1 MC_options_pricing_basic.py — Baseline Monte Carlo for European Call Pricing

Purpose

Illustrates how to price a European call option using Monte Carlo simulation under the **Geometric Brownian Motion (GBM)** model, comparing slow (loop) and fast (vectorized) implementations.

Learning focus

- **Risk-neutral valuation**: Expected discounted payoff under GBM dynamics.
- Shows three approaches:
    1. Multi-step simulation with nested loops (slow, intuitive).
    2. Vectorized simulation (fast, computationally efficient).
    3. Single time-step simulation (valid because GBM increments are independent and normally distributed).
- Also visualises the convergence of the Monte Carlo price and compares it to the market value.

Key intuition

The Monte Carlo estimate converges to the theoretical price as the number of simulations increases, with a Standard Error (SE) quantifying the uncertainty. The market value line lets you spot potential mispricing.

Experiment

Increase M to 100,000 and watch the SE shrink — this demonstrates the law of large numbers in action.

2 MC_variance_reduction_antithetic_variates.py — Antithetic Variates Technique

Purpose

Shows how to improve Monte Carlo precision by pairing each random draw with its **antithetic** counterpart (negative of the shock) to reduce variance.

Learning focus

- Antithetic variates generate two price paths for each random draw:
    - One with +Z
    - One with -Z

- Averaging the payoffs from both paths cancels out some randomness, reducing variance and thus lowering SE without increasing the number of simulations.

Key intuition

Variance reduction is about **efficiency**. You get the same level of accuracy with fewer simulations, which is valuable for pricing complex derivatives under tight computational budgets.

Experiment

Compare the SE from the antithetic method with the SE from the plain Monte Carlo. You will see that the former is noticeably smaller even with the same M.

Practical link between the two

- **MC_options_pricing_basic** is the foundation: it sets up the GBM process, risk-neutral payoff, and discounting.
- **MC_variance_reduction_antithetic_variates** builds on that foundation, showing a real-world enhancement traders and quants use to speed up convergence when pricing options.