

# Monte Carlo Simulation for Asian Option Pricing

## 1 Overview

**1.1 Location** \$(AMDAPPSDKSAMPLESROOT)\samples\opencl\cl\app

**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 \$(AMDAPPSDKSAMPLESROOT)\samples\opencl\bin\x86\ for 32-bit builds, and \$(AMDAPPSDKSAMPLESROOT)\samples\opencl\bin\x86\_64\ for 64-bit builds.

Type the following command(s).

1. MonteCarloAsian  
Runs with the default options  $c = 10$ ,  $i = 50$ ,  $s = 55$ ,  $r = 0.06$ ,  $m = 1$ .
2. MonteCarloAsian -h  
This prints the help file.

**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).
-c	--steps	Steps of the Monte Carlo simulation.
-p	--initPrice	Initial price (default = 50).
-s	--strikePrice	Strike price (default = 55)

Short Form	Long Form	Description
-r	--interest	Interest rate (default = 0.06)
-m	--maturity	Maturity (default = 1).
-i	--iterations	Number of iterations for kernel execution.

## 2 Introduction

The most common definition of an *option* (see reference [1]) is an agreement between two parties, the *option seller* and the *option buyer*, whereby the option buyer is granted a right (but not an obligation), secured by the option seller, to carry out some operation (or *exercise* the option) at some moment in the future. The predetermined price is referred to as the *strike price*; the future date is called the *expiration date*.

There are two basic options types:

- A *call option* grants its holder the right to *buy* the *underlying asset* at a *strike price* at some moment in the future.
- A *put option* gives its holder the right to *sell* the *underlying asset* at a *strike price* at some moment in the future.

There are several types of options, mostly depending on when the option can be exercised.

European options can be exercised only on the expiration date. American-style options are more flexible: they can be exercised any time up to, and including, the expiration date; as such, they are generally priced at least as high as corresponding European options. Other types of options are path-dependent, or have multiple exercise dates (Asian, Bermudian). For a call option, the profit made at the exercise date is the difference between the price of the asset on that date and the strike price, minus the option price paid. For a put option, the profit made at the exercise date is the difference between the strike price and the price of the asset on that date, minus the option price paid. The price of the asset at expiration date and the strike price, therefore, strongly influence how much one is willing to pay for an option.

Other important factors in the price of an option are:

- The time to the expiration date,  $T$ : Longer periods imply a wider range of possible values for the underlying asset on the expiration date; thus, there is more uncertainty about the value of the option.
- The riskless rate of return,  $r$ , which is the annual interest rate of bonds or other “risk-free” investments: Any amount  $P$  of dollars is guaranteed to be worth  $P \cdot e^{rT}$  dollars  $T$  years from now if placed today in one of these investments. In other words, if an asset is worth  $P$  dollars  $T$  years from now, it is worth  $P \cdot e^{-rT}$  today.

## 3 Monte Carlo simulation for Asian Option

Monte Carlo analysis (see reference [1]) is a cornerstone for implementing financial models. These simulations have many advantages, including the ease of implementation, as well as the applicability to multi-dimensional problems commonly encountered in finance. Option pricing can be represented as expectations. An example is an Asian Option Call, which is a financial contract

dependent on the average security price over discrete dates in the future. The asset price at some time,  $t$ , in the future follows the classic Black-Scholes model as follows.

**Equation 1** 
$$S_t = S_0 e^{(r - 0.5 \sigma^2) t + \sigma W_t}$$

Where  $r$  is the risk-free rate of return,  $\sigma$  is volatility of the asset price, and  $dW_t$  is the increment of standard Brownian motion. The price of this option is a function of the strike price,  $K$ , and the option maturity,  $T$ , shown as follows

**Equation 2** 
$$P(T, K) = e^{-rT} \mathbb{E} \{ \max(S_a - K, 0) \mid S_0 = s_0 \}$$

where the average asset price is:

**Equation 3** 
$$S_a = \sum_{i=1}^n S_{ti}$$

The combination of these equations does not have a closed-form solution. We use a Monte Carlo simulation to solve this pricing problem. However, for risk management, hedging, and stress testing of a portfolio, the price-sensitivity as a function of changes to model inputs (*greeks*, as they are commonly known) becomes quite valuable. One greek of interest is *vega*, the option-price sensitivity to changes in the securities volatility, which is:

**Equation 4** 
$$\text{vega} = \frac{dP(T, K)}{d\sigma}$$

The price and vega calculation using Monte Carlo techniques is very time-consuming for several reasons. For simulation accuracy, many Brownian motion trajectories are used for price determination. For each option simulation, there are several contract dates during the option maturity; monthly dates for an annual contract. Also, an accurate picture of price volatility is achieved by rerunning the simulation with many different values for the volatility,  $\sigma$ . The option trader faced with minimizing risk to their client-base and portfolio may want to have this price and volatility analysis before making trades or in post-closing analysis. For very large, multi-commodity portfolios, analysts frequently wait hours for model simulations. This affects their ability to respond quickly to dynamic market situations or to complete a risk analysis before the next day of trading.

## 4 Implementation Details

Each work-item calculates the vector of four samples of price and vega from a given vector of 4 of strike price, stock price, interest, maturity and sigma. The final value of the price and vega are calculated from all the samples (1024) of price and vega on the host side. See reference [1] for more details on how to calculate the final price and vega for a given sigma.

## 5 Recommended Input Option Settings

For best performance, enter the following on the command line: `-c 256 -i 5 -q -t`

## 6 References

1. [http://www.interactivesupercomputing.com/success/pdf/caseStudy\\_financialmodeling.pdf](http://www.interactivesupercomputing.com/success/pdf/caseStudy_financialmodeling.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)  
Forum: [developer.amd.com/openclforum](http://developer.amd.com/openclforum)



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

© 2011 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.