NUMERICAL SCIENTIFIC COMPUTING: Mini project 3

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The assignment

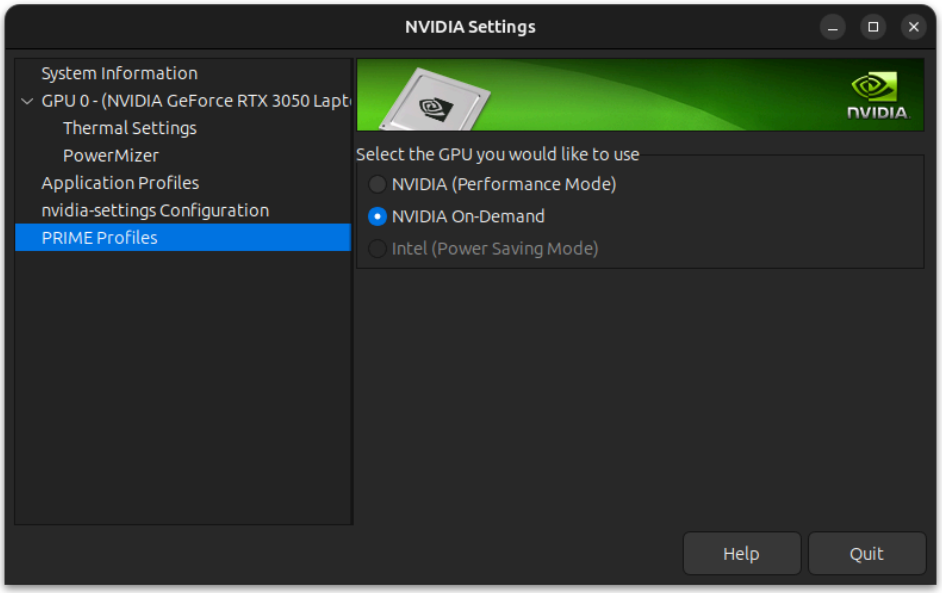
The miniproject is about computing the Mandelbrot set. This can be done in several ways, one faster than the other. Computing this requires a loop to run over each value of a complex matrix, which makes the problem O(x^3).
For each point in the matrix, we must check whether it is stable using the Mandelbrot quadratic complex mapping. This is done for a number of iterations I and with a threshold T. The set is calculated within a predefined area and density.
This time we try to optimize the runtime by using the GPU.

Introspection of available compute resources

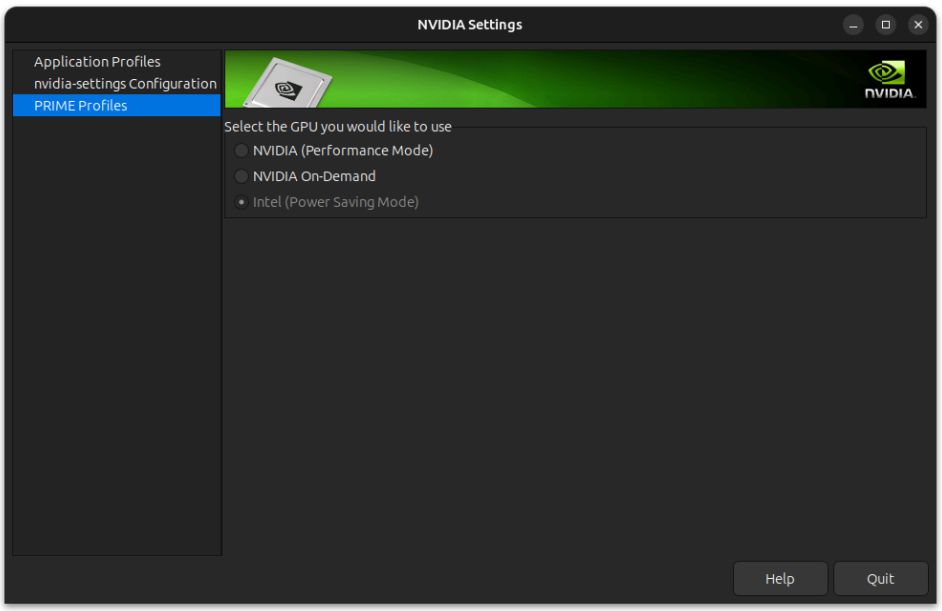
We run the introspection Python program provided in the lectures and see the following:

```
============================================================
OpenCL Platforms and Devices
============================================================
Platform - Name:  NVIDIA CUDA
Platform - Vendor:  NVIDIA Corporation
Platform - Version:  OpenCL 3.0 CUDA 12.2.148
Platform - Profile:  FULL_PROFILE
    --------------------------------------------------------
    Device - Name:  NVIDIA GeForce RTX 3050 Laptop GPU
    Device - Type:  ALL | GPU
    Device - Max Clock Speed:  1500 Mhz
    Device - Compute Units:  16
    Device - Local Memory:  48 KB
    Device - Constant Memory:  64 KB
    Device - Global Memory: 4 GB
    Device - Max Buffer/Image Size: 975 MB
    Device - Max Work Group Size: 1024



Process finished with exit code 0
```

OpenCL only finds one compute device, the Nvidia GPU. Sadly enough we can't test the program on different compute devices. This has probably to do with the following selection window.



After I switched my GPU to the Intel integrated graphics, but then the following happens.




```
/home/larsdepuydt/Documents/numerical-sientific-computing/venv/bin/python /home/larsdepuydt/Documents/nume

============================================================
OpenCL Platforms and Devices
Traceback (most recent call last):
  File "/home/larsdepuydt/Documents/numerical-sientific-computing/introspection.py", line 9, in <module>
    for platform in cl.get_platforms():
                    ^^^^^^^^^^^^^^^^^^
pyopencl._cl.LogicError: clGetPlatformIDs failed: PLATFORM_NOT_FOUND_KHR

Process finished with exit code 1
```

OpenCL doesn't recognize my intel integrated graphics GPU so the code won't run.

Memory types

The solution has the following input header.

```
__kernel void mandelbrot(__global const float2 *C, __global float *M, const int max_iters, const float threshold)
```

- Matrices C and M are *global* because it has to be accessed across different work groups
- Matrix C and constants max_iters and threshold are *constant*, as it doesn't change across different executions and are red frequently
- The variables c, z, x, and y are *private* and specific to each work item.

Runtime

Multiple grid sizes were made and their runtime is compared against each other in the following table. All the implementations were tested with the following parameters:

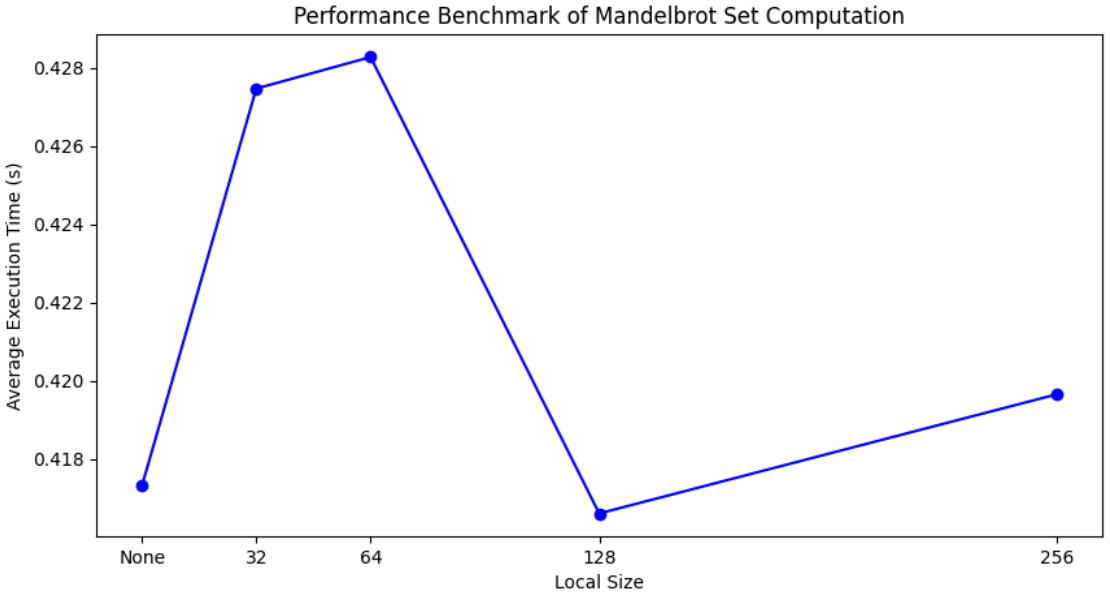
x_min, x_max, y_min, y_max = -2.0, 1.0, -1.5, 1.5
I = 30
T = 2

The matrix C is of type 'complex64' and the result matrix of 'float32'

	Run 1 (s)	**Run 2 (s)**	**Run 3 (s)**	**Average (s)**
p_im, p_re = **5000, 5000** Nvidea GPU	0.0414	0.0412	0.0410	**0,0412**
p_im, p_re = **8000, 8000** Nvidea GPU	0.2512	0.2469	0.2065	**0,2349**
p_im, p_re = **16000, 16000** Nvidea GPU	0.4221	0.4325	0.4222	**0,4256**

Performance changing local_groups parameter

If we change the local_groups parameter, the following results are obtained.



Testing

Some basic tests were included and all of them are passed.

```
Testing started at 10:55 AM ...
Launching pytest with arguments /home/larsdepuydt/Documents/numerical-sientific-computing/test_mandelbrot_openCL.py --no-header --no-summary -q in /home/larsdepuydt/Documents/numerical-sientific-computing

============================ test session starts ============================
collecting ... collected 4 items

test_mandelbrot_openCL.py::test_complex_matrix_dimensions PASSED         [ 25%]
test_mandelbrot_openCL.py::test_complex_matrix_type PASSED               [ 50%]
test_mandelbrot_openCL.py::test_plot_mandelbrot_runs PASSED              [ 75%]
test_mandelbrot_openCL.py::test_mandelbrot_openCL PASSED                 [100%]

======================== 4 passed, 2 warnings in 1.45s =========================

Process finished with exit code 0
```