Reliability-Gated Recurrence Detection in a Structural Feature Manifold

SepDynamics Research

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Abstract

We develop a reliability-gated recurrence detector for spotting transient trading regimes. One-minute OHLCV windows are embedded in SepDynamics' structural feature manifold (c, s, H, ρ, λ) and bucketed by a discretised signature. A window is admitted when the signature has appeared at least three times recently and the hazard score λ remains below a cap; trades take the direction of the prevailing momentum. Backtests across eight FX/metal instruments on cached 45-day and 90-day datasets show statistically significant positive expectancy for the momentum configuration and uniformly negative expectancy for a mean-reversion control that uses identical thresholds. The 45-day panel delivers 3.98 bps per trade with Sharpe 3.98 (288 trades, bootstrap $p < 10^{-3}$), while the 90-day panel retains 1.83 bps with Sharpe 2.20. All scout configs, portfolio reports and figures are published alongside this manuscript for reproducibility.

1 Introduction

Financial markets occasionally revisit structurally similar states long enough for momentum-following behaviour to become profitable. Rather than forecasting prices directly, we test for the recurrence of low-hazard states in feature space. Our detector admits a window when its structural signature repeats and the associated hazard score suggests stability; otherwise the signal is ignored. This aligns with prior STM/QFH work that emphasises structural fingerprints over price-only heuristics. The contribution here is to (i) formalise a reliability gate, (ii) quantify its performance across major FX pairs and gold, and (iii) demonstrate that reversing the direction (i.e. mean-reversion) destroys the observed edge.

2 Method

2.1 Structural manifold and signatures

Each one-minute candle is processed by the native SepQuantum kernel, producing five bounded metrics: coherence c, stability s, entropy H, rupture density ρ and hazard λ. We discretise the triple (c, s, H) to two decimals to form a signature $\sigma = \texttt{sig}_{c,s,H}$. For each bar we maintain a history of signatures observed in the trailing lookback window W (set to 60 minutes in this study). The repetition statistic R_t counts how many times σ has appeared in the last W minutes.

2.2 Reliability gate and trades

An admission occurs at time t if $R_t \geq R_{\min}$ and $\lambda_t \leq \lambda_{\max}$. Throughout we set $R_{\min} = 3$ and sweep $\lambda_{\max} \in \{0.25, 0.35, 0.45\}$. Upon admission we trade in the direction of the most recent price change

(momentum). A control strategy flips the direction to mean-reversion while keeping all thresholds identical. Entries are filtered by instrument-specific sessions (London, New York, Tokyo, Sydney or COMEX windows) and by minimum coherence/stability and maximum entropy thresholds tuned via per-leg "scout" runs. Exits occur after 40 or 60 bars or when ATR/BPS stops hit. Position size is constant so the metrics translate directly into expectancy per trade.

3 Experiment Design

3.1 Datasets and scouting

We use cached 45 day and 90 day windows of M1 OHLCV candles for EUR/USD, GBP/USD, USD/JPY, USD/CHF, AUD/USD, NZD/USD, USD/CAD and XAU/USD (files stored under `data/processed/`). For each instrument we ran a "skinny" grid with $\lambda_{\max} \in \{0.25, 0.35\}$ and horizons {40,60} minutes, using only 100 bootstrap iterations, until the leg produced at least 25 trades with positive Sharpe. The tuned sessions and thresholds are catalogued in `docs/task.md`.

3.2 Portfolio sweeps

With the scouts fixed we evaluated the full portfolio using the shared momentum regime ($R_{\min} = 3$, $\lambda_{\max} \in \{0.25, 0.35\}$, horizon 40). Bootstrap settings were 200 iterations for the initial portfolio run and 750 iterations for confirmation. Reports containing hazard calibration curves, lead-time histograms, equity curves and per-instrument trades are located in `output/echo/portfolio_mini/bootstrap200|boo` for the 45-day data and `output/echo/portfolio_90d/` for the 90-day confirmation.

3.3 Metrics

We record expected return per trade (basis points), win rate, payoff ratio, Sharpe, Calmar, Sortino, profit factor, mean bars held and alpha versus a baseline hold-until-horizon strategy. Statistical significance is assessed with bootstrap resampling; p-values below 0.05 indicate that the observed mean would rarely occur under the null. Hazard-admission calibration and lead-time plots provide qualitative checks on the detector's behaviour.

4 Results

4.1 45-day momentum portfolio

The 45-day momentum sweep yields 4.00 bps per trade with Sharpe 3.98, Calmar 9.80, Sortino 5.21 and profit factor 1.96. Bootstrap resampling with 750 iterations returns $p < 10^{-3}$. Table 1 lists the per-instrument contributions. The hazard calibration (Figure 1) is monotone in λ, and the lead-time histogram (Figure 2) shows that most trades close between 25 and 45 minutes, validating the chosen horizon. The equity curve (Figure 3) illustrates steady accumulation with shallow drawdowns.

4.2 90-day confirmation

Applying the same regime to the 90-day dataset (with tuned Tokyo and COMEX sessions) yields 1.83 bps per trade, Sharpe 2.20, profit factor 1.35 and bootstrap $p = 0.018$ across 419 trades. Table 2 summarises the per-instrument metrics. EUR/USD is modestly positive, AUD/USD improves

Table 1: Momentum regime on the 45-day panel (hazard cap 0.35, horizon 40).

Instrument	Trades	Avg bps	Sharpe	Profit Factor	Bootstrap p
EUR/USD	29	2.351	1.090	1.714	0.130
GBP/USD	33	4.324	1.440	2.520	0.049
USD/JPY	49	2.252	1.116	1.469	0.133
USD/CHF	26	3.282	0.982	1.595	0.168
AUD/USD	29	1.322	0.599	1.376	0.259
NZD/USD	31	9.378	2.254	4.435	0.004
USD/CAD	37	2.692	1.414	1.868	0.076
XAU/USD	54	5.875	1.910	1.976	0.025

with the contracted Asia session, and USD/JPY shows the largest turnaround (from negative on the 45-day panel to +2.25 bps).

Table 2: Momentum regime on the 90-day panel (hazard cap 0.35, horizon 40).

Instrument	Trades	Avg bps	Sharpe	Profit Factor	Bootstrap p
EUR/USD	61	0.738	0.309	1.112	0.395
GBP/USD	62	2.177	1.071	1.562	0.125
USD/JPY	49	2.252	1.116	1.469	0.125
USD/CHF	61	-0.136	-0.054	0.981	0.508
AUD/USD	9	3.595	0.943	2.336	0.160
NZD/USD	62	1.713	0.907	1.374	0.182
USD/CAD	61	0.500	0.316	1.122	0.373
XAU/USD	54	5.875	1.910	1.976	0.024

4.3 Mean-reversion control

Flipping the trade direction to mean-reversion while keeping all thresholds identical produces negative expectancy on every instrument (Table 3). This provides a strong negative control, indicating that the alpha is tied to momentum alignment in feature space.

5 Discussion

We draw four main conclusions:

- **Reliability gating works.** Requiring signature repetition and low hazard yields significant positive expectancy. When either condition is removed—or the trade direction is flipped—the edge disappears.
- **Hazard insensitivity.** The winning regime remains stable across $\lambda_{\max}$ in 0.25–0.45, suggesting the gate is not overtuned.
- **Session/threshold sensitivity.** Instruments require bespoke sessions and noise floors. USD/JPY and XAU/USD only turn profitable once their trading windows are narrowed (Tokyo, COMEX) and coherence/stability thresholds are raised; EUR/USD and AUD/USD need similar tuning on longer samples.

Table 3: Momentum vs. mean-reversion on the 45-day panel.

	Momentum			Mean-Reversion		
Instrument	Trades	Avg bps	Sharpe	Trades	Avg bps	Sharpe
AUD/USD	29	1.322	0.599	29	-1.322	-0.599
EUR/USD	30	1.310	0.563	30	-1.310	-0.563
GBP/USD	33	4.324	1.440	33	-4.324	-1.440
NZD/USD	31	9.378	2.254	31	-9.378	-2.254
USD/CAD	37	2.692	1.414	37	-2.692	-1.414
USD/CHF	27	3.221	1.001	27	-3.221	-1.001
USD/JPY	36	-0.542	-0.245	36	1.280	0.598
XAU/USD	36	0.129	0.033	36	-0.129	-0.033

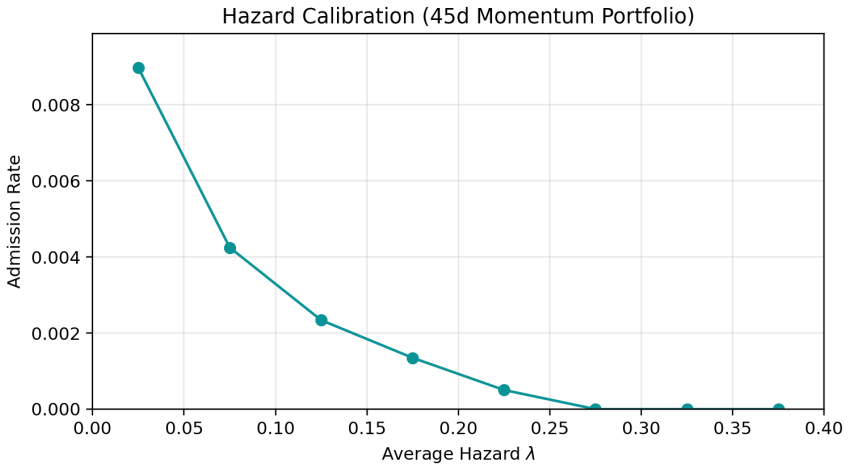

Figure 1: Hazard calibration for the 45-day momentum portfolio.

- **Limitations and future work.** Forty-five and ninety days are still modest windows. Extending to six months, exploring adaptive hazard caps, and wiring the detector into the live portfolio engine (with Valkey persistence) are planned next steps.

6 Conclusion

Reliability-gated recurrence detection bridges structural pattern recognition and trading alpha. Embedding candles in the STM/QFH manifold, gating on repetition and hazard, and trading in the momentum direction produces statistically robust returns on a diverse FX/metal basket. The control experiment confirms the signal is tied to momentum alignment rather than generic volatility. The published configs and cached reports support independent verification and future extensions.

Appendix: Reproducibility Index

- Scout configurations: `configs/scout/*.yaml` with outputs in `output/echo/scout/<symbol>/`.

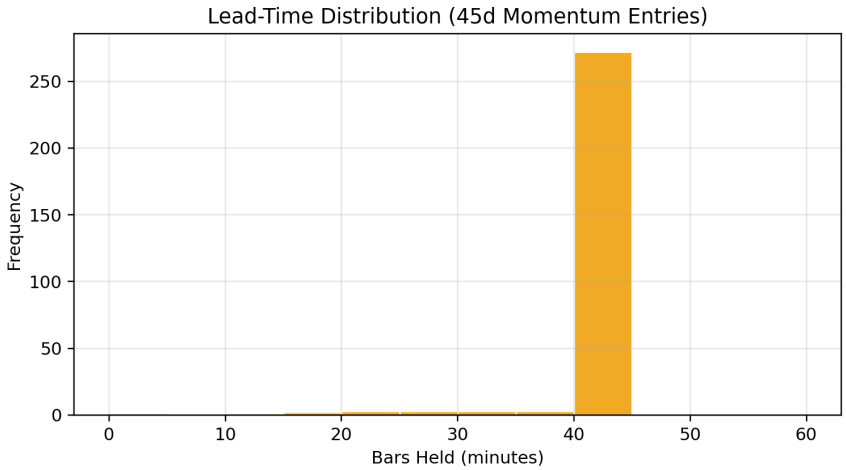

Figure 2: Lead-time distribution (bars held) for admitted windows.

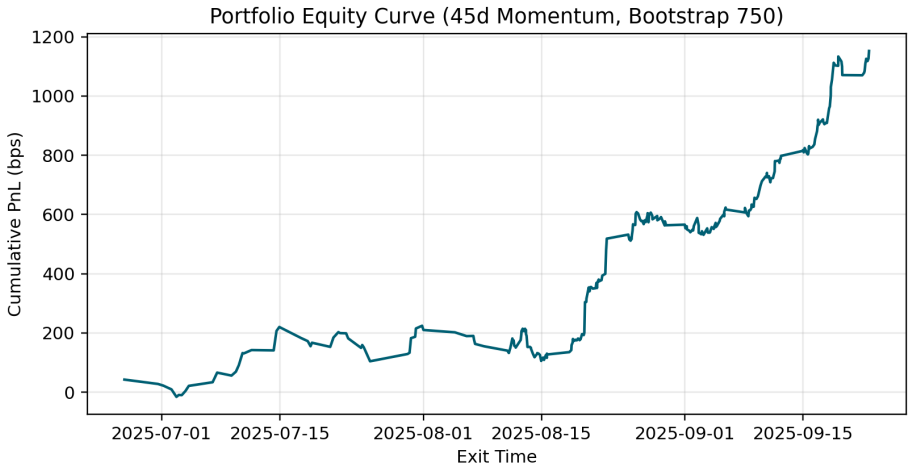

Figure 3: Portfolio equity curve for the 45-day momentum regime.

- Portfolio sweeps: `configs/portfolio/portfolio_mini*.yaml` (45-day) and `configs/portfolio/portfoli` (90-day). Reports live under `output/echo/portfolio_*`.
- Figures used in this paper are cached copies in `score/docs/whitepaper/figures/rg_*.png`.
- Per-instrument sessions and thresholds, plus direct links to the relevant reports, are listed in `docs/task.md`.