Uncertainty Estimation in Time Series Prediction Using Bayesian Neural Network

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1. Problem definition

The goal of this project to predict next-day stock prices with uncertainty estimations.

2. Motivation

Deep learning models are prone to overfitting and overly confident about their predictions. This is problematic for many real-world applications where uncertainty is an important factor – a slight discrepancy can lead to costly consequences. Stochastic neural networks using Bayesian statistics have been proposed to mitigate the risk as Bayesian statistics offers a formalism to understand and quantify the uncertainty associated with deep neural network predictions.

Reliable uncertainty estimation is critical to risk assessment and decision making. Uncertainty estimation is often used for nomaly detection, optimal resource allocation and budget planning. This is particularly important in fields such as self driving cars, medical diagnostics, healthcare, trading and finance, physics applications and more. Good uncertainty estimates quantify when the model's prediction can be trusted. Therefore, it helps us to make more informed decision, mitigate risks, reduce cost and even save lives.

3. Literature review

(1) Jospin, Laurent Valentin, et al. "Hands-on Bayesian Neural Networks–a Tutorial for Deep Learning Users." arXiv preprint arXiv:2007.06823 (2020).

(2) Parikh, Jehill. "Bayesian Neural Networks: LSTM." Medium, Towards Data Science, 1 Sept. 2019, towardsdatascience.com/bayesian-neural-networks-lstm-3616327e8b7c.

(3) BryanB. "CAC40 Stocks Dataset." Kaggle, 24 Mar. 2021, www.kaggle.com/bryanb/cac40-stocks-dataset.

(4) Blundell, Charles, et al. "Weight uncertainty in neural network." International Conference on Machine Learning. PMLR, 2015.

(5) Wiecki, Thomas. "While My MCMC Gently Samples." While My MCMC Gently Samples Atom, twiecki.io/blog/2016/06/01/bayesian-deep-learning/

(6) "Uncertainty Estimation for Neural Network - Dropout as Bayesian Approximation." Medium, Towards Data Science, 2 Feb. 2019, towardsdatascience.com/uncertainty-estimation-for-neural-network-dropout-as-bayesian-approximation-7d30fc7bc1f2#5188.

4. Dataset

The dataset that will be used is the CAC40 [3], is a benchmark French stock market index for funds investing in the French stock market.

5. Proposed method

I will be using Bayesian neural network for my project. For the Bayesian inference part, I may try one or more of the following methods:

- Bayes by Backprop [4]
- Auto Differentiation Variational Inference (ADVI) [5]
- Monte Carlo Dropout [6]

For the neural network model part, I will be focusing on LSTM network.

6. Evaluation

Since the model will output a distribution of possible outcomes, the mean and standard deviation of the outcome distribution will be treated as predicted outcome and its uncertainty, respectively.

Possible metrics to evaluate the performance of the model:

- Mean Squared Error (MSE)
- Root Mean Square Error (RMSE)
- Mean Absolute Error (MAE)

Visualizations of the model outcomes:

- A plot of ground truth and predicted outcome with uncertainties
- Loss vs epoch plot
- Comparison of computational runtime for different Bayesian inference methods