

The Analytical Finance Package

Introduction

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An example of
mathematical theory

Category C

For further reading

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Analytical Finance group at the Mälardalen University develops the Analytical Finance Package (AFP). This is the library of Java applets in the area of analytical finance. The project was initiated in 2003, and it is realising on a permanent base.

Professor Dmitrii Silvestrov and Dr. Anatoliy Malyarenko are leaders of the project. They develop AFP in collaboration with other members of Analytical Finance group and students of the Bachelor programme Analytical Finance and the Master programme Financial Engineering realising at the Mälardalen University.

The initial list of subject areas and number of items available now in each subject area are the following: A — Simulation of pricing processes (11 items); B — Estimation of pricing processes (0 items); C — Evaluation of financial contracts (32 items). The AFP is free software. The access to the program library AFP is available from the web-address:

<http://www.mdh.se/ima/analyticalfinance/af1.software.shtml>

The Analytical Finance Web page



The screenshot shows a web page with an orange header and a yellow sidebar. The main content area has a white background with a yellow border. The sidebar contains a navigation menu with the following items: "Analytical Finance" (highlighted), "e-CONTACT", "FAQ", "Welcome to apply", "Education", "Courses", "Theses", "..... Alumni", "..... Interviews", "Events", "People", "Publications", "Research", "Seminars", "Consulting", "Links", "Software", and "IMA main menu" (highlighted). The main content area features a logo of a hand holding coins, the title "Analytical Finance", and an "Information" section with three paragraphs of text.

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MÄLARDALEN HÖGSKOLA
Institutionen för matematik och fysik

Analytical Finance

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 Analytical Finance

Information

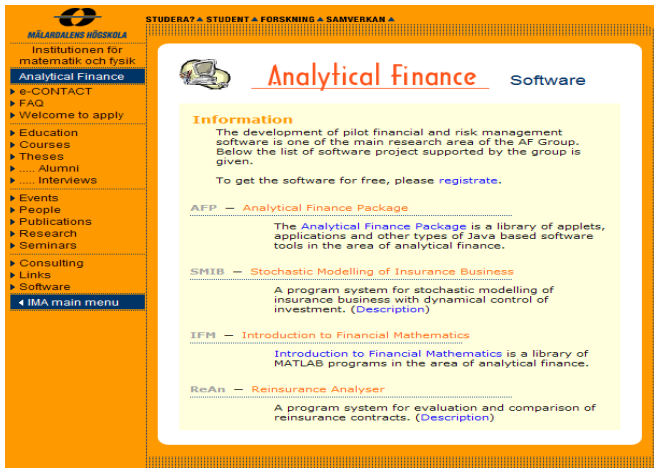
The page represents research, educational and other activities of the AF (Analytical Finance) Group created by the Department of Mathematics and Physics at Mälardalen University in 1999.

The School of Business also supports the activities of the AF Group. Analytical Finance is the research area that includes as a core financial mathematics, financial engineering as well as financial and risk management software. Research studies of the group are concentrated in these domains as well as in some related research areas in applied mathematics, statistics and mathematical economics such as actuarial mathematics, optimisation, applied statistics and stochastic processes, computational game theory, simulation, scientific computing, informatics.

Educational activities of the AF Group are focused on realisation of Bachelor programme "Analytical Finance" (3 years); Master programme "Financial Engineering" (2 years); and Ph.D educational programme (4 years).

The AF Group supports the seminar "Mathematical and Statistical Applications in Economics" (MSAE) acting at Mälardalen University.

The page includes information about the staff of the group, research projects, educational programmes and courses, publications, seminars and software developed by the AF Group. It represents also information about international schools organised under support of the group, proceedings of these schools, as well as additional consulting information and a list of useful links related to analytical finance.



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◀ IMA main menu

 **Analytical Finance** Software

Information

The development of pilot financial and risk management software is one of the main research area of the AF Group. Below the list of software project supported by the group is given.

To get the software for free, please [registerate](#).

AFP – Analytical Finance Package

The **Analytical Finance Package** is a library of applets, applications and other types of Java based software tools in the area of analytical finance.

SMIB – Stochastic Modelling of Insurance Business

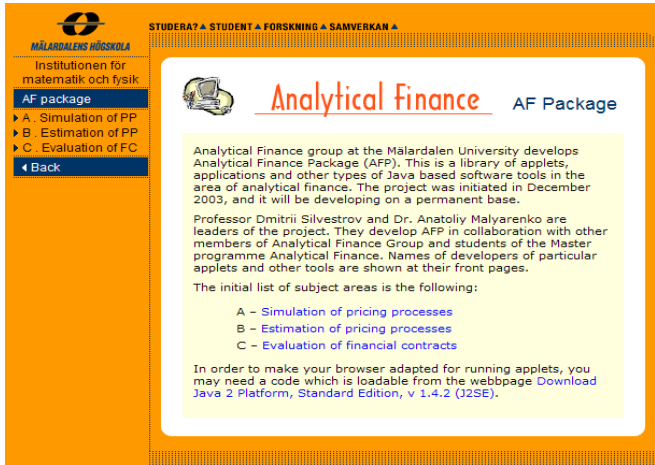
A program system for stochastic modelling of insurance business with dynamical control of investment. ([Description](#))

IFM – Introduction to Financial Mathematics

Introduction to Financial Mathematics is a library of MATLAB programs in the area of analytical finance.

ReAn – Reinsurance Analyser

A program system for evaluation and comparison of reinsurance contracts. ([Description](#))



The screenshot shows a web page with an orange header and sidebar. The header contains the Mälardalen University logo and navigation links: "STUDERA? ▲ STUDENT ▲ FORSKNING ▲ SAMVERKAN ▲". The sidebar on the left includes the text "MÄLARDALENS HÖGSKOLA" and "Institutionen för matematik och fysik". Below this is a menu with "AF package" selected, and sub-items: "▶ A . Simulation of PP", "▶ B . Estimation of PP", "▶ C . Evaluation of FC", and "◀ Back". The main content area has a title "Analytical Finance" in orange and "AF Package" in black. To the left of the title is an icon of a computer monitor. The text below the title describes the Analytical Finance group at Mälardalen University, their work on the Analytical Finance Package (AFP), and lists three subject areas: A - Simulation of pricing processes, B - Estimation of pricing processes, and C - Evaluation of financial contracts. It also provides a link to download Java 2 Platform, Standard Edition, v 1.4.2 (J2SE).

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Institutionen för
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AF package

- ▶ A . Simulation of PP
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Analytical Finance AF Package

Analytical Finance group at the Mälardalen University develops Analytical Finance Package (AFP). This is a library of applets, applications and other types of Java based software tools in the area of analytical finance. The project was initiated in December 2003, and it will be developing on a permanent base.

Professor Dmitrii Silvestrov and Dr. Anatoliy Malyarenko are leaders of the project. They develop AFP in collaboration with other members of Analytical Finance Group and students of the Master programme Analytical Finance. Names of developers of particular applets and other tools are shown at their front pages.

The initial list of subject areas is the following:

- A - [Simulation of pricing processes](#)
- B - [Estimation of pricing processes](#)
- C - [Evaluation of financial contracts](#)

In order to make your browser adapted for running applets, you may need a code which is loadable from the webpage [Download Java 2 Platform, Standard Edition, v 1.4.2 \(J2SE\)](#).

Category A — Simulation of pricing processes



Analytical Finance AF Package

Category A — Simulation of pricing processes

- Applet A01: Autoregressive model**
Authors: Krasimira Kirova and Ying Ni
- Applet A02: Jump-diffusion model**
Author: Robin Lundgren
- Applet A03: Standard user interface for simulation applets**
Authors: Xin Mai and Weiss Amani
- Applet A04: GARCH model**
Authors: Sona Gevorgyan, Enrike Barrientos and Nahir Hanna
- Applet A05: ARMA model**
Authors: Gao Jongjie and Rafael Cortes
- Applet A06: GPI model**
Author: Herve Fandom Tchomgouo
- Applet A07: Stochastic Volatility model**
Authors: Daniela Andersson and Zheng Wang
- Applet A08: Cox-Ross-Rubenstein Model**
Author: Mazyar Rostami
- Applet A09: Automaton Model Simulator**
Author: Robert Byström
- Applet A10: Moving Average**
Authors: Alexander Svahn, David Hefner, Jakob Wernroth and Jonas Gustavsson
- Applet A11: Java Applet for the Pricing of Exotic Options by Monte-Carlo Simulations in a Lévy market with Stochastic Volatility**
Author: Isaac Acheampong

Applet A11 — Pricing of Exotic Options in a Lévy market with Stochastic Volatility (Isaac Acheampong)

LÉVY STOCHASTIC PROCESSES UNDER MONTE-CARLO SIMULATION

Barrier option prices with variance gamma Lévy process

number of Simulations

Standard error of Barrier option prices (variance gamma process)

number of Simulations

Variance gamma NI-gaussian

11.9896	C	18.4815	alpha
25.8523	G	-4.8412	beta
35.5344	M	0.4685	gamma
0.6020	kappa	0.5391	kappa
1.5560	eta	1.5746	eta
1.9992	lambda	1.8772	lambda

number of simulations
 interval plot for simul...

calculate Price graphic illustratio...

Choice of plots: Standard error

Exotics: DIB DOB UIB UOB

Contract t... Call Put

Type of exotic option

Down-and-Out barrier

Down-and-In barrier

Up-and-In barrier

Up-and-Out barrier

Lookback

100.00	Stock price	5.00	Interest rates(...)	Option Price
100.00	Strike price	3.00	Dividend yield(...)	100%
1.00	maturity(years)	1.00	Barrier Size	<input type="button" value="RESET"/>



MÄLARDALENS HÖGSKOLA

Institutionen för Matematik och Fysik

Code: MdH.IMa.Mat.0061-(2006)10p-AF

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MASTER THESIS IN MATHEMATICS /APPLIED MATHEMATICS

**Java Applet for the Pricing of Exotic Options by Monte-Carlo
Simulations in a Lévy market with Stochastic Volatility**

by

Isaac Acheampong

Table: Notation

Symbol	Explanation
t	Current time
$S(t)$	The stock price at time t
$\sigma^2(t)$	The volatility of the underlying stock at time t
r	Risk-free interest rate
α	The speed of volatility mean reversion
θ	The long run mean of the volatility process
β	The volatility of the volatility process
ρ	The correlation coefficient
$B^1(t), B^2(t)$	Two independent Brownian motions
K	The strike price of an Asian call option
T	The expiration time of the option contract

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The formulation of a problem

The price process and the volatility process follow the *Heston model* described by the following system of stochastic differential equations in Itô form.

$$dS(t) = rS(t) dt + S(t)\sigma(t) dB^1(t),$$

$$d\sigma^2(t) = \alpha(\theta - \sigma^2(t)) dt + \beta\sigma(t)(\rho dB^1(t) + \sqrt{1 - \rho^2} dB^2(t)),$$

with $S(0) = S_0$ and $\sigma^2(0) = \sigma_0^2$. We would like to calculate the price of an Asian call option on this asset.

Solution, step 1

Introduce the process

$$I(t) = \int_0^t S(s) ds,$$

and rewrite the Heston model in the Itô integral form

$$\begin{aligned} S(t) &= S_0 + \int_0^t rS(s) ds + \int_0^t S(s)\sigma(s) dB^1(s), \\ \sigma^2(t) &= \sigma_0^2 + \int_0^t \alpha(\theta - \sigma^2(s)) ds + \int_0^t \beta\sigma(s)(\rho dB^1(s) \\ &\quad + \sqrt{1 - \rho^2} dB^2(s)), \\ I(t) &= 0 + \int_0^t S(s) ds. \end{aligned}$$

Let $f(S(T), \sigma^2(T), I(T)) = \max\{I(T)/T - K, 0\}$. Then the price of the Asian call option is $C = Ef(S(T), \sigma^2(T), I(T))$.

Solution, step 2

Introduce the following notation.

$$B^0(s) = s,$$
$$\mathbf{Y}(t) = (S(t), \sigma^2(t), I(t))',$$

and rewrite the model in the Stratonovich integral form

$$\mathbf{Y}(t) = \mathbf{Y}(0) + \sum_{i=0}^2 \int_0^t \mathbf{v}_i(\mathbf{Y}(s)) \circ dB^i(s), \quad (1)$$

where $\mathbf{V}_0, \mathbf{V}_1, \mathbf{V}_2: \mathbb{R}^3 \mapsto \mathbb{R}^3$ are the following functions.

$$\mathbf{V}_0((y_1, y_2, y_3)') = (y_1(r - y_2/2 - \rho\beta/4), \alpha(\theta - y_2) - \beta^2/4, y_1)',$$

$$\mathbf{V}_1((y_1, y_2, y_3)') = (y_1\sqrt{y_2}, \rho\beta\sqrt{y_2}, 0)',$$

$$\mathbf{V}_2((y_1, y_2, y_3)') = (0, \beta\sqrt{(1 - \rho^2)y_2}, 0)'.$$

Solution, step 3

Let ξ_1 , ξ_2 , ξ_3 , and ξ_4 be four independent standard normal random variables. Introduce the following functions.

$$\mathbf{W}_{1,s} = -\frac{1}{2}\mathbf{sV}_0 + \frac{\sqrt{3}}{2}\xi_1\sqrt{\mathbf{sV}_1} + \frac{\sqrt{3}}{2}\xi_3\sqrt{\mathbf{sV}_2},$$

$$\begin{aligned}\mathbf{W}_{2,s} = & \frac{3}{2}\mathbf{sV}_0 - \frac{5\sqrt{3}}{6}\xi_1\sqrt{\mathbf{sV}_1} + \frac{\sqrt{6}}{3}\xi_2\sqrt{\mathbf{sV}_1} - \frac{5\sqrt{3}}{6}\xi_3\sqrt{\mathbf{sV}_2} \\ & + \frac{\sqrt{6}}{3}\xi_4\sqrt{\mathbf{sV}_2}.\end{aligned}$$

Solution, step 4

Consider the following two systems of ordinary differential equations (ODE):

$$\frac{d\mathbf{y}(t)}{dt} = \mathbf{W}_{j,s}(\mathbf{y}(t)), \quad \mathbf{y}(0) = \mathbf{y}_0, \quad j = 1, 2, \quad s > 0.$$

These systems are the ODE-valued random variables in the sense of Ninomiya and Ninomiya (2008).

Let a_{ik} be an $M \times M$ matrix with $a_{ik} = 0$ for $i \leq k$, and let b_i be a vector of length M (specially designed). The M -stage *Runge–Kutta method of order m* for the above mentioned systems is written as follows.

$$\mathbf{y}^{(i)} = \mathbf{y}_0 + s \sum_{k=1}^M a_{ik} \mathbf{W}_{j,s}(\mathbf{y}^{(k)}), \quad 1 \leq i \leq M,$$
$$g(\mathbf{W}_{j,s})(\mathbf{y}_0) = \mathbf{y}_0 + s \sum_{i=1}^M b_i \mathbf{W}_{j,s}(\mathbf{y}^{(i)}).$$

Solution, the last step

Let n be a positive integer. Define recursively the second order scheme as the following sequence of random vectors:

$$\mathbf{Y}_0^{(n)} = \mathbf{Y}(0),$$
$$\mathbf{Y}_{(k+1)T/n}^{(n)} = g(\mathbf{W}_{1,1}) \circ g(\mathbf{W}_{2,1})(\mathbf{Y}_{kT/n}^{(n)}), \quad 0 \leq k \leq n-1,$$

and define the third order scheme by the Romberg extrapolation:

$$\mathbf{X}_T^{(2n)} = \frac{4}{3}\mathbf{Y}_T^{(2n)} - \frac{1}{3}\mathbf{Y}_T^{(n)}.$$

Ninomiya and Ninomiya (2008) proved that the average of $\mathbf{X}_T^{(2n)}$ approximates system (1). In particular,

$$\lim_{n \rightarrow \infty} \text{Ef}(\mathbf{X}_T^{(2n)}) = \text{Ef}(\mathbf{Y}(T)).$$

To calculate $\text{Ef}(\mathbf{X}_T^{(2n)})$, use quasi Monte Carlo.

Category C — Evaluation of financial contracts

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Analytical Finance AF Package

Category C – Evaluation of financial contracts

Applet C01: [American options with dividends](#)
Authors: Ling Wang, Bing Wang and Yanjun Wang

Applet C02: [The Black - Derman - Toy model](#)
Authors: Lei Zhang and Henrik Nyblom

Applet C03: [Pricing European options by binomial model method](#)
Authors: Tina Vedenpää and Cecilia Flink

Applet C04: [Pricing European call options on a forward contract](#)
Authors: Mahsima Ranjbar, Malin Andersson and Cecilia Isaksson

Applet C05: [Binomial pricing of European put options with replication](#)
Authors: Armand Fotsing, Hamadou Hamaoude, David Wellton, Basil Wakid Hassan and Ren Myniy

Applet C06: [Replicating the stock in the binomial pricing model](#)
Author: Fred Takoeta

Applet C07: [Pricing American put options with replication](#)
Authors: Antti Laine, Amir Kheirollah and Toma Boyacioglu

Category C — Evaluation of financial contracts (continue)

Applet C08:	The Hull-White model
Author:	Aminur Roshid
Applet C09:	Bond Price Calculator
Authors:	Aminur Roshid, Isaac Acheampong, Peter Agyemang-Mintah and Yue Song
Applet C10:	Simulation of the short interest rate in the Vasicek model
Authors:	Natalia Spas'ka and Olexander Sheychenko
Applet C11:	Eurobonds problem
Authors:	Kamila Giedrojć, Ewa Tropak and Romans Obrezkova
Applet C12:	Investor's problem
Authors:	Elizabeta Tudzarovska, Izabela Matusiak, Kwok-wai Choy, Sophia Abdi Hassan and Khadija Khapasi
Applet C13:	Bond reselling problem
Authors:	Malgorzata Andros, Matti Simperi and Piotr Liszewski
Applet C14:	Loan repayment applet
Authors:	Osei Benjamin Kwesi Amoako, George Manteaw Anobah, Aleksandra Sroka and Jacek Zniszczol
Applet C15:	Insurance problem
Authors:	Beata Lubecka, Peter Malosha Mayunga, Maziar Saei Aghmiouni and Marek Geringer De Oedenberg

Category C — Evaluation of financial contracts (continue)

Applet C16: Pricing put options using explicit finite difference method in Java graphical user interface

Author: Yue Song

Applet C17: A Java program for pricing options using the trinomial tree

Authors: Youmbi Etien Kalame

Applet C18: Pricing futures using the two-period binomial model in Java

Authors: Minyi Ren and Wakid Hassan Basil

Applet C19: Pricing convertible bonds with Monte Carlo simulations

Author: Cecilia Isaksson

Applet C20: A Java applet for credit risk estimation with Wishart multivariate stochastic volatility

Author: Amoako Osei Benjamin Kwesi

Applet C21: A Java applet for pricing convertible bonds with credit risk

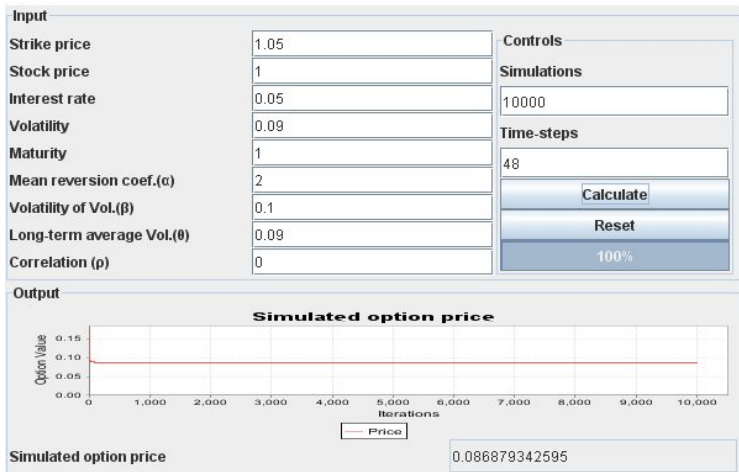
Author: Ntui Charles Etang

Applet C22: A Java applet for simulation of economy with borrowers under costly defaults

Author: Basil Wakid Hassan

Applet C34 — Pricing Asian options under Heston's model using the new Ninomiya weak approximation scheme (Boyko Vasilev)

Heston stochastic volatility model



The Bachelor thesis



School of Education, Culture and Communication
Division of Applied Mathematics

Code: MDH.UKK.TM.0000 (15hp) 2008 AF

BACHELOR THESIS IN MATHEMATICS/APPLIED MATHEMATICS

The Java applet for pricing Asian options under Heston's model using the new Ninomiya weak approximation scheme and quasi-Monte Carlo

by

Boyko Vasilev

The Analytical
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Dmitrii Silvestrov,
Anatoliy Malyarenko



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For further reading



Ninomiya, M. and Ninomiya, S. (2008),
A new weak approximation scheme of stochastic differential
equations by using the Runge–Kutta method,
[arXiv:0709.2434v2 \[math.PR\]](https://arxiv.org/abs/0709.2434v2) 5Jan 2008.

Greetings from Sydney!



The Analytical
Finance Package

Dmitrii Silvestrov,
Anatoliy Malyarenko



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