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## 1 Overview

**1.1 Location** `$<APPSDKSamplesInstallPath>\samples\opencl\cl\`

**1.2 How to Run** See the *Getting Started* guide for how to build samples. You first must compile the sample.

Use the command line to change to the directory where the executable is located. The pre-compiled sample executable is at `$<APPSDKSamplesInstallPath>\samples\opencl\bin\x86\` for 32-bit builds, and `$<APPSDKSamplesInstallPath>\samples\opencl\bin\x86_64\` for 64-bit builds.

Type `Template`. This initializes input from 0 to 255. Multiplies each input element by a scalar multiplier (the default is 2), and stores the result in the output using OpenCL kernels.

## 2 Introduction

This is a stand-alone OpenCL sample, independent of any utility libraries in the SDK. It is an easy sample for a new user to start coding and learn OpenCL.

The Template kernel is an OpenCL kernel that multiplies each element of the input array with a scalar, then stores it in the output array.

A new user can write a new sample by replacing the Template sample.

## 3 Implementation Details

This section shows how to write a simple OpenCL program. An OpenCL program comprises of:

1. Allocating and initializing any input and output memory.
2. Initializing OpenCL.
  - a. Open a device (CPU/GPU) specific context.
  - b. Query for a list of devices in that particular context.
  - c. Open a context on the device of your choice.
  - d. Create a command-queue on the context, which is associated to a device.

OpenCL objects such as memory, program, and kernel objects are created using a context. Operations on these objects are performed using a command-queue. The command-queue can be used to queue a set of operations (referred to as commands) in order. See reference [1].

- e. Create memory buffers (the memory buffers that an OpenCL program/kernel can access).
- f. Create and build an OpenCL program.

An OpenCL program consists of a set of kernels. Programs also can contain auxiliary functions called by the `__kernel` functions and constant data. There are different ways of creating an OpenCL program; one way is to create from a source, the other is to create from the binary that is obtained by compiling the OpenCL program.

- g. Create a Kernel by providing the kernel function name.

A kernel is a program that runs on an OpenCL device/compute device.

3. Provide arguments to the kernels, and run the kernels.
  - a. All the arguments that must be passed to the kernel are set here.
  - b. Run the kernel.
4. Clean up and release all the structures created for OpenCL.
  - a. Release the created OpenCL memory buffers.
  - b. Release the context created.
5. Deallocate any memory allocated specifically for this program unrelated to OpenCL.

See reference [1] for a detailed explanation of the terminology.

### 3.1 Initializing OpenCL

```
context = clCreateContextFromType(0, CL_DEVICE_TYPE_CPU, NULL, NULL, &status);
```

This creates an OpenCL context for the CPU devices on the system; on successful creation, it returns a valid context. The status is set to `CL_SUCCESS` on successful creation of *context*. For error codes, see reference [1].

```
status = clGetContextInfo(context, CL_CONTEXT_DEVICES, 0, NULL, &deviceListSize);
```

By passing only `CL_CONTEXT_DEVICES` as the second argument and *deviceListSize* as the fifth, we get the number of devices in this context to allocate memory for the list of devices.

```
status = clGetContextInfo(context, CL_CONTEXT_DEVICES, deviceListSize, devices, NULL);
```

This passes the *deviceListSize* and *devices* in order to get all the information regarding each of devices on the device list.

```
commandQueue = clCreateCommandQueue(context, devices[0], 0, &status);
```

This creates a command-queue on a specific device; here, *devices[0]*.

```
inputBuffer = clCreateBuffer(context, CL_MEM_READ_WRITE | CL_MEM_USE_HOST_PTR,
sizeof(cl_uint) * width, input, &status);
```

A memory buffer (accessible to OpenCL kernels and programs) is created by providing the necessary arguments. `CL_MEM_READ_WRITE` indicates that the memory buffer object can be used

to read from it and write to it. `CL_MEM_USE_HOST_PTR` indicates that the buffer uses only a host pointer to create the buffer object. This pointer is the *input* of size `sizeof(cl_uint)*width`. This means any read and write operation in the OpenCL kernel is similar to reading and writing to the *input* array. On successful creation of *inputBuffer*, the status stores `CL_SUCCESS`.

```
const char * filename = "Template_Kernels.cl";
const char * source   = convertToString(filename).c_str();
size_t sourceSize[]   = { strlen(source) };
```

The `filename` stores the path for the openCL kernel. The kernel is converted into a string and stored in `source`; `sourceSize` stores the length of the kernels.

```
program = clCreateProgramWithSource(
    context,
    1,
    &source,
    sourceSize,
    &status);
```

This creates a program object for a context so that it can be run on each device that belongs to *devices* array. The 1 denotes the number of devices on which the program object is to be created.

```
status = clBuildProgram(program, 1, devices, NULL, NULL, NULL);
```

This compiles and links all the binary files supplied to the program in the previous step, and builds the `program` object for all the devices in the `devices` list, which is given as an argument. The 1 denotes the number of devices in the `devices` list.

```
kernel = clCreateKernel(program, "templateKernel", &status);
```

This provides a handle to a particular kernel by passing the entry point (the name by which the kernel function is defined).

## 3.2 Run OpenCL Programs

```
globalThreads[0] = width;
localThreads[0]  = 1;
```

These variables define the number of times a kernel executes. Here, it executes in a 1-dimensional index space, with the number of threads equal to *width*.

```
status = clSetKernelArg(kernel, 0, sizeof(cl_mem), (void *)&outputBuffer);
status = clSetKernelArg(kernel, 1, sizeof(cl_mem), (void *)&inputBuffer);
status = clSetKernelArg(kernel, 2, sizeof(cl_uint), (void *)&multiplier);
```

This sets the first, second, and third arguments to the kernel.

```
status = clEnqueueNDRangeKernel(
    commandQueue,
    kernel,
    1,
    NULL,
    globalThreads,
    localThreads,
```

```
0,
NULL,
&events[0]);
```

This queues the instructions for a particular devices through the *commandQueue* of that device. It instructs the device to run the kernel in 1-dimensional index space (third argument) with the dimensions stored in *globalThreads* array. The *events[0]* returns an event object that identifies the particular kernel execution instance.

```
status = clWaitForEvents(1, &events[0]);
```

This is a waiting loop that breaks on successful execution of the kernel.

### 3.2.1 Release and Clean Up OpenCL

```
status = clReleaseMemObject(inputBuffer);
```

This releases the structures created to maintain the memory buffer object used. In this example, it releases all the memory allocation for maintaining *inputBuffer*.

```
status = clReleaseContext(context);
```

This releases the context and all the devices that it has created.

### 3.2.2 OpenCL Kernel

```
__kernel void templateKernel(__global unsigned int * output,
                             __global unsigned int * input,
                             __const unsigned int multiplier)
```

The `__kernel` denotes that the function is a kernel function. It has three arguments: *output* array (the output buffer is passed as an argument), *input* array (the input Buffer created is passed as an argument), and *multiplier* (which is a constant).

```
uint tid = get_global_id(0);
```

This provides the thread id in the global execution space. For this kernel, the execution space is the same size as that of the array (*output*, *input*). Thus, each instance of the kernel that is executed has associated with it an element in the array.

```
output[tid] = input[tid] * multiplier;
```

Depending on the threadid(*tid*), we take an element in the input array, multiply it with a scalar, and store the output at the corresponding location in the output array.

## 4 References

1. <http://www.khronos.org/opencv/>

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