МОСКОВСКИЙ АВИАЦИОННЫЙ ИНСТИТУТ
(НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ)

Институт №8 «Информационные технологии и прикладная математика»
Кафедра 806 «Вычислительная математика и программирование»

Лабораторная работа №1
по курсу «Программирование графических процессоров»

Освоение программного обеспечения для работы с технологией CUDA. Примитивные операции над векторами.

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А.Ю. Морозов

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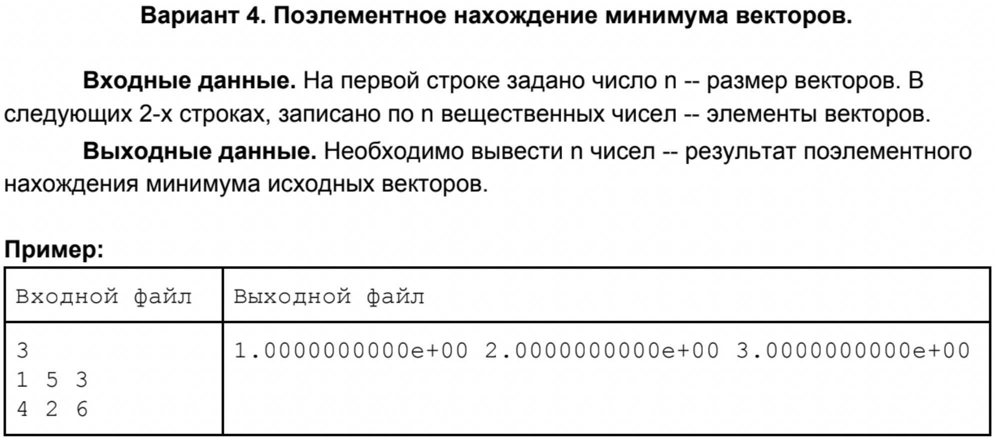
Условие

Цель работы. Ознакомление и установка программного обеспечения для работы с программно-аппаратной архитектурой параллельных вычислений(CUDA). Реализация одной из примитивных операций над векторами.



Вариант 4. Поэлементное нахождение минимума векторов.

Входные данные. На первой строке задано число n -- размер векторов. В следующих 2-х строках, записано по n вещественных чисел -- элементы векторов.

Выходные данные. Необходимо вывести n чисел -- результат поэлементного нахождения минимума исходных векторов.

Пример:

Входной файл	Выходной файл

3
1 5 3
4 2 6
	1.0000000000e+00 2.0000000000e+00 3.0000000000e+00

Программное и аппаратное обеспечение

Компилятор nvcc версии 7.0(g++ версии 4.8.4) на 64-х битной Ubuntu 14.04 LTS. Параметры графического процессора:

Compute capability : 6.1
Name : GeForce GTX 1050
Total Global Memory : 2096103424
Shared memory per block : 49152
Registers per block : 65536
Max threads per block : (1024, 1024, 64)
Max block : (2147483647, 65535, 65535)
Total constant memory : 65536
Multiprocessors count : 5

Метод решения

Ввод данных осуществляется в main, который работает на CPU. Далее заводятся три массива, данные которых будут храниться на стороне GPU, потому что GPU не сможет работать с памятью CPU. Первые два массива - копии введенных, в третий массив будет сохраняться результат обработки. В функции kernel на GPU идет распараллеливание обработки массива. Из-за того, что потоков может не хватить на весь размер n, каждый поток обрабатывает не по одному i-тому элементу, а по несколько через offset - шаг, общее число потоков. Индекс i с которого начинается обработка - абсолютный номер потока.

Далее по завершении обработки данные из результата dev_v3 записываются в v1, и выводятся отформатировано на экран через пробел.

Описание программы

Макрос **CSC** - макрос для отслеживания ошибок со стороны GPU, вызывается около функций для cuda и выводит текст ошибки при cudaError_t не равным cudaSuccess.
kernel - обработка массивов по потокам gpu.
main - ввод данных, подготовка для передачи данных kernel для обработки, вывод результата.

Результаты

Работа с GPU на разных конфигурациях ядер:

Тест:	Результаты в милисекундах:

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	kernel = <<<1, 256>>>, time = 0.008576
	kernel = <<<1, 512>>>, time = 0.008960
	kernel = <<<1, 1024>>>, time = 0.008768
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	kernel = <<<1024, 512>>>, time = 0.050144
	kernel = <<<1024, 1024>>>, time = 0.159360

100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
18 19 20 21 22 23 24 25 26 27 28 29 30 31
32 33 34 35 36 37 38 39 40 41 42 43 44 45
46 47 48 49 50 51 52 53 54 55 56 57 58 59
60 61 62 63 64 65 66 67 68 69 70 71 72 73
74 75 76 77 78 79 80 81 82 83 84 85 86 87
88 89 90 91 92 93 94 95 96 97 98 99
100 99 98 97 96 95 94 93 92 91 90 89 88 87
86 85 84 83 82 81 80 79 78 77 76 75 74 73
72 71 70 69 68 67 66 65 64 63 62 61 60 59
58 57 56 55 54 53 52 51 50 49 48 47 46 45
44 43 42 41 40 39 38 37 36 35 34 33 32 31
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16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
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(натуральные числа, одинаковые массивы)
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	kernel = <<<4, 128>>>, time = 14.532992
	kernel = <<<4, 256>>>, time = 8.678592
	kernel = <<<4, 512>>>, time = 8.086592
	kernel = <<<4, 1024>>>, time = 8.104352
	kernel = <<<8, 32>>>, time = 26.963680
	kernel = <<<8, 64>>>, time = 14.518112
	kernel = <<<8, 128>>>, time = 8.613312
	kernel = <<<8, 256>>>, time = 7.252800
	kernel = <<<8, 512>>>, time = 7.246560
	kernel = <<<8, 1024>>>, time = 7.154112
	kernel = <<<16, 32>>>, time = 14.480000
	kernel = <<<16, 64>>>, time = 8.597280
	kernel = <<<16, 128>>>, time = 7.252800
	kernel = <<<16, 256>>>, time = 7.310112
	kernel = <<<16, 512>>>, time = 7.302720
	kernel = <<<16, 1024>>>, time = 7.278496
	kernel = <<<32, 32>>>, time = 14.400352
	kernel = <<<32, 64>>>, time = 9.688256
	kernel = <<<32, 128>>>, time = 7.512960
	kernel = <<<32, 256>>>, time = 7.120128
	kernel = <<<32, 512>>>, time = 7.023456
	kernel = <<<32, 1024>>>, time = 7.024768
	kernel = <<<64, 32>>>, time = 11.301792
	kernel = <<<64, 64>>>, time = 8.282496
	kernel = <<<64, 128>>>, time = 7.156096
	kernel = <<<64, 256>>>, time = 7.068064
	kernel = <<<64, 512>>>, time = 7.030624
	kernel = <<<64, 1024>>>, time = 7.037024
	kernel = <<<128, 32>>>, time = 12.262656
	kernel = <<<128, 64>>>, time = 7.743232
	kernel = <<<128, 128>>>, time = 7.022464
	kernel = <<<128, 256>>>, time = 6.994752
	kernel = <<<128, 512>>>, time = 6.959456
	kernel = <<<128, 1024>>>, time = 7.019712
	kernel = <<<256, 32>>>, time = 11.622176

	kernel = <<<256, 64>>>, time = 7.289984
	kernel = <<<256, 128>>>, time = 7.007136
	kernel = <<<256, 256>>>, time = 6.968160
	kernel = <<<256, 512>>>, time = 6.956800
	kernel = <<<256, 1024>>>, time = 7.017312
	kernel = <<<512, 32>>>, time = 10.614240
	kernel = <<<512, 64>>>, time = 7.366944
	kernel = <<<512, 128>>>, time = 6.979104
	kernel = <<<512, 256>>>, time = 6.957280
	kernel = <<<512, 512>>>, time = 6.947520
	kernel = <<<512, 1024>>>, time = 7.040928
	kernel = <<<1024, 32>>>, time = 11.458048
	kernel = <<<1024, 64>>>, time = 7.212864
	kernel = <<<1024, 128>>>, time = 6.966656
	kernel = <<<1024, 256>>>, time = 6.957728
	kernel = <<<1024, 512>>>, time = 6.928064
	kernel = <<<1024, 1024>>>, time = 7.085184

Работа на CPU:

Тест:	Результат:

3
1 2 3
4 5 6
	0.002

100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
100 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
	0.004

10000 (натуральные числа, одинаковые массивы)	**0.059**
100000	**0.567**
1000000	**5.452**

10000000	**33.986**

Код программы для CPU:

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>


int main() {
    long long n;
    scanf("%lld", &n);

    double* v1 = (double*)malloc(n * sizeof(double));
    double* v2 = (double*)malloc(n * sizeof(double));

    for(long long i = 0; i < n; i++) {
        v1[i] = i;
    }
    for(long long i = 0; i < n; i++) {
        v2[i] = n - i;
   }

    clock_t begin = clock();
    for (long long i =0; i < n; i++) {
        if (v1[i] > v2[i]) {
            v1[i] = v2[i];
        }
    }
    clock_t end = clock();
    double time_spent = (double)(end - begin) / CLOCKS_PER_SEC;
    printf("%lf\n", time_spent);
    printf("\n");
    free(v1);
    free(v2);
    return 0;
}
```

Выводы

Программирование с распараллеливанием на CUDA осмысленно для больших объемов данных. На представленных мной маленьких массивах такое количество вызванных потоков в kernel лишь замедлило программу, потому что были “лишние” вычисления по определению, какому потоку что делать, и программа чисто на CPU справилась гораздо быстрее, просто последовательно сравнивая все элементы. Поэтому увидеть эффективность программы для GPU можно на очень больших данных, больше порядка 1000000, там время уже на порядок отличается.

Единственная сложность заключается в понимании, что GPU не умеет работать с данными записанными на CPU. Также важно понимать, что без написания специального макроса по отслеживанию ошибок, невозможно будет найти, почему программа отработала некорректно.