AMD Accelerated Parallel Processing TECHNOLOGY

# SAMPLE

# Black-Scholes_Bolt

## 1 Overview

### 1.1 Location

`$(AMDAPPSDKSAMPLESROOT)\samples\bolt\examples`

### 1.2 How to Run

See the *Getting Started* guide for how to build samples. You must first 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\bolt\bin\x86_64\` for 64-bit builds. Bolt currently does not support 32-bit libraries.

Type the following command(s).

1. `BlackScholes`
   This runs the program with the default options;s = (256 * 1024).
2. `BlackScholes -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. |
| `-q` | `--quiet` | Quiet mode. Suppresses most text output. |
| `-e` | `--verify` | Verify results against reference implementation. |
| `-t` | `--timing` | Print timing related statistics. |
| `-v` | `--version` | Bolt library and runtime version string. |
| `-x` | `--samples` | Number of sample input values to be calculated. |
| `-i` | `--iterations` | Number of iterations. |

## 2 Introduction

The Option pricing is a very important problem encountered in financial engineering.This sample shows an implementation of the Black-Scholes model for European options.

The most common definition of an *option* 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 (see reference 1). The pre-determined price is referred to as the *strike price*, and the future date is called the *expiration date*.

The two primary option types are:

- 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 factors to consider in regard to 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 at any time up to, and including, the expiration date; as such, they are gernerally 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. Thus, the price of the asset at expiration date and the strike price strongly influence how much is paid 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. This means 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 of dollars, $P$, 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 Black-Scholes Model

The Black-Scholes model (see reference 2) provides a partial differential equation (PDE) for the evolution of an option price under certain assumptions. For European options, a closed-form solution exists for this PDE.

**Equation 1** $$V_{call} = S \cdot PHI(d_1) - X \cdot e^{-rT} \cdot PHI(d_2)$$

**Equation 2** $$V_{put} = X \cdot e^{-rT} \cdot PHI(-d_2) - S \cdot PHI(-d_1)$$

**Equation 3** $$d_1 = \frac{\log\left(\frac{S}{X}\right) + \left(r + \frac{v^2}{2}\right)T}{v\sqrt{T}}$$

**Equation 4** $$d_2 = \frac{\log\left(\frac{S}{X}\right) + \left(r - \frac{v^2}{2}\right)T}{v\sqrt{T}}$$

where:

| | |
|---|---|
| $V_{call}$ | is the price for an option call. |
| $V_{put}$ | is the price for an option put. |
| $PHI(d)$ | is the cumulative normal distribution function. |
| $S$ | is the current option price. |
| $X$ | is the strike price. |
| $T$ | is the time to expiration. |
| $r$ | is the continuously compounded risk free interest rate. |
| $v$ | is the implied volatility for the underlying stock. |

The cumulative normal distribution function (see reference 3) is computed using the Abromowitz-Stegun approximation.

# 4 Implementation Details

This sample shows the usability of Bolt library's `transform()` as an alternative to `std::transform()` to calculate Black-Scholes' call and put prices. Each iteration of the *Functor* calculates the sample of the call and put price from a given sample of the stock price, strike price, time to expiration, volatility, and sigma. This sample shows the usage of `device_vectors` to allocate buffers on an available device. The input options that are populated on the host are then manually replicated onto the device (using `device_vector`) to gain a performance boost while running the sample using the Bolt library.

The advantage of defining a Functor as a `BOLT_FUNCTOR` is that this code is usable by both `std::transform()` and `bolt::cl::transform()` without modification to user code elsewhere.

# 5 Recommended Input Option Settings

For the best performance, enter the following on the command line: `-x 262144 -i 100 -q -t`

# 6 References

1. http://en.wikipedia.org/wiki/Option_(finance).
2. http://en.wikipedia.org/wiki/Black-Scholes#The_model.
3. Fischer Black and Myron Scholes (1973). "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81 (3): 637-654.

**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**
**Developing:** **developer.amd.com/**
**Forum:** **developer.amd.com/openclforum**