ECE 574 – Cluster Computing
Lecture 17

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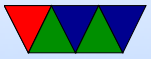
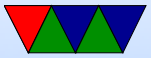
Announcements

- Don't forget HW#8
- HW#9 will be assigned

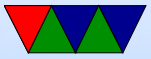


OpenCL

- CUDA is only for NVIDIA GPUs
- What if you have Intel or AMD (ATI) chip? Or ARM MALI? or Raspberry Pi Vcore IV?
- OpenCL is sort of like CUDA, but cross-platform
- Not only for GPUs, but can target regular CPU, DSP, FPGAs, etc
- Vendor provides a driver

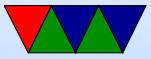


- Khronos (the OpenGL + Vulkan people?) also run OpenCL
- Windows, OSX, Linux



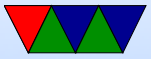
OpenCL History

- Started by Apple
- Donated to Khronos
- Apple has abandoned it



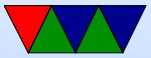
Installing OpenCL (Linux)

- NVIDIA is actually easiest, especially if you already have CUDA going
- AMD you need to install proprietary driver, not very easy
- Intel GPU has project could Beignet

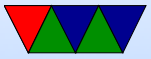


OpenCL program Flow

- Allocate host buffer
- Get platform/device
- Set up platform
- Choose device
- Create context
- Create command queue
- Create memory buffer on device
- Copy buffer to device
- Create a program kernel

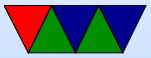


- Build kernel
- Set arguments
- Execute
- Read back results
- clean up and wait to finish
- Release



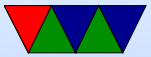
Platforms

- Query number of platforms
- `clGetPlatformIDs()`
- Then malloc space, and use same function to get info
- Can iterate and get NAME, VENDOR, VERSION



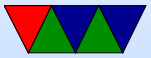
Devices

- Now when got platform, similarly `clGetDeviceIDs()`
- Why multiple? Intel or AMD CPU might have both CPU and GPU



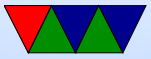
Memory Hierarchy

- global – shared by all, but high latency
- constant – read only by all but cpu, smaller, a bit faster
- local – shared by a group of cores on device
- register – per element



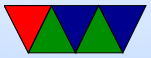
Language

- Based on C
- pointers annotated with memory level
- some things not allowed: recursion, function pointers
- regular data types, some others like vectors
- With OpenCL 2.x more similar to C++
- Plan is to merge it with Vulkan



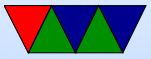
Iterations in the kernel

- A lot like CUDA, where split into 1D, 2D, or 3D grid.
- get_global_id();
- get_local_id();
- get_num_groups();
- get_group_size()
- get_group_id()

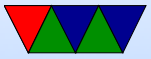


Calling the kernel

```
clEnqueueNDRangeKernel(
    command_Queue kernel,
    work_dim,
    global_work_offset,
    global_work_size,
    local_work_size,
    event_wait_list
    event);
```

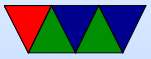


Contexts

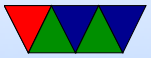


Command Queue

- FIFO or out of order (always issued in order)

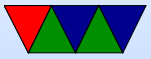


OpenCL ICD (installable client driver)



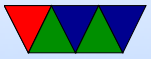
Memory Config

- Memory flags. r/w, ro, wo
- Whether host pointer or not
- Using host pointers might not be fast if
- depending on arch
- sub-buffer?



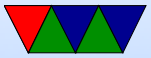
Copying to/from Device

- copying mem
- host to device
- device to device

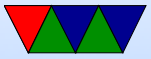


Creating Kernels

- The driver builds them
- From source, you pass in as a string
- Can get binary-only kernels (why?)
  - Proprietary?
  - also, not have to build each time
- clCreateProgramWithSource()
- clCreateProgramWithBinary()
- Can get error log of build when something went wrong

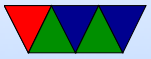


SPIR – standard portable Intermediate Representation

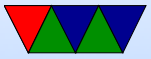


Setting kernel arguments

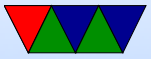
- must do this before running



Executing Kernel

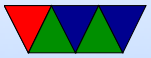


Querying Kernel



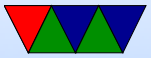
Synchronization

- when neeed?
- single device, out of order queue
- multiple devices?
- coarse grained
  - clFlush/clFinish
- fine grained
  - event based
- memory fences?
- CL event, for communicating

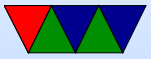


OpenCL C Programming

- Own built in data types: basic app vector app_vector char cl_char charn cl_charn etc
  why? portable. sadly sizes not same on windows/linux
- n element 2,3,4,8,16 sizes
- "half" type for 16-bit fp
- address space qualifiers
  - __global
  - __local
  - __constant

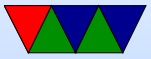


- __private



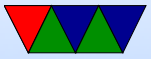
OpenCL – compiling

```
  gcc -I include -L /lib -lOpenCL
saxpyc -o saxxpy
```



Demo, sample code

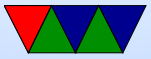
- Try out `clinfo` program



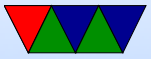
SAXPY Sample Code

Single-precisison A*X+Y vector add

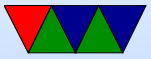
```
void saxpy(int n, float a, float *x, float *y, float *out) {
    for(i=0;i<n;i++) {
        out[i]=a*x[i]+y[i];
    }
}

#include <CL/cl.h>

const char *saxpy_kernel=
"__kernel\n"
"void saxpy_kernel(float a,\n"
"    __global float *A,\n"
"    __global float *B,\n"
"    __global float *out) {\n"
"    int index=get_global_id(0);\n"
"    out[index]=alpha*A[index]+B[index];\n"
"}\n";

#define N 1024
```



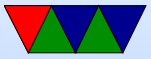
```
int main(int argc, char **argv) {
    int i;
    float alpha=5.0;
    float *A=(float *)malloc(sizeof(float)*N);
    float *B=(float *)malloc(sizeof(float)*N);
    float *C=(float *)malloc(sizeof(float)*N);

    for(i=0;i<N;i++) { A[i]=i; B[i]=10*i; C[i]=0;}

// get platform
cl_platform_id *platforms=NULL;
cl_uint num_platforms;
cl_int clStatus=clGetPlatformIDs(0,NU,&num_platforms);
platforms=(cl_platform_id 8)malloc(sizeof(cl_platform_id)*num_platforms);
clStatus=clGetPlatformIDs(num_platforms, platforms,NULL);

cl_device_id *device_list=NULL;
cl_uint num_devices;
clStatus = clGetDeviceIDs(platforms[0],CL_DEVICE_TYPE_GPU,0,NULL,&num_devices);
device_list=(cl_device_id *)malloc(sizeof(cl_device_ids)*num_devices);
clStatus=clGetDeviceIDs(platforms[0],CL_DEVICE_TYPE_GPU,num_devices,
    device_list,NULL);
// create context
```



```
cl_context context;
context=clCreateContext(NULL, num_devices,device_list,NUL,NULL,&clStatus);
// Create command queue
cl_commad_queue command_queue=clCreateCommandQeueu(contet,device_list[],0,
    &clStatus);
// create memory buffer on device
cl_mem A_clmem=clCreateBuffer(context,CL_MEM_READ_ONLY,
    VECTOR_SIZE*sizeof(float),NULL,&clStatus);
cl_mem B_clmem=clCreateBuffer(context,CL_MEM_READ_ONLY,
    VECTOR_SIZE*sizeof(float),NULL,&clStatus);
CL_MEM_WRITE_ONLY cl_mem C_clmem=clCreateBuffer(context,CL_MEM_READ_ONLY,
    VECTOR_SIZE*sizeof(float),NULL,&clStatus);

// Copy buffer a and b to device
clStatus=clEnqueueWriteBuffer(command_Queue, A_clmem,
    CL_TRUE,0,VECTOR_SIZE*sizeof(float),A,0,NULL,NULL);
clStatus=clEnqueueWriteBuffer(command_Queue, A_clmem,
    CL_TRUE,0,VECTOR_SIZE*sizeof(float),A,0,NULL,NULL);

// create a program
cl_program program=clCreatePrograWithSource(context,1,
        (const char **)&saxpy_kernel,NULL,&clStatus);
// build program
clStatus=clBuildProgram(program,1,device_list,NULL,NULL,NUL);
```



```
// create OpenCL kernel
cl_kernel kerne;=clCreateKernel(program,"saxmpu_kernel",&clStatus);

// Set Arguments
clStatus=clSetKernelArg(kernel,0,sizeof(float),)coid *)&alpha);
clStatus=clSetKernelArg(kernel,1,sizeof(cl_mem),(coid *)&A_clmem);
clStatus=clSetKernelArg(kernel,2,sizeof(cl_mem),
(void *)&B_clmem);
CclStatus=clSetKernelArg(kernel,2,sizeof(cl_mem),
(void *)&B_clmem);

// excute kernel

size_t global_size=VECTOR_SIZE;
size_t local_size=64;
clStatus=clEnqueueNDRangeKernel(command_Queue,ekernel,1,NULL,&global_szize,
    &loca-size,0,NULL,NULL);

// Read out results
clStatus=clEnqueueReadBuffer(command_queue,C_clemem, CL_TRUE,0,
    VECTOR_SIZE*sizef(float),C,0,NULL,NULL)

// cleanp
clStatus=clFlush(command_queue);
```



```
clStatus=clFinish(command_queue);

// display results
for(i=0;i<VECTOR_SIZE;i++)
printf("%d %d %d %d alhpha"A[i],B[i],Cpi[);

// release
clstatus=ClReleaseKenrle(kernel);
clReleaseProgram(program);
clReleaseMemoObject(A_clmem);
clstatus=clReleaseCommandQueue(command_Queue);
clStatus=clReleaseContet(context);
free(A);
free(B);
free(C);
}
```