

lab2(1)

June 18, 2023

1 CUDA - GPU - ćwiczenia

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TODO - pliki wrzucić tak jak trzeba, żeby się poprawnie kompilowało - podzielić logicznie cellki w notebooku - dodać odpowiednie kompilacje - napisać wnioski

Estimated time < 2h

1.1 Przygotowanie środowiska wykonawczego

```
[ ]: !nvcc --version
```

```
nvcc: NVIDIA (R) Cuda compiler driver
Copyright (c) 2005-2022 NVIDIA Corporation
Built on Wed_Sep_21_10:33:58_PDT_2022
Cuda compilation tools, release 11.8, V11.8.89
Build cuda_11.8.r11.8/compiler.31833905_0
```

```
[ ]: !pip install git+https://github.com/andreinechaev/nvcc4jupyter.git
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-
wheels/public/simple/
Collecting git+https://github.com/andreinechaev/nvcc4jupyter.git
  Cloning https://github.com/andreinechaev/nvcc4jupyter.git to /tmp/pip-req-
build-4ejnqvhv
    Running command git clone --filter=blob:none --quiet
https://github.com/andreinechaev/nvcc4jupyter.git /tmp/pip-req-build-4ejnqvhv
    Resolved https://github.com/andreinechaev/nvcc4jupyter.git to commit
aac710a35f52bb78ab34d2e52517237941399eff
    Preparing metadata (setup.py) ... done
Building wheels for collected packages: NVCCPlugin
  Building wheel for NVCCPlugin (setup.py) ... done
    Created wheel for NVCCPlugin: filename=NVCCPlugin-0.0.2-py3-none-any.whl
size=4287
sha256=26fd59658972fc5e8f4ae1394d4b9c553f03664ad46a75bbd8b3f720d96a7c73
    Stored in directory: /tmp/pip-ephem-wheel-cache-5h_fi45v/wheels/a8/b9/18/23f8e
f71ceb0f63297dd1903aedd067e6243a68ea756d6f6ea
Successfully built NVCCPlugin
```

Installing collected packages: NVCCPlugin
Successfully installed NVCCPlugin-0.0.2

```
[ ]: %load_ext nvcc_plugin
```

created output directory at /content/src
Out bin /content/result.out

```
[ ]: !nvidia-smi
```

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```
+-----+
| NVIDIA-SMI 525.85.12      Driver Version: 525.85.12      CUDA Version: 12.0      |
+-----+-----+-----+-----+-----+-----+
| GPU  Name           Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
|                                           MIG M. |
+=====+=====+=====+=====+=====+=====+
|   0   Tesla T4              Off | 00000000:00:04.0 Off |                    0 |
| N/A   51C    P8      10W /  70W |  0MiB / 15360MiB |      0%      Default |
|                                           N/A |
+-----+-----+-----+-----+-----+-----+

```

```
+-----+
| Processes:
| GPU  GI    CI       PID   Type   Process name                      GPU Memory
|      ID    ID                                   Usage
+=====+
| No running processes found
+-----+

```

```
[ ]: %cu
#include <iostream>
int
main()
{
    std::cout << "Welcome To Informatyka na WIET\n";
    return 0;
}
```

Welcome To Informatyka na WIET

```
[ ]: %cu
#include <cstdio>
#include <iostream>

using namespace std;
```

```

__global__ void maxi(int* a, int* b, int n)
{
    int block = 256 * blockIdx.x;
    int max = 0;

    for (int i = block; i < min(256 + block, n); i++) {

        if (max < a[i]) {
            max = a[i];
        }
    }
    b[blockIdx.x] = max;
}

int main()
{

    int n;
    n = 3 >> 2;
    int a[n];

    for (int i = 0; i < n; i++) {
        a[i] = rand() % n;
        cout << a[i] << "\t";
    }

    cudaEvent_t start, end;
    int *ad, *bd;
    int size = n * sizeof(int);
    cudaMalloc(&ad, size);
    cudaMemcpy(ad, a, size, cudaMemcpyHostToDevice);
    int grids = ceil(n * 1.0f / 256.0f);
    cudaMalloc(&bd, grids * sizeof(int));

    dim3 grid(grids, 1);
    dim3 block(1, 1);

    cudaEventCreate(&start);
    cudaEventCreate(&end);
    cudaEventRecord(start);

    while (n > 1) {
        maxi<<<grids, block>>>(ad, bd, n);
        n = ceil(n * 1.0f / 256.0f);
        cudaMemcpy(ad, bd, n * sizeof(int), cudaMemcpyDeviceToDevice);
    }
}

```

```

        cudaEventRecord(end);
        cudaEventSynchronize(end);

        float time = 0;
        cudaEventElapsedTime(&time, start, end);

        int ans[2];
        cudaMemcpy(ans, ad, 4, cudaMemcpyDeviceToHost);

        cout << "The maximum element is : " << ans[0] << endl;

        cout << "The time required : ";
        cout << time << endl;
    }

```

The maximum element is : 0
The time required : 0.00256

1.2 Przygotowanie środowiska pod laby

```
[ ]: !git clone https://github.com/pkrucz00/parallel-programming.git
```

```

Cloning into 'parallel-programming'...
remote: Enumerating objects: 355, done.
remote: Counting objects: 100% (154/154), done.
remote: Compressing objects: 100% (77/77), done.
remote: Total 355 (delta 80), reused 116 (delta 75), pack-reused 201
Receiving objects: 100% (355/355), 40.20 MiB | 17.90 MiB/s, done.
Resolving deltas: 100% (172/172), done.

```

```
[ ]: %cd parallel-programming/
!git checkout gpu
```

```

/content/parallel-programming
Branch 'gpu' set up to track remote branch 'gpu' from 'origin'.
Switched to a new branch 'gpu'

```

```
[ ]: !nvidia-smi
!free -g
```

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```

+-----+
| NVIDIA-SMI 525.85.12      Driver Version: 525.85.12      CUDA Version: 12.0      |
+-----+-----+-----+-----+-----+-----+
| GPU  Name            Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
|                                       | MIG M.         |
+=====+=====+=====+=====+=====+=====+

```

0	Tesla T4	Off	00000000:00:04.0	Off	0
N/A	50C	P8	10W / 70W	0MiB / 15360MiB	0% Default
					N/A

```

+-----+
| Processes:                                     |
| GPU   GI   CI          PID    Type    Process name                      GPU Memory |
|      ID   ID                                   Usage                        |
|=====|
| No running processes found                    |
+-----+

```

	total	used	free	shared	buff/cache	available
Mem:	12	0	8	0	3	11
Swap:	0	0	0			

```
[ ]: %cd gpu/CUDA-Lab02
```

```
/content/parallel-programming/gpu/CUDA-Lab02
```

```
[ ]: !ls
```

```

'1 Reduction'          '3 Loop Unrolling'      '5 Histogram'  helper_timer.h
'2 Warp Divergence'    '4 Atomic Operations'  exception.h    lab2.ipynb

```

1.3 Ćwiczenie 1

1.3.1 Reduction

```
[ ]: %cd "1 Reduction"
```

```
/content/parallel-programming/gpu/CUDA-Lab02/1 Reduction
```

```
[ ]: !ls
```

```

analyser.bat    reduction_global.cpp    reduction_shared.cpp
exception.h     reduction_global_gpu.bat reduction_shared_kernel.cu
helper_timer.h  reduction_global_kernel.cu
profiler.bat    reduction.h

```

Globalna

```
[ ]: !nvcc -o reduction_global_gpu reduction_global.cpp reduction_global_kernel.cu
↪-arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !chmod 777 reduction_global_gpu
!./reduction_global_gpu
```

```

Time= 14.344 msec, bandwidth= 4.678633 GB/s
host: 0.996007, device 0.996007

```

```
[ ]: !nvprof ./reduction_global_gpu
```

```
==1311== NVPROF is profiling process 1311, command: ./reduction_global_gpu
Time= 14.762 msec, bandwidth= 4.546142 GB/s
```

```
host: 0.996007, device 0.996007
```

```
==1311== Profiling application: ./reduction_global_gpu
```

```
==1311== Profiling result:
```

Name	Type	Time(%)	Time	Calls	Avg	Min	Max
GPU activities:		95.30%	1.41337s	2424	583.07us	452.22us	790.52us
global_reduction_kernel(float*, float*, int, int)		3.72%	55.098ms	100	550.98us	545.63us	553.31us
[CUDA memcpy DtoD]		0.98%	14.589ms	1	14.589ms	14.589ms	14.589ms
[CUDA memcpy HtoD]		0.00%	1.7600us	1	1.7600us	1.7600us	1.7600us
[CUDA memcpy DtoH]		0.00%	1.7600us	1	1.7600us	1.7600us	1.7600us
API calls:		90.06%	1.45614s	101	14.417ms	3.8490us	35.061ms
cudaDeviceSynchronize		7.67%	123.98ms	2	61.992ms	172.72us	123.81ms
cudaMalloc		1.10%	17.753ms	102	174.05us	15.773us	14.767ms
cudaMemcpy		0.98%	15.774ms	2424	6.5070us	3.3680us	171.26us
cudaLaunchKernel		0.13%	2.0283ms	2	1.0141ms	310.63us	1.7176ms
cudaFree		0.06%	960.91us	1	960.91us	960.91us	960.91us
cuDeviceGetPCIBusId		0.01%	153.13us	101	1.5160us	124ns	86.240us
cuDeviceGetAttribute		0.00%	23.783us	1	23.783us	23.783us	23.783us
cuDeviceGetName		0.00%	1.7770us	3	592ns	194ns	1.2920us
cuDeviceGetCount		0.00%	941ns	2	470ns	149ns	792ns
cuDeviceGet		0.00%	566ns	1	566ns	566ns	566ns
cuModuleGetLoadingMode		0.00%	327ns	1	327ns	327ns	327ns
cuDeviceTotalMem		0.00%	245ns	1	245ns	245ns	245ns
cuDeviceGetUuid		0.00%	245ns	1	245ns	245ns	245ns

Współdzielona

```
[ ]: !nvcc -o reduction_shared_gpu reduction_shared.cpp reduction_shared_kernel.cu
↳ -arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !chmod 777 reduction_shared_gpu
!./reduction_shared_gpu
```

```
Time= 2.589 msec, bandwidth= 25.918062 GB/s
host: 0.996007, device 0.996007
```

```
[ ]: !nvprof ./reduction_shared_gpu
```

```
==1876== NVPROF is profiling process 1876, command: ./reduction_shared_gpu
```

```
Time= 2.972 msec, bandwidth= 22.580601 GB/s
```

```
host: 0.996007, device 0.996007
```

```
==1876== Profiling application: ./reduction_shared_gpu
```

```
==1876== Profiling result:
```

Name	Type	Time(%)	Time	Calls	Avg	Min	Max
GPU activities:		77.90%	242.19ms	303	799.32us	4.4160us	2.5105ms
reduction_kernel(float*, float*, unsigned int)		17.53%	54.511ms	101	539.71us	538.17us	542.37us
[CUDA memcpy DtoD]		4.57%	14.207ms	1	14.207ms	14.207ms	14.207ms
[CUDA memcpy HtoD]		0.00%	1.6640us	1	1.6640us	1.6640us	1.6640us
[CUDA memcpy DtoH]		0.00%	1.6640us	1	1.6640us	1.6640us	1.6640us
API calls:		66.47%	295.33ms	1	295.33ms	295.33ms	295.33ms
cudaDeviceSynchronize		29.52%	131.18ms	2	65.590ms	163.33us	131.02ms
cudaMalloc		3.39%	15.049ms	103	146.11us	4.1480us	14.384ms
cudaMemcpy		0.32%	1.4026ms	2	701.29us	241.61us	1.1610ms
cudaFree		0.27%	1.2169ms	303	4.0160us	2.8600us	20.430us
cudaLaunchKernel		0.03%	111.25us	101	1.1010us	125ns	47.293us
cuDeviceGetAttribute		0.01%	25.600us	1	25.600us	25.600us	25.600us
cuDeviceGetName		0.00%	6.3580us	1	6.3580us	6.3580us	6.3580us
cuDeviceGetPCIBusId		0.00%	1.9350us	3	645ns	180ns	1.4420us
cuDeviceGetCount		0.00%	991ns	2	495ns	142ns	849ns
cuDeviceGet		0.00%	374ns	1	374ns	374ns	374ns
cuModuleGetLoadingMode		0.00%	329ns	1	329ns	329ns	329ns
cuDeviceTotalMem		0.00%	214ns	1	214ns	214ns	214ns

```
cuDeviceGetUuid
```

```
[ ]: %cd ..
```

```
/content/parallel-programming/gpu/CUDA-Lab02
```

Podsumowanie

Dzięki programowi `nvprof` można łatwo zauważyć, że program wykorzystujący globalną pamięć jest zdecydowanie wolniejszy niż jego odpowiednik używający pamięci współdzielonej, ponieważ w pierwszym synchronizacja `cudaDeviceSynchronize` zajmuje aż ok. 1.5 s, a w drugim raptem 300 ms.

1.4 Ćwiczenie 2

```
[ ]: %cd "2 Warp Divergence"
```

```
/content/parallel-programming/gpu/CUDA-Lab02/2 Warp Divergence
```

```
[ ]: !nvcc -o reduction_interleaving reduction.cpp reduction_kernel_interleaving.cu
↪-arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !nvcc -o reduction_sequential reduction.cpp reduction_kernel_sequential.cu
↪-arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !chmod 744 reduction_interleaving
!chmod 744 reduction_sequential

!./reduction_interleaving
!./reduction_sequential
```

```
Time= 3.024 msec, bandwidth= 22.192085 GB/s
host: 0.996007, device 0.996007
Time= 2.486 msec, bandwidth= 26.990372 GB/s
host: 0.996007, device 0.996007
```

```
[ ]: %cd ..
```

```
/content/parallel-programming/gpu/CUDA-Lab02
```

Podsumowanie

Sekwencyjne wykonywanie ma zdecydowanie lepsze wyniki. Osiąga również lepszy bandwidth.

1.5 Ćwiczenie 3

```
[ ]: %cd "3 Loop Unrolling"
```

```
[Errno 2] No such file or directory: '3 Loop Unrolling'
/content/parallel-programming/gpu/CUDA-Lab02/4 Atomic Operations
```



```
[ ]: !nvcc -o reduction_cg reduction.cpp reduction_cg_kernel.cu -arch=sm_50
    ↪-allow-unsupported-compiler -I.
```

```
[ ]: !nvcc -o reduction_wp reduction.cpp reduction_wp_kernel.cu -arch=sm_50
    ↪-allow-unsupported-compiler -I.
```

```
[ ]: !chmod 744 reduction_cg
    !chmod 744 reduction_wp

    !./reduction_cg
    !./reduction_wp
```

```
Time= 0.813 msec, bandwidth= 82.537621 GB/s
host: 0.996007, device 0.996007
Time= 0.809 msec, bandwidth= 82.912888 GB/s
host: 0.996007, device 0.996007
```

```
[ ]: %cd ..
```

```
/content/parallel-programming/gpu/CUDA-Lab02
```

Podsumowanie

Oba programy osiągają porównywalne wyniki. Oznacza to, że rozwijanie pętli nie zawsze przyspiesza program.

1.6 Ćwiczenie 4

```
[ ]: %cd "4 Atomic Operations"
```

```
/content/parallel-programming/gpu/CUDA-Lab02/4 Atomic Operations
```

```
[ ]: !nvcc -o reduction reduction.cpp reduction_kernel.cu -arch=sm_50
    ↪-allow-unsupported-compiler -I.
```

```
[ ]: !nvcc -o reduction_blk reduction.cpp reduction_blk_atmc_kernel.cu -arch=sm_50
    ↪-allow-unsupported-compiler -I.
```

```
[ ]: !nvcc -o reduction_wrp reduction.cpp reduction_wrp_atmc_kernel.cu -arch=sm_50
    ↪-allow-unsupported-compiler -I.
```

```
[ ]: !chmod 744 reduction
    !chmod 744 reduction_blk
    !chmod 744 reduction_wrp

    !./reduction
    !./reduction_blk
    !./reduction_wrp
```

```
Time= 35.418 msec, bandwidth= 1.894742 GB/s
host: 0.996007, device 0.995957
```

```
Time= 0.807 msec, bandwidth= 83.178024 GB/s
host: 0.996007, device 0.996007
Time= 0.807 msec, bandwidth= 83.177002 GB/s
host: 0.996007, device 0.996008
```

```
[ ]: %cd ..
```

```
/content/parallel-programming/gpu/CUDA-Lab02
```

Podsumowanie

Używanie atomowych operacji daje zdecydowanie lepsze wyniki niż podejście naiwne. Oba sposoby na atomowe operacje są równie dobre.

1.7 Ćwiczenie 5

```
[ ]:
```

```
[ ]: %cd "5 Histogram"
```

```
[Errno 2] No such file or directory: '5 Histogram'
/content/parallel-programming/gpu/CUDA-Lab02/5 Histogram
```

```
[ ]: !nvcc -o histo histo.cu -arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !nvcc -o reduce reduce.cu -arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !chmod 744 histo
!chmod 744 reduce

!./histo
!./reduce
```

Using device 0:

Tesla T4; global mem: -1344471040B; compute v7.5; clock: 1590000 kHz

Running naive histo

```
bin 0: count 1
bin 1: count 2
bin 2: count 1
bin 3: count 2
bin 4: count 1
bin 5: count 2
bin 6: count 1
bin 7: count 2
bin 8: count 1
bin 9: count 2
bin 10: count 1
bin 11: count 3
bin 12: count 1
bin 13: count 3
```

```
bin 14: count 2
bin 15: count 2
Using device 0:
Tesla T4; global mem: -1344471040B; compute v7.5; clock: 1590000 kHz
Running global reduce
average time elapsed: 0.136013
```

```
[ ]: !nvcc -o histo2 histo.cu -arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !nvcc -o reduce reduce.cu -arch=sm_50 -allow-unsupported-compiler -I.
```

```
[ ]: !chmod 744 histo2
!chmod 744 reduce

!./histo2
!./reduce
```

Strumieniowane dane wyjściowe obcięte do 5000 ostatnich wierszy.

```
bin 126076: count 0
bin 126077: count 0
bin 126078: count 0
bin 126079: count 0
bin 126080: count 0
bin 126081: count 0
bin 126082: count 0
bin 126083: count 0
bin 126084: count 0
bin 126085: count 0
bin 126086: count 0
bin 126087: count 0
bin 126088: count 0
bin 126089: count 0
bin 126090: count 0
bin 126091: count 0
bin 126092: count 0
bin 126093: count 0
bin 126094: count 0
bin 126095: count 0
bin 126096: count 0
bin 126097: count 0
bin 126098: count 0
bin 126099: count 0
bin 126100: count 0
bin 126101: count 0
bin 126102: count 0
bin 126103: count 0
bin 126104: count 0
bin 126105: count 0
```

bin 126106: count 0
bin 126107: count 0
bin 126108: count 0
bin 126109: count 0
bin 126110: count 0
bin 126111: count 0
bin 126112: count 0
bin 126113: count 0
bin 126114: count 0
bin 126115: count 0
bin 126116: count 0
bin 126117: count 0
bin 126118: count 0
bin 126119: count 0
bin 126120: count 0
bin 126121: count 0
bin 126122: count 0
bin 126123: count 0
bin 126124: count 0
bin 126125: count 0
bin 126126: count 0
bin 126127: count 0
bin 126128: count 0
bin 126129: count 0
bin 126130: count 0
bin 126131: count 0
bin 126132: count 0
bin 126133: count 0
bin 126134: count 0
bin 126135: count 0
bin 126136: count 0
bin 126137: count 0
bin 126138: count 0
bin 126139: count 0
bin 126140: count 0
bin 126141: count 0
bin 126142: count 0
bin 126143: count 0
bin 126144: count 0
bin 126145: count 0
bin 126146: count 0
bin 126147: count 0
bin 126148: count 0
bin 126149: count 0
bin 126150: count 0
bin 126151: count 0
bin 126152: count 0
bin 126153: count 0

bin 126154: count 0
bin 126155: count 0
bin 126156: count 0
bin 126157: count 0
bin 126158: count 0
bin 126159: count 0
bin 126160: count 0
bin 126161: count 0
bin 126162: count 0
bin 126163: count 0
bin 126164: count 0
bin 126165: count 0
bin 126166: count 0
bin 126167: count 0
bin 126168: count 0
bin 126169: count 0
bin 126170: count 0
bin 126171: count 0
bin 126172: count 0
bin 126173: count 0
bin 126174: count 0
bin 126175: count 0
bin 126176: count 0
bin 126177: count 0
bin 126178: count 0
bin 126179: count 0
bin 126180: count 0
bin 126181: count 0
bin 126182: count 0
bin 126183: count 0
bin 126184: count 0
bin 126185: count 0
bin 126186: count 0
bin 126187: count 0
bin 126188: count 0
bin 126189: count 0
bin 126190: count 0
bin 126191: count 0
bin 126192: count 0
bin 126193: count 0
bin 126194: count 0
bin 126195: count 0
bin 126196: count 0
bin 126197: count 0
bin 126198: count 0
bin 126199: count 0
bin 126200: count 0
bin 126201: count 0

bin 126202: count 0
bin 126203: count 0
bin 126204: count 0
bin 126205: count 0
bin 126206: count 0
bin 126207: count 0
bin 126208: count 0
bin 126209: count 0
bin 126210: count 0
bin 126211: count 0
bin 126212: count 0
bin 126213: count 0
bin 126214: count 0
bin 126215: count 0
bin 126216: count 0
bin 126217: count 0
bin 126218: count 0
bin 126219: count 0
bin 126220: count 0
bin 126221: count 0
bin 126222: count 0
bin 126223: count 0
bin 126224: count 0
bin 126225: count 0
bin 126226: count 0
bin 126227: count 0
bin 126228: count 0
bin 126229: count 0
bin 126230: count 0
bin 126231: count 0
bin 126232: count 0
bin 126233: count 0
bin 126234: count 0
bin 126235: count 0
bin 126236: count 0
bin 126237: count 0
bin 126238: count 0
bin 126239: count 0
bin 126240: count 0
bin 126241: count 0
bin 126242: count 0
bin 126243: count 0
bin 126244: count 0
bin 126245: count 0
bin 126246: count 0
bin 126247: count 0
bin 126248: count 0
bin 126249: count 0

bin 126250: count 0
bin 126251: count 0
bin 126252: count 0
bin 126253: count 0
bin 126254: count 0
bin 126255: count 0
bin 126256: count 0
bin 126257: count 0
bin 126258: count 0
bin 126259: count 0
bin 126260: count 0
bin 126261: count 0
bin 126262: count 0
bin 126263: count 0
bin 126264: count 0
bin 126265: count 0
bin 126266: count 0
bin 126267: count 0
bin 126268: count 0
bin 126269: count 0
bin 126270: count 0
bin 126271: count 0
bin 126272: count 0
bin 126273: count 0
bin 126274: count 0
bin 126275: count 0
bin 126276: count 0
bin 126277: count 0
bin 126278: count 0
bin 126279: count 0
bin 126280: count 0
bin 126281: count 0
bin 126282: count 0
bin 126283: count 0
bin 126284: count 0
bin 126285: count 0
bin 126286: count 0
bin 126287: count 0
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Using device 0:
Tesla T4; global mem: -1344471040B; compute v7.5; clock: 1590000 kHz
Running global reduce
average time elapsed: 0.136126
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Tworzenie histogramów (przydzielanie do kubelków) dobrze zrównoległa się na kartach graficznych. Zwiększenie liczby kubelków nie wpływa na czas wykonania programu.

[]: