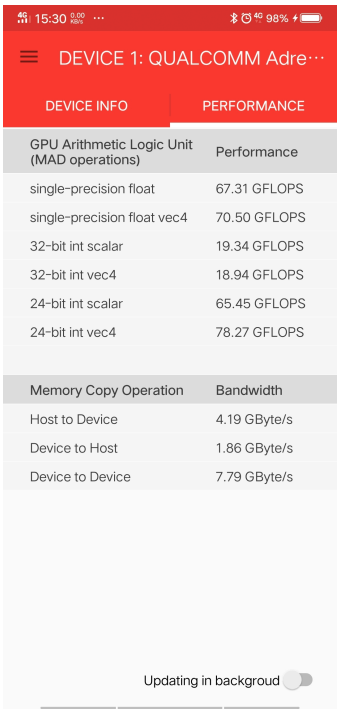
Android--学习笔记--OpenCL接口编程类

OpenCL支持API 21以上的某些Android设备，具体支持得看芯片厂商爸爸给不给力了，不仅仅如此，OpenCL在X86体系基本都有集成，不仅仅是Mac、Ubuntu、Windows、Android等os。详细的网站页可以参考：

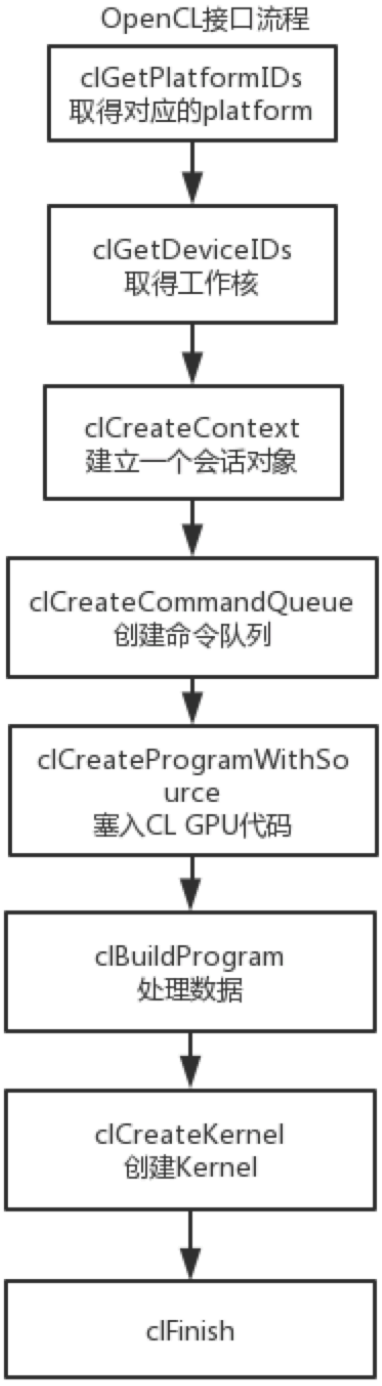
https://software.intel.com/en-us/iocl-tec-opg-opencl-standard

对应的官方文档中，都有详细的介绍，如果是Android，想要查看是否支持OpenCL GPU运算。可以用一个GPU测试工具OpenCL-Z工具去查看，可以显示当前手机GPU的型号和厂商信息。包括有几个GPU核心都可以看到。

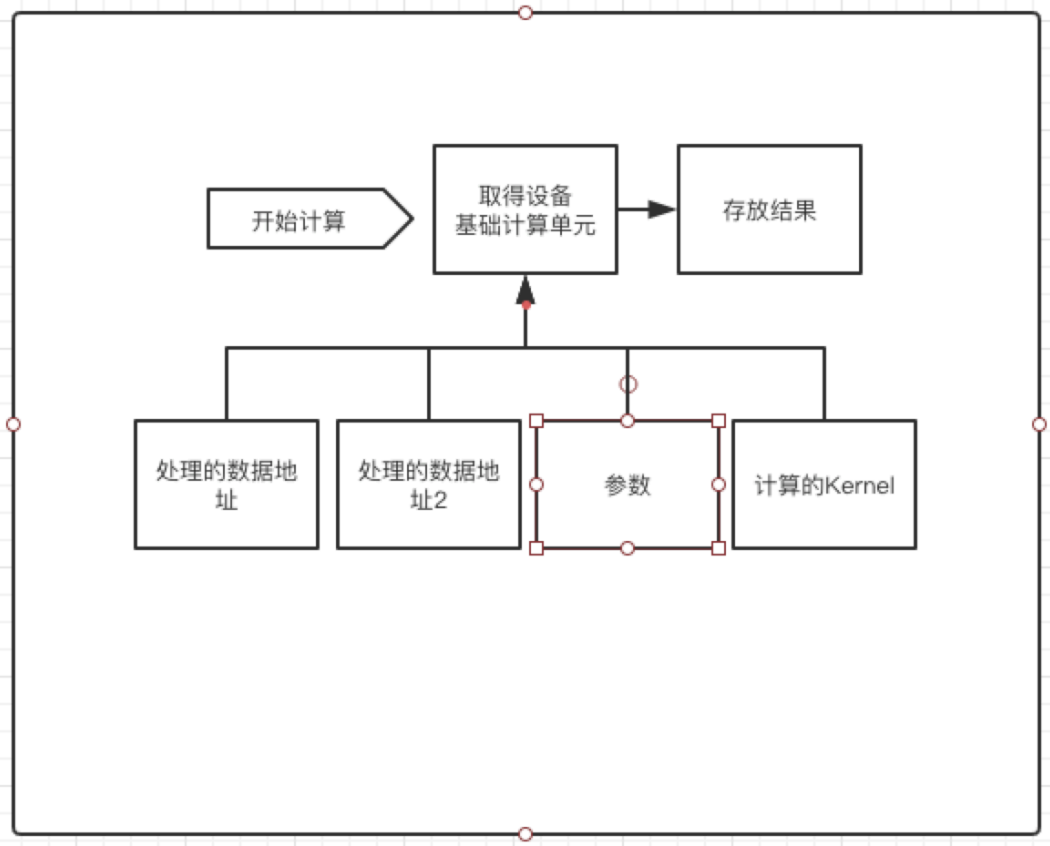


笔者使用的是某国产手机，就是性价比极低，总喜欢用低价的硬件卖优化的某厂出品。但是凑活着能用。

看完Inter关于OpenCL的介绍，我们大致上可以了解到一些关于openCL是什么，他本身就是GPU开放给第三方应用的FPGA接口API的形式。撸了一遍源码，发现了一个大致的使用流程如下：



当中在塞入GPU代码段方面，还有配置参数、设置输入数据和输出数据地址方面的动作，具体视业务模块变化而变化。可能熟悉FPGA的同学都明白FPGA是一种可编程的硬件模块，并且运算效率算是比较高的。FPGA可以模拟任何的数字电路元器件，可以是GPU，也可以是CPU。而CL的接口实现原理差不多也沿用了这种思维模式。首先取得一个设备，然后在这个设备计算单元中塞入数据、代码。然后控制模块计算按照建立的模型计算数据，最后，从地址中读取相应的计算结果。差不多就是这样的一个流程。



上面那个流程比较形象的说明具体的流程模式。接下来是实际的介绍如何开始第一个应用程序的编写了。首先在官网取得对应版本OpenCL的接口方法定义头文件，这里有两个方式去搞：

- 自己编写Android.mk或者新的bp，然后去引用系统的so、头文件。官方源历程也是这样编写的。（只是用了mac，而且inter介绍的英文太多，下载了studio和docker，感觉那是一堆LOT的东西，比较烦）。
- 在cmake中包含库、头文件。打包成so，和普通集成的AS环境类似。(这里可以用省力的方式，直接提取手机的libopencl.so)

- 例子(我们现在要实现的测试功能是A数组和B数组进行累加计算，并且把结果保存到result数组中)

第一种方式觉得比较麻烦，这里重点介绍一下第二种方式的实际运行过程。首先新弄一个工程叫imageDemo，然后link C++，新建一个JAVA类比如叫ImageNativeInterface.java，然后开始编写我们的Demo接口：

```
package com.genesis.imageNative;

import android.graphics.Bitmap;
```

```
/**
* 项目名称：ImageDemo
* 类描述：
* 创建人：genesis
* 创建时间：2019/4/10 5:45 PM
* 修改人：genesis
* 修改时间：2019/4/10 5:45 PM
* 修改备注：
*/
public class ImageNativeInterface {

    private static volatile ImageNativeInterface mInterface;

    public static ImageNativeInterface getInstance () {
        if (mInterface == null) {
            mInterface = new ImageNativeInterface();
        }
        return mInterface;
    }
    private ImageNativeInterface () {

    }
    public int openclDemo (int[] arrayA, int[] arrayB, int[] result, String
kernelCode,
                           float[] runningTime) {
        return nOpenCLDemo(arrayA, arrayB, result, kernelCode,
runningTime);
    }
    public int nativeAdd (int[] arrayA, int[] arrayB, int[] result) {
        return nNativeAdd(arrayA, arrayB, result);
    }
    //fixme 接口native
    private static native int nOpenCLDemo (int[] arrayA, int[] arrayB,
int[] result,
                                           String kernelCode, float[]
runningTime);
    //fixme 本地C++ CPU计算数组
    private static native int nNativeAdd(int[] arrayA, int[] arrayB, int[]
result);
    static {
        try {
            System.loadLibrary("gimage");
        } catch (Exception e) {
            System.out.println("LoadLib error");
        }
    }
}
```

接着编写相关C++的代码实现部分：

```
#include <jni.h>
```

```
#include <string>
#include <android/log.h>
#include <android/bitmap.h>
#include <cstring>
#include <android/asset_manager.h>
#include <android/log.h>
#include <cstring>
#include <android/asset_manager.h>
#include <time.h>
#include <stdlib.h>
#include "CL/cl.h"


#define    EXIT_FAILURE    1
#define    EXIT_SUCCESS    0

#define    RAND_MAX    0x7fffffff
#define  LOG_TAG    "libGenesisBitmap"

#define  LOGI(...)
__android_log_print(ANDROID_LOG_INFO,LOG_TAG,__VA_ARGS__)
#define  LOGE(...)
__android_log_print(ANDROID_LOG_ERROR,LOG_TAG,__VA_ARGS__)
#define MAX_PLATFORMS_COUNT     16
#define CL_SUCCEEDED(clErr) CL_SUCCESS==clErr
#define CL_FAILED(clErr) CL_SUCCESS!=clErr

void addArrays(const int* arrayA, const int* arrayB, const int*
Result, int length,
               const char* kernelCode, float* runTime)
{

    cl_platform_id     platform     = 0;
    cl_device_type     clDEviceType = CL_DEVICE_TYPE_CPU; //
default
    cl_kernel          kernel       = 0;
    cl_command_queue   cmd_queue    = 0;
    cl_context         context      = 0;
    cl_mem             memobjs[3];
    cl_program         program      = 0;
    cl_int             clErr;
    unsigned long long startTime    = 0, endTime = 0;

    // get current platform id, assuming there are no more than 16
platforms in the system
    cl_platform_id pPlatforms[MAX_PLATFORMS_COUNT] = {0};
    cl_uint        uiPlatformsCount                = 0;
    clErr = clGetPlatformIDs(MAX_PLATFORMS_COUNT, pPlatforms,
&uiPlatformsCount);
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
uiPlatformsCount: %d", clErr,
```

```
                            uiPlatformsCount);
    if (CL_FAILED(clErr) || 0 == uiPlatformsCount)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "ERROR:
Failed to find any platform.");
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
uiPlatformsCount: %d", clErr,
                                uiPlatformsCount);
        return;
    }

    // go through the available platform and select our (vendor =
"Intel Corporation")
    cl_uint num_device;
    cl_uint num_platform;
    cl_platform_id* platformtag;
    cl_device_id  * devices;


    clErr       = clGetPlatformIDs(0, 0, &num_platform);
    platformtag = (cl_platform_id*) malloc(sizeof(cl_platform_id)
* num_platform);
    clErr       = clGetPlatformIDs(num_platform, platformtag,
NULL);

    clErr   = clGetDeviceIDs(platformtag[0], CL_DEVICE_TYPE_GPU,
0, NULL, &num_device);
    devices = (cl_device_id*) malloc(sizeof(cl_device_id) *
num_device);
    clErr   = clGetDeviceIDs(platformtag[0], CL_DEVICE_TYPE_GPU,
num_device, devices, NULL);

    //create context
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "create
context");
    cl_context_properties properties[] = {CL_CONTEXT_PLATFORM,
(cl_context_properties) platform,
                                          (cl_context_properties)
NULL};
    context = clCreateContext(NULL, num_device, devices, NULL,
NULL, &clErr);;
    if (0 == context)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to create context",
                                clErr);
        return;
    }

    // get context's devices
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "get context's
```

```
devices");
    cl_device_id device = 0;
    clErr = clGetContextInfo(context, CL_CONTEXT_DEVICES,
sizeof(cl_device_id), &device, NULL);
    if (CL_FAILED(clErr) || 0 == device)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to get context info",
                            clErr);
        clReleaseContext(context);
        return;
    }

    // create a command-queue
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "create a
command-queue");
    cmd_queue = clCreateCommandQueue(context, device, 0, NULL);
    if (cmd_queue == (cl_command_queue) 0)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG,
                            "clErr: %d - Failed to create command
queue", clErr);
        goto release_context;
    }
    size_t global_work_size[1];
    size_t local_work_size[1];

    // allocate the buffer memory objects
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "allocate the
buffer memory objects");

    memobjs[0] = clCreateBuffer(context, CL_MEM_READ_ONLY |
CL_MEM_USE_HOST_PTR,
                                sizeof(int) * length, (void*)
arrayA, NULL);
    if (memobjs[0] == (cl_mem) 0)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "Failed to
create memobjs[0]");
        goto release_queue;
    }

    memobjs[1] = clCreateBuffer(context, CL_MEM_READ_ONLY |
CL_MEM_USE_HOST_PTR,
                                sizeof(int) * length, (void*)
arrayB, NULL);
    if (memobjs[1] == (cl_mem) 0)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "Failed to
create memobjs[1]");
        goto release_mem0;
```

```
    }

    memobjs[2] = clCreateBuffer(context, CL_MEM_READ_WRITE,
sizeof(int) * length, NULL, NULL);
    if (memobjs[1] == (cl_mem) 0)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "Failed to
create memobjs[2]");
        goto release_mem1;
    }

    // create program
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "create
program");
    program = clCreateProgramWithSource(context, 1, (const char**)
&kernelCode, NULL, &clErr);
    if (CL_FAILED(clErr) || 0 == program)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to create program",
                            clErr);
        goto release_mem2;
    }

    // build program
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "build
program");
    clErr = clBuildProgram(program, 1, &device, NULL, NULL, NULL);
    if (CL_FAILED(clErr))
    {
        size_t len;
        char   buffer[2048];
        clGetProgramBuildInfo(program, device,
CL_PROGRAM_BUILD_LOG, sizeof(buffer), buffer, &len);
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG,
                            "clErr: %d - Failed to build program\n
Log: %s", clErr, buffer);
        goto release_program;
    }

    // create the kernel
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "create
kernel");
    kernel = clCreateKernel(program, "vadd", NULL);
    if (kernel == (cl_kernel) 0)
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to create kernel",
                            clErr);
        goto release_program;
    }
```

```
    // set the args values
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "set the args
values");
    clErr = clSetKernelArg(kernel, 0, sizeof(cl_mem), (void*)
&memobjs[0]);

    clErr |= clSetKernelArg(kernel, 1, sizeof(cl_mem), (void*)
&memobjs[1]);

    clErr |= clSetKernelArg(kernel, 2, sizeof(cl_mem), (void*)
&memobjs[2]);

    if (CL_FAILED(clErr))
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG,
                            "clErr: %d - Failed to set kernel
arguments", clErr);
        goto release_all;
    }

    // set work-item dimensions
    global_work_size[0] = length;
    local_work_size[0]  = 512;

    // execute kernel
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "execute
kernel");
    struct timespec tp;
    clock_gettime(CLOCK_MONOTONIC, &tp);
    startTime = (unsigned long long) (tp.tv_sec * 1000000000 +
tp.tv_nsec);
    clErr     = clEnqueueNDRangeKernel(cmd_queue, kernel, 1, NULL,
global_work_size,
                                       local_work_size, 0, NULL,
NULL);
    if (CL_FAILED(clErr))
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to execute kernel",
                            clErr);
        goto release_all;
    }
    clErr = clFinish(cmd_queue);
    if (CL_FAILED(clErr))
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to finish queue",
                            clErr);
        goto release_all;
    }
```

```
    clock_gettime(CLOCK_MONOTONIC, &tp);
    endTime = (unsigned long long) (tp.tv_sec * 1000000000 +
tp.tv_nsec);
    *runTime = (endTime - startTime) / 1000000.0f;
    // read output Buffer
    __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "read output
Buffer");

    clErr = clEnqueueReadBuffer(cmd_queue, memobjs[2], CL_TRUE, 0,
length * sizeof(int),
                                (void*) Result, 0, NULL, NULL);
    if (CL_FAILED(clErr))
    {
        __android_log_print(ANDROID_LOG_DEBUG, LOG_TAG, "clErr: %d
- Failed to read output Buffer",
                            clErr);
        goto release_all;
    }

    __android_log_print(ANDROID_LOG_INFO, LOG_TAG, "Done!");

    //release kernel, program, and memory objects
    release_all:
    clReleaseKernel(kernel);
    release_program:
    clReleaseProgram(program);
    release_mem2:
    clReleaseMemObject(memobjs[2]);
    release_mem1:
    clReleaseMemObject(memobjs[1]);
    release_mem0:
    clReleaseMemObject(memobjs[0]);
    release_queue:
    clReleaseCommandQueue(cmd_queue);
    release_context:
    clReleaseContext(context);
    return;
}

extern "C"
JNIEXPORT jint
JNICALL
Java_com_genesis_imageNative_ImageNativeInterface_nOpenCLDemo(JNIEnv* env,
jclass type,
                                                              jintArray
arrayA_, jintArray arrayB_,
                                                              jintArray
result_,
                                                              jstring
kernelCode_,
                                                              jfloatArray
```

```
runningTime)
{
    int   * c_arrayA  = env->GetIntArrayElements(arrayA_, NULL);
    int   * c_arrayB  = env->GetIntArrayElements(arrayB_, NULL);
    int   * c_Result  = env->GetIntArrayElements(result_, NULL);
    float* c_runTime = env->GetFloatArrayElements(runningTime, NULL);
    int length = env->GetArrayLength(arrayA_);
    const char* nativeKernelCode = env->GetStringUTFChars(kernelCode_, 0);
    addArrays(c_arrayA, c_arrayB, c_Result, length, nativeKernelCode,
c_runTime);
    env->ReleaseIntArrayElements(arrayA_, c_arrayA, 0);
    env->ReleaseIntArrayElements(arrayB_, c_arrayB, 0);
    env->ReleaseIntArrayElements(result_, c_Result, 0);
    env->ReleaseFloatArrayElements(runningTime, c_runTime, 0);
    return 1;
}

extern "C"
JNIEXPORT jint JNICALL
Java_com_genesis_imageNative_ImageNativeInterface_nNativeAdd(JNIEnv* env,
jclass type,
                                                             jintArray
arrayA_, jintArray arrayB_,
                                                             jintArray
result_)
{
    jint* arrayA = env->GetIntArrayElements(arrayA_, NULL);
    jint* arrayB = env->GetIntArrayElements(arrayB_, NULL);
    jint* result = env->GetIntArrayElements(result_, NULL);
    int length = env->GetArrayLength(arrayA_);
    for (int i = 0; i < length; ++i)
    {
        result[i] = arrayA[i] + arrayB[i];
    }
    env->ReleaseIntArrayElements(arrayA_, arrayA, 0);
    env->ReleaseIntArrayElements(arrayB_, arrayB, 0);
    env->ReleaseIntArrayElements(result_, result, 0);
    return 1;
}
```

那么问题来了，对应的CL接口代码是什么呢？接下来的这段字符文件即可：

```
__kernel void vadd(__global const int *a, __global const int *b, __global
int *c)
{
    int gid = get_global_id(0);
    c[gid] = a[gid] + b[gid];
}
```

关联OpenCL头文件和so.

```
# For more information about using CMake with Android Studio, read the
```

```
# documentation: https://d.android.com/studio/projects/add-native-code.html
# Sets the minimum version of CMake required to build the native library

cmake_minimum_required(VERSION 3.4.1)

# Creates and names a library, sets it as either STATIC
# or SHARED, and provides the relative paths to its source code.
# You can define multiple libraries, and CMake builds them for you.
# Gradle automatically packages shared libraries with your APK.

include_directories(${CMAKE_SOURCE_DIR}/src/main/cpp/include)
#add_library(libOpenCL SHARED IMPORTED)
#set_target_properties(libOpenCL PROPERTIES IMPORTED_LOCATION
#
${CMAKE_SOURCE_DIR}/src/main/jniLibs/opencl/${ANDROID_ABI}/libOpenCL.so)
add_library( # Sets the name of the library.
        gimage

        # Sets the library as a shared library.
        SHARED

        # Provides a relative path to your source file(s).
        src/main/cpp/native-lib.cpp)

# Specifies libraries CMake should link to your target library. You
# can link multiple libraries, such as libraries you define in this
# build script, prebuilt third-party libraries, or system libraries.

target_link_libraries( # Specifies the target library.
        gimage
        -ljnigraphics
        -lOpenCL
        log
        # Links the target library to the log library
        # included in the NDK.
        ${log-lib})
```

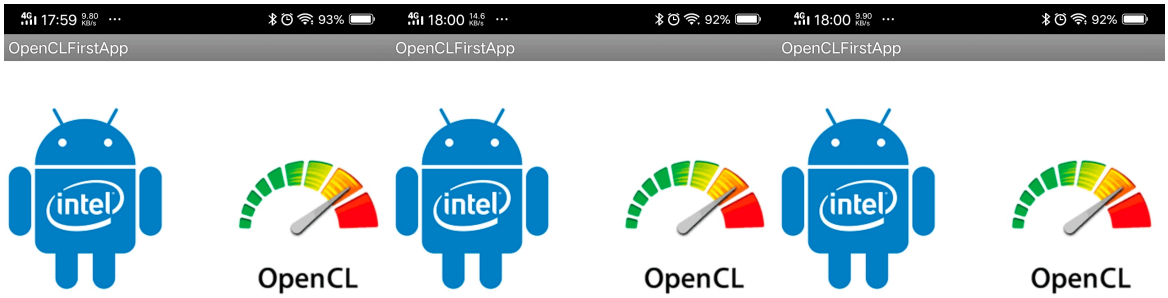
如上，我们就基本就实现了a数组和b数组进行叠加存入c数组的操作咯。OpenCL接口功能很强大，也具有一套自己的语法编辑规则。后面会举例其他例子。这里在贴下上层Java的代码段：

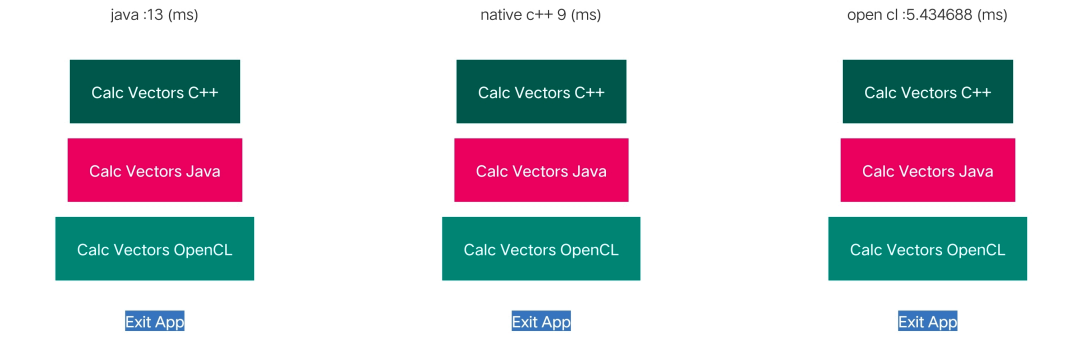
```
private static final int ARRAY_SIZE = 262144;

public void calcVectors (View view) {
    int[] arrayA = new int[ARRAY_SIZE];
    int[] arrayB = new int[ARRAY_SIZE];
    int[] arrayC = new int[ARRAY_SIZE];
    float[] execTime = new float[1];
    execTime[0] = 0;
    AssetManager am = getAssets();
    try {
```

```
        initArrays(arrayA, arrayB, arrayC, ARRAY_SIZE);
        InputStream is = am.open("OpenCLFirstApp_kernel.cl");
        String kernelCode = convertInputStreamToString(is);
        ImageNativeInterface.getInstance().openclDemo(arrayA, arrayB,
arrayC, kernelCode,
                execTime);
        //fixme 调用其他函数得到计算数据
    } catch (IOException e) {
        Log.d("oclDebug", e.toString());
    }
    String print = String.valueOf(execTime[0]);
    print += " (ms)";
    TextView myTextField = (TextView) findViewById(R.id.tv1);
    myTextField.setText(print);
}
```

调用这段方法就可以在OpenCL当中在GPU计算262144个数组累加的计算了。

运算结果对比：





OpenCL的算法编写是以字符的形式传入，我们这里也可以说说其他的代码，如果需要实际例子，可以参考openCV的相关kernel代码，有很多类比如高斯模糊，卷积都用了这类OpenCL接口。

- 总结

以上仅对Android 单纯单核心运算做了介绍，事实上，在Android 8.0之后的版本中，存在对AIT的优化，特别是循环运算、浮点数运算等等做了优化，实际上跑大容量固定值算法的时间周期在第一次可能会比较慢，但是在第二次启动同一段JAVA算法段，AIT会对相应的代码做优化处理。结果就会直接反应在性能上。8.0指令优化的点包括：

- 消除边界检查
    - 静态：在编译时证明范围位于边界内
    - 动态：运行时测试确保循环始终位于边界内（否则不进行优化）
- 消除归纳变量
    - 移除无用归纳
    - 用封闭式表达式替换仅在循环后使用的归纳
- 消除循环主体内的无用代码，移除整个死循环
- 强度降低
- 循环转换：逆转、交换、拆分、展开、单模等
- **SIMDization**（也称为矢量化）