ALPHA-X™ AND ALPHA DRK™ ORDER TYPE AND FUNCTIONALITY GUIDE

TMX

As at December 14, 2023

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Alpha-X™ and Alpha DRK™ - New Order Types

The new TMX market is made up of two separate order books - a displayed order book (Alpha-X) and an undisplayed book (Alpha DRK). From an order entry perspective, these two books do not interact with each other.

Alpha-X and the Smart Limit Order Type

In addition to the suite of order types currently available on TSX Alpha Exchange, Alpha-X also provides a new Smart Limit order type. A resting Smart Limit order behaves like a regular limit order, with the following additional order management features:

- If a Smart Limit order is resting at the quote (the Protected National Best Bid/Offer (Protected NBBO)) and the quote is likely to imminently decay (as signaled by the TMX Quote Decay Signal™ (TMX QDS™), described below), the Smart Limit order is repriced one tick less aggressive than the current quote, in anticipation of the predicted new quote.
- If the quote winds up not decaying, the repriced Smart Limit order is restored to its original limit price.
- If the quote improves after decaying, the repriced Smart Limit order is again repriced, following the improving quote, up to (but not beyond) its original limit price.

Alpha DRK and the Smart Peg™ Order Type

The Alpha DRK book provides the standard suite of Dark pegged and limit order types currently available on TSX DRK. In addition, Alpha DRK provides a new Smart Peg order type. A resting Smart Peg order behaves like a regular Primary Peg order, in that it pegs at or near the passive side of the Protected NBBO; in addition, the Smart Peg order has the ability to trade against incoming active liquidity at more aggressive ("discretionary") prices than its pegged price, up to the midpoint of the Protected NBBO.

Note that unlike the Smart Limit order type, the Smart Peg order type has no interaction with TMX QDS.

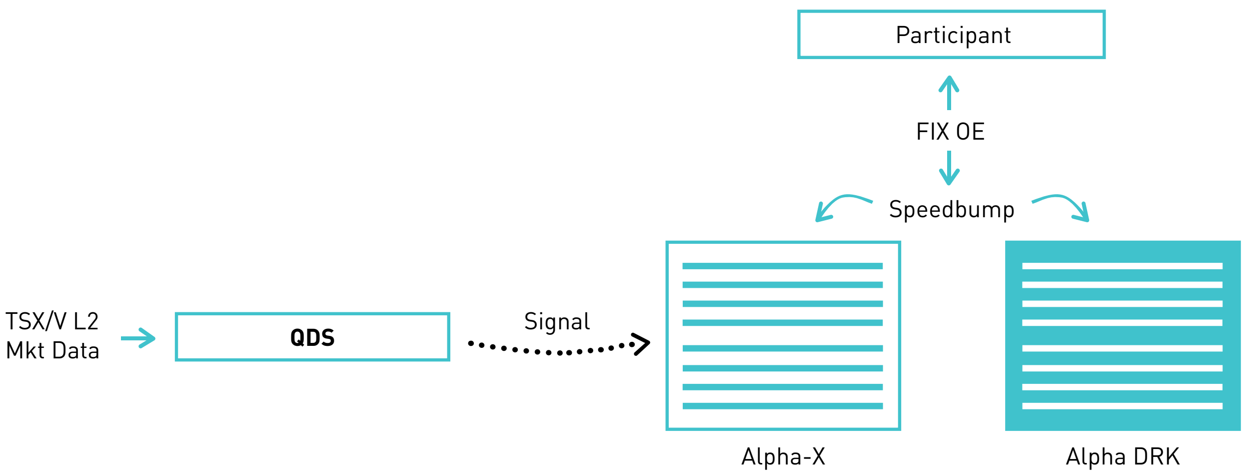
TMX QDS Overview

The TMX QDS is a system which ingests real-time TSX and TSXV market data and makes inferences, based on the input data, on imminent changes to the Protected NBBO.

In effect, TMX QDS performs continuous analysis on both sides of the quote for all securities trading on TSX and TSXV, simultaneously and independently of one another.

The results of this analysis are predictions of imminent decays to the Protected NBBO. These predictions are communicated to the Alpha-X order book, which uses them to manage the prices on its resting Smart Limit orders.

Here is a high-level illustration of TMX QDS and the Alpha-X/Alpha DRK market:



TMX QDS Input

The data ingested by TMX QDS is the TSX and TSXV public real-time Level 2 (L2) data that is available on the TMX client data feeds, as well as on the TMX IP. No private data is used by TMX QDS. L2 data is delivered to TMX QDS and the TMX IP simultaneously.

TMX QDS Processing

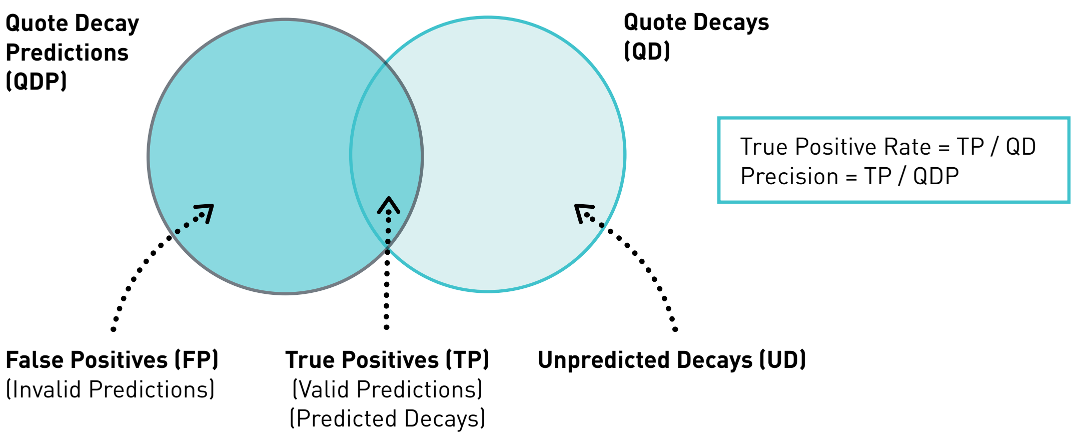
TMX QDS processes the TSX and TSXV L2 input data via a "Decision Tree" machine learning algorithm, which has been trained and optimized using many months of historical data. As data is ingested and analyzed, TMX QDS continually re-evaluates the state of all traded securities. Its algorithm has been trained to detect conditions where a "decay" in a symbol's quote (i.e. its Protected NBB or NBO) is likely to occur in the near future. A Protected NBB or NBO "decay" means a move to a less aggressive price. For example, a Protected NBB move from 10.00 to 9.99 is a quote "decay"; a move from 10.00 to 10.01 is not a decay.

In the current implementation of TMX QDS, "near future" means 20 milliseconds. In other words, when TMX QDS predicts that a quote is about to decay, it is predicting that it will decay within the next 20 milliseconds.

Quote decay prediction is a probabilistic exercise. It is not expected that TMX QDS will correctly predict all quote decays, nor that all of its predictions will be followed by actual decays. The training of TMX QDS is with a view to a balanced objective between these two ideals.

The following diagram is a high-level schematic view of the elements involved in the TMX QDS quote decay prediction process.

Overview



The True Positive Rate and the Precision, as indicated above, tend to be inversely correlated; the TMX QDS training is with a view to balancing these two metrics.

The Smart Peg and Smart Limit order types are intended to improve execution quality on Alpha DRK and Alpha-X, respectively. The Smart Peg and Smart Limit order types do not alleviate, and market participants continue to be responsible for, best execution requirements under National Instrument 23-101 - Trading Rules and the Universal Market Integrity Rules.

TMX QDS Output

When an imminent quote decay is predicted, TMX QDS sends an "on" message to the Alpha-X order book, so that Alpha-X is aware of the prediction and can reprice the affected Smart Limit orders accordingly.

When the 20-millisecond prediction period expires, TMX QDS sends a follow-up "off" message to Alpha-X, so that Alpha-X is aware that the quote decay is no longer predicted.

Sequence

Here is an example illustrating the interplay between TMX QDS and the Alpha-X order book.

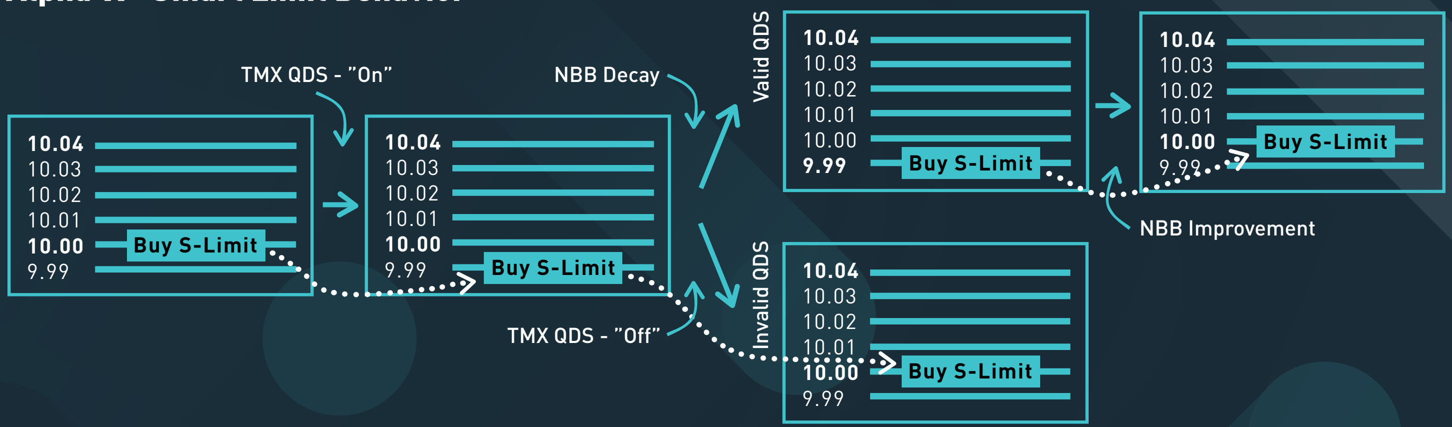
1. Protected National Best Bid/Offer (P-NBBO) is 10.00 - 10.04. This is the BBO across all protected markets and therefore does not include the quote on the (unprotected) Alpha-X order book itself.
2. A participant places a Buy Smart Limit order on Alpha-X, at 10.00. This order is at the Protected National Best Bid (NBB), and rests at the top of the Alpha-X book on the buy side.
3. TMX QDS, based on its own market data analysis, makes a prediction that the Protected NBB is about to decay; i.e. about to change from 10.00 to the less-aggressive 9.99. It sends an "on" signal to Alpha-X, informing it of that prediction.
4. Alpha-X reacts to the "on" signal by repricing the Buy Smart Limit order from 10.00 to 9.99; i.e. repricing it to the predicted new value of the Protected NBB.

At this point, one of two flows may occur:

5. **The Protected NBB does decay as predicted:**
   a. No action is taken on the Buy Smart Limit order - it is left at its repriced value of 9.99.
   b. After 20 milliseconds, TMX QDS follows up the "on" signal with an "off" signal.
   c. The "off signal" is ignored by Alpha-X.
   d. After some time, the Protected NBB may "improve"; i.e. it may move back to 10.00. Alpha-X reacts to this change by repricing the Buy Smart Limit order back to 10.00 so that it remains at the Protected NBB. Note that if the Protected NBBO subsequently "improves" to 10.01, the Buy Smart Limit order is *not* repriced to 10.01 as it would then be more aggressive than its originally entered limit price.
6. **The Protected NBBO does not decay as predicted:**
   a. After 20 milliseconds, TMX QDS follows up the "on" signal with an "off" signal.
   b. Alpha-X reacts to the "off" signal by reversing the repricing of the Buy Smart Limit order in step 4) above, and repricing it back to its previous value of 10.00.

This sequence is illustrated in the following diagram.

Alpha-X - Smart Limit Behavior



What is a decision tree and why do we use it?

A decision tree is a type of supervised machine learning technique. Supervised learning means that the model is built by training it on datasets where the outcomes are already known. In essence, a supervised machine learning algorithm finds patterns in the training dataset to create a model that can subsequently make predictions on the outcomes for a different but similar dataset.

The model resulting from the training process is essentially a sequence of IF statements on various "features" and decision boundaries. A "feature" is simply a value that is computed from one or more known attributes. For example, whether a symbol is an ETF or common-stock can be considered a "feature". Similarly, the volume traded for a symbol in the past 5 milliseconds could be considered a "feature".

Using this technique allows us to provide a long list of "features" (well over a thousand), and let the training process decide which features have the most predictive value.

What are the “features” used by the model?

The TMX QDS utilizes a number of features including but not limited to:

- Symbol attributes (e.g. Equity securities or ETFs)
- TSX Top of Book (“TOB”) volume
- TOB order count
- TOB spread
- TOB price
- Change in state of TOB over a time period

The TMX QDS only considers orders and trades in the Central Limit Order Book and excludes, among other things, crosses and dark trades.

How is the model’s performance measured?

There are a few key dimensions along which we measure performance:

- Coverage is the percent of all quote decays that the model could predict. In our case, it is the percent of quote decays that were preceded by a quote/trade event within the lookahead window period.
- Precision is the percentage of times a “True” prediction is followed by a quote decay within the lookahead window.
- True Positive Rate is the percent of all quote decays that the model predicts correctly (TPR includes quote decays that are not covered, Covered TPR excludes them).
- False (True) Positive Duration is the cumulative amount of time the signal is on due to a False (True) Positive prediction.

To further illustrate our measurement methodology, consider the example below:

- Assume that on a day, 1000 quote decays are observed.
- 600 were preceded by an event within the lookahead window (say 20ms)
- The model predicts that the quote will decay 1500 times, with 500 of them correct

In this scenario:

Coverage is 600/1000 = 60%

Precision is 500/1500 = 33%

True Positive Rate is 500/1000 = 50%

Covered True Positive Rate is 500/600 = 83%

False Positive Duration is 1000 * 20ms = 20s.

True Positive Duration is 10s

In general, optimizing for better Precision leads to a True Positive Rate (as the model becomes more selective/ less aggressive). Optimizing for higher TPR leads to lower Precision (as the model becomes more aggressive, with more False Positives).

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