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**Introduction to GPU programming**

*Practice 3. Vector addition*

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**Author: S.I. Bastrakov**

# Objectives

The objective of this practice is to develop a simple implementation of vector addition and saxpy BLAS operation using CUDA, and address data alignment and workload distribution problems.

# Abstract

This practice is devoted to development a simple implementation of vector addition and saxpy BLAS operation using CUDA. We address data alignment and workload distribution problems.

# BRIEF OVERVIEW

We consider a problem of addition of two single-precision floating-point vectors. This problem is obviously data parallel and thus allows simple implementation using CUDA. A CPU implementation is trivial:

void vecAdd(int n, float \* x, float \* y)

{

for (int i = 0; i < n; ++i)

y[i] += x[i];

}

In CUDA a loop with independent iterations is replaced by kernel where each thread computes its global index and computes the corresponding element of the result:

\_\_global\_\_ void vecAdd\_kernel(int n, float \* x, float \* y)

{

int i = blockIdx.x \* blockDim.x + threadIdx.x;

if (i < n)

y[i] += x[i];

}

Note that we have to check that global index of a thread is inside vector, because in general case total number of threads can be greater than vector size due to requirement that all thread blocks have the same size. A function to invoke the kernel is as follows:

void vecAdd\_gpu(int n, float \* x, float \* y)

{

const int threads\_per\_block = 256;

int num\_blocks = (n + threads\_per\_block - 1) / threads\_per\_block;

dim3 grid(num\_blocks, 1, 1);

dim3 blocks(threads\_per\_block, 1, 1);

vecAdd\_kernel<<<grid, blocks>>>(n, x, y);

}

We fix block size and compute number of blocks as upper integer part of ratio of vector size and block size. This explains, why did we have to check if (i < n) in the kernel. This problem is typical for GPU programming.

A more general implementation of vector addition is function axpy from BLAS level 1. It is defined as follows: ∀i ∈ 0..n: y[i \* incy] ← y[i \* incy] + a \* x[i \* incx], where incx and incy are constant parameters. For a = incx = incy = 1 axpy is a common vector addition. Implementations on CPU and GPU are generally similar to vector addition.

Implementation on CPU:

void saxpy(int n, float a, float \* x, int incx, float \* y, int incy)

{

for (int i = 0; i < n; ++i)

y[i \* incy] += a \* x[i \* incx];

}

Again, the loop has independent iterations, thus can be easily transformed into a kernel:

\_\_global\_\_ void saxpy\_kernel(int n, float a, float \* x, int incx, float \* y, int incy)

{

int i = blockIdx.x \* blockDim.x + threadIdx.x;

if (i < n)

y[i \* incy] += a \* x[i \* incx];

}

A function to invoke the kernel is similar to vector addition function.

# FOR STUDENTS

CUDA C language is described in [1, 2].

# References

1. Sanders J., Kandrot E. CUDA by Example: An Introduction to General-Purpose GPU Programming. – Addison-Wesley Professional, 2010. – 312 p.
2. NVIDIA CUDA C Programming Guide. [http://docs.nvidia.com/cuda/cuda-c-programming-guide/].

# Individual work

1. Implement axpy operation for complex numbers.
2. Modify axpy kernel so that it will work for any amount of block and threads per block.