

Algorithmic Trading Strategies¹

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¹Reference: Avellaneda (2011), Maglaras (2015)

Algo Trading Systems: Typically Decomposed into 3 Steps

- **Trade scheduling (macro-trader):** splits parent order into ~ 5 min slices (**Lecture 2**)
 - Relevant time-scale: minutes-hours
 - Schedule follows user selected strategy (VWAP, POV, IS, ...)
 - Reflects urgency, alpha, risk/return tradeoff
 - Schedule updated during execution to reflect price/liquidity/...
- **Optimal execution of a slice (micro-trader):** further divides slice into child orders (**Lecture 3**)
 - Relevant time-scale: secondsminutes
 - Strategy optimizes pricing and placing of orders in the LOB
 - Execution adjusts to speed of LOB dynamics, price momentum, ...
- **Order routing:** decides where to send each child order (**Lecture 4**)
 - Relevant time-scale: $\sim 1 - 50$ ms
 - Optimizes fee/rebate tradeoff, liquidity/price, latency, etc

Algo Trading Strategies: VWAP

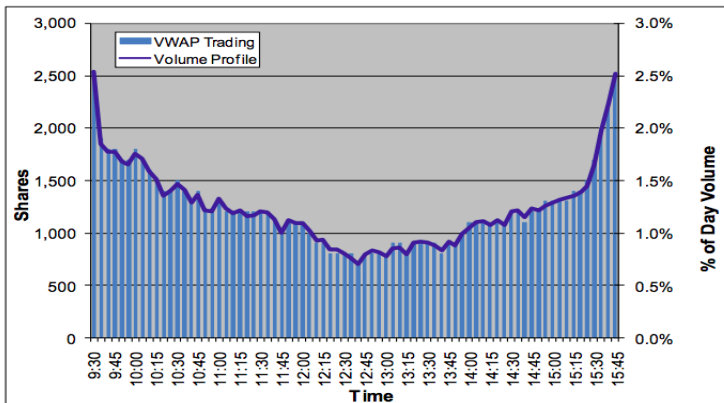
- **VWAP (Volume-Weighted Average Price):** Trades according to forecasted volume profile to achieve (or beat) the market VWAP.
 - ² If an asset during some time interval has N trades with price p_k and volume v_k , its VWAP is

$$VWAP = \frac{\sum_{k=1}^N v_k p_k}{\sum_{k=1}^N v_k}$$

- Passive strategy.
 - Subject to significant market risk.
- Algorithm:
 - Estimate the average volume traded in every 5 minute interval using historical data.
 - In each time-interval, execute an amount proportional to the normative volume for that interval.

²Yang (n.d.)

Volume-Weighted Average Price



- Properties:

- The algorithm always concludes (trade sizes are known in advance).
- Volume function is estimated using historical data. This may not correspond exactly to *ex-post* VWAP.

Algo Trading Strategies: TWAP

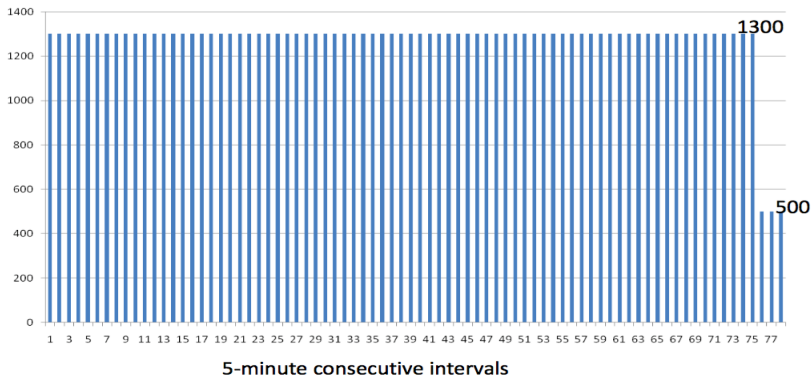
- **TWAP (Time-Weighted Average Price):** Trades uniformly over time to achieve (or beat) TWAP benchmark.
 - Passive strategy
 - Also subject to market risk
- ³ Such a simple protocol has a risk of exposure of the traders intentions to other market participants:
 - *For example, some scalpers may realize that a large order is being traded and start trading the same instrument in expectation that the large trading volume will inevitably move the price.*
- To prevent information leak, TWAP schedule may be randomized in terms of size and submission time of child orders.
 - *For example, if the trading interval is four hours, 25% of the trading volume must be executed each hour, and the child order size may be adjusted deterministically for each hour.*

³Yang (n.d.)

Time-Weighted Average Price

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Figure 1: Example: 100,000 shares TWAP/all day



- Equal amount of shares in each period of time.
- Not very popular in practice.

⁴Avellaneda (2011)

VWAP vs. TWAP

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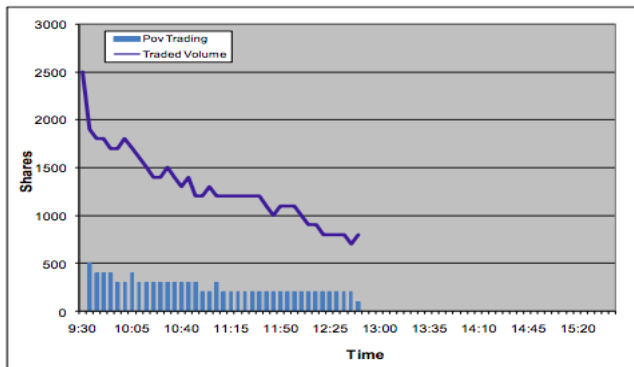
- During a slow trading day, the TWAP may be very similar to the VWAP, even to the penny at times. However, in a volatile session, or when volume is higher than usual, the two indicators may diverge.

⁵Yang (n.d.)

- **POV (Percent of Volume):** Submit child orders with sizes equal to a certain percentage of the *total trading volume*.
 - Execute while tracking the realized volume profile at a constant target participation rate, e.g., buy IBM at 15% participation rate.
 - Controls behavior during volume spikes to avoid excessive cost.
 - Popular in practice with $\sim 5\% - 30\%$ participation rates.
 - Participation rate is highly related to transaction cost.

Price of Volume

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- The POV (Percentage of Volume) algorithm addresses the problem of VWAP by using the actual total traded volume of the day as benchmark.

⁶Avellaneda (2011)

- **IS (Implementation Shortfall):** Schedules trade so as to optimally tradeoff *expected shortfall* (cost) against *execution risk*.
 - Objective functions is usually a weighted linear sum of execution cost and execution risk.
 - Execution speed adapts with respect to changes in market conditions.
 - Popular, especially with portfolios with intricate cost/risk tradeoff.

Implementation Shortfall

- (Almgren and Chriss, 2000) **Expected Fall**

- Stock price is subject to price impact.

$$\tilde{S}_t = S_t - \eta \frac{dQ(t)}{dt}.$$

- *Expected execution cost* is the volume-weighted execution price along the time:

$$E = -\mathbb{E}\left[\int_{t=0}^T \tilde{S}_t \frac{dQ(t)}{dt} dt\right].$$

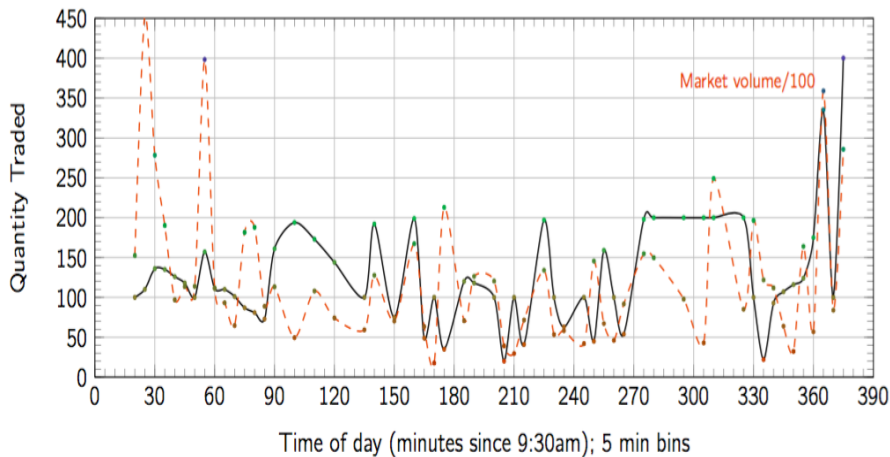
- *Execution risk* is the variance of execution position:

$$V = \text{Var}\left[\int_{t=0}^T Q(t) dS_t\right]$$

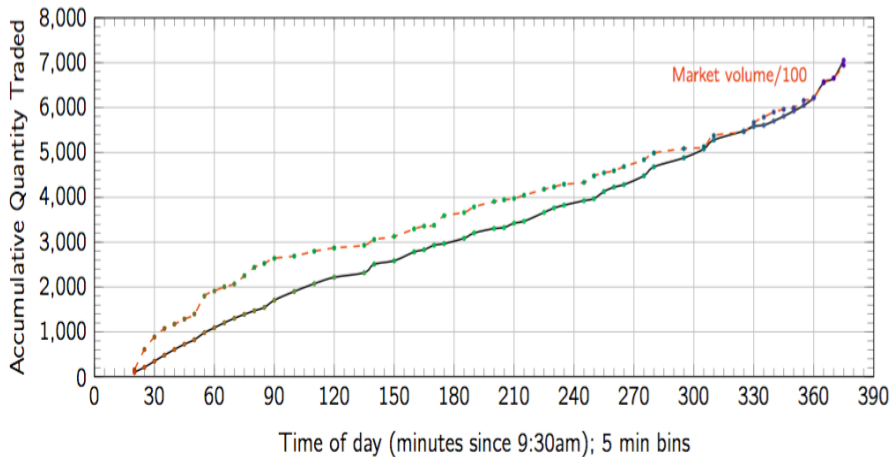
- The optimal position is the one that minimizes the sum of *execution cost* and *execution risk*:

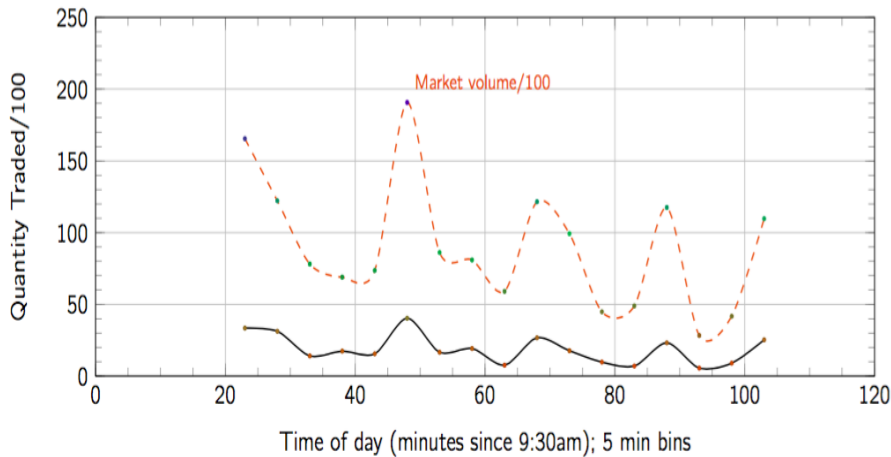
$$\min_Q \{E + \lambda V\}$$

VWAP, XLY, 07/22/2013 (.15%ADV)

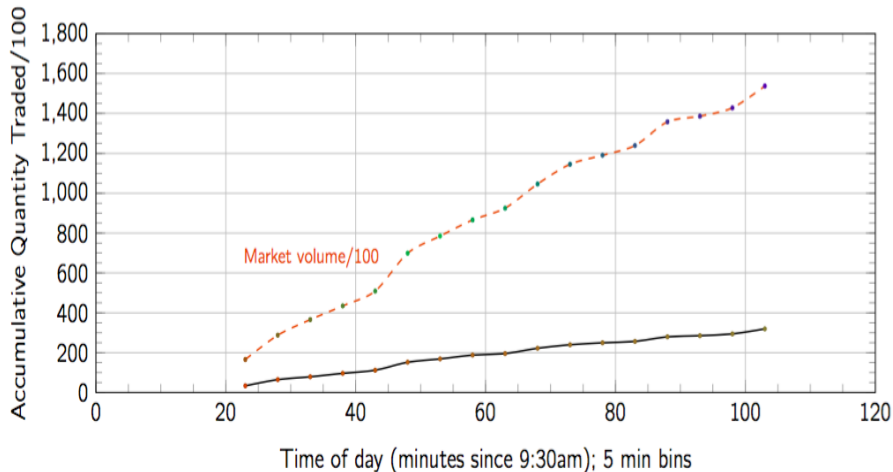


VWAP, XLY, 07/22/2013 (cumulative quantity)

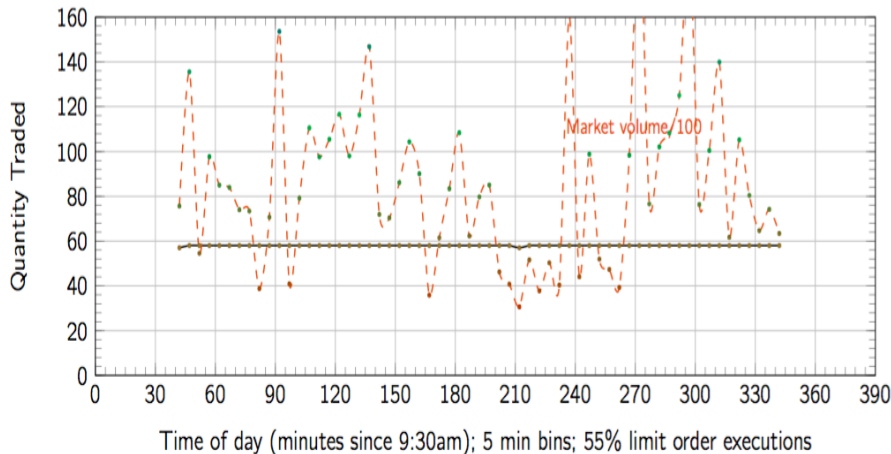




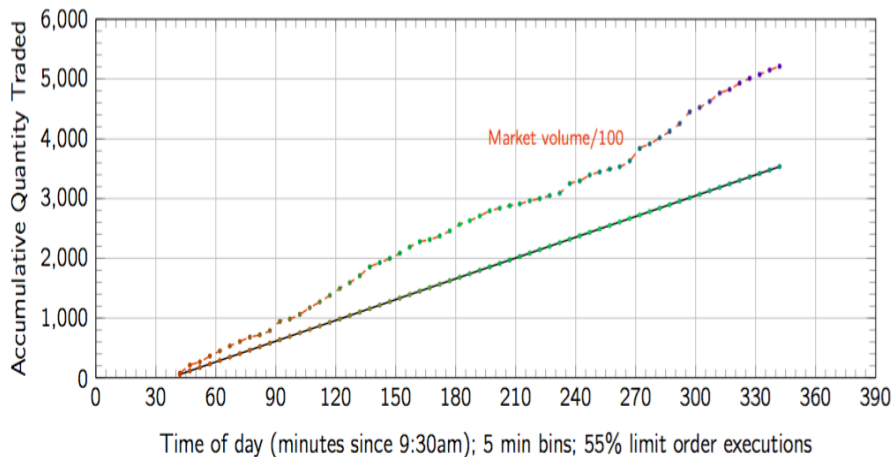
POV, ACT, 07/08/2013 (cumulative quantity)



Schematic of execution profiles: TWAP, XLY, 07/02/2013



TWAP, XLY, 07/02/2013 (cumulative quantity)



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