## 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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**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 п чисел -- результат поэлементного нахождения минимума исходных векторов.

#### Пример:

Входной файл	Выходной файл
3 1 5 3 4 2 6	1.000000000e+00 2.000000000e+00 3.000000000e+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:
3	kernel = <<<1, 32>>>, time = 0.025568
1 2 3	kernel = <<<1, 64>>>, time = 0.010528
4 5 6	kernel = <<<1, 128>>>, time = 0.008864
4 3 0	kernel = <<<1, 256>>>, time = 0.008576
	kernel = <<<1, 512>>>, time = 0.008960
	kernel = <<<1, 1024>>>, time = 0.008768
	kernel = <<<2, 32>>>, time = 0.008640
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	kernel = <<<2, 128>>>, time = 0.008288
	kernel = <<<2, 256>>>, time = 0.008672
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	kernel = <<<4, 128>>>, time = 0.008448
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	kernel = <<<8, 1024>>>, time = 0.008960
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	kernel = <<<16, 128>>>, time = 0.008448
	kernel = <<16, 256>>>, time = 0.008512
	kernel = $<<<16, 512>>>$ , time = $0.009024$
	kernel = <<<16, 1024>>>, time = 0.010336 kernel = <<<32, 32>>>, time = 0.008416
	kernel = <<32, 64>>>, time = 0.008410
	kernel = <<<32, 128>>>, time = 0.008448 kernel = <<<32, 256>>>, time = 0.008736
	kernel = <<<32, 512>>>, time = 0.008730
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	kernel = <<<64, 512>>>, time = 0.019440
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	Kerner 120, 52 , time - 0.007550

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18 19 20 21 22 23 24 25 26 27 28 29 30 31
                                                         kernel = <<<1, 256>>>, time = 0.008960
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                                                         kernel = <<<4, 128>>>, time = 0.009152
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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kemel = < <li>kemel = &lt;</li> <li>6, 64&gt;&gt;&gt;, time = 0.082720</li> <li>kemel = &lt;</li> <li>6, 256&gt;&gt;&gt;, time = 0.083552</li> <li>kemel = &lt;</li> <li>6, 256&gt;&gt;, time = 0.083552</li> <li>kemel = &lt;</li> <li>6, 512&gt;&gt;&gt;, time = 0.082560</li> <li>kemel = &lt;&lt;</li> <li>6, 1024&gt;&gt;, time = 0.083648</li> <li>kermel = &lt;&lt;&lt;</li> <li>3, 23&gt;&gt;, time = 0.083648</li> <li>kermel = &lt;&lt;&lt;</li> <li>3, 25&gt;&gt;, time = 0.097408</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>2, 64&gt;&gt;&gt;, time = 0.080992</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>2, 25</li> <li>time = 0.080032</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>2, 512&gt;&gt;&gt;, time = 0.080032</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>2, 512&gt;&gt;&gt;, time = 0.083360</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>4, 28&gt;&gt;&gt;, time = 0.17408</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>4, 64</li> <li>52&gt;&gt;&gt;, time = 0.079968</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>4, 512&gt;&gt;&gt;, time = 0.079968</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>4, 512&gt;&gt;&gt;, time = 0.079968</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>4, 512&gt;&gt;&gt;, time = 0.079968</li> <li>kermel = &lt;&lt;&lt;</li> <li>4, 512&gt;&gt;&gt;, time = 0.078968</li> <li>kermel = &lt;&lt;&lt; <li>5, 12&gt;&gt;, time = 0.078968</li> <li>kermel = &lt;&lt;&lt;&lt;</li> <li>128, 64&gt;&gt;&gt;, time = 0.078968</li> <li>kermel = &lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;128, 12&gt;&gt;&gt;, time = 0.078880</li> <li>kermel = &lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;128, 12&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;128, 12&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;128, 12&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;128, 512&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;6, 63&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&gt;&gt;6, 63&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;6, 12&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;5, 12&gt;&gt;&gt;, time = 0.078304</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;6, 64&gt;&gt;&gt;, time = 0.0795248</li> <li>kermel = &lt;&lt;&lt;&lt;&lt;&lt;&gt;&gt;6, 64&gt;&gt;&gt;, time = 0.079524</li> <li>kermel = &lt;&lt;&lt;&lt; &lt;&lt;&lt;&lt;&gt;&gt;10, 12&gt;&gt;, time = 0.079024</li> <li>kermel = &lt;&lt;&lt;&lt; &lt;&lt;&lt;&lt;&gt;&gt;10, 12&gt;&gt;, time = 0.079024</li> <li>kermel = &lt;&lt;&lt;&lt; &lt;&lt;&lt;&lt;&gt;10, 12&gt;&gt;, time = 0.079026</li> <li>kermel = &lt;&lt;&lt;&lt; &lt;&lt;&lt;&gt;10, 12&gt;&gt;, time = 0.079008</li> <li>kermel = &lt;&lt;&lt;&lt; &lt;&lt;&lt;&gt;10, 12&gt;&gt;, time = 0.079008</li> <li>kermel = &lt;&lt;&lt;&lt;</li></li>		1
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kernel = <<256, 32>>>, time = 0.113504 kernel = <<256, 64>>>, time = 0.081984 kernel = <<256, 128>>>, time = 0.078336 kernel = <<256, 256>>>, time = 0.077952 kernel = <<256, 512>>>, time = 0.080032 kernel = <<256, 1024>>>, time = 0.112512 kernel = <<512, 32>>>, time = 0.115584 kernel = <<512, 64>>>, time = 0.083776 kernel = <<512, 128>>>, time = 0.077408 kernel = <<512, 128>>>, time = 0.077408 kernel = <<512, 256>>>, time = 0.079008 kernel = <<512, 512>>>, time = 0.090528 kernel = <<512, 512>>>, time = 0.150176 kernel = <<1024, 32>>>, time = 0.115488 kernel = <<1024, 32>>>, time = 0.083712 kernel = <<1024, 64>>>, time = 0.083712 kernel = <<1024, 128>>>, time = 0.080288 kernel = <<1024, 256>>>, time = 0.088704 kernel = <<1024, 512>>>, time = 0.111712 kernel = <<1024, 1024>>>>, time = 0.111712 kernel = <<1024, 1024>>>>, time = 0.25600		1
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kernel = <<<256, 128>>>, time = 0.078336 kernel = <<<256, 256>>>, time = 0.077952 kernel = <<<256, 512>>>, time = 0.080032 kernel = <<<256, 1024>>>, time = 0.112512 kernel = <<<512, 32>>>, time = 0.115584 kernel = <<<512, 64>>>, time = 0.083776 kernel = <<<512, 128>>>, time = 0.077408 kernel = <<<512, 128>>>, time = 0.079008 kernel = <<<512, 256>>>, time = 0.079008 kernel = <<<512, 1024>>>, time = 0.150176 kernel = <<<1024, 32>>>, time = 0.150176 kernel = <<<1024, 32>>>, time = 0.083712 kernel = <<<1024, 128>>>, time = 0.083712 kernel = <<<1024, 128>>>, time = 0.080288 kernel = <<<1024, 512>>>, time = 0.080288 kernel = <<<1024, 512>>>, time = 0.080704 kernel = <<<1024, 512>>>, time = 0.11712 kernel = <<<1024, 1024>>>, time = 0.11712 kernel = <<<1024, 512>>>, time = 0.225600		1
$\begin{aligned} & \text{kernel} = <<<256, 256>>>, \text{time} = 0.077952\\ & \text{kernel} = <<<256, 512>>>, \text{time} = 0.080032\\ & \text{kernel} = <<<256, 1024>>>, \text{time} = 0.112512\\ & \text{kernel} = <<<512, 32>>>, \text{time} = 0.115584\\ & \text{kernel} = <<<512, 64>>>, \text{time} = 0.083776\\ & \text{kernel} = <<<512, 128>>>, \text{time} = 0.077408\\ & \text{kernel} = <<<512, 128>>>, \text{time} = 0.077408\\ & \text{kernel} = <<<512, 256>>>, \text{time} = 0.079008\\ & \text{kernel} = <<<512, 512>>>, \text{time} = 0.0990528\\ & \text{kernel} = <<<512, 1024>>>, \text{time} = 0.150176\\ & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488\\ & \text{kernel} = <<<1024, 432>>>, \text{time} = 0.080288\\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288\\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704\\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712\\ & \text{kernel} = <<<1024, 1024>>>>, \text{time} = 0.225600\\ \end{aligned}$		· · · · · ·
kernel = <<256, 512>>>, time = 0.080032 kernel = <<256, 1024>>>, time = 0.112512 kernel = <<512, 32>>>, time = 0.115584 kernel = <<512, 64>>>, time = 0.083776 kernel = <<512, 128>>>, time = 0.077408 kernel = <<512, 256>>>, time = 0.079008 kernel = <<512, 512>>>, time = 0.090528 kernel = <<512, 512>>>, time = 0.150176 kernel = <<1512, 1024>>>, time = 0.150176 kernel = <<1024, 32>>>, time = 0.115488 kernel = <<1024, 64>>>, time = 0.083712 kernel = <<1024, 128>>>, time = 0.080288 kernel = <<1024, 56>>>, time = 0.088704 kernel = <<1024, 512>>>, time = 0.111712 kernel = <<1024, 1024>>>, time = 0.111712 kernel = <<<1024, 1024>>>, time = 0.225600		
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$\begin{aligned} & \text{kernel} = <<<512, 32>>>, \text{time} = 0.115584 \\ & \text{kernel} = <<<512, 64>>>, \text{time} = 0.083776 \\ & \text{kernel} = <<<512, 128>>>, \text{time} = 0.077408 \\ & \text{kernel} = <<<512, 256>>>, \text{time} = 0.079008 \\ & \text{kernel} = <<<512, 512>>>, \text{time} = 0.090528 \\ & \text{kernel} = <<<512, 1024>>>, \text{time} = 0.150176 \\ & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488 \\ & \text{kernel} = <<<1024, 64>>>, \text{time} = 0.083712 \\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288 \\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704 \\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712 \\ & \text{kernel} = <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $1000000$ $\begin{aligned} & \text{kernel} = <<<1, 32>>>, \text{time} = 20.691263 \\ & \text{kernel} = <<<1, 64>>>, \text{time} = 10.530560 \end{aligned}$		
kernel = <<<512, 64>>>, time = 0.083776 kernel = <<<512, 128>>>, time = 0.077408 kernel = <<<512, 256>>>, time = 0.079008 kernel = <<<512, 512>>>, time = 0.090528 kernel = <<<512, 1024>>>, time = 0.150176 kernel = <<<1024, 32>>>, time = 0.15488 kernel = <<<1024, 64>>>, time = 0.083712 kernel = <<<1024, 128>>>, time = 0.080288 kernel = <<<1024, 256>>>, time = 0.088704 kernel = <<<1024, 512>>>, time = 0.111712 kernel = <<<1024, 1024>>>, time = 0.225600  1000000  kernel = <<<1, 32>>>, time = 20.691263 kernel = <<<1, 64>>>, time = 10.530560		
kernel = <<<512, 128>>>, time = 0.077408 $kernel = <<<512, 256>>>, time = 0.079008$ $kernel = <<<512, 512>>>, time = 0.090528$ $kernel = <<<512, 1024>>>, time = 0.150176$ $kernel = <<<1024, 32>>>, time = 0.115488$ $kernel = <<<1024, 64>>>, time = 0.083712$ $kernel = <<<1024, 128>>>, time = 0.080288$ $kernel = <<<1024, 256>>>, time = 0.088704$ $kernel = <<<1024, 512>>>, time = 0.111712$ $kernel = <<<1024, 1024>>>, time = 0.111712$ $kernel = <<<1024, 1024>>>, time = 0.225600$ $kernel = <<<1, 32>>>, time = 20.691263$ $kernel = <<<1, 64>>>, time = 10.530560$		kernel = <<<512, 32>>>, time = 0.115584
$\begin{aligned} & \text{kernel} = <<<512, 256>>>, \text{time} = 0.079008 \\ & \text{kernel} = <<<512, 512>>>, \text{time} = 0.090528 \\ & \text{kernel} = <<<512, 1024>>>, \text{time} = 0.150176 \\ & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488 \\ & \text{kernel} = <<<1024, 64>>>, \text{time} = 0.083712 \\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288 \\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704 \\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712 \\ & \text{kernel} = <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $1000000$ $  \text{kernel} = <<<1, 32>>>, \text{time} = 20.691263 \\ & \text{kernel} = <<<1, 64>>>, \text{time} = 10.530560}$		kernel = <<<512, 64>>>, time = 0.083776
$\begin{aligned} & \text{kernel} = <<<512, 512>>>, \text{time} = 0.090528 \\ & \text{kernel} = <<<512, 1024>>>, \text{time} = 0.150176 \\ & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488 \\ & \text{kernel} = <<<1024, 64>>>, \text{time} = 0.083712 \\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288 \\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704 \\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712 \\ & \text{kernel} = <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $1000000$ $\begin{aligned} & \text{kernel} = <<<1, 32>>>, \text{time} = 20.691263 \\ & \text{kernel} = <<<1, 64>>>, \text{time} = 10.530560 \end{aligned}$		kernel = <<<512, 128>>>, time = 0.077408
$\begin{aligned} & \text{kernel} = <<<512, 1024>>>, \text{time} = 0.150176 \\ & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488 \\ & \text{kernel} = <<<1024, 64>>>, \text{time} = 0.083712 \\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288 \\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704 \\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712 \\ & \text{kernel} = <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $\begin{aligned} & loop of the example o$		kernel = <<<512, 256>>>, time = 0.079008
$\begin{aligned} & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488 \\ & \text{kernel} = <<<1024, 64>>>, \text{time} = 0.083712 \\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288 \\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704 \\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712 \\ & \text{kernel} = <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $\begin{aligned} & loop of the example of the e$		kernel = <<<512, 512>>>, time = 0.090528
$\begin{aligned} & \text{kernel} = <<<1024, 32>>>, \text{time} = 0.115488 \\ & \text{kernel} = <<<1024, 64>>>, \text{time} = 0.083712 \\ & \text{kernel} = <<<1024, 128>>>, \text{time} = 0.080288 \\ & \text{kernel} = <<<1024, 256>>>, \text{time} = 0.088704 \\ & \text{kernel} = <<<1024, 512>>>, \text{time} = 0.111712 \\ & \text{kernel} = <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $\begin{aligned} & loop of the example of the e$		kernel = <<<512, 1024>>>, time = 0.150176
$\begin{aligned} \text{kernel} &= <<<1024, 64>>>, \text{time} = 0.083712\\ \text{kernel} &= <<<1024, 128>>>, \text{time} = 0.080288\\ \text{kernel} &= <<<1024, 256>>>, \text{time} = 0.088704\\ \text{kernel} &= <<<1024, 512>>>, \text{time} = 0.111712\\ \text{kernel} &= <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $1000000$ $\begin{aligned} \text{kernel} &= <<<1, 32>>>, \text{time} = 20.691263\\ \text{kernel} &= <<<1, 64>>>, \text{time} = 10.530560 \end{aligned}$		
$\begin{aligned} \text{kernel} &= <<<1024, 128>>>, \text{time} = 0.080288 \\ \text{kernel} &= <<<1024, 256>>>, \text{time} = 0.088704 \\ \text{kernel} &= <<<1024, 512>>>, \text{time} = 0.111712 \\ \text{kernel} &= <<<1024, 1024>>>, \text{time} = 0.225600 \end{aligned}$ $\begin{aligned} \text{kernel} &= <<<1, 32>>>, \text{time} = 20.691263 \\ \text{kernel} &= <<<1, 64>>>, \text{time} = 10.530560 \end{aligned}$		
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kernel = <<<1024, 1024>>>, time = 0.225600  kernel = <<<1, 32>>>, time = 20.691263 kernel = <<<1, 64>>>, time = 10.530560		
1000000 kernel = <<<1, 32>>>, time = 20.691263 kernel = <<<1, 64>>>, time = 10.530560		
kernel = <<<1, 64>>>, time = 10.530560		101101 1. 1021, 1021 , tillio 0.220000
kernel = <<<1, 64>>>, time = 10.530560	1000000	kernel = <<<1, 32>>>, time = 20.691263
	100000	
Keller 881, 12077, time 5.257707		
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# 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 СРU:
#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.