2022.1 Multicore Computing, Project #4

Problem 1

Document

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**- (a) execution environment (OS/CPU/GPU type or Colab?)**

**I use my Computer to run Project #4 code.**

CPU : AMD Ryzen 5 5600X Six-Core Processor (12 CPUs), 3.7GHz

Memory : DDR4 16384MB RAM

OS : Windows 10

**(b) how to compile**

**- openmp\_ray.c**

gcc -g openmp\_ray.c -o openmp\_ray -fopenmp

* Cuda\_ray.cu

Use Microsoft visual studio Community 2017 version.

Install cuda 11.7 version

텍스트이(가) 표시된 사진

자동 생성된 설명

Set Windows SDK version to 10.0.17763.0

텍스트이(가) 표시된 사진

자동 생성된 설명

Set CUDA Toolkit Custom Dir like above picture

1>C:\Users\song\source\repos\CUDA 11.7 Runtime1\CUDA 11.7 Runtime1>"..\..\..\..\..\..\Program Files\NVIDIA GPU Computing Toolkit\CUDA\v11.7\bin\nvcc.exe" -gencode=arch=compute\_52,code=\"sm\_52,compute\_52\" --use-local-env -ccbin "C:\Program Files (x86)\Microsoft Visual Studio\2017\Community\VC\Tools\MSVC\14.16.27023\bin\HostX86\x64" -x cu -I"..\..\..\..\..\..\Program Files\NVIDIA GPU Computing Toolkit\CUDA\v11.7\include" -I"..\..\..\..\..\..\Program Files\NVIDIA GPU Computing Toolkit\CUDA\v11.7\include" -G --keep-dir x64\Debug -maxrregcount=0 --machine 64 --compile -cudart static -g -DWIN32 -DWIN64 -D\_DEBUG -D\_CONSOLE -D\_MBCS -Xcompiler "/EHsc /W3 /nologo /Od /Fdx64\Debug\vc141.pdb /FS /Zi /RTC1 /MDd " -o "C:\Users\song\source\repos\CUDA 11.7 Runtime1\CUDA 11.7 Runtime1\x64\Debug\cuda\_ray.cu.obj" "C:\Users\song\source\repos\CUDA 11.7 Runtime1\CUDA 11.7 Runtime1\cuda\_ray.cu"

And compile project like above. Nvcc ~~~ cuda\_ray.cu

**(c) how to execute**

- openmp\_ray.c

Just type ‘openmp\_ray.exe 4’ ( 4 is # of threads )

* cuda\_ray.cu

Build visual studio target solution, and type

‘cuda\_ray.exe’ (no parameter)

**Entire source code**

* openmp\_ray.c
* //
* // Created by song on 2022-05-30.
* //
* #include <omp.h>
* #include <stdio.h>
* #include <stdlib.h>
* //#include <sys/time.h>
* //#include <windows.h>
* #include <time.h>
* #include <math.h>
* #define CUDA 0
* #define OPENMP 1
* #define SPHERES 20
* #define rnd( x ) (x \* rand() / RAND\_MAX)
* #define INF 2e10f
* #define DIM 2048
* void ppm\_writes();
* void kernel();
* struct Sphere {
* //define Sphere ( there is no hit function in sphere)
* float   r,b,g;
* float   radius;
* float   x,y,z;
* };
* void ppm\_writes(unsigned char\* bitmap, int xdim,int ydim, FILE\* fp)
* {
* //ppm write function
* int i,x,y;
* fprintf(fp,"P3\n");
* fprintf(fp,"%d %d\n",xdim, ydim);
* fprintf(fp,"255\n");
* for (y=0;y<ydim;y++) {
* for (x=0;x<xdim;x++) {
* i=x+y\*xdim;
* fprintf(fp,"%d %d %d ",bitmap[4\*i],bitmap[4\*i+1],bitmap[4\*i+2]);
* }
* fprintf(fp,"\n");
* }
* }
* int isPrime(int);
* int main (int argc, char\*\* args){
* //    unsigned long startTime = timeGetTime();
* clock\_t start, end;
* start = clock(); //define start time
* int num\_threads;
* omp\_set\_num\_threads(atoi(args[1])); //parse num of thread parameter
* num\_threads = atoi(args[1]);
* int x,y;
* unsigned char\* bitmap;
* FILE\* fp = fopen("result.ppm","w"); //write result.ppm file
* struct Sphere \*temp\_s = (struct Sphere\*)malloc( sizeof(struct Sphere) \* SPHERES ); //define spheres array
* for (int i=0; i<SPHERES; i++) {
* temp\_s[i].r = rnd( 1.0f );
* temp\_s[i].g = rnd( 1.0f );
* temp\_s[i].b = rnd( 1.0f );
* temp\_s[i].x = rnd( 2000.0f ) - 1000;
* temp\_s[i].y = rnd( 2000.0f ) - 1000;
* temp\_s[i].z = rnd( 2000.0f ) - 1000;
* temp\_s[i].radius = rnd( 200.0f ) + 40;
* }
* bitmap=(unsigned char\*)malloc(sizeof(unsigned char)\*DIM\*DIM\*4); //define bitmap
* #pragma omp parallel for schedule(guided) collapse(2) // run kernel function with omp parallel (collapse(2)) nested loop
* for (x = 0; x < DIM; x++){
* for (y = 0; y < DIM; y++) {
* kernel(x, y, temp\_s, bitmap);
* }
* }
* end = clock();
* printf("OpenMP (%d threads) ray tracing: %lf sec\n",num\_threads,(double)(end - start)/1000.0);
* ppm\_writes(bitmap, DIM, DIM, fp); //ppm write
* fclose(fp);
* free(bitmap);
* free(temp\_s);
* printf("[result.ppm] was generated.");
* }
* float hit(struct Sphere s, float ox, float oy, float \*n){
* //hit function
* float dx = ox - s.x;
* float dy = oy - s.y;
* if (dx\*dx + dy\*dy < s.radius\*s.radius) {
* float dz = sqrtf( s.radius\*s.radius - dx\*dx - dy\*dy );
* \*n = dz / sqrtf( s.radius \* s.radius );
* return dz + s.z;
* }
* return -INF;
* }
* void kernel(int x, int y, struct Sphere\* s, unsigned char\* ptr)
* {
* //kernel function to point a pixel which has circle area
* int offset = x + y\*DIM;
* float ox = (x - DIM/2);
* float oy = (y - DIM/2);
* float r=0, g=0, b=0;
* float   maxz = -INF;
* for(int i=0; i<SPHERES; i++) {
* //check all spheres
* float   n;
* float   t = hit( s[i],ox, oy, &n );
* if (t > maxz) {
* float fscale = n;
* r = s[i].r \* fscale;
* g = s[i].g \* fscale;
* b = s[i].b \* fscale;
* maxz = t;
* }
* }
* ptr[offset\*4 + 0] = (int)(r \* 255);
* ptr[offset\*4 + 1] = (int)(g \* 255);
* ptr[offset\*4 + 2] = (int)(b \* 255);
* ptr[offset\*4 + 3] = 255;
* }
* Cuda\_ray.cu
* #include "cuda\_runtime.h"
* #include "device\_launch\_parameters.h"
* #include <stdio.h>
* #include <stdio.h>
* #include <string.h>
* #include <stdlib.h>
* #include <time.h>
* #include <math.h>
* #include <omp.h>
* #include <cuda.h>
* #define CUDA 0
* #define OPENMP 1
* #define SPHERES 20
* #define rnd( x ) (x \* rand() / RAND\_MAX)
* #define INF 2e10f
* #define DIM 2048
* #define GRID\_SIZE 128
* #define BLOCK\_SIZE 16
* struct Sphere {
* //define Sphere with hit function
* float   r, b, g;
* float   radius;
* float   x, y, z;
* \_\_device\_\_ float hit(float ox, float oy, float \*n) {
* float dx = ox - x;
* float dy = oy - y;
* if (dx\*dx + dy \* dy < radius\*radius) {
* float dz = sqrtf(radius\*radius - dx \* dx - dy \* dy);
* \*n = dz / sqrtf(radius \* radius);
* return dz + z;
* }
* return -INF;
* }
* };
* \_\_global\_\_ void kernel(unsigned char \*c, Sphere\* s)
* {
* int x = blockIdx.x\*blockDim.x + threadIdx.x; //define x axis
* int y = blockIdx.y\*blockDim.y + threadIdx.y; //define y axis
* int offset = x + y \* DIM;
* float ox = (x - DIM / 2);
* float oy = (y - DIM / 2);
* float r = 0, g = 0, b = 0;
* float   maxz = -INF;
* for (int i = 0; i < SPHERES; i++) { //find all Spheres to print a pixel
* float   n;
* float   t = s[i].hit(ox, oy, &n);
* if (t > maxz) {
* float fscale = n;
* r = s[i].r \* fscale;
* g = s[i].g \* fscale;
* b = s[i].b \* fscale;
* maxz = t;
* }
* }
* c[offset \* 4 + 0] = (int)(r \* 255);
* c[offset \* 4 + 1] = (int)(g \* 255);
* c[offset \* 4 + 2] = (int)(b \* 255);
* c[offset \* 4 + 3] = 255;
* }
* void ppm\_write(unsigned char\* bitmap, int xdim, int ydim, FILE\* fp)
* {
* //ppm write function to write result.ppm file
* int i, x, y;
* fprintf(fp, "P3\n");
* fprintf(fp, "%d %d\n", xdim, ydim);
* fprintf(fp, "255\n");
* for (y = 0; y < ydim; y++) {
* for (x = 0; x < xdim; x++) {
* i = x + y \* xdim;
* fprintf(fp, "%d %d %d ", bitmap[4 \* i], bitmap[4 \* i + 1], bitmap[4 \* i + 2]);
* }
* fprintf(fp, "\n");
* }
* }
* cudaError\_t cudaRun(); // cudaRun function to help run cuda function
* int main()
* {
* cudaError\_t cudaStatus = cudaRun(); // cuda Run
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaRun failed!");
* return -1;
* }
* cudaStatus = cudaDeviceReset();
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaRun failed!");
* return 1;
* }
* return 0;
* }
* cudaError\_t cudaRun()
* {
* FILE \*fp = fopen("result.ppm", "w"); //write empty ppm file
* Sphere\* dev\_s = 0;
* unsigned char \*dev\_bitmap;
* unsigned char \*bitmap;
* bitmap = (unsigned char\*)malloc(sizeof(unsigned char)\*DIM\*DIM \* 4); // allocate memory to host
* cudaError\_t cudaStatus;
* Sphere \*temp\_s = (Sphere \*) malloc(sizeof(Sphere) \* SPHERES); //define random sphere array
* for (int i = 0; i < SPHERES; i++) {
* temp\_s[i].r = rnd(1.0f);
* temp\_s[i].g = rnd(1.0f);
* temp\_s[i].b = rnd(1.0f);
* temp\_s[i].x = rnd(2000.0f) - 1000;
* temp\_s[i].y = rnd(2000.0f) - 1000;
* temp\_s[i].z = rnd(2000.0f) - 1000;
* temp\_s[i].radius = rnd(200.0f) + 40;
* }
* cudaStatus = cudaSetDevice(0); //set cuda device
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "CudaSetDevice failed! Do you have a CUDA-capable GPU installed?");
* goto Error;
* }
* clock\_t start, end;
* start = clock();
* cudaStatus = cudaMalloc((void\*\*)&dev\_s, SPHERES \* sizeof(Sphere)); // memory allocate for gpu(device) with spheres
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaMalloc failed!");
* goto Error;
* }
* cudaStatus = cudaMalloc((void\*\*)&dev\_bitmap, sizeof(unsigned char) \* DIM \* DIM \* 4); // memory allocate for gpu(device) with bitmap
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaMalloc failed!");
* goto Error;
* }
* cudaStatus = cudaMemcpy(dev\_s, temp\_s, SPHERES \* sizeof(Sphere), cudaMemcpyHostToDevice); // copy variable from host to device (spheres)
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaMemcpy failed!");
* goto Error;
* }
* cudaStatus = cudaMemcpy(dev\_bitmap, bitmap, sizeof(unsigned char) \* DIM \* DIM \* 4, cudaMemcpyHostToDevice);  // copy variable from host to device (bitmap) maybe empty bitmap
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaMemcpy failed!");
* goto Error;
* }
* dim3 dimGrid(GRID\_SIZE, GRID\_SIZE, 1); // define grid
* dim3 dimBlock(BLOCK\_SIZE, BLOCK\_SIZE, 1); //define block
* kernel<<<dimGrid, dimBlock>>>(dev\_bitmap, dev\_s); // run kernel function
* cudaStatus = cudaGetLastError();
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaRun launch failed : %s\n", cudaGetErrorString(cudaStatus));
* goto Error;
* }
* cudaStatus = cudaDeviceSynchronize();
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaDeviceSynchronize returned error code %d after launching addKernel!\n", cudaStatus);
* goto Error;
* }
* cudaStatus = cudaMemcpy(bitmap, dev\_bitmap,DIM\*DIM \* sizeof(unsigned char)\*4, cudaMemcpyDeviceToHost); // copy result device to host
* if (cudaStatus != cudaSuccess)
* {
* fprintf(stderr, "cudaMemcpy failed!");
* goto Error;
* }
* end = clock(); // measure cuda program run time
* printf("CUDA ray tracing: %lf sec\n", (double)(end - start) / 1000.0);
* ppm\_write(bitmap,DIM,DIM,fp); // ppm write
* printf("[result.ppm] was generated.\n");
* fclose(fp);
* Error:
* //free memory allocate to gpu memory
* cudaFree(dev\_s);
* cudaFree(dev\_bitmap);
* return cudaStatus;
* }

**Program output result**

* openmp\_ray.c

실내, 풀볼이(가) 표시된 사진

자동 생성된 설명

[result.ppm] by openmp\_ray

텍스트이(가) 표시된 사진

자동 생성된 설명

* cuda\_ray.cu
* 실내, 풀볼이(가) 표시된 사진

  자동 생성된 설명

[result.ppm] by cuda\_ray

텍스트이(가) 표시된 사진

자동 생성된 설명

텍스트이(가) 표시된 사진

자동 생성된 설명

Block size = (32,32)

텍스트이(가) 표시된 사진

자동 생성된 설명

Block size = (16,16)

텍스트이(가) 표시된 사진

자동 생성된 설명

Block size = (8,8)

텍스트이(가) 표시된 사진

자동 생성된 설명

Block size = (4,4)

텍스트이(가) 표시된 사진

자동 생성된 설명

Block size = (2,2)

텍스트이(가) 표시된 사진

자동 생성된 설명

Block size = (1,1)

Program execution

**Experimental results**

**Openmp\_ray**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Exec time(unit: sec) | 1 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
|  | 1.1 | 0.56 | 0.284 | 0.177 | 0.203 | 0.142 | 0.129 | 0.137 | 0.133 |

**Cuda\_ray**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Block size(unit: sec) | 1 | 2 | 4 | 8 | 16 | 32 |
|  | 1.514 | 0.409 | 0.159 | 0.129 | 0.121 | 0.112 |

**Interpretation/explanation**

Openmp is slowest when there is one thread, and performance increases rapidly until the number of threads increases to six, with little increase in performance since the number of threads exceeds eight.

This is because it is about that time when the overhead of switching is greater as the context increases rather than the performance increases due to the increase in threads.

The cuda can use the concept of grid and block to parallelize arrays of sizes 2048x2048. The grid is a little bit bigger, and the block is how you're going to split the threads in the grid.

The larger the block size, the more likely it is to be parallel. Therefore, when the block size was (1,1), it was slower than openmp, and while the block size increased to (2,2), (4,4), (8,8), (16, 16), (32, 32), the performance increased very quickly.

Because cuda has a block size limit (approximately 1024), it has not been used since 64x64=4096.