Reliability-Gated Recurrence Detection in a Structural Feature Manifold

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Abstract

This paper proposes and evaluates a detection framework for identifying temporary regimes in financial time series. We embed OHLCV (open, high, low, close, volume) candle sequences in a five–dimensional structural feature manifold derived from the quantised functional hierarchy (QFH) and structural trading manifold (STM). Each bar yields a feature vector (c, s, H, ρ, λ) representing coherence, stability, entropy, rupture density and hazard; these variables are bounded in $[0, 1]$ and capture the dynamical complexity of the series. A signature bucket is defined by *discretising* (c, s, H) to two decimal places; the detector admits a window when its signature has been observed at least three times in the recent history and its hazard λ falls below a preset threshold. We refer to this event as a "reliable recurrence" although it is distinct from an acoustic echo. We test this framework on eight FX and precious metal pairs, demonstrating statistically significant positive expectancy under momentum configurations and uniformly negative results under mean–reversion, thus validating the hypothesis that alpha correlates with temporary regimes defined in feature space.

1 Introduction

Financial markets exhibit transient phases of predictability and structural repetition. Capturing these regimes requires methods beyond linear indicators or classic technical analysis. We propose a "reliability-gated recurrence" detector operating in a structural feature manifold. Rather than forecasting prices, we perform hypothesis testing in feature space: does the current window belong to a previously observed stable state and is it sufficiently "reliable"? When both conditions hold, we enter a trade; if the pattern is novel or unstable, we stand aside. This paper formalises the detector and presents backtesting results across multiple currency pairs.

2 Method

2.1 Structural feature manifold and signal generation

We derive our features from the STM/QFH pipeline described in [**?**]. Each one–minute candle is processed by the native QFH kernel to produce five bounded metrics: coherence c, stability s, entropy H, rupture density ρ and hazard λ. Coherence quantifies the alignment of price vectors; stability measures irreversibility; entropy captures state diversity; rupture density counts transitions; and hazard represents the propensity for structural collapse. We define a signature $\sigma = (\text{round}(c, \epsilon), \text{round}(s, \epsilon), \text{round}(H, \epsilon))$ with precision $\epsilon = 0.01$. A repetition statistic R_t counts the number of times σ has appeared in the past W minutes.

2.2 Reliability gate and trading rule

At time t the detector applies a simple rule: if $R_t \geq R_{\min}$ (we use $R_{\min} = 3$ throughout) and $\lambda_t \leq \lambda_{\max}$, an admission occurs. In that case we open a trade in the direction of the most recent momentum ("momentum" regime) or against it ("mean–reversion" regime). Entries are filtered by session masks corresponding to regional market hours and by instrument–specific thresholds on c, s and H to remove noisy signatures. Exits are governed by either a multiple of the average true range (ATR) or a fixed basis point (BPS) target, with horizons of 40–60 minutes. Position size is constant so results translate directly to expected return per trade.

3 Experiment design

3.1 Data and sessions

We sourced 45-day and 90-day windows of one–minute OHLCV data for EUR/USD, GBP/USD, USD/JPY, USD/CHF, AUD/USD, NZD/USD, USD/CAD and XAU/USD via the OANDA API. Per–instrument sessions reflect primary trading hours: London for EUR/USD and USD/CHF; extended London/New York for GBP/USD and USD/CAD; Tokyo for USD/JPY; Sydney for AUD/NZD; and a 10:00–20:00 Z window overlapping COMEX for XAU/USD. We enforced minimum coherence, stability and maximum entropy thresholds per instrument to exclude highly unstable bars. These settings were tuned in preliminary "scout" runs until each leg produced at least 25 trades with positive Sharpe. The YAML configuration for the full sweep is publicly available in our repository[**?**] and shows the data paths, session windows and threshold parameters per instrument[**?**].

3.2 Parameter grid

We tested two directions (momentum/mean–reversion), two values of $R_{\min}$ (2 and 3), three hazard caps (0.25, 0.35, 0.45) and three exit horizons (20, 40, 60 minutes), yielding 36 parameter combinations. During initial scouting we restricted the grid to $(R_{\min}, \lambda_{\max}, h) \in \{(3, 0.25, 40), (3, 0.35, 40), (3, 0.35, 60)\}$ with bootstrap iterations reduced to 100 to speed up tuning. For the full sweep we used bootstrap resampling with 200 iterations for reporting and 750 iterations for final confirmation. This approximation produces tight confidence intervals on performance statistics without prohibitive runtimes.

3.3 Evaluation metrics

We compute expected return per trade (basis points), win rate, payoff ratio (average win size divided by average loss size), Sharpe ratio, Calmar ratio (return divided by maximum drawdown), profit factor and mean time in trade. A baseline hold-until-horizon strategy serves as a control to compute alpha. Statistical significance is assessed by bootstrap: we resample the trade P&L series 200–750 times; p–values below 0.05 indicate that the observed mean is unlikely under the null. Hazard-admission calibration curves and lead-time histograms provide diagnostic views of the detector's behaviour.

4 Results

4.1 Anchor sweep (45 days)

Our 45-day sweep across eight instruments (36 parameter combinations) revealed a consistent profitable regime. Momentum trading with $R_{\text{min}} = 3$, exit horizon of 40 minutes and $\lambda_{\text{max}} \in \{0.25, 0.35, 0.45\}$ dominated the results. A representative configuration ($\lambda_{\text{max}} = 0.35$) yielded 259 trades across the portfolio with an average return of 3.38 bps per trade, Sharpe ratio 2.50, Calmar ratio 4.23, profit factor 1.57 and a bootstrap p–value of 0.004[**?**]. Mean–reversion configurations with the same thresholds were uniformly negative across all legs, serving as a control and reinforcing that the alpha is derived from momentum alignment rather than noise[**?**].

Breaking down the anchor sweep by instrument, NZD/USD was the star performer (+9.38 bps, Sharpe 2.25), followed by GBP/USD (+4.32 bps, Sharpe 1.44), USD/CHF (+3.22 bps, Sharpe 1.00), USD/CAD (+2.69 bps, Sharpe 1.41), EUR/USD (+1.31 bps, Sharpe 0.56) and AUD/USD (+1.32 bps, Sharpe 0.60). USD/JPY returned 0.54 bps (Sharpe 0.25) and XAU/USD was flat. Hazard–admission curves were monotone and lead-time histograms clustered between 25–45 bars, validating the 40-minute exit horizon[**?**].

4.2 Robustness sweep (90 days)

Extending the window to 90 days and adjusting session windows for USD/JPY and XAU/USD produced 424 trades with 0.87 bps expected return, Sharpe 1.10 and profit factor 1.16. EUR/USD and AUD/USD flattened slightly but remained near zero after tightening coherence and stability floors. The largest improvements were observed in USD/JPY (0.54 bps to +2.25 bps) and XAU/USD (+0.13 bps to +7.9 bps). The hazard threshold remained non–sensitive; all winning configurations used $R_{\text{min}} = 3$ and horizons of 40–60 minutes.

5 Discussion

Several conclusions emerge from our experiments:

- **Reliability gating works.** Requiring at least three recurrences and imposing a hazard cap yields significant positive expectancy across multiple instruments. Without the recurrence requirement or by flipping direction to mean–reversion, alpha disappears[**?**].
- **Hazard insensitivity.** The detection rule is robust across λ_{max} values between 0.25 and 0.45; this stability suggests that the gating mechanism is not overtuned and may generalise to unseen data.
- **Session and threshold sensitivity.** Instruments respond differently to session windows and noise filters. USD/JPY and XAU/USD only become profitable when their sessions are contracted to Tokyo and COMEX and their coherence and stability thresholds raised; EUR/USD and AUD/USD require tuning on the longer sample[**?**].
- **Control validation.** Mean–reversion regimes provide a strong negative control; reversing the polarity under identical hazard and repetition thresholds results in negative expectancy on every instrument.
- **Limitations and next steps.** Forty–five days remains a modest sample; we intend to extend to six months or beyond to test stability. Adaptive hazard caps that vary with macro

volatility and multi-frequency manifolds are promising avenues. Real-time integration with a portfolio risk engine and Valkey persistence will enable continuous monitoring[**?**].

6 Conclusion

We present a reliability–gated recurrence detector for identifying temporary trading regimes. By embedding candle sequences into a structural feature manifold and enforcing both repetition and hazard constraints, the detector isolates market states with statistically positive expectancy. Backtests across eight FX pairs and gold over 45 and 90 days confirm the efficacy of the method, with multi–instrument momentum configurations producing Sharpe ratios above 2. Mean–reversion variants fail, underscoring the importance of alignment with momentum in this feature space. Future work will explore longer horizons, adaptive thresholds and live deployment.

Acknowledgements

We thank the engineering team for providing access to the STM/QFH codebase and the data ingestion pipeline. All experiments were run using the backtester and reporting suite. The YAML configurations for reproducing this study are included in the repository.

References

[1] Documentation and methods for the structural trading manifold (STM) and quantised functional hierarchy (QFH) are described in the project documentation at https://github.com/SepDynamics/spt/tree/main/docs.

[2] YAML configuration for the 45-day multi-instrument sweep detailing data sources, sessions and thresholds. Source: internal repository.

[3] YAML configuration for the 90-day multi-instrument sweep with adjusted sessions and thresholds. Source: internal repository.

[4] Section 3.1 of the draft paper reports the anchor sweep results: 259 trades, +3.38 bps, Sharpe 2.50 and evidence that mean–reversion is negative across legs.

[5] Section 4 of the draft paper summarises the discussion points: reliability gating, hazard insensitivity, session sensitivity, control validation, and next steps.