EE-147 Lab 1
Simple Vector Add

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April 16, 2018

1 Introduction

For this lab our main goal is to become familiar with writing, compiling and running cuda code. For this lab we are given a code template and are tasked with filling in the necessary cuda operations to add two vectors together. We must fill in the host code to read and write data to the GPU and we are writing the device code to add the vectors in parallel.

2 Questions

1. How many total thread blocks do we use?
   The total amount of thread blocks will vary with the size of the vector and the block size. By default we have a vector length of 1000 and block size 256, so we use 4 blocks. More generally we use $\left\lceil \frac{n}{block\_size} \right\rceil$ blocks, where n is the number of elements in our vectors.

2. Are all thread blocks full? That is, do all threads in thread blocks have data to operate on?
   Generally we will only use every thread in every block if the number of elements is an integer multiple of the block size. Since 1000 is not a integer multiple the last block will have $256 - 1000\%256$, or 24, free threads.

3. How can this basic vector add program be improved?
   You could do this by trying to minimize the amount of unused threads. If you dynamically calculate the block size to be a integer multiple of the number of elements, or minimize the number of unused when that is not possible, then it would leave those threads open to be used by other applications.

3 Code

3.1 Main.cu

For the main file we fill in the code necessary to read and write the vectors to the GPU. We doe this by allocating an appropriately sized vector on the GPU and then copy the values from host memory to the device memory. To get the result we run the kernel and then copy the result from the device memory to the host.

```
/***************************************************************************
 *cr
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 *cr                        University of Illinois
 *cr                         All Rights Reserved
 *cr
 ***************************************************************************/

#include <stdio.h>
#include <stdlib.h>
#include "kernel.cu"
```

```
#include "support.cu"

int main (int argc, char *argv[])
{
    //set standard seed
    srand(217); //Defualt value 217, DO NOT TOUCH

    Timer timer;
    cudaError_t cuda_ret;

    // Initialize host variables ----------------------------------------------------

    printf("\nSetting up the problem..."); fflush(stdout);
    startTime(&timer);

    float *A_h, *B_h, *C_h;
    float *A_d, *B_d, *C_d;
    size_t A_sz, B_sz, C_sz;
    unsigned VecSize;

    dim3 dim_grid, dim_block;

    if (argc == 1) {
        VecSize = 1000;
    } else if (argc == 2) {
        VecSize = atoi(argv[1]);
    } else {
        printf("\nOh no!\nUsage: ./vecAdd <Size>");
        exit(0);
    }

    A_sz = VecSize;
    B_sz = VecSize;
    C_sz = VecSize;
    A_h = (float*) malloc( sizeof(float)*A_sz );
    for (unsigned int i=0; i < A_sz; i++) { A_h[i] = (rand()%100)/100.00; }

    B_h = (float*) malloc( sizeof(float)*B_sz );
    for (unsigned int i=0; i < B_sz; i++) { B_h[i] = (rand()%100)/100.00; }

    C_h = (float*) malloc( sizeof(float)*C_sz );

    stopTime(&timer); printf("%f s\n", elapsedTime(timer));
    printf("    size Of vector: %u x %u\n  ", VecSize);

    // Allocate device variables ----------------------------------------------------

    printf("Allocating device variables..."); fflush(stdout);
    startTime(&timer);

    //INSERT CODE HERE
    cudaMalloc((void **) &A_d, sizeof(float)*A_sz);
    cudaMalloc((void **) &B_d, sizeof(float)*B_sz);
    cudaMalloc((void **) &C_d, sizeof(float)*C_sz);

    cudaDeviceSynchronize();
    stopTime(&timer); printf("%f s\n", elapsedTime(timer));

    // Copy host variables to device ------------------------------------------

    printf("Copying data from host to device..."); fflush(stdout);
    startTime(&timer);

    //INSERT CODE HERE
    cudaMemcpy(A_d, A_h, sizeof(float)*A_sz, cudaMemcpyHostToDevice);
    cudaMemcpy(B_d, B_h, sizeof(float)*B_sz, cudaMemcpyHostToDevice);

    cudaDeviceSynchronize();
    stopTime(&timer); printf("%f s\n", elapsedTime(timer));

    // Launch kernel  ----------------------------
```

```
    printf("Launching kernel..."); fflush(stdout);
    startTime(&timer);
    basicVecAdd(A_d, B_d, C_d, VecSize); //In kernel.cu

    cuda_ret = cudaDeviceSynchronize();
        if(cuda_ret != cudaSuccess) FATAL("Unable to launch kernel");
    stopTime(&timer); printf("%f s\n", elapsedTime(timer));

    // Copy device variables from host ----------------------------------------

    printf("Copying data from device to host..."); fflush(stdout);
    startTime(&timer);

    //INSERT CODE HERE
    cudaMemcpy(C_h, C_d, sizeof(float)*C_sz, cudaMemcpyDeviceToHost);

    cudaDeviceSynchronize();
    stopTime(&timer); printf("%f s\n", elapsedTime(timer));

    // Verify correctness -----------------------------------------------------

    printf("Verifying results..."); fflush(stdout);

    verify(A_h, B_h, C_h, VecSize);


    // Free memory ------------------------------------------------------------

    free(A_h);
    free(B_h);
    free(C_h);

    //INSERT CODE HERE
    cudaFree(A_d);
    cudaFree(B_d);
    cudaFree(C_d);
    return 0;

}
```

3.2 Kernel.cu

The kernel code is fairly straight forward. The basicVecAdd function determines the number of blocks needed and then calls the device code with the appropriate block and grid size. The VecAdd function runs on the GPU and adds together each element of the vector. It determines which element to add based on its thread and block ID.

```
/***************************************************************************
 *cr
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 *cr                        University of Illinois
 *cr                         All Rights Reserved
 *cr
 ***************************************************************************/

#include <stdio.h>


__global__ void VecAdd(int n, const float *A, const float *B, float* C) {

    /*************************************************************
     *
     * Compute C = A + B
     *   where A is a (1 * n) vector
     *   where B is a (1 * n) vector
     *   where C is a (1 * n) vector
     *
     *************************************************************/

```

```
    // INSERT KERNEL CODE HERE
    int i = threadIdx.x+blockDim.x*blockIdx.x;
    if(i<n) C[i] = A[i] + B[i];
}


void basicVecAdd( float *A,  float *B, float *C, int n)
{

    // Initialize thread block and kernel grid dimensions ----------------------

    const unsigned int BLOCK_SIZE = 256;

    //INSERT CODE HERE
    dim3 DimGrid((n-1)/BLOCK_SIZE+1,1,1);
    dim3 DimBlock(BLOCK_SIZE,1,1);
    VecAdd<<<DimGrid, DimBlock>>>(n,A,B,C);
}
```

4 Program Output

```
Setting up the problem...0.000031 s
    size Of vector: 1000 x 0
  Allocating device variables...0.509891 s
Copying data from host to device...0.000036 s
Launching kernel...0.000041 s
Copying data from device to host...0.000022 s
Verifying results...     0.990000/0.990000       1.160000/1.160000
0.510000/0.510000       1.230000/1.230000       0.610000/0.610000
0.780000/0.780000       1.440000/1.440000       0.840000/0.840000
0.580000/0.580000       0.720000/0.720000       0.670000/0.670000
0.610000/0.610000       1.040000/1.040000       0.690000/0.690000
0.860000/0.860000       0.530000/0.530000       0.330000/0.330000
1.000000/1.000000       0.440000/0.440000       0.930000/0.930000
0.770000/0.770000       1.090000/1.090000       1.240000/1.240000
0.980000/0.980000       0.450000/0.450000       1.040000/1.040000
1.210000/1.210000       0.960000/0.960000       1.120000/1.120000
1.440000/1.440000       0.670000/0.670000       0.630000/0.630000
1.120000/1.120000       1.240000/1.240000       1.390000/1.390000
0.730000/0.730000       1.540000/1.540000       1.350000/1.350000
0.610000/0.610000       0.640000/0.640000       0.600000/0.600000
1.290000/1.290000       1.270000/1.270000       1.680000/1.680000
0.500000/0.500000       0.650000/0.650000       0.740000/0.740000
0.890000/0.890000       1.180000/1.180000       0.710000/0.710000
1.340000/1.340000       0.990000/0.990000       1.320000/1.320000
1.590000/1.590000       1.010000/1.010000       1.300000/1.300000
1.150000/1.150000       0.220000/0.220000       1.780000/1.780000
1.310000/1.310000       1.670000/1.670000       0.980000/0.980000
0.470000/0.470000       1.320000/1.320000       1.740000/1.740000
1.380000/1.380000       0.580000/0.580000       0.800000/0.800000
0.770000/0.770000       0.720000/0.720000       0.970000/0.970000
0.890000/0.890000       1.530000/1.530000       0.760000/0.760000
1.100000/1.100000       1.090000/1.090000       0.930000/0.930000
1.850000/1.850000       0.980000/0.980000       1.150000/1.150000
1.600000/1.600000       0.840000/0.840000       1.660000/1.660000
0.450000/0.450000       0.430000/0.430000       0.680000/0.680000
1.280000/1.280000       1.640000/1.640000       0.940000/0.940000
```

0.580000/0.580000	0.950000/0.950000	0.660000/0.660000
0.080000/0.080000	0.950000/0.950000	0.510000/0.510000
0.830000/0.830000	0.850000/0.850000	0.610000/0.610000
1.150000/1.150000	0.640000/0.640000	0.850000/0.850000
0.650000/0.650000	1.050000/1.050000	0.920000/0.920000
1.410000/1.410000	1.160000/1.160000	1.530000/1.530000
0.400000/0.400000	1.050000/1.050000	1.510000/1.510000
1.550000/1.550000	1.180000/1.180000	1.390000/1.390000
0.750000/0.750000	1.630000/1.630000	0.830000/0.830000
0.470000/0.470000	0.950000/0.950000	1.510000/1.510000
1.420000/1.420000	0.540000/0.540000	0.470000/0.470000
0.610000/0.610000	0.620000/0.620000	0.420000/0.420000
1.120000/1.120000	0.980000/0.980000	1.330000/1.330000
0.770000/0.770000	1.180000/1.180000	0.970000/0.970000
0.150000/0.150000	1.830000/1.830000	0.540000/0.540000
1.590000/1.590000	1.300000/1.300000	0.230000/0.230000
1.120000/1.120000	1.700000/1.700000	0.320000/0.320000
0.670000/0.670000	0.290000/0.290000	0.500000/0.500000
0.060000/0.060000	0.080000/0.080000	1.180000/1.180000
1.940000/1.940000	1.080000/1.080000	1.130000/1.130000
1.450000/1.450000	1.030000/1.030000	0.670000/0.670000
0.450000/0.450000	1.160000/1.160000	0.830000/0.830000
0.920000/0.920000	1.320000/1.320000	0.850000/0.850000
1.250000/1.250000	0.610000/0.610000	1.030000/1.030000
0.740000/0.740000	0.760000/0.760000	0.920000/0.920000
1.290000/1.290000	0.880000/0.880000	1.220000/1.220000
1.040000/1.040000	1.040000/1.040000	0.440000/0.440000
0.380000/0.380000	0.720000/0.720000	1.770000/1.770000
0.920000/0.920000	0.310000/0.310000	0.870000/0.870000
1.110000/1.110000	0.770000/0.770000	0.950000/0.950000
1.250000/1.250000	1.280000/1.280000	0.500000/0.500000
1.450000/1.450000	0.730000/0.730000	0.700000/0.700000
1.320000/1.320000	0.690000/0.690000	1.540000/1.540000
0.690000/0.690000	0.470000/0.470000	0.670000/0.670000
0.780000/0.780000	0.730000/0.730000	0.970000/0.970000
1.700000/1.700000	1.070000/1.070000	0.890000/0.890000
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1.610000/1.610000	0.960000/0.960000	1.440000/1.440000
0.500000/0.500000	0.920000/0.920000	1.090000/1.090000
1.480000/1.480000	1.360000/1.360000	1.190000/1.190000
0.680000/0.680000	1.580000/1.580000	1.190000/1.190000
0.740000/0.740000	0.190000/0.190000	1.340000/1.340000
0.580000/0.580000	0.800000/0.800000	0.750000/0.750000
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1.830000/1.830000	0.860000/0.860000	1.210000/1.210000
0.420000/0.420000	0.700000/0.700000	0.770000/0.770000
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1.300000/1.300000	0.950000/0.950000	0.660000/0.660000
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0.550000/0.550000	0.530000/0.530000	1.820000/1.820000
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1.530000/1.530000	1.710000/1.710000	0.410000/0.410000
0.190000/0.190000	1.150000/1.150000	0.940000/0.940000
0.540000/0.540000	1.140000/1.140000	0.940000/0.940000
0.290000/0.290000	1.100000/1.100000	0.440000/0.440000
1.400000/1.400000	1.170000/1.170000	0.980000/0.980000
1.270000/1.270000	0.540000/0.540000	0.890000/0.890000
1.630000/1.630000	1.230000/1.230000	1.660000/1.660000
0.940000/0.940000	1.590000/1.590000	0.850000/0.850000
1.420000/1.420000	0.670000/0.670000	1.660000/1.660000
0.350000/0.350000	0.940000/0.940000	1.570000/1.570000
0.360000/0.360000	0.520000/0.520000	0.810000/0.810000
1.830000/1.830000	1.240000/1.240000	1.480000/1.480000
1.290000/1.290000	0.830000/0.830000	1.140000/1.140000
0.760000/0.760000	0.160000/0.160000	0.760000/0.760000
1.200000/1.200000	1.570000/1.570000	0.470000/0.470000
0.190000/0.190000	0.840000/0.840000	1.530000/1.530000
1.120000/1.120000	1.520000/1.520000	0.760000/0.760000
0.300000/0.300000	0.990000/0.990000	0.880000/0.880000
1.160000/1.160000	1.410000/1.410000	1.070000/1.070000
1.340000/1.340000	0.800000/0.800000	1.540000/1.540000
0.910000/0.910000	1.180000/1.180000	1.590000/1.590000
0.770000/0.770000	0.050000/0.050000	1.350000/1.350000
1.780000/1.780000	1.340000/1.340000	0.180000/0.180000
1.450000/1.450000	0.100000/0.100000	0.860000/0.860000
1.220000/1.220000	1.310000/1.310000	0.960000/0.960000
0.210000/0.210000	0.550000/0.550000	0.330000/0.330000
0.260000/0.260000	1.710000/1.710000	1.850000/1.850000
0.540000/0.540000	1.020000/1.020000	1.370000/1.370000
1.460000/1.460000	0.700000/0.700000	1.820000/1.820000
1.070000/1.070000	1.040000/1.040000	1.160000/1.160000
1.650000/1.650000	1.480000/1.480000	1.380000/1.380000
1.240000/1.240000	0.260000/0.260000	1.430000/1.430000
1.110000/1.110000	1.080000/1.080000	1.290000/1.290000
0.820000/0.820000	0.530000/0.530000	1.400000/1.400000
1.210000/1.210000	0.280000/0.280000	1.750000/1.750000
0.690000/0.690000	1.010000/1.010000	1.340000/1.340000
1.070000/1.070000	1.800000/1.800000	1.060000/1.060000
0.970000/0.970000	1.390000/1.390000	1.600000/1.600000
1.340000/1.340000	0.900000/0.900000	1.340000/1.340000
1.220000/1.220000	1.490000/1.490000	0.380000/0.380000
0.420000/0.420000	0.670000/0.670000	0.900000/0.900000
0.800000/0.800000	0.430000/0.430000	0.200000/0.200000
1.270000/1.270000	1.590000/1.590000	0.810000/0.810000
1.560000/1.560000	0.930000/0.930000	1.350000/1.350000
1.000000/1.000000	0.670000/0.670000	1.150000/1.150000
0.750000/0.750000	0.370000/0.370000	0.220000/0.220000
1.620000/1.620000	1.480000/1.480000	1.020000/1.020000
1.200000/1.200000	1.460000/1.460000	0.450000/0.450000
1.320000/1.320000	1.330000/1.330000	1.360000/1.360000
1.180000/1.180000	1.070000/1.070000	0.370000/0.370000
0.610000/0.610000	0.530000/0.530000	1.560000/1.560000
1.030000/1.030000	1.330000/1.330000	0.520000/0.520000

1.250000/1.250000	1.120000/1.120000	0.640000/0.640000
1.580000/1.580000	1.210000/1.210000	0.570000/0.570000
1.450000/1.450000	1.210000/1.210000	1.290000/1.290000
0.660000/0.660000	1.010000/1.010000	1.190000/1.190000
0.880000/0.880000	0.150000/0.150000	0.670000/0.670000
0.940000/0.940000	1.880000/1.880000	0.660000/0.660000
1.400000/1.400000	1.720000/1.720000	0.520000/0.520000
0.810000/0.810000	0.430000/0.430000	1.110000/1.110000
0.700000/0.700000	0.560000/0.560000	0.650000/0.650000
0.800000/0.800000	0.600000/0.600000	1.500000/1.500000
1.840000/1.840000	0.890000/0.890000	1.150000/1.150000
0.480000/0.480000	0.990000/0.990000	0.400000/0.400000
1.580000/1.580000	0.980000/0.980000	1.610000/1.610000
0.870000/0.870000	0.640000/0.640000	1.140000/1.140000
0.580000/0.580000	1.040000/1.040000	0.830000/0.830000
0.790000/0.790000	0.500000/0.500000	1.230000/1.230000
0.970000/0.970000	0.420000/0.420000	1.480000/1.480000
1.010000/1.010000	0.230000/0.230000	1.430000/1.430000
1.650000/1.650000	1.470000/1.470000	0.520000/0.520000
0.300000/0.300000	0.790000/0.790000	1.170000/1.170000
0.840000/0.840000	0.630000/0.630000	0.580000/0.580000
1.030000/1.030000	0.640000/0.640000	0.100000/0.100000
1.430000/1.430000	0.740000/0.740000	1.120000/1.120000
1.090000/1.090000	1.140000/1.140000	1.280000/1.280000
1.750000/1.750000	1.770000/1.770000	0.840000/0.840000
0.580000/0.580000	1.080000/1.080000	0.870000/0.870000
0.860000/0.860000	1.090000/1.090000	0.330000/0.330000
0.870000/0.870000	1.110000/1.110000	1.100000/1.100000
0.820000/0.820000	1.280000/1.280000	1.090000/1.090000
1.390000/1.390000	0.620000/0.620000	0.400000/0.400000
1.080000/1.080000	0.980000/0.980000	0.550000/0.550000
1.180000/1.180000	0.540000/0.540000	0.710000/0.710000
1.810000/1.810000	0.970000/0.970000	0.970000/0.970000
1.450000/1.450000	1.100000/1.100000	1.160000/1.160000
1.260000/1.260000	0.870000/0.870000	0.460000/0.460000
1.620000/1.620000	1.490000/1.490000	0.580000/0.580000
0.530000/0.530000	0.880000/0.880000	0.680000/0.680000
0.880000/0.880000	0.270000/0.270000	1.310000/1.310000
1.020000/1.020000	1.620000/1.620000	0.600000/0.600000
0.630000/0.630000	1.010000/1.010000	1.260000/1.260000
0.550000/0.550000	1.140000/1.140000	0.260000/0.260000
0.620000/0.620000	0.330000/0.330000	0.800000/0.800000
0.380000/0.380000	0.660000/0.660000	0.820000/0.820000
0.870000/0.870000	0.650000/0.650000	0.450000/0.450000
1.040000/1.040000	0.430000/0.430000	0.840000/0.840000
0.540000/0.540000	0.060000/0.060000	1.860000/1.860000
1.120000/1.120000	1.120000/1.120000	1.260000/1.260000
0.810000/0.810000	1.040000/1.040000	0.540000/0.540000
1.170000/1.170000	1.060000/1.060000	0.690000/0.690000
0.300000/0.300000	1.690000/1.690000	0.220000/0.220000
0.560000/0.560000	0.760000/0.760000	1.410000/1.410000
0.340000/0.340000	1.430000/1.430000	0.790000/0.790000
1.670000/1.670000	0.810000/0.810000	0.490000/0.490000
0.540000/0.540000	0.200000/0.200000	1.140000/1.140000
0.510000/0.510000	1.290000/1.290000	1.580000/1.580000
0.880000/0.880000	0.830000/0.830000	0.690000/0.690000

1.260000/1.260000	1.490000/1.490000	0.850000/0.850000
1.050000/1.050000	0.340000/0.340000	0.900000/0.900000
0.590000/0.590000	0.510000/0.510000	0.960000/0.960000
1.800000/1.800000	1.330000/1.330000	1.700000/1.700000
1.080000/1.080000	1.430000/1.430000	0.980000/0.980000
0.010000/0.010000	0.770000/0.770000	0.410000/0.410000
0.800000/0.800000	0.490000/0.490000	1.260000/1.260000
1.820000/1.820000	1.550000/1.550000	0.990000/0.990000
0.490000/0.490000	0.590000/0.590000	1.290000/1.290000
1.120000/1.120000	0.990000/0.990000	0.640000/0.640000
0.810000/0.810000	0.770000/0.770000	0.650000/0.650000
1.180000/1.180000	0.820000/0.820000	1.000000/1.000000
1.600000/1.600000	0.470000/0.470000	1.040000/1.040000
1.090000/1.090000	0.790000/0.790000	1.380000/1.380000
0.790000/0.790000	0.390000/0.390000	0.850000/0.850000
0.810000/0.810000	1.450000/1.450000	1.150000/1.150000
0.750000/0.750000	1.250000/1.250000	0.170000/0.170000
0.530000/0.530000	0.600000/0.600000	0.760000/0.760000
1.040000/1.040000	1.100000/1.100000	1.870000/1.870000
0.850000/0.850000	0.740000/0.740000	0.860000/0.860000
0.550000/0.550000	1.590000/1.590000	0.670000/0.670000
0.200000/0.200000	1.290000/1.290000	1.030000/1.030000
0.730000/0.730000	0.420000/0.420000	1.500000/1.500000
1.300000/1.300000	1.030000/1.030000	1.330000/1.330000
0.720000/0.720000	0.860000/0.860000	1.260000/1.260000
1.580000/1.580000	1.670000/1.670000	1.710000/1.710000
1.250000/1.250000	1.460000/1.460000	0.490000/0.490000
0.940000/0.940000	0.520000/0.520000	0.620000/0.620000
1.230000/1.230000	0.560000/0.560000	0.240000/0.240000
1.100000/1.100000	0.430000/0.430000	1.500000/1.500000
1.010000/1.010000	0.980000/0.980000	0.610000/0.610000
0.200000/0.200000	1.220000/1.220000	1.420000/1.420000
1.230000/1.230000	1.480000/1.480000	0.880000/0.880000
0.770000/0.770000	1.300000/1.300000	0.910000/0.910000
1.120000/1.120000	1.550000/1.550000	1.290000/1.290000
1.380000/1.380000	0.650000/0.650000	1.010000/1.010000
1.130000/1.130000	0.900000/0.900000	1.470000/1.470000
0.620000/0.620000	0.890000/0.890000	0.990000/0.990000
1.280000/1.280000	1.120000/1.120000	1.080000/1.080000
1.040000/1.040000	1.260000/1.260000	1.030000/1.030000
0.580000/0.580000	1.790000/1.790000	1.050000/1.050000
1.190000/1.190000	1.000000/1.000000	1.800000/1.800000
1.140000/1.140000	1.760000/1.760000	0.810000/0.810000
1.020000/1.020000	1.540000/1.540000	1.150000/1.150000
0.980000/0.980000	1.180000/1.180000	1.700000/1.700000
0.270000/0.270000	0.600000/0.600000	1.390000/1.390000
1.280000/1.280000	1.260000/1.260000	0.330000/0.330000
0.800000/0.800000	0.920000/0.920000	0.220000/0.220000
0.790000/0.790000	1.220000/1.220000	1.380000/1.380000
1.400000/1.400000	0.300000/0.300000	1.170000/1.170000
1.470000/1.470000	0.900000/0.900000	0.960000/0.960000
1.050000/1.050000	1.610000/1.610000	1.010000/1.010000
1.380000/1.380000	1.800000/1.800000	0.780000/0.780000
0.710000/0.710000	1.350000/1.350000	0.840000/0.840000
0.860000/0.860000	0.860000/0.860000	0.550000/0.550000
0.610000/0.610000	0.650000/0.650000	0.670000/0.670000

```
1.000000/1.000000       0.990000/0.990000       0.450000/0.450000
1.340000/1.340000       1.310000/1.310000       1.380000/1.380000
0.610000/0.610000       0.630000/0.630000       1.640000/1.640000
1.520000/1.520000       1.560000/1.560000       0.950000/0.950000
1.730000/1.730000       0.550000/0.550000       0.370000/0.370000
0.230000/0.230000       1.130000/1.130000       0.990000/0.990000
0.760000/0.760000       1.030000/1.030000       1.310000/1.310000
1.060000/1.060000       1.260000/1.260000       0.670000/0.670000
1.420000/1.420000       0.640000/0.640000       0.570000/0.570000
1.010000/1.010000       0.770000/0.770000       1.270000/1.270000
1.730000/1.730000       0.820000/0.820000       0.260000/0.260000
1.220000/1.220000       1.690000/1.690000       1.580000/1.580000
0.650000/0.650000       1.820000/1.820000       0.730000/0.730000
1.290000/1.290000       0.380000/0.380000       0.810000/0.810000
0.770000/0.770000       0.130000/0.130000       0.890000/0.890000
0.660000/0.660000       0.880000/0.880000       1.550000/1.550000
1.180000/1.180000       0.160000/0.160000       1.100000/1.100000
1.020000/1.020000       0.750000/0.750000       0.890000/0.890000
0.730000/0.730000       1.210000/1.210000       0.570000/0.570000
0.830000/0.830000       1.280000/1.280000       0.880000/0.880000
1.110000/1.110000       0.530000/0.530000       0.220000/0.220000
1.890000/1.890000       0.760000/0.760000       0.950000/0.950000
0.510000/0.510000       0.940000/0.940000       0.290000/0.290000
0.760000/0.760000       0.230000/0.230000
TEST PASSED
```