

## 1 Overview

**1.1 Location** `$<AMDAPPSDKSamplesInstallPath>\samples\bolt\`

**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 pre-compiled sample executable is at `$<AMDAPPSDKSamplesInstallPath>\samples\bolt\bin\x86\` for 32-bit builds, and `$<AMDAPPSDKSamplesInstallPath>\samples\bolt\bin\x86_64\` for 64-bit builds.

Type the following command(s).

1. `BoxFilterSAT`  
This command applies a box blur filter on the input image, using the default options.
2. `BoxFilterSAT -h`  
This command prints the help file.
3. `BoxFilterSAT_TBB -h`  
This command generates a build with the multiCoreCpu path (the Thread Building Block library), enabled.

**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	Explicit device selection for Bolt [auto/openCL/multiCoreCpu/SerialCpu]
-q	--quiet	Quiet mode. Suppresses most text output.
-e	--verify	Verify results against reference implementation.
-t	--timing	Print timing.
-v	--version	Bolt and AMD APP SDK version string.
-i	--iterations	Number of iterations for kernel execution.
-w	--width	Filter width.

**Note:** The `--device multiCoreCpu` option becomes available when the sample is compiled with `ENABLE_TBB` defined. Microsoft Visual Studio build configurations `Debug_TBB` and `Release_TBB` are created for this purpose. These configurations have `ENABLE_TBB` defined to enable the TBB path (multiCoreCpu) for all the AMD BOLT functions used in the sample.

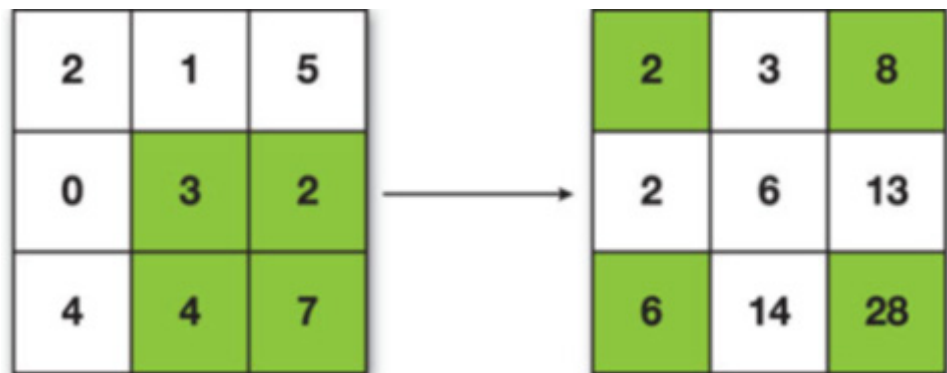
## 2 Introduction

Box filtering, also known as average or mean filtering, is a method of reducing the intensity variation between pixels in an image, and is a commonly used technique to reduce noise. The Box filter can be implemented using different techniques. This sample uses the precomputed Summed Area Tables (SAT) technique.

## 3 Implementation Details

### 3.1 BoxFilter with SAT

Summed-area tables (SATs) were introduced by Crow (see reference [1]) to accelerate texture filtering. Each element in a SAT is the sum of all texture elements in the rectangle above and to the left of the element, as shown in Figure 1.



**Figure 1** Sample data and the corresponding SAT

The sum of any rectangular region then can be determined in constant time using:

$$s = t[x_{\max}, y_{\max}] - t[x_{\max}, y_{\min}] - t[x_{\min}, y_{\max}] + t[x_{\min}, y_{\min}]$$

The average over this region can be computed by dividing by the number of pixels in the region.

SATs let us sample arbitrary rectangular regions, which is sufficient for applying a box filter of any size on an image.

### 3.2 Computing the SAT

Computing the SAT is done in two passes.

1. Horizontal pass: the prefix sum is applied on each row separately.
2. Vertical pass: the prefix sum is applied on each column separately.

After computing a SAT, a final BoxFilter kernel requires fetching only four values from a global buffer to compute the final filtered image.

This technique is very fast for interactive applications, because, after applying the pre-computation, the filter size can be changed immediately without degrading performance.

Note that the value of the sums (and, thus, the dynamic range) can become very large; the table entries require extended precision. The number of bits of precision needed per component is calculated using the following formula:

$$P_s = \log_2(w) + \log_2(h) + P_i$$

In the above formula,

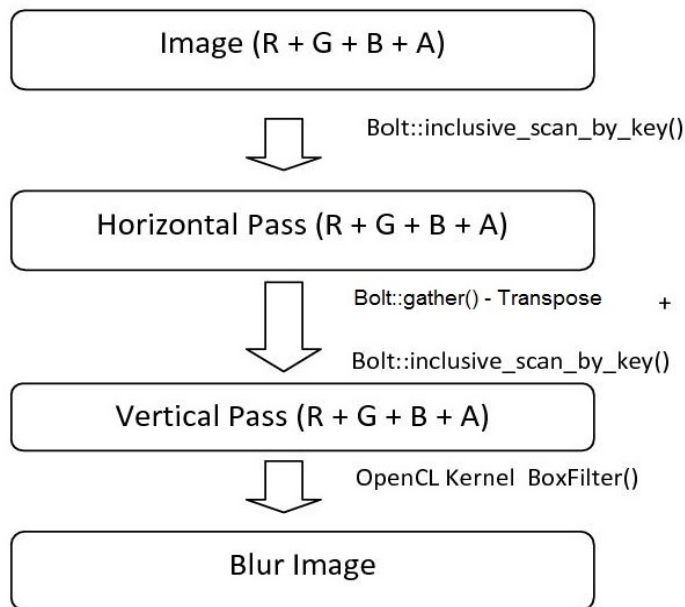
- $w$  and  $h$  are the width and height, respectively, of the input image.
- $P_s$  is the precision required to hold values in the SAT.
- $P_i$  is the number of bits of precision of the input.

Given this formula, a 256 x 256 texture with eight-bit components requires a SAT with 24 bits of storage per component. Thus, 32 bits per pixel image data ( $12 + 12 + 8 = 32$ ) are used for the calculation of the SAT. This technique can maximally process a 4096 x 4096 image.

### 3.3 BoxFilter using BOLT APIs

Box filter is applied on each component (R, G, B, and A) of the pixels of the input image. As discussed in the preceding section, generating the SAT requires two passes, one for the horizontal scan and the other for the vertical scan.

The `inclusive_scan_by_key()` BOLT API is used for performing the horizontal scan and it uses a key buffer for each pixel (the key is the same as the row number). For the vertical scan, the result matrix from the horizontal scan is first transposed and is then followed by the prefix scan. The BOLT `gather()` API has been used for transpose operation and the transposed matrix is passed to the next scan operation. The following flowchart illustrates the workflow.



## 4 References

1. Crow, Franklin (1984). "Summed-area tables for texture mapping". *SIGGRAPH '84: Proceedings of the 11th annual conference on Computer graphics and interactive techniques*, pp. 207–212.

### 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.