from another kernel

Optional:

- ❐ Pointers with length <32 bit
- ❐ Writing support for 3D images
- ❐ Double and half types
- ❐ Atomic functions

On the positive side:

❒ Integrated functions for reading / writing 2D images and reading 3D images
❒ Converting functions incl. explicit rounding and saturation
❒ math.h, all functions with different precisions
❒ Vector support (2-, 3- and 4-dimensional)

Available primitive datatypes:
❒ Bool,char,int,long,float,size_t,void,+unsigned versions

Mix of OpenCL and OpenGL possible
❒ Can share data structures and variables (without copying)
❒ API functions available

How about that setup?

1) Get a list of platforms

2) Choose a platform

3) Get a list of devices

4) Choose a device

5) Create a context

6) Load and compile kernel code

Then we can start working

7) Allocate memory

8) Copy data to device

9) Run kernel

10) Wait for kernel to complete

11) Read data from device

12) Free resources

1-5: Where to run

```
cl_platform_id platform;
unsigned int no_plat;
err =  clGetPlatformIDs(1,&platform,&no_plat);
```

Simplified here - might fail!

```
// Where to run
err = clGetDeviceIDs(platform, CL_DEVICE_TYPE_GPU, 1, &device_id, NULL);
if (err != CL_SUCCESS) return -1;
```

Context

```
context = clCreateContext(0, 1, &device_id, NULL, NULL, &err);
if (!context) return -1;
commands = clCreateCommandQueue(context, device_id, 0, &err);
if (!commands) return -1;
```

6: Kernel

```
    // What to run
program =
clCreateProgramWithSource(context, 1, (const
char **) & KernelSource, NULL, &err);
if (!program) return -1;

err = clBuildProgram(program, 0, NULL, NULL,
NULL, NULL);
if (err != CL_SUCCESS) return -1;
kernel = clCreateKernel(program, "hello", &err);
if (!kernel || err != CL_SUCCESS) return -1;
```

```
const char *KernelSource = "\n" \
"__kernel void hello(             \n" \
"   __global char* a,          \n" \
"   __global char* b,          \n" \
"   __global char* c,          \n" \
"   const unsigned int count)  \n" \
"{                          \n" \
"   int i = get_global_id(0);  \n" \
"   if(i < count)            \n" \
"       c[i] = a[i] + b[i];   \n" \
"}                          \n" \
"\n";
```

Most programs also load kernels from files

7-8: Get the data in there

```
    // Create space for data and copy a and b to device (note that we could also use clEnqueueWriteBuffer to upload)
    input = clCreateBuffer(context,  CL_MEM_READ_ONLY | CL_MEM_USE_HOST_PTR,  sizeof(char) * DATA_SIZE, a, NULL);
    input2 = clCreateBuffer(context,  CL_MEM_READ_ONLY | CL_MEM_USE_HOST_PTR,  sizeof(char) * DATA_SIZE, b, NULL);
    output = clCreateBuffer(context, CL_MEM_WRITE_ONLY, sizeof(char) * DATA_SIZE, NULL, NULL);
    if (!input || !output) return -1;

    // Send data
    err  = clSetKernelArg(kernel, 0, sizeof(cl_mem), &input);
    err |= clSetKernelArg(kernel, 1, sizeof(cl_mem), &input2);
    err |= clSetKernelArg(kernel, 2, sizeof(cl_mem), &output);
    err |= clSetKernelArg(kernel, 3, sizeof(unsigned int), &count);
    if (err != CL_SUCCESS) return -1;
```

9-10: Run kernel, wait for completion

```
// Run kernel!
err = clEnqueueNDRangeKernel(commands, kernel, 1,
NULL, &global, &local, 0, NULL, NULL);

if (err != CL_SUCCESS) return -1;

clFinish(commands);
```

11-12: Read back data, release

```
// Read result
err = clEnqueueReadBuffer( commands, output, CL_TRUE, 0,
sizeof(char) * count, c, 0, NULL, NULL );
if (err != CL_SUCCESS) return -1;

//    Print result
printf("%s\n", c);

// Clean up
clReleaseMemObject(input);
clReleaseMemObject(output);
clReleaseProgram(program);
clReleaseKernel(kernel);
clReleaseCommandQueue(commands);
clReleaseContext(context);
```

”Platform” vs ”device”

Platform = an OpenCL implementation

Device = a chip which the platform supports

Language freedom… sort of

+ Very easy to call from any language! Anything that can call into a C API can call OpenCL!

- Kernel code is only C-style (although a specific implementation may choose to support more).

Performance

Investigations report remarkably small differences

Our research on FFT so far has CUDA up to 2x faster

Very hard to compare, due to multiple OpenCL implementations

Some report CUDA to be better on NVidia platforms... some report a draw even there.

Our experience: Usually very close!

Conclusions on OpenCL

Don’t fear the complex setup phase! The rest is similar to CUDA.

Performance tend to be on par with CUDA or almost.

Speciality: heterogenous systems!