Statistical Outlier Detection Notes

Outlier Detection Using Mean and Standard Deviation (Z-Score Based Outlier Detection)

To detect outliers in a dataset Δ, we use the mean and standard deviation:

- $\mu(\Delta)$: Mean of the data
- $\sigma(\Delta)$: Standard deviation of the data

Normal Range

The normal range is defined as:

$$\mu(\Delta) \pm 2\sigma(\Delta)$$

This means most data points (about 95% if normally distributed) are expected to lie within this range.

Outlier Condition

A value is considered an outlier if:

$$\Delta < \mu(\Delta) - 2\sigma(\Delta) \quad \text{or} \quad \Delta > \mu(\Delta) + 2\sigma(\Delta)$$

- Δ - Orderbook Delta Depth of 5% from Coinbase
- $\mu(\Delta)$ - Mean of Δ
- $\sigma(\Delta)$ - Standard deviation of the dataset

Strength of Signal

To not only detect outlier price points but also see how far they are expanded from the mean I use the Z-score for each data point being detected as an outliers

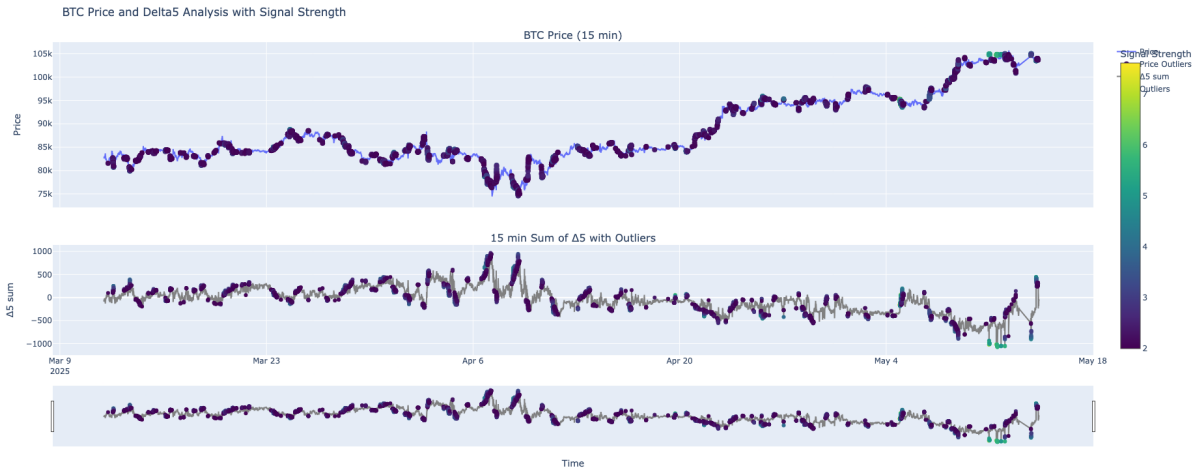

Figure 1: Heatmap Outlier

The Z-score is calculated as:

$$Z = \frac{\Delta_5 - \mu(\Delta_5)}{\sigma(\Delta_5)}$$

Only points outside the $[\mu - 2\sigma, \mu + 2\sigma]$ interval are considered outliers. For these, the signal strength is defined as $|Z|$, indicating how extreme the value is compared to the distribution.

Example: A point with a Z-score of $+3.1$ is a stronger signal than one at $+2.1$, since it is farther from the mean. Non-outliers receive a signal strength of 0. [1]

[1] Visualisation inside of Figure 1

Idea behind

- This method assumes data is roughly normally distributed.
- Using 2σ captures approximately 95% of data points under a normal distribution.
- You can adjust the multiplier (e.g., 3σ) for stricter or looser thresholds.

Future Plans

- Test on more data
- use rolling windows (e.g. 1 day or 1 week) for local context.
- Compare sensitivity with +- 1.5σ or +-2.5σ

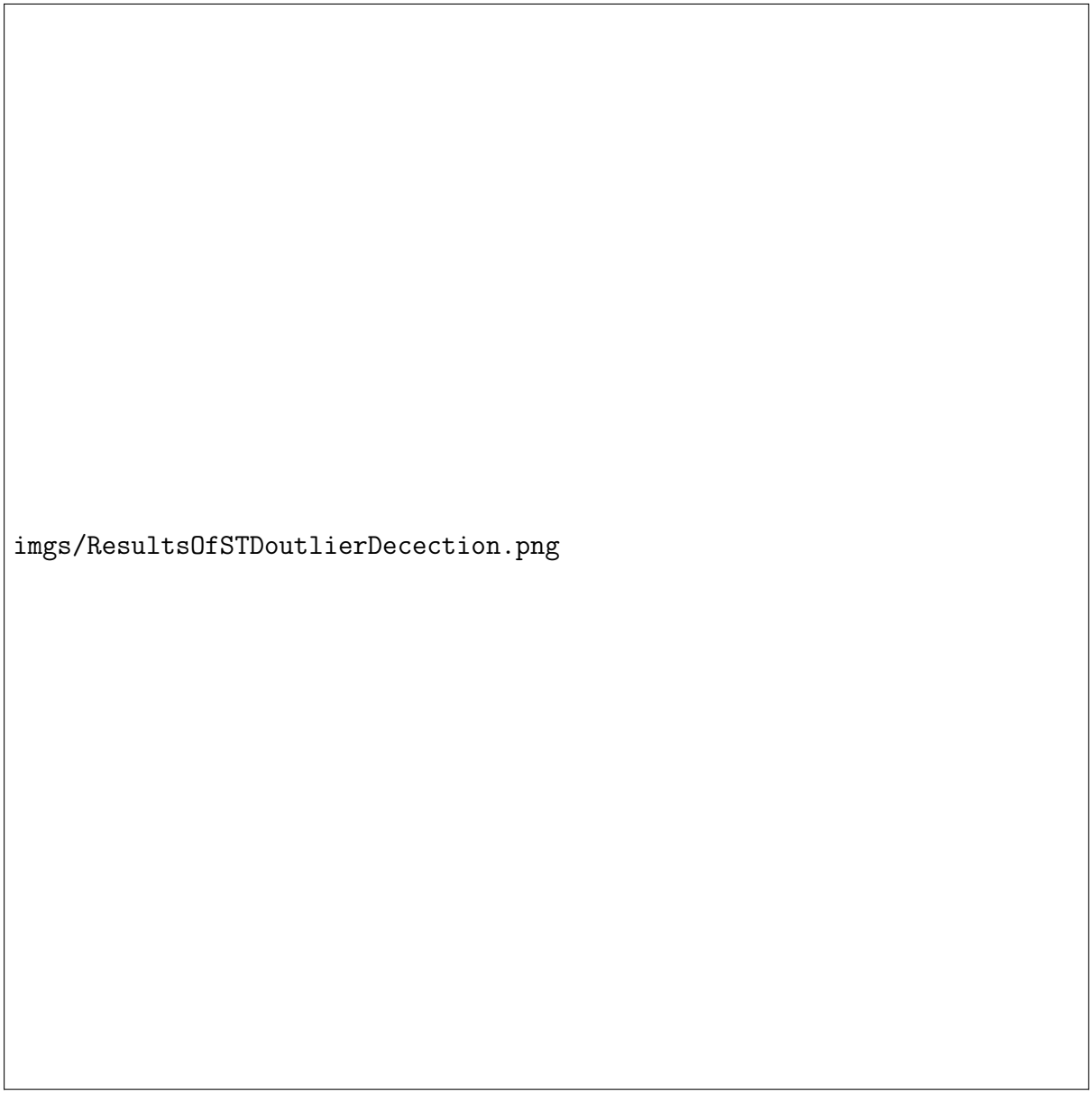

Figure 2: results over a two month data set

Order Book Delta RSI (14-period)

The Relative Strength Index (RSI) applied to the order book delta Δ is defined as:

$$\mathrm{RSI}_{\Delta}(t) = 100 - \frac{100}{1 + RS(t)}$$

where

$$RS(t) = \frac{\text{Average Gain over 14 periods}}{\text{Average Loss over 14 periods}}$$

Dictionary of Terms

- $\Delta(t)$ — Order book delta at time t (e.g., 5% depth imbalance)
- Gain — Positive change in Δ: $\Delta(t) - \Delta(t-1) > 0$

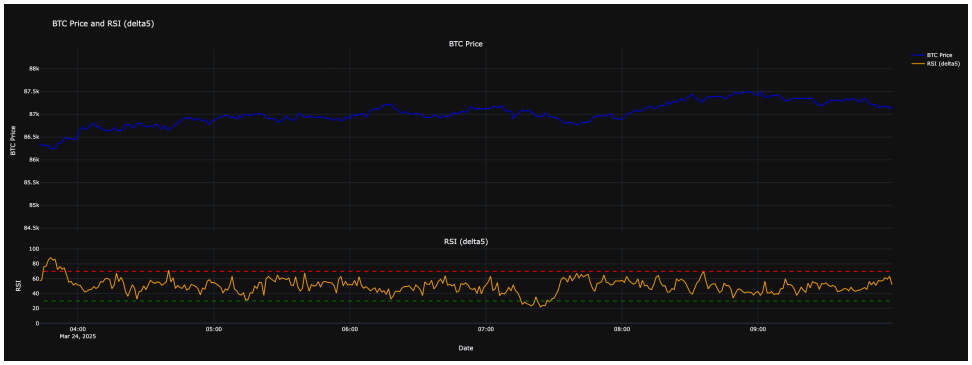

Figure 3: 1 min time frame RSI orderbook depth 5%

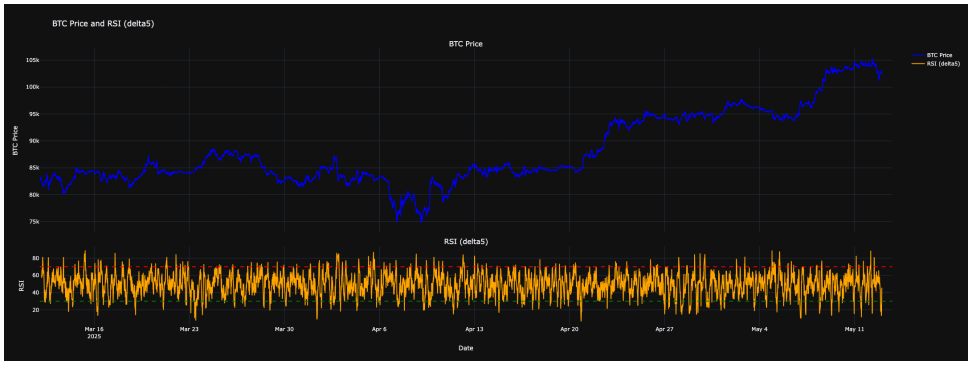

Figure 4: 15 min time frame RSI orderbook depth 5%

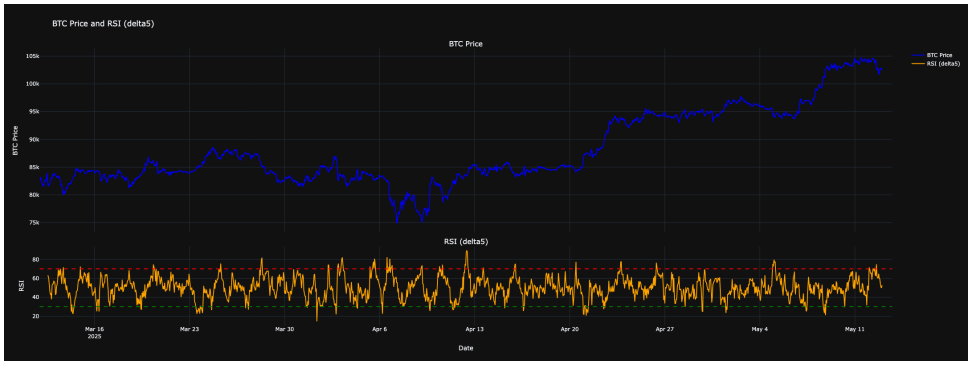

Figure 5: 60 min time frame RSI orderbook depth 5%

EMA compression/expanssion