Uncertainty Quantification for Cryptocurrency Price Forecasting

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Introduction

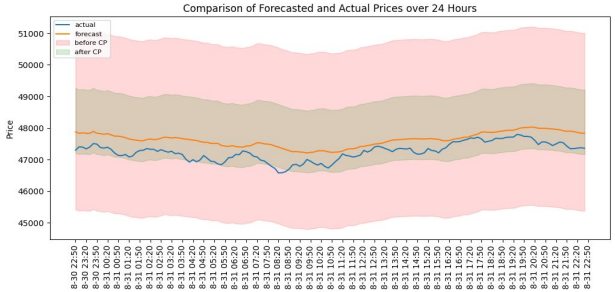
- UQ helps quantify and manage inherent uncertainties in financial models and data
- Cryptocurrency markets are highly volatile
  - Predicting price movements and managing risk is particularly challenging for short term cryptocurrency data
  - Many ML/UQ studies on stock markets, but few studies on cryptocurrency markets
- **Goal: Apply UQ to highly volatile cryptocurrency price forecasts to obtain robust confidence intervals**
- **Idea: Compare the prediction and CI of ARIMA with BNN after calibrating CI using conformal prediction**

Methods

- Dataset
  - Bitcoin tether order book data (millisecond bid/ask prices and volumes) collected from June to September 2021
  - Compute open, close, low, and high prices for ten-minute intervals
  - Train-test split: 70% train, 30% test
- Predictive models used to predict next time step open price
  - Traditional statistical method: ARIMA (AutoRegressive Integrated Moving Average)
  - Newer ML based method: Bayesian Neural Networks (BNNs).
- Conformal Prediction using α = 0.1
  - Calibrate using first 1000 points of the test set
  - Allows for comparison of model CI
- Evaluation
  - Comparison of CI for both models after CP using various metrics

BNN

- Architecture
  - 14 neurons, two hidden layers of 20 neurons, output layer of 1 neuron
- AutoDiagonalNormal guide
- Adam optimizer with learning rate of 1e-3
- Coverage
  - Before CP: 0.998
  - After CP: 0.847



Evaluation: CI Comparison

- CI Gap (s1)

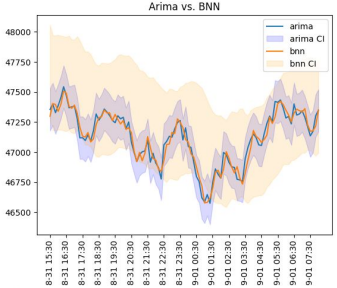
$$s_1 = \sum_{t=1}^{n} (\mathrm{UCI}_t - \mathrm{LCI}_t)$$

  - ARIMA: 35160
  - BNN: 75675
- Change w/ Variance (s2)

$$s_2 = -\sum_{t=1}^{n} \frac{\mathrm{UCI}_{t+1} - \mathrm{LCI}_t}{\sigma_{t+1} - \sigma_t}$$

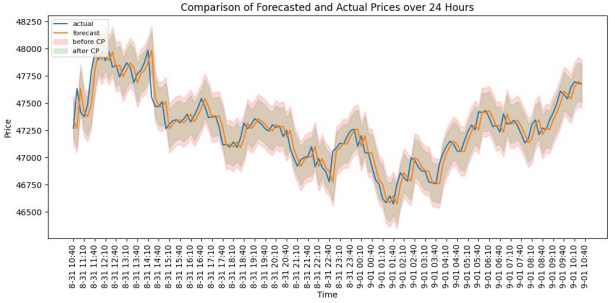
  - ARIMA: 25
  - BNN: 3037
- Expected CI Gap (s3)
  - ARIMA: 373
  - BNN: 681

$$s_3 = \sum_{t=1}^{n} \frac{(\mathrm{UCI}_t - \mathrm{LCI}_t)\sigma_t}{\sum_{t'} \sigma_{t'}}$$



ARIMA

- Best model found with auto ARIMA
  - ARIMA(0, 1, 0) (random walk), where $\hat{y}_t = \mu + y_{t-1}$
- Coverage
  - Before CP: 0.935
  - After CP: 0.896



Conclusion/Future Directions

- After CP, ARIMA model gives better confidence interval compared to BNN model under evaluation metrics
- Future directions
  - Investigate different ML models for price prediction
  - Incorporate price variance as one of calibration parameters of confidence interval

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