Xilinx SDAccel Mandelbrot Example by Impulse Accelerated
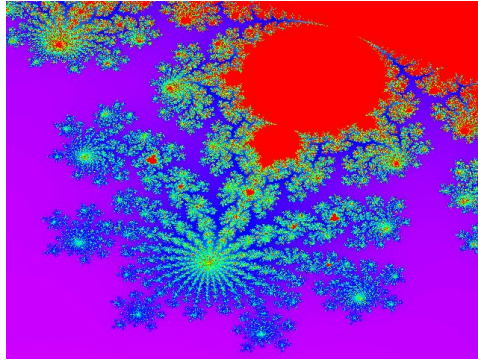

Description

Impulse Accelerated Technologies has written this example of an OpenCL implementation for creating an image by applying the Mandelbrot equation to each pixel and then coloring the pixel according to the results.

The Mandelbrot equation is used to determine whether the complex number c is part of the Mandelbrot set. The equation is defined as:

$z(n+1) = z(n)^2 + c$

The complex number c is in the Mandelbrot set if the absolute value (magnitude) of z(n), starting with z(0)=0, is bounded for n=0…infinity.

To create an image using the Mandelbrot equation, the complex number c of the form x + y*i is tested over the range Xmin <= x <= Xmax and Ymin <= y <= Ymax to see whether the given complex number is a member of the Mandelbrot set. The complex numbers tested are chosen using numbers within the ranges for x and y which have been linearly mapped to the (x,y) pixel coordinates of an image of size width-by-height. Calculating the mapped value for c for a pixel at (x,y):

dx = (Xmax – Xmin) / width
dy = (Ymax – Ymin) / height
c = (Xmin + x * dx) + (Ymin + y * dy)*i

The Mandelbrot equation is calculated looping over 0 <= n <= maxIterations, testing the magnitude of z(n) for divergence and exiting the loop when detected. The result of the calculation for each coordinate is the number of iterations performed which is converted into an RGB color value relative to maxIterations and then output as a bitmap image file.

Kernel Arguments

void mandelbrot(__global unsigned int* output,

        int xmin,

        int ymin,

        int dx,

        int dy,

        int max_iteraions)

  Arguments:

- output = Output image buffer
- xmin = Minimum fixed-point value of x for coordinate (0,0)
- ymin Minimum fixed-point value of y for coordinate (0,0)
- dx = Fixed-point step size for x-dimension when calculating x for coordinate (x,y)
- dy = Fixed-point step size for y-dimension when calculating y for coordinate (x,y)
- max_iteraions = Maximum number of iterations to perform

Kernel Operation

The kernel uses fixed-point arithmetic to calculate the Mandelbrot equation in the slightly modified form of:

$$z(n) = z(n-1)^2 + c$$

and tests the magnitude of $z(n-1)$. This allows for more efficient sharing of values when calculating $z(n)$ and magnitude($z(n-1)$). All arguments passed to the kernel are provided by the host in the necessary fixed-point format. A work item is defined as a single pixel and the image size is specified by the host using a 2-dimensional global work group size when calling clEnqueueNDRangeKernel(). The 1- or 2-dimensional local work group size is specified by the host indicating the number of work items that are to be processed as a group.

Building and Running the Example

To run CPU emulation

        sdaccel run_sda_emu_cpu.tcl

        The output bitmap image will be located at:

            ./prj_mandelbrot_emu_cpu/impl/sim/alg/mandelbrot.bmp

To build system for hardware

        sdaccel run_sda_build_hardware.tcl

To run system in hardware

        ./run_hardware.sh

        NOTES:

1) You may need to first make the script executable using the command:
   > chmod 755 run_hardware.sh
2) Be sure that one of the environment variables is set:
   a) XILINX_OPENCL=<SDAccel installation directory>
      i) example: export XILINX_OPENCL=/opt/Xilinx/SDAccel/2014.3.5
   b) XILINX_VIVADO=<Vivado location in SDAccel installation directory>
      i) example: export XILINX_VIVADO=/opt/Xilinx/SDAccel/2014.3.5/Vivado

The output bitmap image will be located at:
> ./mandelbrot.bmp

About Impulse

Founded in 2002, Impulse Accelerated Technologies, Inc. is a Xilinx Partner specializing in helping software teams accelerate their designs in FPGA. Impulse has helped hundreds of teams accelerate data, signal, image and other applications in FPGA. We feature excellent documentation and ongoing maintenance.

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Contact info@ImpulseAccelerated.com to discuss your application.