MS&E 448

Trading forex with distributed limit order book

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With data provided by Integral
Under guidance of Dr. Lisa Borland and Enguerrand Horel.

Outline

1. Intro/Problem Statement
2. Data
    a. What does each data point look like
    b. Statistics
        i. Across time
        ii. Across currency pairs (e.g. correlations)
        iii. Across LPs (I haven't thought of a good one for this yet)
3. Related Work / Existing Methods
4. Methods
    a. Baseline method
    b. Next steps method

Data from Integral

8 Currency pairs

- USDCAD, USDCHF, USDJPY, USDSEK,
- AUDUSD, EURUSD, GBPUSD, NZDUSD

Across 1 month, 5 LPs

- February 1st, 2019 - March 1st, 2019
- Sunday: starting at 1800 (discard, too few trades)
- Monday-Thursday: 24 hours
- Friday: Ends at 2200 (discard after 1800)
- 25 days, ~400 active hours

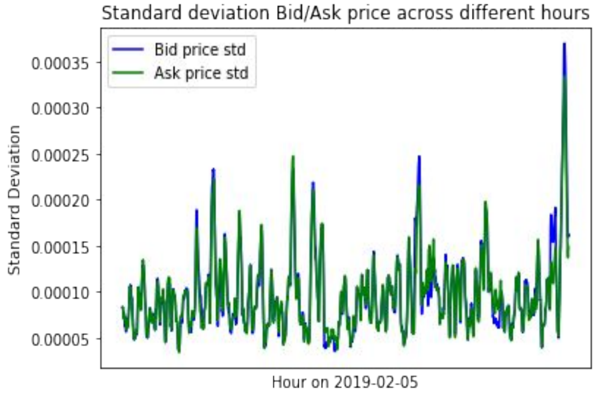
Data from Integral

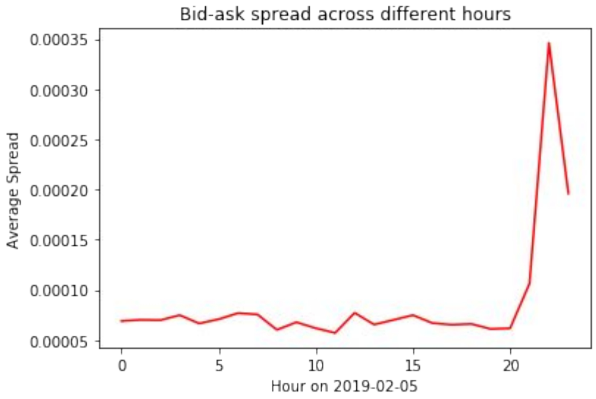
provider	currency pair	time	bid price	bid volume	ask price	ask volume
LP-1	EURUSD	02.25.2019 00:00:00.819	1.13417	1000000	1.13424	1000000
LP-1	EURUSD	02.25.2019 00:00:00.819	1.13417	1000000	1.13423	1000000
LP-1	EURUSD	02.25.2019 00:00:00.819	1.13417	1000000	1.13423	1000000
LP-1	EURUSD	02.25.2019 00:00:00.841	1.13411	1000000	1.13423	1000000
LP-1	EURUSD	02.25.2019 00:00:00.841	1.13411	1000000	1.13423	1000000
LP-1	EURUSD	02.25.2019 00:00:00.841	1.13411	1000000	1.13423	1000000
LP-1	EURUSD	02.25.2019 00:00:00.895	1.1341	1000000	1.13422	1000000
LP-1	EURUSD	02.25.2019 00:00:00.896	1.1341	1000000	1.13422	1000000
LP-1	EURUSD	02.25.2019 00:00:00.896	1.1341	1000000	1.13422	1000000
LP-1	EURUSD	02.25.2019 00:00:00.940	1.13414	1000000	1.13421	1000000
LP-1	EURUSD	02.25.2019 00:00:00.940	1.13414	1000000	1.13421	1000000
LP-1	EURUSD	02.25.2019 00:00:00.940	1.13414	1000000	1.13421	1000000
LP-1	EURUSD	02.25.2019 00:00:00.958	1.13414	1000000	1.1342	1000000
LP-1	EURUSD	02.25.2019 00:00:00.958	1.13414	1000000	1.1342	1000000
LP-1	EURUSD	02.25.2019 00:00:00.959	1.13414	1000000	1.1342	1000000
LP-1	EURUSD	02.25.2019 00:00:01.039	1.13414	1000000	1.13421	1000000
LP-1	EURUSD	02.25.2019 00:00:01.039	1.13414	1000000	1.13421	1000000
LP-1	EURUSD	02.25.2019 00:00:01.039	1.13414	1000000	1.13421	1000000
LP-1	EURUSD	02.25.2019 00:00:01.671	1.13412	1000000	1.13419	1000000
LP-1	EURUSD	02.25.2019 00:00:01.671	1.13412	1000000	1.13419	1000000
LP-1	EURUSD	02.25.2019 00:00:01.671	1.13412	1000000	1.13419	1000000
LP-1	EURUSD	02.25.2019 00:00:01.734	1.13408	1000000	1.1342	1000000
LP-1	EURUSD	02.25.2019 00:00:01.734	1.13408	1000000	1.1342	1000000

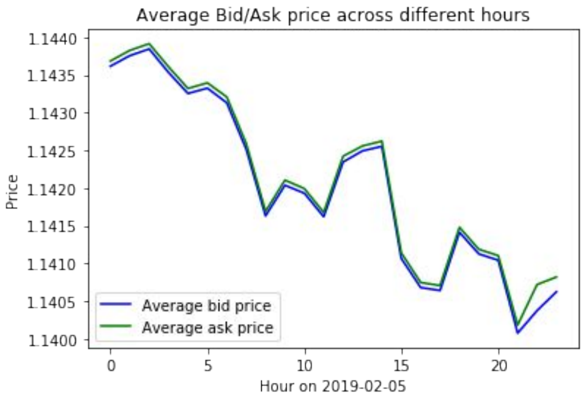
- Liquidity Provider
- Currency pair
- Exact Time
- Bid price
- Bid volume
- Ask price
- Ask volume

Example Statistics

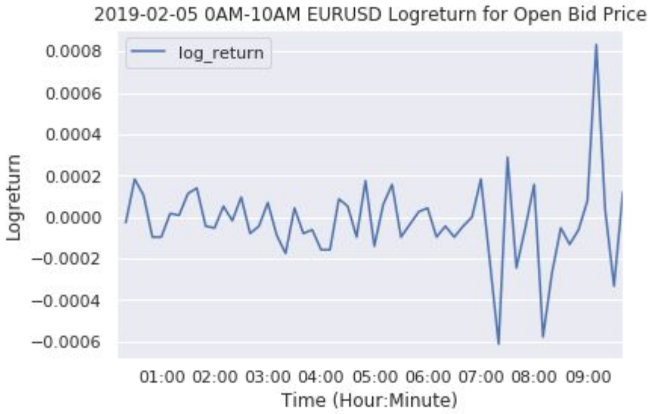
EUR/USD Feb. 5 th, 2019

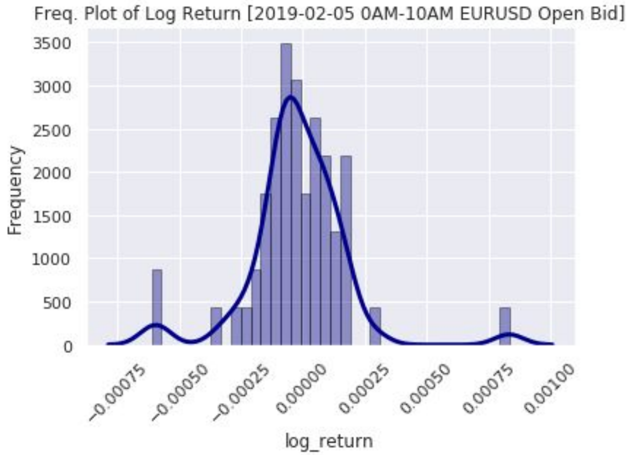


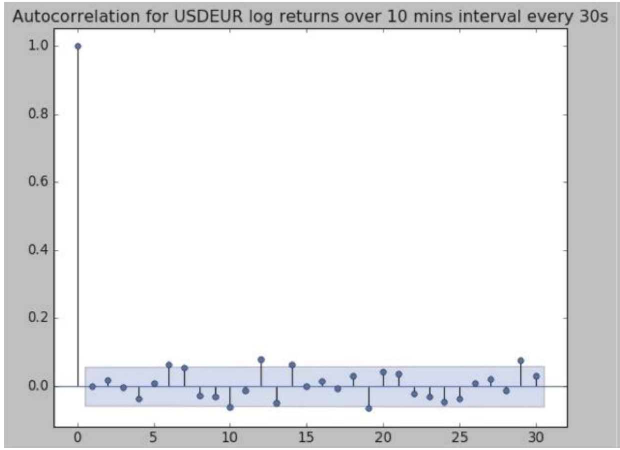


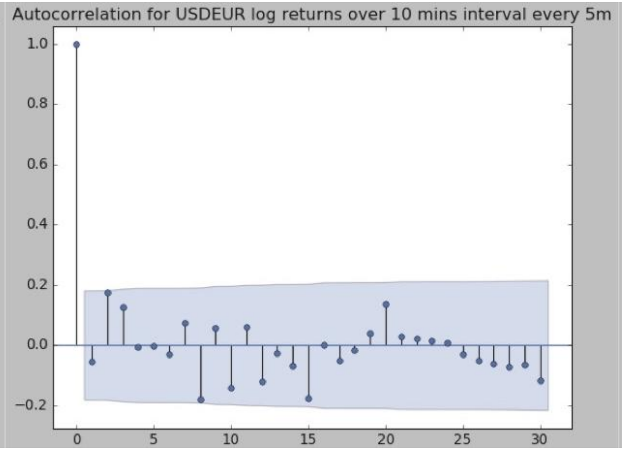


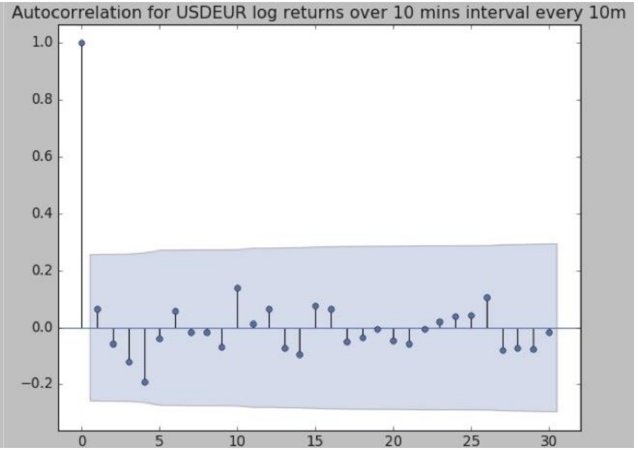
Example Statistics



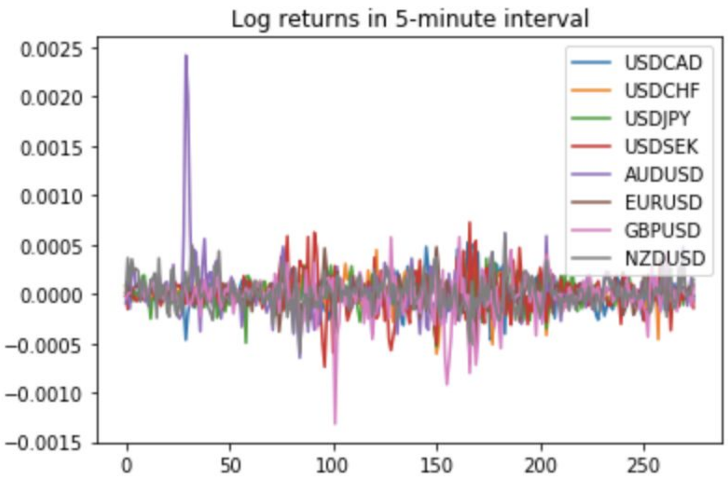


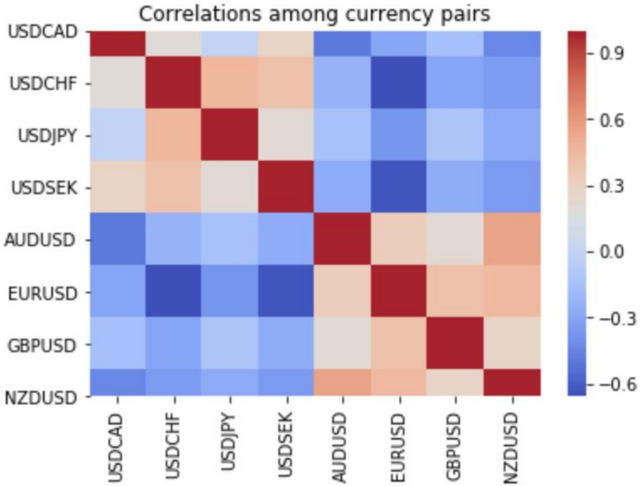


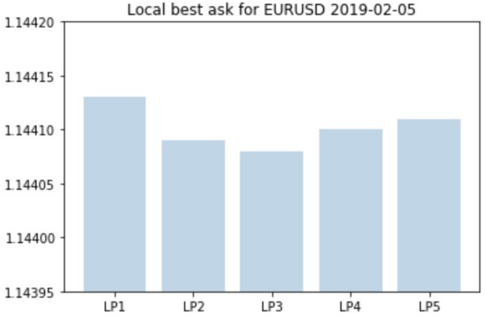


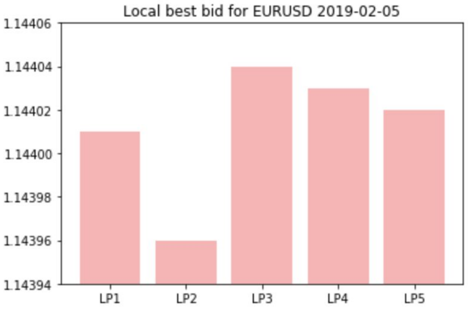


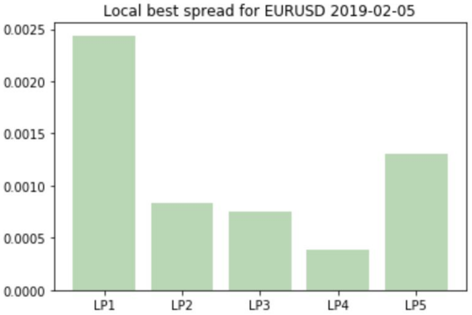
Example Statistics







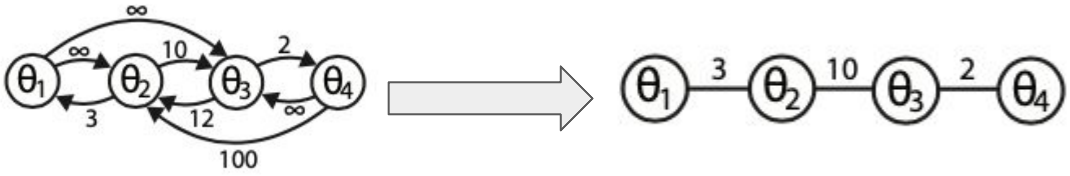




Related Works

Quasi-centralized limit order books (QCLOBs) (Gould, Porter, and Howison, 2017)

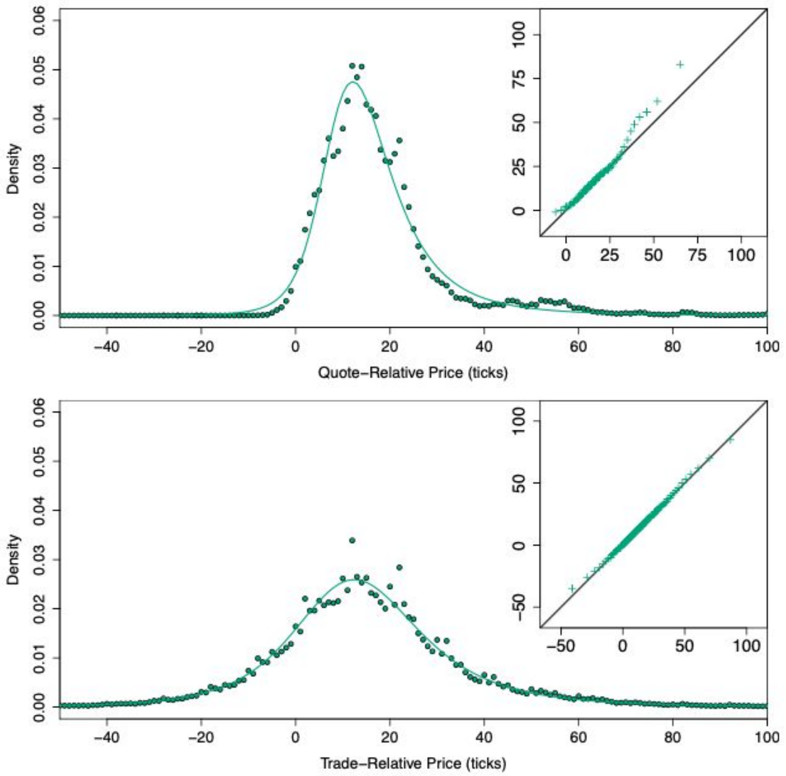
- Financial institutions access only the trading opportunities offered by counterparties with whom they possess sufficient bilateral credit



- QCLOB is global but LOB for each LP is local
  - QCLOB is not visible to all LPs

Statistics of QCLOBs

- Obtained data from the Hotspot FX platform
- Results
  - For all queue lengths, the mean size of arriving marketing orders is *strictly* smaller than the queue length
  - The authors use the generalized *t*-distribution to model the distribution of the limit orders for EUR/USD in one day



Reinforcement Learning for FX Trading (2019 Group): Policy-Based RL

- Picked a currency pair to trade at best bids and offers across LPs
- States
  - Previous action and best bids and asks of all currencies over last 8 time steps
- Actions
  - How much to short/long the pair (as a fraction of current quote currency holdings)
- Model
  - 3-layer policy network trained using REINFORCE (Monte Carlo policy gradient), with dropout and SGD

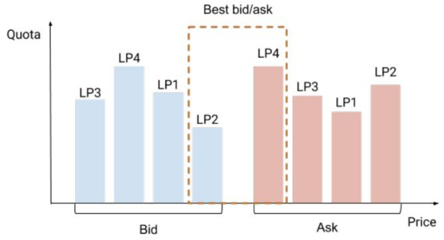
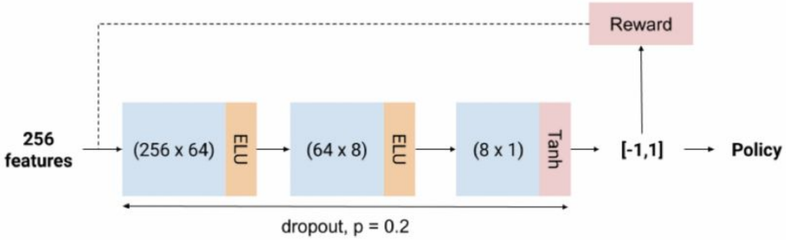


Figure 2: Order Book



Algorithm 1: Deep reinforcement learning

Initialize: Differentiable policy parameterization $\pi(a|s,\theta)$ (i.e., trading agent)
for $l \leftarrow 0$ **to** L **do**
  Generate a new episode $(s_0, a_0, r_1, ..., a_{\tau-1}, r_\tau)$ following current $\pi(a|s,\theta)$
  for $t \leftarrow 0$ **to** $\tau = 3,600$ **do**
    Cumulative return $G \leftarrow$ return from step t (G_t)
    $\theta \leftarrow \theta + \alpha\gamma^t G \nabla_\theta \ln \pi(a_t|s_t,\theta)$
    $t = t + 1$
  end
end

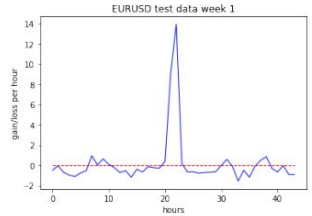
Reinforcement Learning for FX Trading (2019 Group): Policy-Based RL

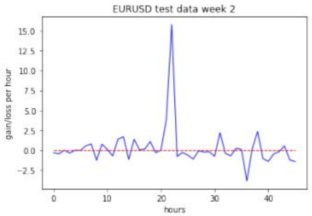
	2/1	2/3	2/4	2/5	2/6	Train Week 1
Eval/test Week 1	2/7	2/8	2/10	2/11	2/12	Train Week 2
Eval/test Week 2	2/13	2/14	2/15	2/17	2/18	Train Week 3
Eval/test Week 3	2/19	2/20	2/21	2/22	2/24	
	2/25	2/26	2/27	2/28	3/1	

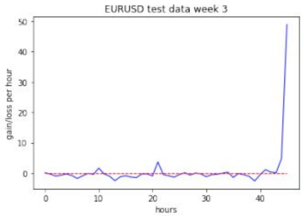
- Experiments
  - Trained on 3 different currency pairs
  - Maximized profit over hour long episodes chosen from the training window
  - for three different weeks, using the first four days of the week as the training set, the fifth day as the eval/val set, and the sixth day as the test set.
- Results: inconclusive

Table 3: EURUSD model performance summary on test data set

	week 1	week 2	week 3
Mean Return ($)	0.18	0.30	0.69
Variance ($)	2.758	2.593	7.291
Yield	0.014%	0.023%	0.052%







Baseline Model

- Input
  - Bid, ask and volume from across LP for 1 currency pair
  - Lookback 500 quotes
- Output
  - Regression (price/fluctuation prediction)
  - Classification (trend determination, up, down, flat)
- Model
  - Gradient boosting decision tree (LightGBM)

	Price Regression (mean abs error)	Trend Classification (-1.5, +1.5, 7 classes) (accuracy)
EURUSD	32 pips	37%
AUDUSD	44 pips	26%

Current Progress

- Infrastructure setup on Google Cloud Compute
  - Cloud storage of pre-processed data
  - Shared environment for running experiments
- Data pipeline for deep learning and reinforcement learning
  - Simple API for querying

```
api = utils.DataAPI()
df_usdcad = api.get('USDCAD', '1', start_time='2019-02-01 16:30:00', end_time='2019-02-01 16:45:00')
```

  - PyTorch based data loading

Next Step

- More complex deep learning models
    - Multiple layers
    - Trend classification through embedding generation
- Adaptation for reinforcement learning models
    - Adapt/refine methods from existing RL papers
- Trading simulation environment
    - Handle multiple currency pairs
    - Properly account for bid-ask spread
    - Incorporate account information with trading model

Thanks