

## 1 Overview

**1.1 Location** `$<AMDAPPSDKSamplesInstallPath>\samples\opencl\cl\2.0`

**1.2 How to Run** See the *Getting Started* guide for how to build samples. You first must compile the sample.

Use the command line to change to the directory where the executable is located. The default executables are placed in `$<AMDAPPSDKSamplesInstallPath>\samples\opencl\bin\x86_64\` for 64-bit builds.

Type the following command(s).

1. `RecursiveGaussian_ProgramScope`  
This applies recursive Gaussian filter on input image.
2. `RecursiveGaussian_ProgramScope -h`  
This prints the help message.

**1.3 Command Line Options** [Table 1](#) lists, and briefly describes, the command line options.

**Table 1 Command Line Options**

Short Form	Long Form	Description
-h	--help	Shows all command options and their respective meaning.
	--device	Devices on which the program is to be run. Acceptable values are <code>cpu</code> or <code>gpu</code> .
-q	--quiet	Quiet mode. Suppresses all text output.
-e	--verify	Verify results against reference implementation.
-t	--timing	Print timing.
	--dump	Dump binary image for all devices.
	--load	Load binary image and execute on device.
	--flags	Specify compiler flags to build the kernel.
-p	--platformId	Select platformId to be used (0 to N-1, where N is the number of available platforms).
-d	--deviceId	Select deviceId to be used (0 to N-1, where N is the number of available devices).
-v	--version	AMD APP SDK version string.
-i	--iterations	Number of iterations for kernel execution.

## 2 Introduction

This sample demonstrates the use of Program Scope Variables, a new feature of OpenCL 2.0. Program scope variables can be defined either in the constant address space or in the global address space and their scope is the program lifetime. These variables could be shared by more than one compute unit. Program scope variables are demonstrated in this sample by using the Recursive Gaussian filter implementation.

The Gaussian filter is a filter whose impulse response is a Gaussian function. It has the minimum possible group delay. Gaussian filter modifies the input signal by convolution with a Gaussian function. The advantages of using the Gaussian filter are:

- Combined effect of differentiation and low pass filtering yields a filter with a smooth impulse response.
- Used to compute running averages.

The Gaussian function is non-zero for  $x \in [-\infty, \infty]$  and would theoretically require an infinite window length. However, since it decays rapidly, it is often reasonable to truncate the filter window and implement the filter directly for narrow windows, in effect by using a simple rectangular window function.

The Gaussian filters can be implemented using scale space windowing technique. In this sample, Gaussian filter implementation is done using Recursive filters which is a type of scale space windowing technique.

## 3 Implementation

The Recursive Gaussian filter is implemented using two kernels, one a RecursiveGaussian Kernel, and another, Transpose Kernel.

In the RecursiveGaussian Kernel, both Forward and reverse filter are used to ensure the response is symmetrical.

The Forward filter is as follows,:

$$Y_f(m, n) = a_0 * X(m, n) + a_1 * X(m, n-1) - b_1 * Y_f(m, n-1) - b_2 * Y_f(m, n-2),$$

The Reverse filter is as follows:

$$Y_r(m, n) = a_2 * X(m, n) + a_3 * X(m, n+1) - b_1 * Y_r(m, n+1) - b_2 * Y_r(m, n+2),$$

where  $a_0, a_1, a_2, a_3, b_0$  and  $b_1$  are Gaussian filter parameters.  $X$  is the input image pixels and  $Y_f, Y_r$  is the output of the forward and reverse recursive filter respectively, and the  $m$  and  $n$  axis are parallel to width and height respectively.

The Final Output will be :

$$Y(m, n) = Y_f(m, n) + Y_r(m, n).$$

After the execution of the Recursive Gaussian Kernel, data is transposed using transpose kernel. Further, Recursive Gaussian kernel is applied on the transposed image to filter in the other direction. Finally again transpose kernel is applied to bring back the filtered image to original position. In all these data transitions, the intermediate results of the Recursive Gaussian kernel are held in a program scope array.

## 4 References

1. [http://en.wikipedia.org/wiki/Gaussian\\_filter](http://en.wikipedia.org/wiki/Gaussian_filter)
2. [http://en.wikipedia.org/wiki/Scale\\_space\\_implementation](http://en.wikipedia.org/wiki/Scale_space_implementation)
3. <http://www.cwp.mines.edu/Meetings/Project06/cwp546.pdf>
4. <http://homepage.tudelft.nl/e3q6n/publications/1998/ICPR98LVTPV/ICPR98LVTPV.pdf>

---

### Contact

Advanced Micro Devices, Inc.  
One AMD Place  
P.O. Box 3453  
Sunnyvale, CA, 94088-3453  
Phone: +1.408.749.4000

For AMD Accelerated Parallel Processing:  
URL: [developer.amd.com/appsdk](http://developer.amd.com/appsdk)  
Developing: [developer.amd.com/](http://developer.amd.com/)  
Support: [developer.amd.com/appsdksupport](http://developer.amd.com/appsdksupport)



The contents of this document are provided in connection with Advanced Micro Devices, Inc. ("AMD") products. AMD makes no representations or warranties with respect to the accuracy or completeness of the contents of this publication and reserves the right to make changes to specifications and product descriptions at any time without notice. The information contained herein may be of a preliminary or advance nature and is subject to change without notice. No license, whether express, implied, arising by estoppel or otherwise, to any intellectual property rights is granted by this publication. Except as set forth in AMD's Standard Terms and Conditions of Sale, AMD assumes no liability whatsoever, and disclaims any express or implied warranty, relating to its products including, but not limited to, the implied warranty of merchantability, fitness for a particular purpose, or infringement of any intellectual property right.

AMD's products are not designed, intended, authorized or warranted for use as components in systems intended for surgical implant into the body, or in other applications intended to support or sustain life, or in any other application in which the failure of AMD's product could create a situation where personal injury, death, or severe property or environmental damage may occur. AMD reserves the right to discontinue or make changes to its products at any time without notice.

#### Copyright and Trademarks

© 2015 Advanced Micro Devices, Inc. All rights reserved. AMD, the AMD Arrow logo, ATI, the ATI logo, Radeon, FireStream, and combinations thereof are trademarks of Advanced Micro Devices, Inc. OpenCL and the OpenCL logo are trademarks of Apple Inc. used by permission by Khronos. Other names are for informational purposes only and may be trademarks of their respective owners.