Machine Learning in Finance Workshop 2021

Improving Bond Trading Workflows by Learning to Rank RFQs

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Engineering

Machine Learning in Finance 2021
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Overview: Stock Market vs. Fixed Income Market

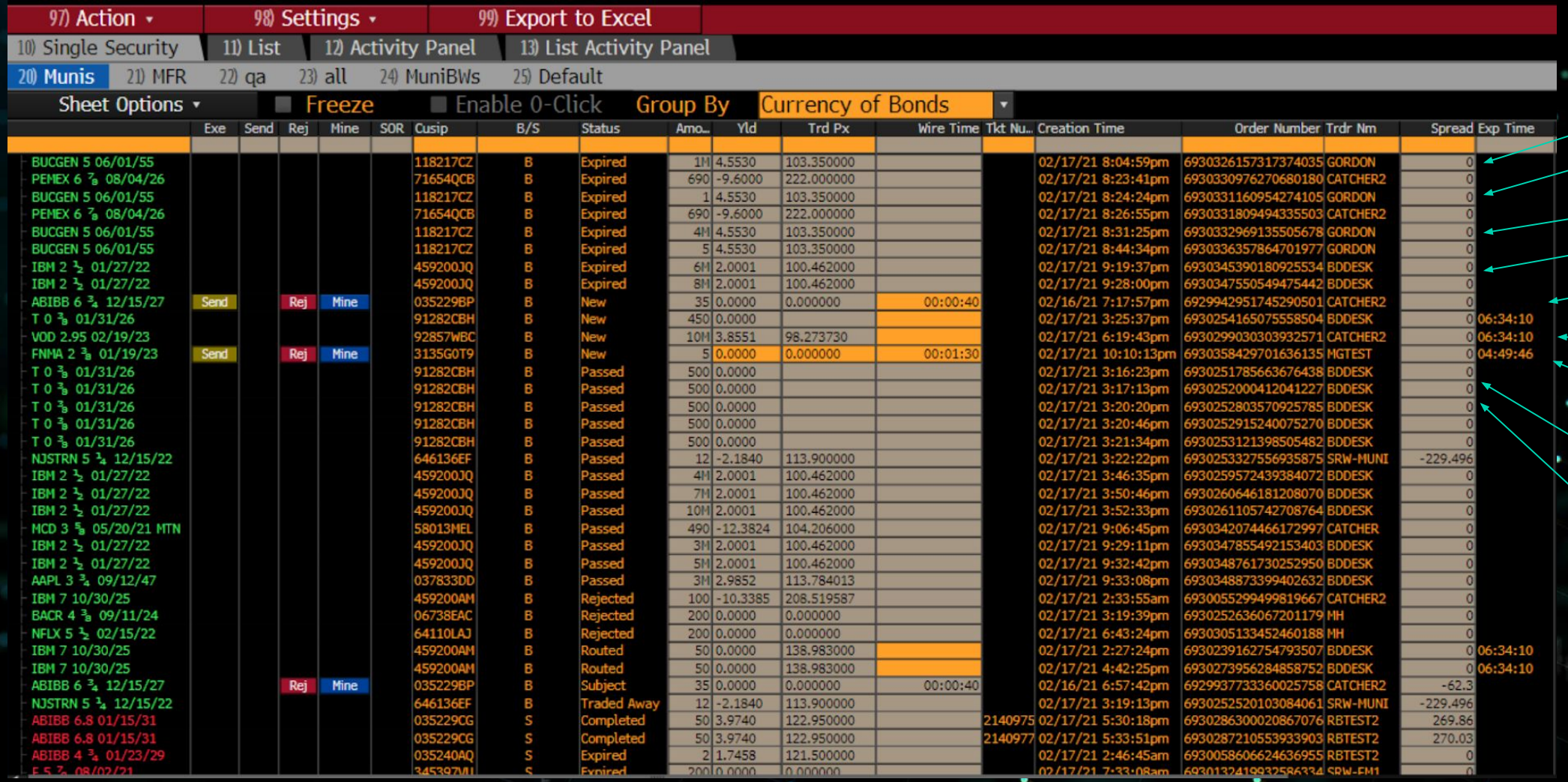
Stock Market

- Trades on centralized exchanges
  - Ex. NYSE, NASDAQ, London Stock Exchange
- Strict trade reporting requirements
- Higher volatility
- Largely automated

Fixed Income Market

- Trades over-the-counter, largely through major banks (termed the “Sell Side”)
  - Ex. JP Morgan, Wells Fargo
- Looser trade reporting requirements
- Lower volatility
- Human effort required to facilitate trades

The Life of a Bond Trader: SSOX <GO>



	Exe	Send	Rej	Mine	SOR	Cusip	B/S	Status	Amo…	Yld	Trd Px	Wire Time	Tkt Nu…	Creation Time	Order Number	Trdr Nm	Spread	Exp Time
BUCGEN 5 06/01/55						118217CZ	B	Expired	1M	4.5530	103.350000			02/17/21 8:04:59pm	6930326157317374035	GORDON	0	
PEMEX 6 7/8 08/04/26						71654QCB	B	Expired	690	-9.6000	222.000000			02/17/21 8:23:41pm	6930330976270680180	CATCHER2	0	
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VOD 2.95 02/19/23						92857WBC	B	New	10M	3.8551	98.273730			02/17/21 6:19:43pm	6930299030303932571	CATCHER2	0	06:34:10
FNMA 2 3/8 01/19/23	Send		Rej	Mine		3135G0T9	B	New	5	0.0000	0.000000	00:01:30		02/17/21 10:10:13pm	6930358429701636135	MGTEST	0	04:49:46
T 0 3/8 01/31/26						91282CBH	B	Passed	500	0.0000				02/17/21 3:16:23pm	6930251785663676438	BDDESK	0	
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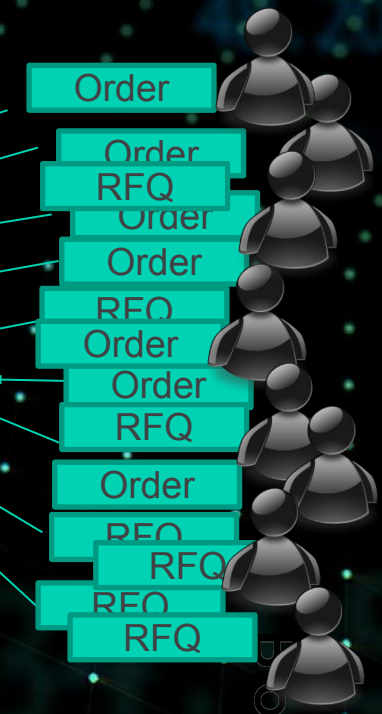
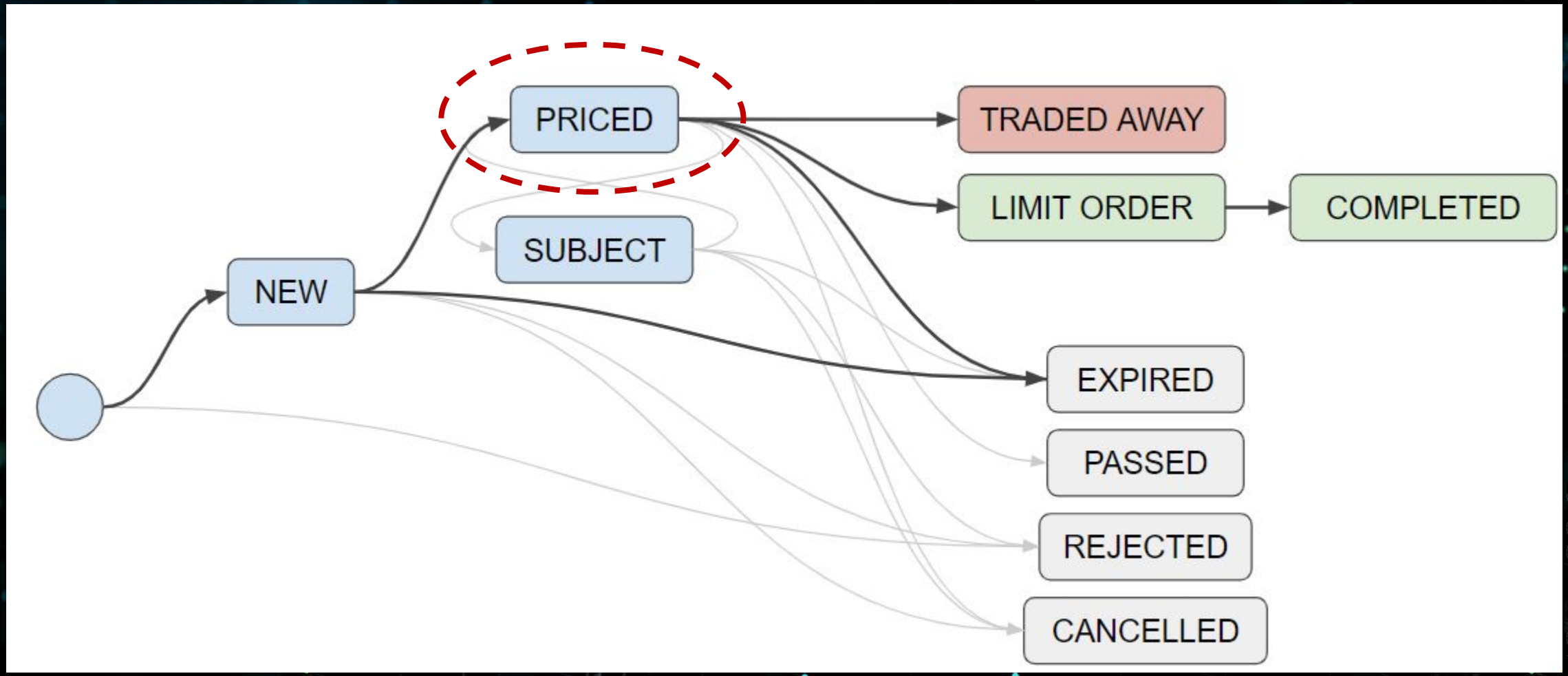
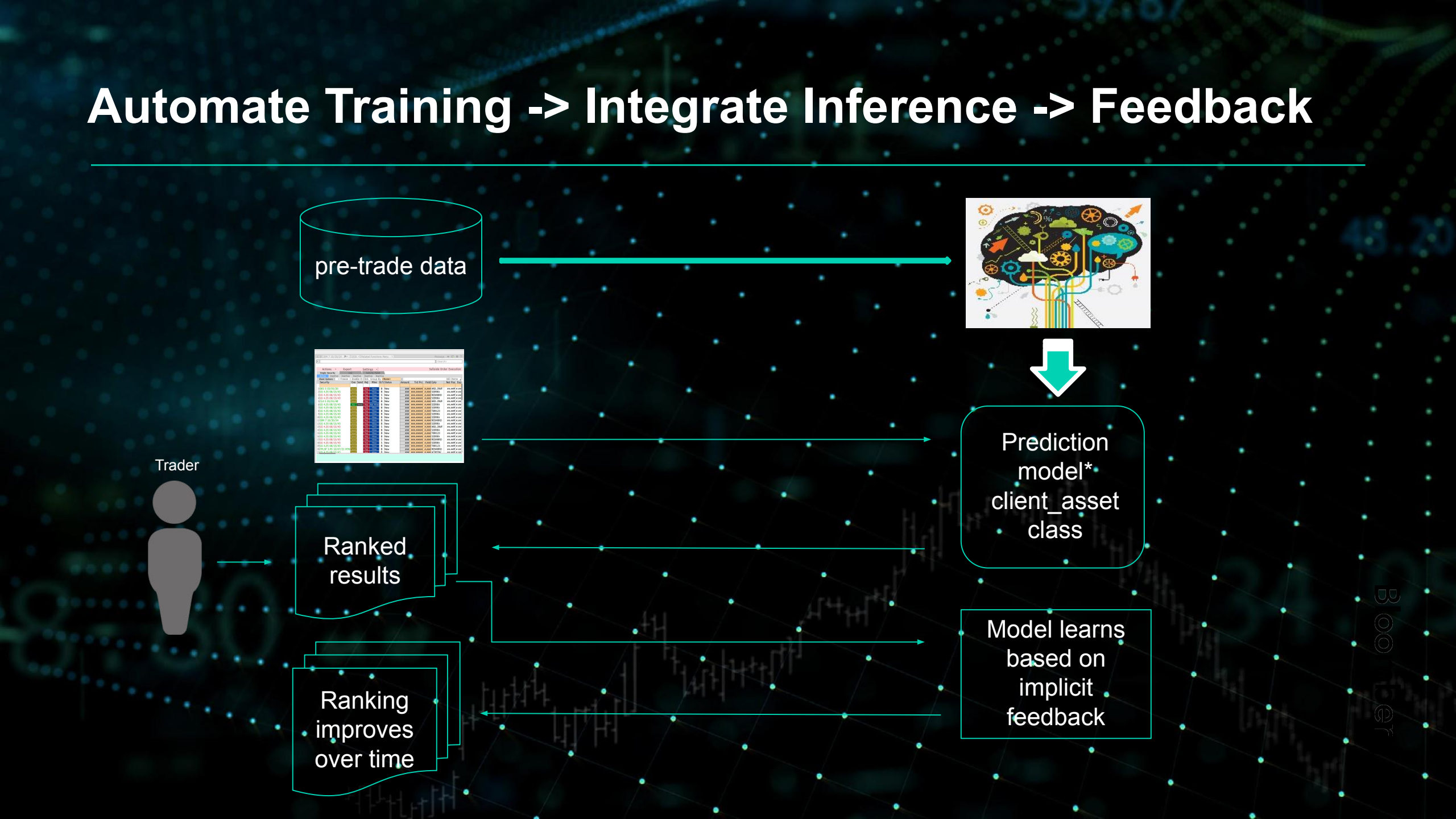
F 5 7/8 08/02/21						345397WU	S	Expired	200	0.0000	0.000000			02/17/21 7:33:08am	6930132419932586334	SRW-FM1	0	



RFQ Workflow



Automate Training -> Integrate Inference -> Feedback



Machine Learning Problem Statement

Task

Rank RFQs in a useful way

Approach

Rank by the probability that an RFQ will be priced. This transforms our ranking problem into **binary classification**.

Implementation

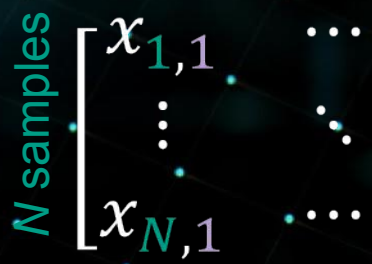
We use a **random forest** model to predict the **probability** that an RFQ will be priced based on its characteristics (amount, price, side, etc.) trained on RFQs from the previous months. We retrain periodically.

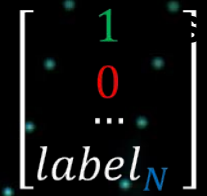
Training / Inference Pipeline

Input Data

- Trade attributes
- Dealer attributes

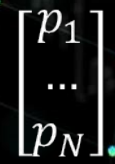
Featurization



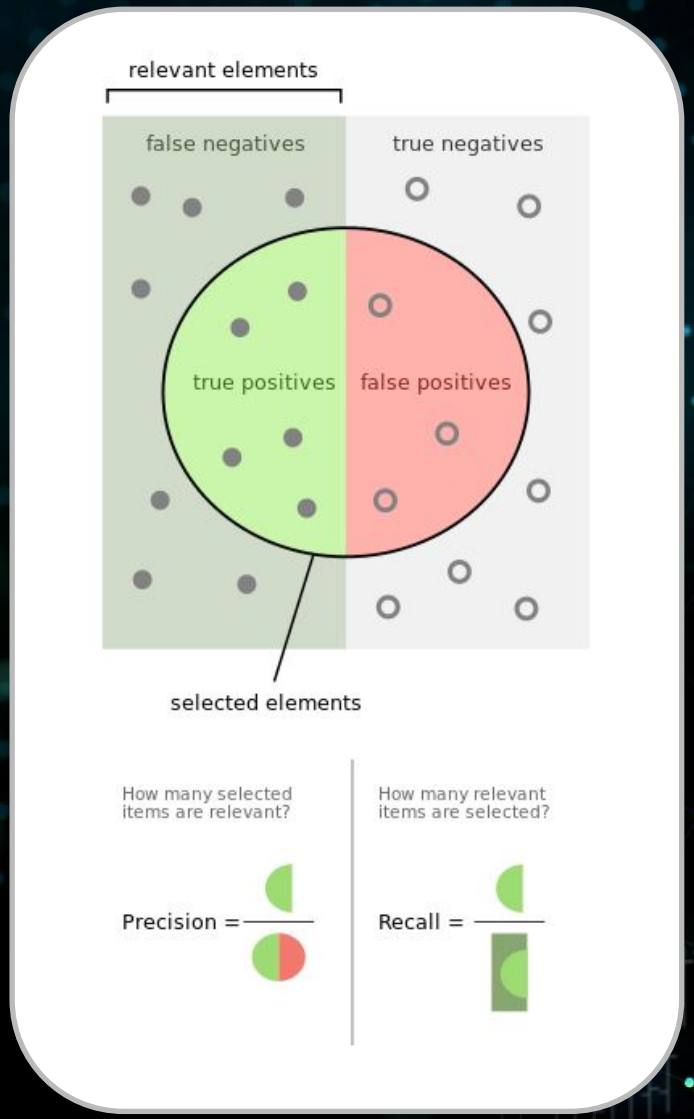


ML Model
(Random Forest)

ML Score



Binary Classification Metrics: Precision and Recall



Threshold = 0.5
Precision = 2/2 = 1.0
Recall = 2/7 = 0.29

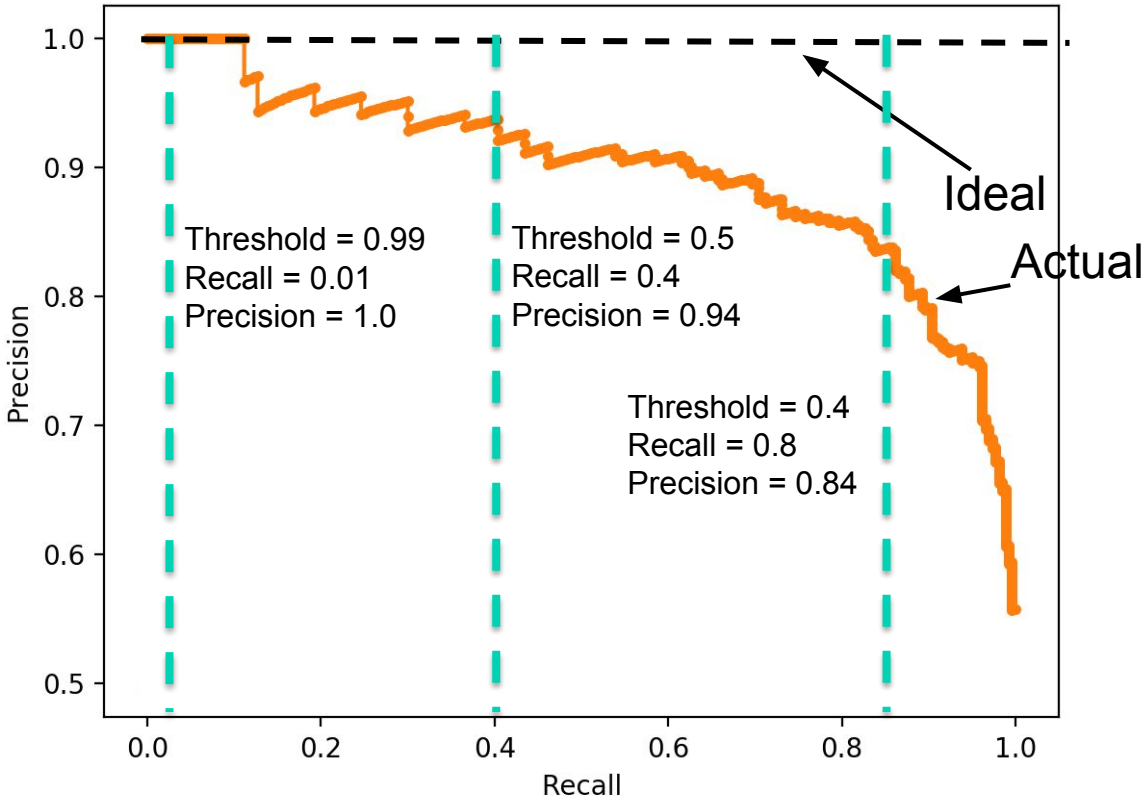
Threshold = 0.1
Precision = 5/6 = 0.83
Recall = 5/7 = 0.71

Threshold = 0.0
Precision = 7/13 = 0.54
Recall = 7/7 = 1.0

	Outcome
0.67	PRICED
0.52	PRICED
0.49	PRICED
0.43	PRICED
0.31	NOT PRICED
0.19	PRICED
0.09	NOT PRICED
0.05	NOT PRICED
0.03	PRICED
0.03	NOT PRICED
0.02	NOT PRICED
0.01	PRICED
0.00	NOT PRICED

Binary Classification Metrics: AUC-PR

Area Under the Precision Recall Curve (AUC-PR) measures how well the model performs across all possible confidence thresholds



- Each confidence threshold leads to a specific precision and specific recall
- AUC-PR measures the area under the curve (optimal = 1.0)

Ranking Metrics – Precision @ N

$$Precision@N = \frac{P_N}{N}$$

$P_N = True\ positives\ in\ N\ highest\ ranked\ samples$

Example 1
Precision@10 = 0.6

ML Score	Outcome
0.67	PRICED
0.52	PRICED
0.49	PRICED
0.43	PRICED
0.31	NOT PRICED
0.19	PRICED
0.09	NOT PRICED
0.05	NOT PRICED
0.03	PRICED
0.03	NOT PRICED
0.02	NOT PRICED
0.01	PRICED
0.00	NOT PRICED

Example 2
Precision@10 = 0.3

ML Score	Outcome
0.98	PRICED
0.92	PRICED
0.71	PRICED
0.10	NOT PRICED
0.09	NOT PRICED
0.09	NOT PRICED
0.09	NOT PRICED
0.05	NOT PRICED
0.04	NOT PRICED
0.02	NOT PRICED
0.02	NOT PRICED
0.00	NOT PRICED
0.00	NOT PRICED

Discounted Cumulative Gain (DCG) @ N

$$DCG_{@N} = \sum_{i=1}^{N} \frac{(Scored\ Correctly)}{\log_2(i+1)}$$

Higher ranked orders matter more

Example 1

ML Score	Outcome
0.67	PRICED
0.52	PRICED
0.49	PRICED
0.43	PRICED
0.31	NOT PRICED
0.19	PRICED

Precision@5 = 0.8

DCG@5 = 2.56

Example 2

ML Score	Outcome
0.78	NOT PRICED
0.61	PRICED
0.42	PRICED
0.39	PRICED
0.35	PRICED
0.21	PRICED

Precision@5 = 0.8

DCG@5 = 1.95

Ranking Metrics – NDCG @ N

NDCG = Normalized DCG
(Discounted Cumulative Gain)

$$NDCG@N = \frac{DCG_{@N}}{IDCG_{@N}}$$

$DCG_{@N} = DCG\ for\ N\ highest\ ranked\ samples$

$IDCG_{@N} = Best\ possible\ DCG\ for\ N\ samples$

Example 1
NDCG@10 = 0.97

ML Score	Outcome
0.67	PRICED
0.52	PRICED
0.49	PRICED
0.43	PRICED
0.31	NOT PRICED
0.19	PRICED
0.09	NOT PRICED
0.05	NOT PRICED
0.03	PRICED
0.03	NOT PRICED
0.02	NOT PRICED
0.01	PRICED
0.00	NOT PRICED

Example 2
NDCG@10 = 1.0

ML Score	Outcome
0.98	PRICED
0.92	PRICED
0.71	PRICED
0.10	NOT PRICED
0.09	NOT PRICED
0.09	NOT PRICED
0.09	NOT PRICED
0.05	NOT PRICED
0.04	NOT PRICED
0.02	NOT PRICED
0.02	NOT PRICED
0.00	NOT PRICED
0.00	NOT PRICED

Calibration

- If a group of orders have probability of approximately 20%, then approximately 20% of them should be priced

- A separate model monotonically transforms the output of the Random Forest “probability” so that the above statement becomes more correct, while preserving order

ML Score	Outcome
0.67	PRICED
0.52	PRICED
0.49	PRICED
0.43	PRICED
0.31	NOT PRICED
0.19	PRICED
0.09	NOT PRICED
0.05	NOT PRICED
0.03	PRICED
0.03	NOT PRICED
0.02	NOT PRICED
0.01	PRICED
0.00	NOT PRICED

ML Score	Outcome
0.82	PRICED
0.81	PRICED
0.80	PRICED
0.79	PRICED
0.78	NOT PRICED
0.51	PRICED
0.50	NOT PRICED
0.50	NOT PRICED
0.49	PRICED
0.34	NOT PRICED
0.33	NOT PRICED
0.32	PRICED
0.00	NOT PRICED

Recap: Model Performance Metrics

AUC-PR: The **most direct measure** of how the model performs its **stated task**

Precision@10: An **interpretable ranking metric** that measures how well our top ranked RFQs perform

NDCG@10: Incorporates weights for order and is relative to an idealized ranking, making it our **best metric** for describing **ranking performance**

Results Conclusion

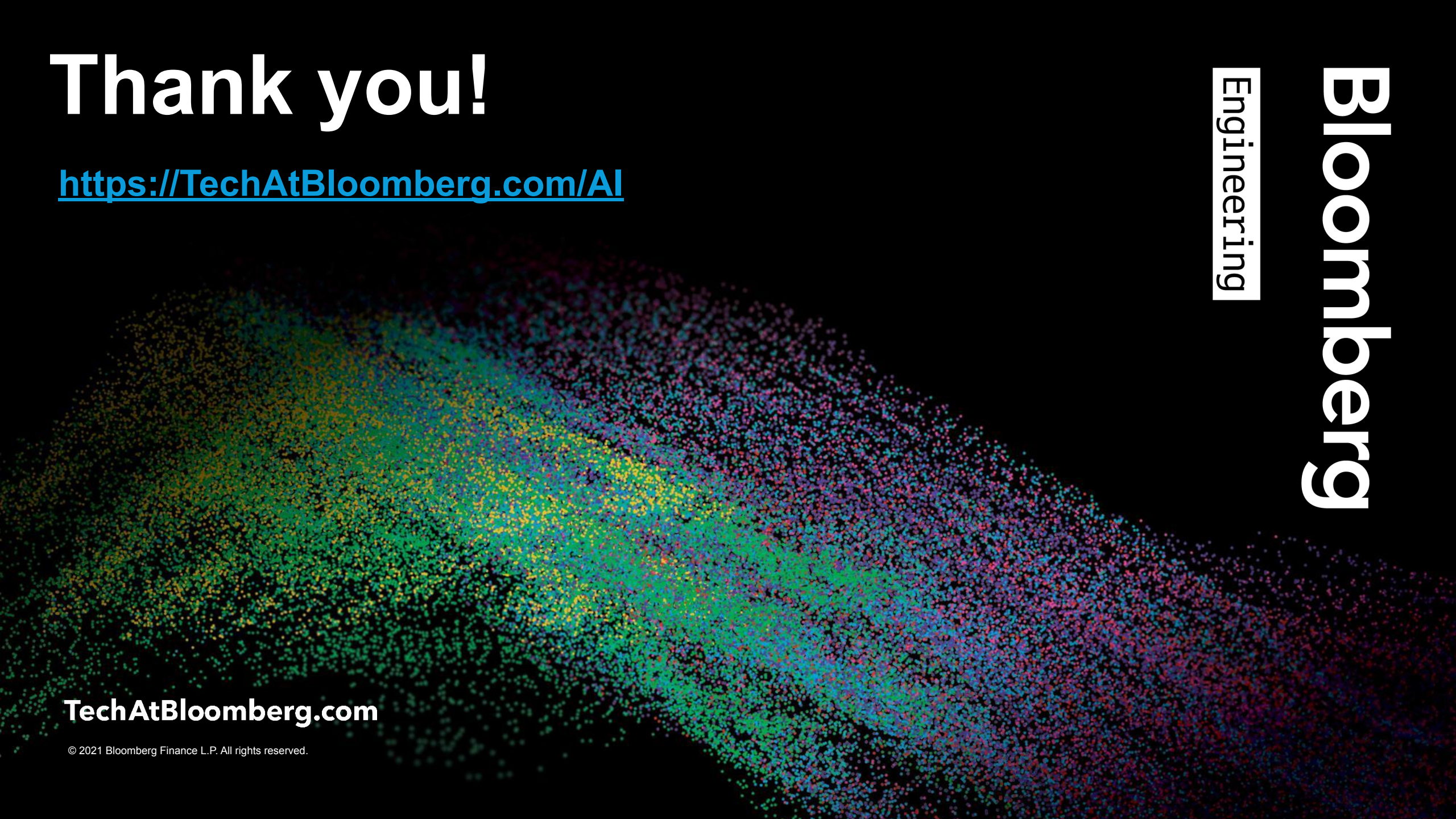
All models perform significantly better than the baseline* across all metrics

Client	AUC-PR (baseline)	Precision@10 (baseline)	NDCG@10 (baseline)
A	**0.087** (0.014)	**0.100** (0.022)	**0.115** (0.022)
B	**0.637** (0.174)	**0.804** (0.211)	**0.853** (0.226)
C	**0.278** (0.017)	**0.331** (0.023)	**0.389** (0.033)
D	**0.521** (0.150)	**0.592** (0.156)	**0.609** (0.161)
E	**0.175** (0.044)	**0.148** (0.044)	**0.365** (0.117)
F	**0.781** (0.062)	**0.712** (0.084)	**0.869** (0.101)
G	**0.884** (0.624)	**0.751** (0.508)	**0.913** (0.605)

*Baselines are by amount and by timestamp: best performing baseline is chosen for comparison
Best performing baseline for E and G is **amount**, for all others it is **timestamp**

Thank you!

https://TechAtBloomberg.com/AI



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