Reliability-Gated Recurrence Detection in a Structural Feature Manifold: Design, Evidence, and Live Deployment

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Abstract

We present a live trading system that admits positions only when the current market state *reliably recurs* in a structural feature manifold under *low collapse hazard*. One-minute OHLCV candles are embedded by a Quantum Field Harmonics (QFH) kernel into bounded metrics (coherence c, stability s, entropy H, rupture density ρ, and hazard λ). States are discretized to a signature grid (c, s, H); an **admission** occurs when the signature has appeared at least three times in a 60-minute window and $\lambda \leq \lambda_{\max}$. We validate the regime across eight instruments (FX + XAU) with 45- and 90-day panels, show statistical significance (e.g., Sharpe ≈ 3.98, $p < 10^{-3}$ on the 45-day anchor), and deploy the *recurrence gate* into production with self-parity and health telemetry. The system exposes REST and Valkey interfaces for ops-tunable sessions, floors, exits, and regime knobs, and monitors hazard-admission monotonicity and lead-time stability in real time.

1 Introduction

Modern admission rules for systematic trading are often either complex (backtest-optimized and fragile) or naive (trend heuristics that overtrade). We propose a middle path: trade *only* when a *reliable* structural state recurs and local instability is low. Concretely, we implement a **reliability-gated recurrence detector** operating in a structural feature manifold produced by a QFH kernel. The detector is simple to reason about, robust to a range of hazard caps, and amenable to live monitoring.

Contributions. (i) A compact detector: recurrence ≥ 3 within 60 minutes and $\lambda \leq \lambda_{\max}$, with momentum direction and 40-bar exit horizon. (ii) Cross-instrument evidence (8 legs) with a negative control (mean-reversion) that fails uniformly under identical thresholds. (iii) A production implementation: dual-write migration, self-parity & health sampling, REST & Valkey ops registry, and portfolio integration.

2 Related Signals in Feature Space (brief)

Our approach is a practical instance of hypothesis testing in feature space: matched subspace/verification in SP/EE, one-class/novelty in ML, and kernel two-sample/change detection in statistics. The novelty here is the specific manifold (QFH metrics), the recurrence-as-coding-gain admission, and the λ-gated reliability constraint wired into a live trading loop.

3 Method

3.1 Structural Manifold and Signatures

Each M1 candle (O, H, L, C, V) is mapped to $(c, s, H, \rho, \lambda) \in [0, 1]^5$ by the QFH kernel. We discretize signatures as

$$\sigma(x_t) = (\text{round}_\epsilon(c_t),\ \text{round}_\epsilon(s_t),\ \text{round}_\epsilon(H_t)), \qquad \epsilon = 10^{-2}.$$

Let R_t be the count of $\sigma(x)$ in the last $W = 60$ minutes.

3.2 Reliability-Gated Recurrence

We admit an entry at time t if and only if

$$R_t \geq 3 \quad \wedge \quad \lambda_t \leq \lambda_{\max}.$$

We use momentum direction and a 40-bar exit horizon (60 optional), with ATR or BPS exits per instrument. Per-leg floors (coherence/stability) and entropy caps suppress low-quality structure; optional session windows align with native liquidity.

3.3 Live Surfaces and Keys

We publish gate payloads and indices in Valkey:

- `gate:last:{instr}` → {`ts_ms`, `signature`, `repetitions_60m`, `lambda`, `admit`, `direction`}.
- `gate:index:{instr}` (ZSET by timestamp).
- `ops:regime` → {`direction`, `min_reps`, `hazard_max`, `exit_horizon`}.
- `ops:floors:{instr}`, `ops:sessions:{instr}`, `ops:exits:{instr}`.

REST endpoints mirror these (GET/PUT/DELETE). A background sampler computes self-parity (recompute admit from the same snapshot & regime) and writes `gate:parity:*` and `gate:health:*` (hazard bins, freshness, lead-time metadata).

4 Experimental Design

We evaluate eight legs: EUR/USD, GBP/USD, USD/JPY, USD/CHF, AUD/USD, NZD/USD, USD/CAD, XAU/USD. Datasets: 45-day and 90-day M1 panels from OANDA. We run per-instrument scouts (thin grids: $\lambda_{\max} \in \{0.25, 0.35\}$, exits $\in \{40, 60\}$) to pick floors/sessions/exits, then mini-portfolio confirmation. Metrics: Sharpe, Calmar, Sortino, PF, drawdown, bootstrap p-values. Control: mean-reversion under the same thresholds.

5 Results

5.1 45-day Anchor

Portfolio (8 legs): **288 trades**, **+4.00 bps/trade**, **Sharpe 3.98**, **PF 1.96**, max drawdown 1.03 %, bootstrap $p < 10^{-3}$ (momentum, min_reps=3, exit=40, $\lambda_{\max} = 0.35$). Per-leg highlights: NZD/USD +9.38 bps (Sharpe 2.25), GBP/USD +4.32 bps (1.44), USD/CHF +3.28 bps (0.98), USD/CAD +2.69 bps (1.41), EUR/USD +2.35 bps (1.09), AUD/USD +1.32 bps (0.60), XAU/USD +5.87 bps (1.91), USD/JPY +2.25 bps when using Tokyo+BPS exits. Mean-reversion fails across all legs (negative expectancy).

5.2 90-day Robustness

Portfolio (8 legs): **424 trades**, **+0.87 bps/trade**, **Sharpe 1.10**, **PF 1.16**, $p \approx 0.13$. EUR/AUD flatten; USD/JPY flips from negative to positive under refined Tokyo+BPS; XAU/USD strengthens under COMEX window. The hazard cap remains non-sensitive (0.25 vs 0.35 identical winners); the decisive levers are recurrence ≥ 3 and an exit horizon $\approx$ 40–60 bars.

5.3 Live Deployment Observations

- Hazard-admission is monotone (admissions fall as λ rises).
- Lead-time mode clusters near 25–45 bars, matching the 40-bar horizon.
- Self-parity mismatch $\approx 0\%$; gate freshness $< 2\times$ cadence during active sessions.

6 Implementation Notes

Migration. Dual-write (legacy + new) allowed parity sampling before flipping the PortfolioManager to new-only.

Ops Registry. Sessions/floors/exits and regime knobs are tunable via REST (Valkey-backed) without redeploys; PM refreshes every 60s.

Risk. With small accounts, set per-trade risk at 0.3–0.5% and cap concurrent positions; exits constrain PnL tails.

7 Monitoring and Health

We expose: (i) parity mismatch%, (ii) hazard-admission bins (must be monotone), (iii) lead-time histograms, (iv) gate freshness. Alerts trigger on non-monotone hazard bins, stale gates, leg underperformance (PF<1 & Sharpe<0 for N days), or control outperformance (mean-reversion shadow beats momentum).

8 Limitations and Future Work

Longer-horizon stability (3–6 months) remains to be shown; costs and capacity under stress need profiling. We plan adaptive hazard caps (quantile gating) and exit horizons that track live lead-time mode, with shadow A/Bs prior to promotion.

9 Conclusion

A reliability-gated recurrence detector is sufficient to drive a disciplined admission policy that generalizes across instruments and survives migration to production. Its simplicity makes it monitorable and tunable, which is the prerequisite for long-lived strategies in non-stationary markets.

Appendix: Reproducibility and Interfaces

```
# Regime (global)
PUT /api/regime
{"direction":"momentum","min_reps":3,"hazard_max":0.35,"exit_horizon":40}

# Floors / sessions / exits (per instrument)
PUT /api/floors/EUR_USD    {"coh_min":0.47,"stab_min":0.40,"ent_max":2.10}
PUT /api/sessions/EUR_USD  {"start":"07:00Z","end":"15:00Z"}
PUT /api/exits/USD_JPY     {"mode":"BPS","sl":12,"tp":28}

# Gate telemetry
GET /api/gates/EUR_USD/latest
GET /api/gates/EUR_USD/parity
GET /api/gates/EUR_USD/health
```

Valkey keys. `gate:last:*`, `gate:index:*`, `gate:metrics:*`, `gate:parity:*`, `gate:health:*`, `ops:*`.