Monte Carlo Methods in Python with Financial Applications

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Timetable: 16 hrs. First lecture on May 22nd, 2023, 09:00, Room 2BC30 (see calendar at https://dottorato.math.unipd.it/calendar)

Course requirements:

- Knowledge of the basic concepts of stochastic processes.
- Knowledge of basic mathematical finance could be helpful but not required.
- Basic programming experience with Python as well as basic knowledge of object-oriented programming.
- Visual Studio Code (preferable) or Pycharm (non-professional edition) will be used as editors.

Examination and grading: Project in Python.

SSD: MAT/06 Probability and Mathematical Statistics, SECS-S/06 Mathematical Methods for Economics, Actuarial Science and Finance.

Course contents:

Day 1 **Principles of Monte Carlo and simulation of basic processes (4 hours)**

- Crude Monte Carlo: central limit theorem and law of large numbers.
- Methods for the generation of random variables: inverse transform, rejection sampling.
- Examples: simulation from the exponential law, mixture laws, discrete distributions.
- Examples: simulation from the multidimensional Gaussian law. Cholesky decomposition, PCA.
- Examples: generation of the skeleton of the multidimensional Brownian motion and the Ornstein-Uhlenbeck process.
- Examples: Brownian bridge and basic subordination (Stretch).

References: Glasserman [3], Devroye [2].

Day 2 and day 3 **Python Applications (6 hours):**

- Python, virtual environments, and notebooks.
- Projects setting: cookiecutters, poetry, isort, flake8, mypy and all of that.
- All the way to pydantic and Utests.
- Examples: simulation of basic processes and the pricing of some financial contracts.

References: `https://www.python.org/`

Day 4 **Variance Reduction Techniques (3 hours)**:

- Principles and rationale.
- Control Variates and importance sampling.
- Stratification and Latin Hypercube Sampling, some words on Quasi-Monte Carlo.
- Examples: application to some common financial contracts.

References: Glasserman [3], Niederreiter [4].

Day 5 **Lévy-Processes and non-Gaussian Ornstein-Uhlenbeck processes (Stretch). (3h):**

- Simulation of Poisson and compound Poisson processes.
- Simulation of gamma, inverse Gaussian and tempered stable processes.
- Simulation of variance gamma and normal inverse processes.
- $\mathcal{D}$-OU vs OU-$\mathcal{D}$ processes (Stretch).
- Examples: Γ-OU, OU-Γ, IG-OU, OU-IG, VG-OU, OU-VG, NIG-OU, OU-NIG and their simulation (Stretch).

References: Glasserman [3], Cont and Tankov [1], Schoutens [8], Sabino and Cufaro Petroni [7], Sabino [5, 6]

References

[1] R. Cont and P. Tankov. *Financial Modelling with Jump Processes*. Chapman and Hall, London, 2004.

[2] L. Devroye. *Non-Uniform Random Variate Generation*. Springer-Verlag, New York, 1986.

[3] P. Glasserman. *Monte Carlo Methods in Financial Engineering*. Springer-Verlag New York, 2004.

[4] H. Niederreiter. *Random Number Generation and Quasi-Monte Carlo Methods*. S.I.A.M. Philadelphia, 1992.

[5] P. Sabino. Exact Simulation of Variance Gamma Related OU Proceses: Application to the Pricing of Energy Derivatives. *Applied Mathematical Finance*, 27(3):207–227, 2020.

[6] P. Sabino. Normal Tempered Stable Processes and the Pricing of Energy Derivatives. 2022. Accepted in SIAM Journal of Financial Mathematics.

[7] P. Sabino and N. Cufaro Petroni. Gamma-related Ornstein-Uhlenbeck Processes and their Simulation*. *Journal of Statistical Computation and Simulation*, 91(6):1108–1133, 2021.

[8] W. Schoutens. *Lévy Proceses in Finance: Pricing Financial Derivatives*. John Wiley and Sons Inc, Chichester, 2003.