Risky order book detection

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***Abstract*—In order to prevent the occurrence of high slippage orders when executing on behalf of our retail customer, we must detect risky order book and trade accordingly.**

- **Detect inflexion points in the order book**
- **Cap maximum limit order price**
- **Expand time window to pass maker below the max price**
- **Fill with treasury the order part that would occur to big a slippage**

I. Snapshot only, no comparative historical data

A. Slippage definition

Depth	Price	Quantity
ask depth n	...	...
...		
ask depth 2	...	...
best ask	...	...
best bid	...	...
bid depth 2	...	...
...		
bid depth n	...	...

Let's define:

$$P_{mid\ market} = \frac{P_{best\ bid} + P_{best\ ask}}{2} \tag{1}$$

Let's define for an amount to pass A the maximal depth d at which the amount to pass would be filled if we ripped the order book.

$$d^* = \sup \left\{ d / \sum_{j=1}^{d} q_j < A \right\} + 1 \tag{2}$$

The execution price is then defined by the average price over all the depth up to d^* (the last depth not being totally ripped off, just enough so that the A amount is reached).
The execution price is then defined:

$$P_{execution}(A) = \frac{\sum_{j=1}^{d^*(S)} q_j * p_j}{\sum_{j=1}^{d^*(S)} q_j} \tag{3}$$

And finally the slippage definition:

$$slippage(A) = \frac{P_{execution}(S) - P_{mid\ market}}{P_{mid\ market}} \tag{4}$$

B. Slippage acceleration

We define the slippage acceleration as :

$$slippage\_acceleration(A) = \frac{d\left(slippage(A)\right)}{dA} \tag{5}$$

C. Rules and absolute thresholds for slippage

Absolute threshold definition Let's denote S the slippage vector for different amounts:

$$S = \begin{pmatrix} S(100) \\ S(500) \\ \vdots \\ S(50000) \\ S(100000) \end{pmatrix}$$

We define the absolute thresholds as the x% quantile from the S vector distribution:

$$t = \begin{pmatrix} t(100) \\ t(500) \\ \vdots \\ t(50000) \\ t(100000) \end{pmatrix} \tag{6}$$

where

$$\mathbb{P}\left[S < t\right] = x$$

D. Common rule for all amounts

We assess the riskiness of an order book with the following metrics:

$$R = \frac{\sum_{a_i} q_i * 1_{s(a_i) \geq t(a_i)}}{\sum_i q_i} \tag{7}$$

where $(a_i)_{i \in [1,..,n]} = [100, 500, \ldots, 50000, 100000]$ is the predefined range of amount and q_i is a weighting here to emphasize that slower amount threshold break are more important than bigger amount. We propose first a linear weighting: if $a_i = [100, 500, 1000]$ then $q_i = [3, 2, 1]$

$$q_i = range(len(a_i), 1, -1)$$

E. Rule for one amount only

We assess the riskiness of an order book for a single amount to pass a with the following metrics:

$$R = 1_{s(a) \geq t(a)} \tag{8}$$

where a is the predefined amount. The order book is deemed risky if its slippage for the amount a is above the x% threshold.

F. *Rule subsequent action*

If the order book slippage for the asked amount a is above the the absolute threshold $t(a)$:
Find a^* such that $a^* < a$ and $slippage(a^*) = t(a)$ (possible as the slippage is an increasing function of the amount).
Fill the order till $a*$, and then 2 solutions :

- Fill the other part with the treasury.
- Wait for the market maker to bring back liquidity below the last execution price

II. ROLLING THRESHOLDS

We do the exact same analysis, but do calibrate the thresholds with quantile at 90% from a rolling distribution.
The rolling window size must be defined and the quantiles recomputed dynamically.

III. DYNAMICAL HISTORICAL THRESHOLDS

The dynamical part is the harder one. It implies to submit best bid/ask limit orders and inspect the repercussion of those depth quantities change over the order book.
This is actually where we found the most litterature about.

IV. CONCLUSION