Algo_LatencyArb

Sunday, April 27, 2025 10:32 AM

Parameter Adjustment Algorithm

You want to **adjust X** based on the **magnitude of volumeImbalance**. Here's a flexible, production-style approach:

Adjustment Function

```python
def adjust_parameter_X(volume_imbalance, base_X, k):
    """
    Adjusts X based on volume imbalance.
    - base_X: the baseline parameter value
    - k: sensitivity factor
    """
    # e.g., X increases linearly with the absolute imbalance
    # You can use other functions (exponential, piecewise, etc.) as needed
    return base_X + k * abs(volume_imbalance)
```

In practice, you might want to cap X within bounds.

```python
def adjust_parameter_X(self, product_id, counterparty_type):
        imbalance = self.get_volume_imbalance(product_id, counterparty_type)
        # Example adjustment: linear with cap
        X = self.base_X + self.k * abs(imbalance)
        return min(max(X, 0.5), 5.0)  # Clamp X between 0.5 and 5.0
```

$EMA_{new} = \alpha \times value_{new} + (1-\alpha) \times EMA_{old}$

α (smoothing factor) defines how quickly old values lose influence (typical: 0.01–0.2).
In your context, each trade updates the EMA of volumeImbalance.

This is often called a **continuous-time EMA** and is **ideal for irregularly-timed events** (like trades that don't arrive exactly every second). Here's how and why it works, plus sample code.

Why Time-Based EMA?

- In financial trading, trades can occur at any moment.
- If you use a fixed alpha (as in regular EMA), the "decay" rate is tied to trade frequency, not wall-clock time.
- **Time-based EMA** ensures that the impact of a trade decays at a consistent rate over real time, regardless of how often trades arrive.

$\alpha = 1 - \exp(-\Delta t / \tau)$

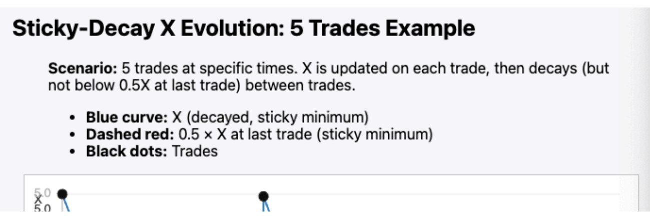
$EMA_{new} = \alpha \times x_{new} + (1-\alpha) \times EMA_{old}$

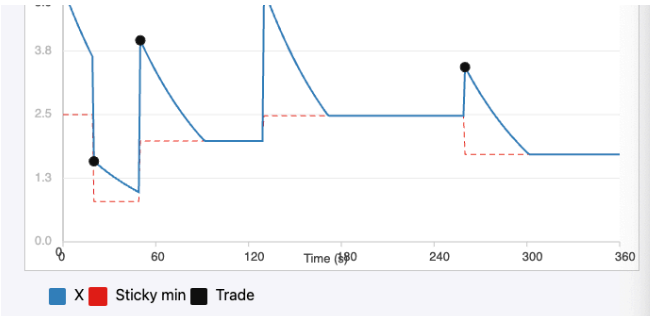
Key Points

- **(\tau)**: Higher τ means slower decay (old trades matter longer); lower τ means faster decay (recent trades matter more).
- **Handles irregular intervals**: If many seconds pass between trades, alpha is higher (old EMA "forgets" faster).

Retail Market-making Algorithm

- On each trade
  - update imbalance (via time-based EMA or running sum)
  - Compute a new X:
    - X new = k * imbalance
- Between trades
  - If there's no new activity, X should decay over time
  - However, X cannot decay below a "sticky minimum", which is 0.5 x the last nonzero X
- Implementation plan
  - Track last trade time and last adjusted X
  - On each trade
    - Update the running sum of imbalance
    - Compute new X
    - Set the new sticky minimum: Xmin = 0.5 * Xnew
  - On each X query (even without new trades):
    - Decay X using the time-based EMA (with no new input, so input = 0)
    - Clamp X to Xmin





step_num = floor(EMA imbalance / threshold).

- If step_num increases, increment X by k for each step up.
- If step_num decreases, decrement X by k for each step down.
- sticky_min = 0.5 * abs(X) * Math.sign(X)
- Between trades, **decay X exponentially towards zero but do not cross the sticky minimum** (sticky min is always half the magnitude of the last X after a step).

1. Initialization

- Set parameters:
  - k: the increment/decrement per threshold crossed (e.g., 1.0)
  - threshold: the imbalance threshold for each step (e.g., 50)
  - tau: EMA decay time constant (e.g., 60 seconds)
  - sticky_factor: fraction for sticky minimum (e.g., 0.5)

  Initialize for each trading pair (product_id, counterparty_type):
  - ema_imbalance = 0
  - X = 0
  - last_step_num = 0
  - sticky_min = 0
  - last_update_time = None

2. On Each Trade

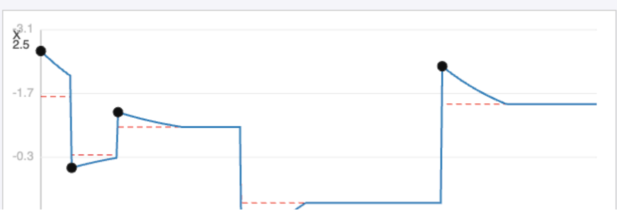
- **2.1. Decay EMA and X to the current trade's timestamp** (if any time has passed):
  - $\mathrm{dt} = \mathrm{trade.time} - \mathrm{last\_update\_time}$
  - $\mathrm{ema\_imbalance} \leftarrow \mathrm{ema\_imbalance} \times e^{-\mathrm{dt}/\tau}$
  - $X \leftarrow X \times e^{-\mathrm{dt}/\tau}$
  - Clamp X to not cross the sticky minimum:
    - If $X > 0$: $X \leftarrow \max(X, \mathrm{sticky\_min})$
    - If $X < 0$: $X \leftarrow \min(X, \mathrm{sticky\_min})$
- **2.2. Update EMA imbalance with the new trade:**
  - $\mathrm{ema\_imbalance} \leftarrow \mathrm{ema\_imbalance} + \mathrm{trade.qty}$
- **2.3. Calculate the new step number (can be negative):**
  - $\mathrm{step\_num} = \mathrm{floor}(\mathrm{ema\_imbalance}/\mathrm{threshold})$
- **2.4. If the step number changed (up or down):**
  - $\mathrm{steps\_change} = \mathrm{step\_num} - \mathrm{last\_step\_num}$
  - $X \leftarrow X + \mathrm{steps\_change} \times k$
  - $\mathrm{sticky\_min} \leftarrow \mathrm{sticky\_factor} \times |X| \times \mathrm{sign}(X)$
  - $\mathrm{last\_step\_num} \leftarrow \mathrm{step\_num}$
- **2.5. Update last update time:**
  - $\mathrm{last\_update\_time} = \mathrm{trade.time}$

3. Between Trades (when you want to check X at any time)

- Decay EMA and X to the current time as in step 2.1.
- Clamp X to sticky minimum as above.

Scenario: X increases or decreases by **k** every time the signed EMA imbalance crosses a multiple of the threshold (50).

- **Blue curve:** X (stepwise, sticky minimum)
- **Dashed red:** Sticky min (always 0.5 × |X| × sign(X) after last step)
- **Black dots:** Trades
- X can go negative if imbalance reverses direction!



Code Implementation

Here's how you can **implement this logic in Pandas** as a function that adds the computed z, level_num, and sticky_min columns to your DataFrame for each counterpartyType, following your description.

Step-by-Step Approach

1. **Sort** your DataFrame by counterpartyType and timeBin.
2. **For each counterpartyType**, process the group in time order:
   - Initialize variables:
     - z = 0
     - level_num = 0
     - sticky_min = 0
     - last_level_num = 0
     - last_update_time = None
   - For each row:
     - Compute dt = time difference in seconds from last_update_time (set dt = 0 for the first row).
     - Decay z as:
       z = z * exp(-dt / tau)
     - Clamp z to sticky_min:
       - If z > 0: z = max(z, sticky_min)
       - If z < 0: z = min(z, sticky_min)
     - Compute new level_num = floor(volumeImbalance / threshold)
     - Compute level_change = level_num - last_level_num
     - Update z = z + level_change * k
     - Clamp z to [min_z, max_z]
     - Update sticky_min = sticky_factor * z
     - Save values to new columns.
     - Update last_level_num, last_update_time.

Python/Pandas Implementation

Assume your DataFrame is called df and has columns:

- "timeBin" (as string or pd.Timestamp)
- "counterpartyType"
- "volumeImbalance" (numeric)

```
import pandas as pd
import numpy as np
def add_algo_live_settings(
  df,
  tau=600,
  k=1,
  threshold=1_000_000,
  sticky_factor=0.7,
  max_factor=10,
  min_factor=10,
  time_format='%H:%M:%S'
):
  # Ensure timeBin is datetime
  if not np.issubdtype(df['timeBin'].dtype, np.datetime64):
    df = df.copy()
    df['timeBin'] = pd.to_datetime(df['timeBin'], format=time_format)

  df = df.sort_values(['counterpartyType', 'timeBin']).reset_index(drop=True)
  df['algo_z'] = 0.0
  df['algo_level_num'] = 0
  df['algo_sticky_min'] = 0.0
max_z = k * max_factor
  min_z = -k * min_factor
# Process each counterpartyType group
  for cpty, group_idx in df.groupby('counterpartyType').groups.items():
    idxs = list(group_idx)
    z = 0.0
    sticky_min = 0.0
    last_update_time = None
    last_level_num = 0
for i in idxs:
      row = df.loc[i]
      t = row['timeBin']
      volumeImb = row['volumeImbalance']
      # dt in seconds
      if last_update_time is None:
        dt = 0
      else:
        dt = (t - last_update_time).total_seconds()
      # Decay z
      z = z * np.exp(-dt / tau)
```

```
        # Clamp z to sticky min
        if z > 0:
            z = max(z, sticky_min)
        elif z < 0:
            z = min(z, sticky_min)
        # Level
        level_num = int(np.floor(volumeImb / threshold))
        level_change = level_num - last_level_num
        # Update z by steps
        z = z + level_change * k
        # Clamp z within allowed range
        z = max(min(z, max_z), min_z)
        # Update sticky min
        sticky_min = sticky_factor * z
        # Store
        df.at[i, 'algo_z'] = z
        df.at[i, 'algo_level_num'] = level_num
        df.at[i, 'algo_sticky_min'] = sticky_min
        # Update state
        last_level_num = level_num
        last_update_time = t
return df
# Example usage:
# df = pd.DataFrame({...}) # as described in your format
# df = add_algo_live_settings(df)
# print(df)
```

What This Does

- **Adds** `algo_z`, `algo_level_num`, and `algo_sticky_min` columns.
- **Handles** time decay, sticky minimum, and step-wise increments per counterparty.
- **Works** for any DataFrame with your described columns.