Regime-Switching Exponential Decay/Amplification Operator (RSEDAO)

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Introduction

Classical option pricing frameworks, most notably the Black–Scholes–Merton model and its stochastic-volatility descendants such as Heston, rely on probabilistic diffusion assumptions. These models, while elegant, require volatility estimation, risk-neutral measure calibration, and extensive parameter fitting — tasks that often produce instability when applied to short-term or highly nonlinear market conditions.

The **Regime-Switching Exponential Decay/Amplification Operator (RSEDAO)** is introduced as a *deterministic alternative* that discards explicit volatility and stochastic diffusion. Instead, RSEDAO constructs option surfaces by applying *operator calculus* to a forward-propagation kernel, embedding market structure through regime-switching exponential operators. Liquidity and discretionary adjustments are incorporated via a **Micro-Market Risk (MMR)** perturbation layer, which acts as a tunable premium injector.

The model generates *pseudo-volatility smiles* and skew dynamics without any stochastic drivers. Its philosophy is "**operator-first**": rather than simulate random paths, we manipulate deterministic exponential operators, project them into strike space, and perturb with MMR to capture the market's messy microstructure.

Literature Review

The foundation of modern option pricing is the **Black–Scholes–Merton (1973)** framework, which assumes lognormal diffusion of the underlying under a risk-neutral measure. Extensions such as the **Heston model (1993)** introduced stochastic volatility, while later approaches like **SABR (Stochastic Alpha Beta Rho)** and **Stochastic Local Volatility (SLV)** models attempted to capture empirical smile and skew effects.

Despite their widespread adoption, these models suffer from calibration instability, parameter explosion, and computational overhead — particularly in high-frequency and short-dated trading contexts. Empirical research (e.g., Andersen & Piterbarg, Gatheral, Fouque) has highlighted the fragility of volatility surface modeling under classical SDE-based frameworks.

More recently, interest has grown in *operator-based methods* and *spectral techniques*, where option prices are obtained by transforming underlying kernels via functional analysis rather than simulating stochastic trajectories. RSEDAO builds on this paradigm by discarding stochasticity entirely, instead applying **regime-switching exponential operators** with perturbative overlays to generate pseudo-stochastic surfaces. This places it in the lineage of "deterministic operator finance" — a frontier that seeks tractability without sacrificing smile/skew realism.

Annotated Operator Equations

$$\mathcal{F}_{\pm}(T) = \sum_{n\geq 0} e^{\pm\frac{T}{\tau}\lambda_n}\,\Pi_n, \quad \Pi_n = \langle \cdot, \phi_n\rangle\phi_n$$

(spectral drift anisotropy expansion)

$$\mathcal{F}_{\pm}(T)[S_0] = \int_{\Gamma} S_0(\lambda)\, e^{\pm\frac{T}{\tau}\lambda}\rho(\lambda)\, d\lambda$$

(Mellin-type kernel with synthetic regime weighting)

$$\mathcal{V}_{\pm}(K,T) = \langle K, (\mathcal{D}^{\pm}_{\tau}(T)\circ\mathcal{F}_{\pm}(T))[S_0]\rangle + \mathcal{P}_{\mathrm{MMR}}[K,T]$$

(premium functional with perturbative MMR injection)

$$V_{\mathrm{PE}}(K,T) = \Big(K - \mathcal{D}^{-}_{\tau}(T)\,\mathcal{F}_{-}(T)[S_0]\Big) + \mathrm{PV}\int_0^T \kappa(s;K)\,\frac{\partial^{\alpha}}{\partial s^{\alpha}}(\mathcal{F}_{-}(s)[S_0])\,ds + \mathrm{MMR}$$

(put operator + fractional Volterra correction)

$$V_{\mathrm{CE}}(K,T) = \Big(\mathcal{D}^{+}_{\tau}(T)\,\mathcal{F}_{+}(T)[S_0] - K\Big) + \sum_{m=0}^{\infty}\frac{c_m(K)}{m!}\,\partial_T^{(m)}(\mathcal{F}_{+}(T)[S_0]) + \mathrm{MMR}$$

(call operator + spectral Taylor cascade)

$$\mathcal{S}(\lambda;K,T) = \pm\tfrac{T}{\tau}\lambda - \log\rho(\lambda) - \log\mathcal{A}(\lambda;K)$$

(saddlepoint action functional)

$$V(K,T) \sim \exp(-\mathcal{S}(\lambda^\star;K,T))\sqrt{\frac{2\pi}{\mathcal{S}''(\lambda^\star;K,T)}} \quad (K \to \infty)$$

(WKB asymptotics under steepest descent)

$$V(K,T) = \mathrm{Tr}(\Pi_K\,\mathrm{Op}(\sigma_\tau)(\mathcal{F}_\pm(T))\,\Pi_K^*) + \mathcal{O}(\epsilon)$$

(pseudo-differential trace in operator algebra)

$$V(K,T) = \mathrm{Re}\left\{\int_\Gamma e^{\pm\frac{T}{\tau}\lambda}\rho(\lambda)\left[(K - \mathrm{Op}(\sigma_\tau(\lambda)))^{-1} + \mathcal{R}(\lambda)\right]d\lambda\right\} + \sum_{j=0}^{N}\Lambda_j\,\partial_T^{(j)}(\mathcal{F}(T)[S_0])$$

(collapsed operator-integral with calibration tensors)

Conclusion

The RSEDAO framework demonstrates how deterministic operator methods can generate realistic option surfaces without stochastic diffusion models. By embedding regime-switching exponential kernels and overlaying them with Micro-Market Risk (MMR) perturbations, the model yields pseudo-stochastic smiles and skews in closed form. This opens the door to computationally lightweight, structurally rich analytics suitable for both academic study and applied trading contexts. Future research may extend RSEDAO toward quantum finance path-integral methods, hybrid machine learning calibration, or market microstructure-aware operator deformations.

Disclaimer

This document is a theoretical research-style note prepared for illustrative and educational purposes. The RSEDAO framework as described is not an industry-standard pricing model and has not been validated against real market data. It should not be interpreted as investment advice, trading strategy, or a guaranteed pricing methodology. Readers are encouraged to exercise caution and apply independent judgment before using any concepts described herein in practical financial contexts.