Computational Science on Many-Core Architectures Exercise 4

Example 1 Multiple Dot Products (4 Points total)

a)

First I tried to implement this with a given y-matrix, but it does work that well and I got a SEGMENTATION error.

Listing 1: kernel for 1a)

```
#include <stdio.h>
# include "timer.hpp"
#include <vector>

__global__ void dot_pro(int N, double *x, double *y0, double *y1, double *y2,
double *y3, double *y4, double *y5, double *y6, double *y7, double *dot)
{

    unsigned int ind = threadIdx.x + blockDim.x*blockIdx.x;
    unsigned int str = blockDim.x*gridDim.x;

    __shared__ double cache0[256];
    __shared__ double cache1[256];
    __shared__ double cache2[256];
    __shared__ double cache3[256];
    __shared__ double cache4[256];
    __shared__ double cache5[256];
    __shared__ double cache6[256];
    __shared__ double cache7[256];

    double tmpsum0 = 0.0;
    double tmpsum1 = 0.0;
    double tmpsum2 = 0.0;
    double tmpsum3 = 0.0;
    double tmpsum4 = 0.0;
    double tmpsum5 = 0.0;
    double tmpsum6 = 0.0;
    double tmpsum7 = 0.0;

    double val = x[0];

    while(ind < N)
    {
    for (int i = blockIdx.x * blockDim.x + threadIdx.x; i < N; i += blockDim.x *
    {
        val = x[i];
        tmpsum0 += val * y0[i];
        tmpsum1 += val * y1[i];
        tmpsum2 += val * y2[i];
```

```
            tmpsum3 += val * y3[i];
            tmpsum4 += val * y4[i];
            tmpsum5 += val * y5[i];
            tmpsum6 += val * y6[i];
            tmpsum7 += val * y7[i];
        }

        ind += str;
        }

        cache0[threadIdx.x] = tmpsum0;
        cache1[threadIdx.x] = tmpsum1;
        cache2[threadIdx.x] = tmpsum2;
        cache3[threadIdx.x] = tmpsum3;
        cache4[threadIdx.x] = tmpsum4;
        cache5[threadIdx.x] = tmpsum5;
        cache6[threadIdx.x] = tmpsum6;
        cache7[threadIdx.x] = tmpsum7;

        __syncthreads();

        for(int i = blockDim.x/2; i>0; i/=2)
        {
            __syncthreads();
            if(threadIdx.x < i)
            {
                cache0[threadIdx.x] += cache0[threadIdx.x + i];
                cache1[threadIdx.x] += cache1[threadIdx.x + i];
                cache2[threadIdx.x] += cache2[threadIdx.x + i];
                cache3[threadIdx.x] += cache3[threadIdx.x + i];
                cache4[threadIdx.x] += cache4[threadIdx.x + i];
                cache5[threadIdx.x] += cache5[threadIdx.x + i];
                cache6[threadIdx.x] += cache6[threadIdx.x + i];
                cache7[threadIdx.x] += cache7[threadIdx.x + i];
            }
        }

        if(threadIdx.x == 0)
        {
            atomicAdd(dot + 0,cache0[0]);
            atomicAdd(dot + 1,cache1[0]);
            atomicAdd(dot + 2,cache2[0]);
            atomicAdd(dot + 3,cache3[0]);
            atomicAdd(dot + 4,cache4[0]);
            atomicAdd(dot + 5,cache5[0]);
            atomicAdd(dot + 6,cache6[0]);
            atomicAdd(dot + 7,cache7[0]);
        }
}
```

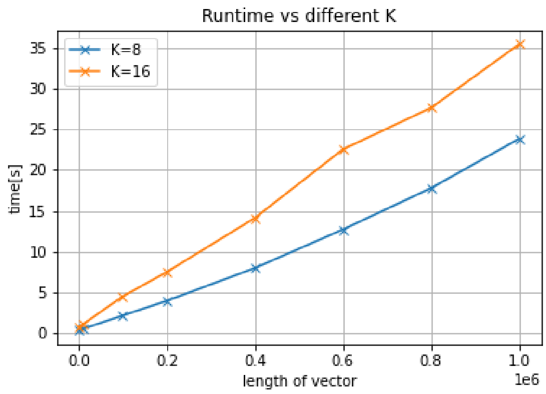
b)

Listing 2: kernel for 1a)

```
#include <stdio.h>
# include "timer.hpp"
#include <vector>
for (int g = 0; g < anz; g++)
{
    for (int i=0; i<K/8; ++i)
Bandwidth_offset    {
        cudaDeviceSynchronize();
        cudaMemcpy(d_y0, y[i*8+0], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y1, y[i*8+1], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y2, y[i*8+2], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y3, y[i*8+3], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y4, y[i*8+4], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y5, y[i*8+5], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y6, y[i*8+6], sizeof(double)*N, cudaMemcpyHostToDevice);
        cudaMemcpy(d_y7, y[i*8+7], sizeof(double)*N, cudaMemcpyHostToDevice);
        dot_pro<<<s, s>>>(N, d_x, d_y0, d_y1, d_y2, d_y3, d_y4
        , d_y5, d_y6, d_y7, d_res_cblas);
        cudaMemcpy(resultslarge+i*8, d_res_cblas
        , sizeof(double)*8, cudaMemcpyDeviceToHost);
        for (int j = 0; j < 8; j++)
        {
            res_cblas[j] = 0;
        }
    cudaMemcpy(d_res_cblas, res_cblas, sizeof(double)*8, cudaMemcpyHostToDevice)
    }
}
printf("Dot product took %g seconds", 1000*timer.get()/anz);
```

c)

I got a error message that I did not understand and tht's why I could not ran the programm with the other K-values.



Inconsistency detected by ld.so: dl-fini.c: 87: _dl_fini: Assertion `ns != LM_ID_BASE || i == nloaded' failed!

d)

On approach could be to store the an arbitory number of vectors in a matirx and send it to the kernel and then in kernel calculate the dot-product with a dynamic and static arrays.

Pipelined CG (4 Points total)

Different Kernels

Listing 3: kernel line 7 to 9)

```
 __global__ void x_plus_a_p(int N, double *x, double *p, double *r, double *Ap,
 double alpha, double beta)
{
    for (int i = blockIdx.x * blockDim.x + threadIdx.x; i < N;
    i += blockDim.x * gridDim.x)
    {
        x[i] = x[i] + alpha * p[i];
        r[i] = r[i] - alpha * Ap[i];
        p[i] = r[i] + beta * p[i];
    }
}
```

Listing 4: kernel line 10 to 12)

```
__global__ void diff_dot_prod(int N, double *Ap, double *p, double *r,
double *ApAp, double *pAp, double *rr, int *csr_rowoffsets,
int *csr_colindices, double *csr_values)
{
    __shared__ double cache0[512];
    __shared__ double cache1[512];
    __shared__ double cache2[512];

    double tmpsum0 = 0;
    double tmpsum1 = 0;
    double tmpsum2 = 0;

    for (int i = blockIdx.x * blockDim.x + threadIdx.x; i < N; i += blockDim.x *
    {
        double sum = 0;
        for (int k = csr_rowoffsets[i]; k < csr_rowoffsets[i + 1]; k++)
        {
            sum += csr_values[k] * p[csr_colindices[k]];
        }
        Ap[i] = sum;

        tmpsum0 += Ap[i] * Ap[i];
        tmpsum1 += p[i] * Ap[i];
        tmpsum2 += r[i] * r[i];
    }

    cache0[threadIdx.x] = tmpsum0;
    cache1[threadIdx.x] = tmpsum1;
    cache2[threadIdx.x] = tmpsum2;



```

```
    for (int k = blockDim.x / 2; k > 0; k /= 2)
    {
        __syncthreads();
        if (threadIdx.x < k)
        {
            cache0[threadIdx.x] += cache0[threadIdx.x + k];
            cache1[threadIdx.x] += cache1[threadIdx.x + k];
            cache2[threadIdx.x] += cache2[threadIdx.x + k];
        }
    }

    if (threadIdx.x == 0)
    {
        atomicAdd(ApAp, cache0[0]);
        atomicAdd(pAp, cache1[0]);
        atomicAdd(rr, cache2[0]);
    }
}
```

Listing 5: major loopc for iteration

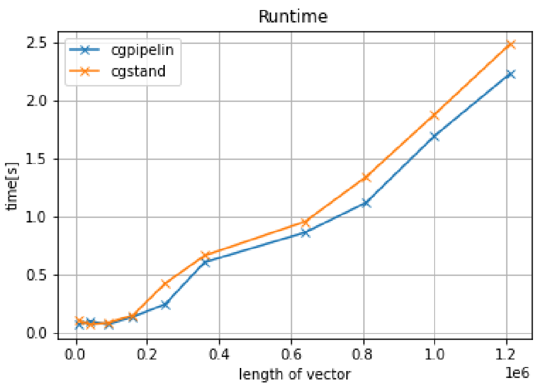
```
while (1)
{
    x_plus_a_p<<<512,512>>>(N, cuda_solution, cuda_p, cuda_r, cuda_Ap,
     alpha, beta);


    cudaMemcpy(cuda_ApAp, &zero, sizeof(double), cudaMemcpyHostToDevice);
    cudaMemcpy(cuda_pAp, &zero, sizeof(double), cudaMemcpyHostToDevice);
    cudaMemcpy(cuda_rr, &zero, sizeof(double), cudaMemcpyHostToDevice);
    diff_dot_prod<<<512,512>>>(N, cuda_Ap, cuda_p, cuda_r, cuda_ApAp,
     cuda_pAp, cuda_rr, csr_rowoffsets, csr_colindices, csr_values);

    cudaMemcpy(&beta, cuda_ApAp, sizeof(double), cudaMemcpyDeviceToHost);
    cudaMemcpy(&alpha, cuda_pAp, sizeof(double), cudaMemcpyDeviceToHost);
    cudaMemcpy(&residual_norm_squared, cuda_rr, sizeof(double),
     cudaMemcpyDeviceToHost);


    // line convergence check:
    if (std::sqrt(residual_norm_squared / initial_residual_squared) < 1e-6)
    {
        break;
    }

    // line 13:
    alpha = residual_norm_squared / alpha;

    // line 14:
    beta = alpha * alpha * beta / residual_norm_squared - 1;

```

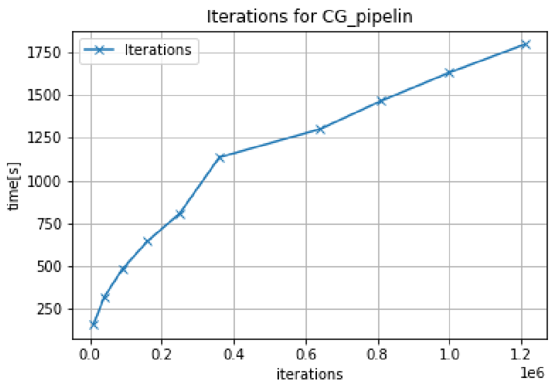
```
    if (iters > 10000)
    break; // solver didn't converge
    ++iters;
}
```

Listing 6: main

```
for(int i = 100; i < 1200;i = i + 100)
{
    solve_system(i);
    std::cout << "i:" << i << std::endl;
    std::cout << "" << std::endl;
    std::cout << "" << std::endl;
}
```

Benchmark





I expacted that the pipeline CG should perform better and also that the number of iterations should be reduced but the number od iterations are exaktly the same. Maybe I have to wotk on the second kernel in the iteration.