Class: Final Year (Computer Science and Engineering)

Year: 2022-23 **Semester:** 1

Course: High Performance Computing Lab

Practical No. 9

PRN : 2019BTECS00070

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Problem Statement 1:

Implement Vector-Vector addition using CUDA C. State and justify the speedup using different sizes of threads and blocks.

Information #:

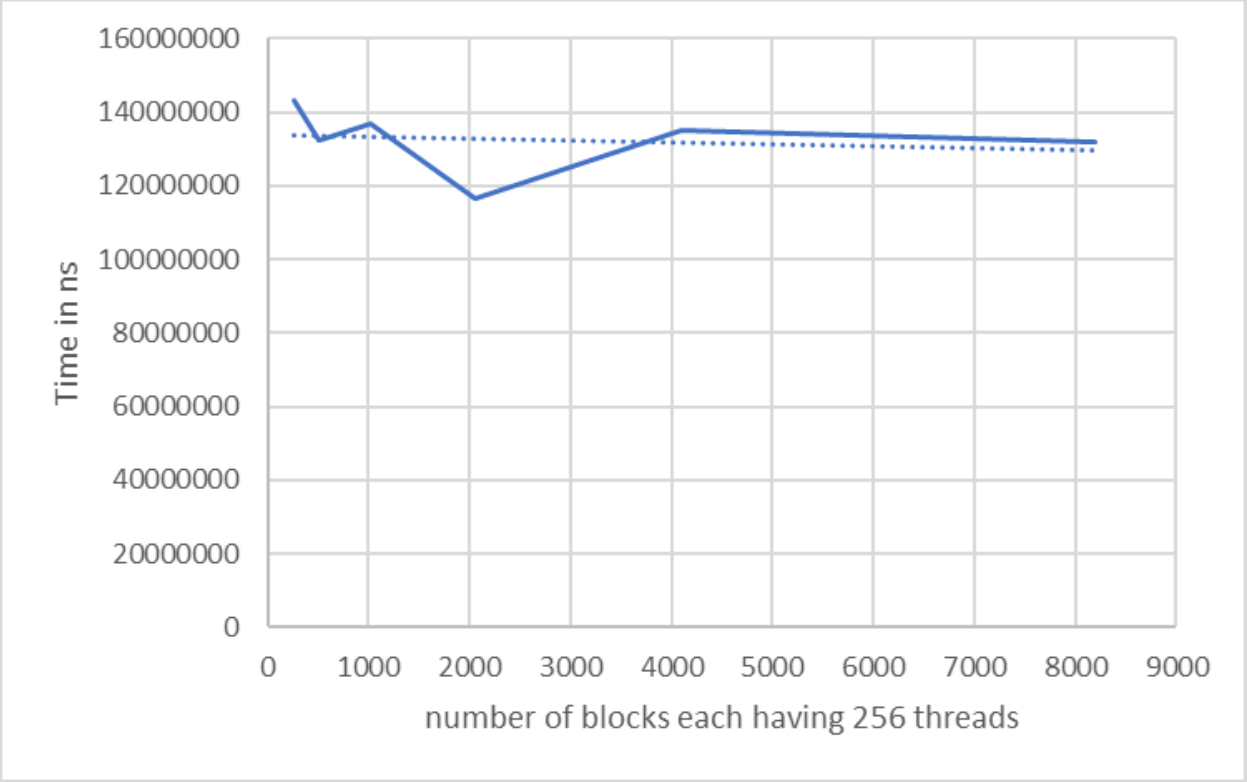
```
#include <stdio.h>

void initWith(float num, float *a, int N)
{
        for(int i = 0; i < N; ++i)
        {
                a[i] = num;
        }
}

__global__ void addVectorsInto(float *result, float *a, float *b, int N)
{
        int index = threadIdx.x + blockIdx.x * blockDim.x;
```

```
        int stride = blockDim.x * gridDim.x;

        for(int i = index; i < N; i += stride)
        {
                result[i] = a[i] + b[i];
        }
}

void checkElementsAre(float target, float *vector, int N)
{
        for(int i = 0; i < N; i++)
        {
                if(vector[i] != target)
                {
                        printf("FAIL: vector[%d] - %0.0f does not equal %0.0f\n",
i, vector[i], target);
                        exit(1);
                }
        }
        printf("Success! All values calculated correctly.\n");
}

int main()
{
        int deviceId;
        int numberOfSMs;

        cudaGetDevice(&deviceId);
        cudaDeviceGetAttribute(&numberOfSMs,
cudaDevAttrMultiProcessorCount, deviceId);

        const int N = 2<<24;
        size_t size = N * sizeof(float);
```

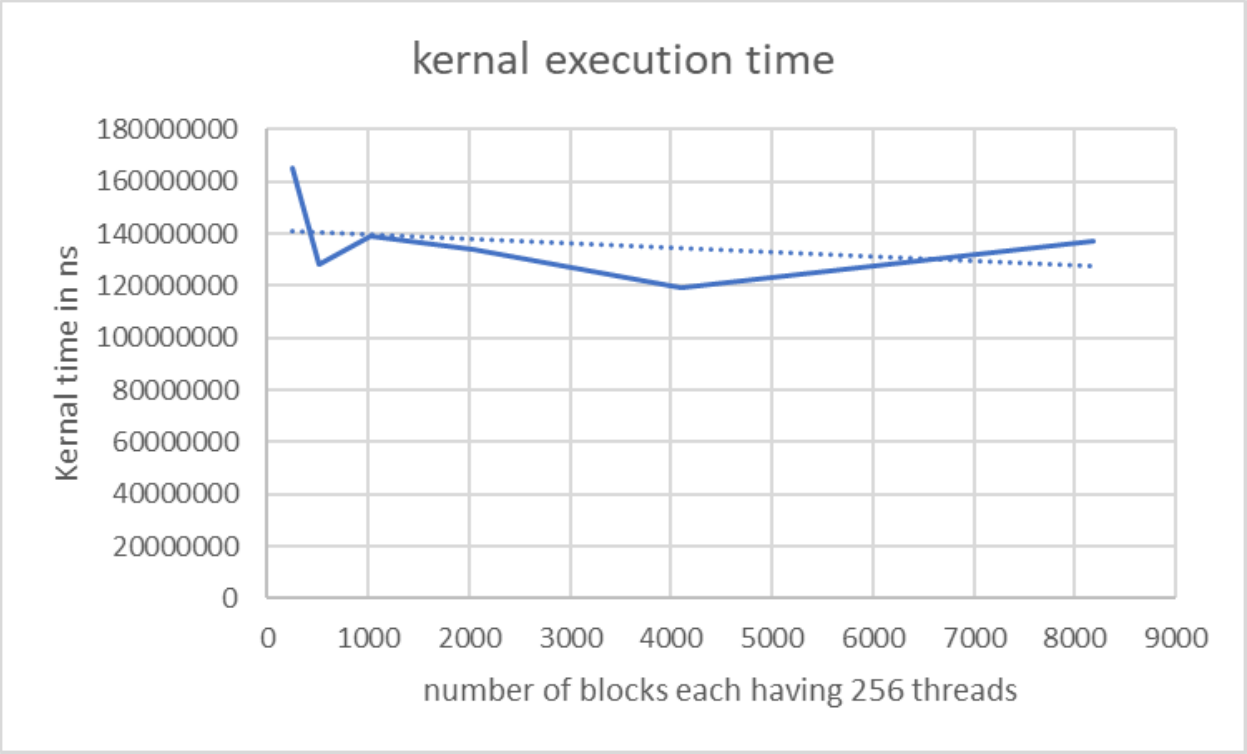
```
    float *a;
    float *b;
    float *c;

    cudaMallocManaged(&a, size);
    cudaMallocManaged(&b, size);
    cudaMallocManaged(&c, size);

    initWith(3, a, N);
    initWith(4, b, N);
    initWith(0, c, N);

    size_t threadsPerBlock;
    size_t numberOfBlocks;

    threadsPerBlock = 256;
    numberOfBlocks = 32 * numberOfSMs;

    cudaError_t addVectorsErr;
    cudaError_t asyncErr;

    addVectorsInto<<<numberOfBlocks, threadsPerBlock>>>(c, a, b, N);

    addVectorsErr = cudaGetLastError();
    if(addVectorsErr != cudaSuccess) printf("Error: %s\n",
cudaGetErrorString(addVectorsErr));

    asyncErr = cudaDeviceSynchronize();
    if(asyncErr != cudaSuccess) printf("Error: %s\n",
cudaGetErrorString(asyncErr));

    checkElementsAre(7, c, N);

    cudaFree(a);
```

```
        cudaFree(b);
        cudaFree(c);
    }
```

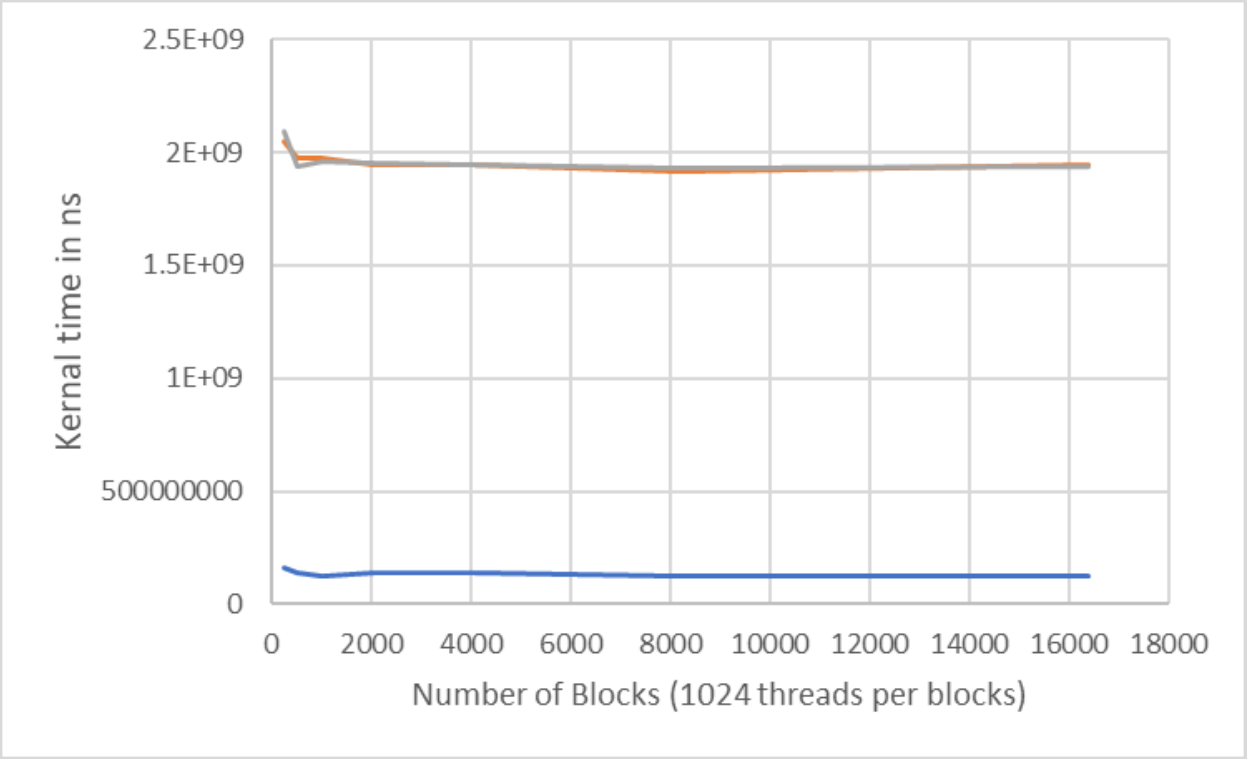
Blocks (thread constant 256)	kernal execution time
256	**143037294**
512	**132251553**
1024	**137069194**
2048	**116664576**
4096	**134966460**
8192	**131768554**



Blocks (thread constant 512)	kernal execution time
256	164921246
512	128164468
1024	139115093
2048	133940673
4096	118931852
8192	136805724



	for 2<<24 data	for data INT_MAX/sizeof(float)	
Blocks (thread constant 1024)	kernal execution time	kernal execution time	kernal execution time
256	160442261	2048682679	2091322925
512	141213279	1976524493	1941007817
1024	123889652	1975526236	1963358116
2048	137103827	1945817299	1949938430
4096	138071974	1942471645	1944636331
8192	124432532	1914443571	1929313649
16384	127385691	1944251296	1941889782



Conclusion:

By observing the above graph we have concluded that for the constant threads and increasing block number and for the constant blocks and increasing threads number the execution time is decreasing upto the certain point and after that due to communication overhead execution time is increasing.

Problem Statement 2:

Implement N-Body Simulator using CUDA C. State and justify the speedup using different sizes of threads and blocks.

Information #:

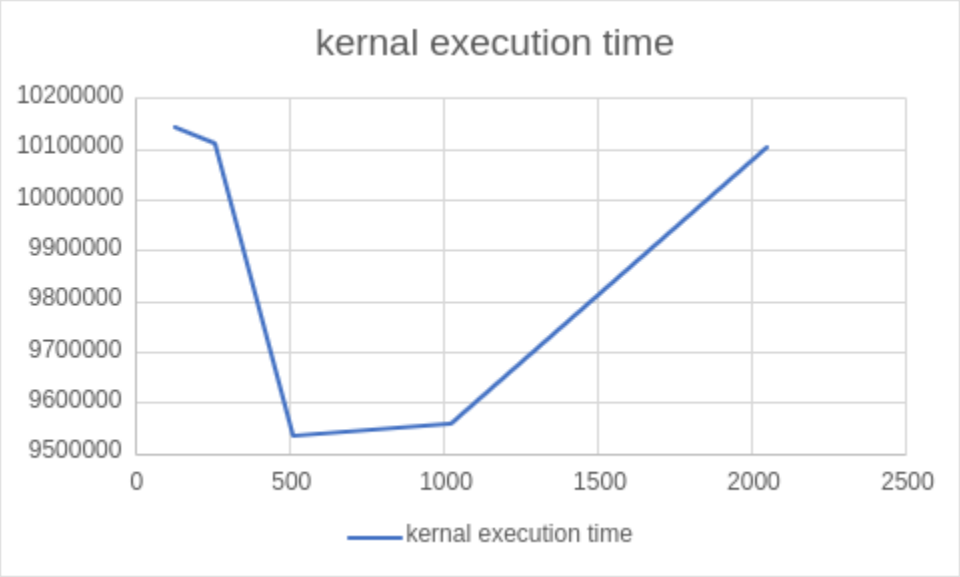
```
#include <math.h>
#include <stdio.h>
#include <stdlib.h>
#include "timer.h"
#include "files.h"

#define SOFTENING 1e-9f

typedef struct { float x, y, z, vx, vy, vz; } Body;

__global__ void bodyForce(Body *p, float dt, int n)
{
	int index = threadIdx.x + blockIdx.x * blockDim.x;
	int stride = blockDim.x * gridDim.x;

	for(int i = index; i < N; i += stride)
	{
		float Fx = 0.0f; float Fy = 0.0f; float Fz = 0.0f;

		for (int j = 0; j < n; j++)
		{
			float dx = p[j].x - p[i].x;
			float dy = p[j].y - p[i].y;
```

```
                        float dz = p[j].z - p[i].z;
                        float distSqr = dx*dx + dy*dy + dz*dz + SOFTENING;
                        float invDist = rsqrtf(distSqr);
                        float invDist3 = invDist * invDist * invDist;

                        Fx += dx * invDist3; Fy += dy * invDist3; Fz += dz *
invDist3;
                }

                p[i].vx += dt*Fx; p[i].vy += dt*Fy; p[i].vz += dt*Fz;
        }
}


int main(const int argc, const char** argv)
{
        // The assessment will test against both 2<11 and 2<15.
        // Feel free to pass the command line argument 15 when you
generate ./nbody report files
        y report files
        int nBodies = 2<<11;
        if (argc > 1) nBodies = 2<<atoi(argv[1]);

        // The assessment will pass hidden initialized values to check for
correctness.
        // You should not make changes to these files, or else the assessment
will not work.
        const char * initialized_values;
        const char * solution_values;

        if (nBodies == 2<<11)
        {
                initialized_values = "09-nbody/files/initialized_4096";
                solution_values = "09-nbody/files/solution_4096";
```

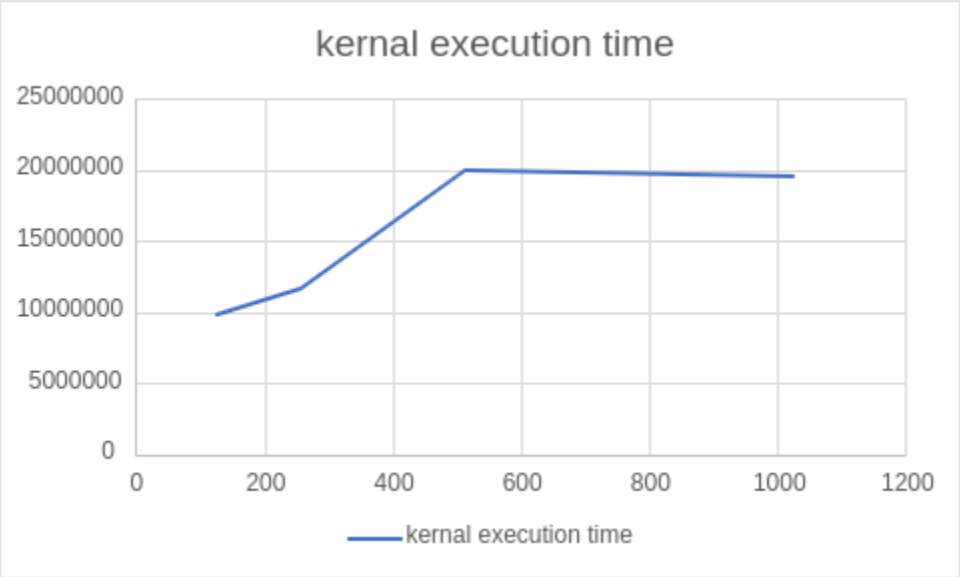
```
        }
        else
        { // nBodies == 2<<15
                initialized_values = "09-nbody/files/initialized_65536";
                solution_values = "09-nbody/files/solution_65536";
        }

        if (argc > 2)
                initialized_values = argv[2];
        if (argc > 3)
                solution_values = argv[3];

        const float dt = 0.01f; // Time step
        const int nIters = 10;  // Simulation iterations

        int bytes = nBodies * sizeof(Body);
        float *buf;

        buf = (float *)malloc(bytes);
        cudaMallocManaged(&buf, bytes)

        Body *p = (Body*)buf;

        read_values_from_file(initialized_values, buf, bytes);

        double totalTime = 0.0;

        for (int iter = 0; iter < nIters; iter++) {
                StartTimer();

                bodyForce<<<1024,32>>>(p, dt, nBodies); // compute
interbody forces
                cudaDeviceSynchronize();
```

```
                for (int i = 0 ; i < nBodies; i++)
                { // integrate position
                        p[i].x += p[i].vx*dt;
                        p[i].y += p[i].vy*dt;
                        p[i].z += p[i].vz*dt;
                }

                const double tElapsed = GetTimer() / 1000.0;
                totalTime += tElapsed;
        }

        double avgTime = totalTime / (double)(nIters);
        float billionsOfOpsPerSecond = 1e-9 * nBodies * nBodies / avgTime;
        write_values_to_file(solution_values, buf, bytes);

        printf("%0.3f Billion Interactions / second\n",
billionsOfOpsPerSecond);

        cudaFree(buf);
}
```

Blocks (thread constant 128)	kernal execution time
128	10140858
256	10110051
512	9533352
1024	9559230
2048	10101743



Threads(Block Constant 128)	kernal execution time
128	9780649
256	11664735
512	19929743
1024	19626103



Conclusion:

a. For constant number of blocks we have concluded that the execution time is increasing with the increasing number of threads per block
b. For constant number of threads we have concluded that the execution time is decreasing until a certain point and after that it is increasing due to communication overhead by increasing the number of block

Github Link:
https://github.com/killedar27/HPC-assignments/tree/main/assignment9