Msc thesis proposal:

Calibration of stochastic volatility models via machine learning methods

Fang Fang[[1]](#footnote-2)

In the past a few years, there have been increasing interests in applying machine-learning techniques for fast valuation of derivatives and/or directly the fast calibration of model parameters.

This thesis project is dedicated to employ two particular types of machine learning method in the calibration of stochastic volatility models: Gaussian process regression (GPR) method and Chebyshev Tenor method.

**Background**

The tremendous increase in computing power and data storage capacity during the last decade has resulted in the rapid development of machine learning and data mining with diverse applications in economics, finance, science, engineering, and technology. In the finance area, machine learning models have elicited considerable attention from many researchers because of their predictive power.

A few recent articles from literature have attempted to solve the derivative pricing problem and/or related implied volatility calibration problem using various types of machine learning methods.

In [3], a generative Bayesian learning model is proposed, which incorporates a prior reflecting a risk-neutral pricing structure to provide fair prices for the deep ITM and the deep OTM options that are rarely traded.

In [1], the authors illustrate that, for many classical problems, speed-ups of several orders of magnitude by deploying machine learning techniques based on Gaussian process regression (GPR). The price one has to pay for this extra speed is some loss of accuracy. To be more precise, they start with showing the strengths of the method with fitting a non-trivial Gamma profile. Next, they illustrate the fitting ability by letting the machine learn the implied volatility surface of a given underlier on a given day. As a second line of applications, they apply the techniques in the setting of the pricing of exotic derivatives under advanced models.

Authors in [2] use convolutional neural networks (CNN) to find the Hölder exponent of simulated sample paths of the rBergomi model, a recently proposed stock price model used in mathematical finance.

A deep learning method is employed in [6] to approximate expected exposures and potential future exposures of Bermudan options.

A data-driven approach called CaNN (Calibration Neural Network) is proposed in [5] to calibrate financial asset price models using an Artificial Neural Network (ANN). Determining optimal values of the model parameters is formulated as training hidden neurons within a machine learning framework, based on available financial option prices.

Instead of using CNN or DNN (Deep Neural Nets), authors of [7] built Chebyshev tenors, either directly or with the help of the Tensor Extension Algorithms, to tackle the computational bottleneck associated with the calibration of the rough Bergomi volatility model. Results are encouraging as the accuracy of model calibration via Chebyshev Tensors is similar to that when using Deep Neural Nets, but with building efforts that range between 5 and 100 times more efficient in the experiments run.

**Challenge**

The Bayesian learning methods exhibit a lower level of accuracy than other two types of methods.

CNN and DNN methods are subject to poor mathematical tractability, as the networks are within a black-box based on off-the-shelf machine learning techniques. Further, mathematically there is no proof of error convergence to ensure the stability and accuracy of the approximations. At last, the activation function is still chosen based on “experiences” without any mathematical justification or by accounting for the problem-specific information.

Tenor-based methods are much more tractable mathematically, but face the curse of dimensionality and are seen to be too complicated to be embraced by the industry.

**The goal and content of this thesis**

The goal is to develop a mathematically tractable yet simple-enough machine learning method for practical usage. Based on the literature review, we consider GPR method and Chebyshev Tenor method are better candidates than other methods, due to their transparency and explanatory power.

Hence, we propose to do the following in this thesis:

* Start the research by replicating some results in [7] for the rough Bergomi volatility;
* Explore whether the approach can be applied to other stochastic volatility models such as SABR or Heston’s stochastic volatility model;
* Replicate some results in [1];
* then adjust the methodology of [1] to cope with stochastic volatility models, such as SABR model and/or Heston’s stochastic vol and/or rough volatility models;
* Compare the performance of these two approaches;
* If time permits, try to improve the performance with the help of theoretical and numerical error analysis. Potential means to improve the methods include, but are not limited to, using different basis functions in the GPR method and try to fit the characteristic function (ch.f.) instead.

**Reference**

1. Machine learning for quantitative finance: fast derivative pricing, hedging and fitting. JAN DE SPIEGELEER, DILIP B. MADAN, SOFIE REYNERS and WIM SCHOUTENS, Quantitative Finance, 2018, Vol. 18, No. 10, 1635–1643
2. Calibrating rough volatility models: a convolutional neural network approach, Henry Stone (2020), Quantitative Finance, 20:3, 379-392
3. Generative Bayesian neural network model for risk-neutral pricing of American index options, HUISU JANG and JAEWOOK LEE, Quantitative Finance, 2019 Vol. 19, No. 4, 587–603
4. On Calibration Neural Networks for extracting implied information from American options, Shuaiqiang Liu, Álvaro Leitao, Anastasia Borovykh, Cornelis W. Oosterlee, 31 Jan 2020
5. A neural network-based framework for financial model calibration, S. Liu, A.I. Borovykh, L.A. Grzelak and C.W. Oosterlee, Journal of Mathematics in Industry, Volume 9 - Issue 1
6. A deep learning approach for computations of exposure profiles for high-dimensional Bermudan options, K. Andersson and C.W. Oosterlee, 2020
7. Tensoring volatility calibration: Calibration of the rough Bergomi volatility model via Chebyshev Tensors, Mariano Zeron and Ignacio Ruiz, August 2020.
8. A novel option pricing method based on Fourier-cosine series expansions. F. Fang and C. W. Oosterlee. SIAM J. Sci. Comput.,31(2):826-848, 2008

**Contact**

If you are interested to enter the field of quantitative risk analysis, this is a very good starting point. Please feel free to contact me directly if this topic is of your interest, or if you would like to learn more details: fang.fang@ffquant.nl or f.fang@tudelft.nl

**About FF Quant Advisory B.V.**

KvK nr.: 70817979

<http://fsquaredquant.nl/>

We provide quantitative consulting services to banks, insurance companies and other financial institutions. Our expertise include the development, validation and audit of regulatory and non-regulatory risk models and of pricing models for financial instruments.

We are also specialized in researching, developing and testing quantitative toolkits. Other services include, but are not limited to, backtesting of trading strategies, applying machine learning techniques to replace traditional quantitative models, etc.

1. Part-time Assistant professor at the Applied Mathematics Department of TU Delft; Director of FF Quant Advisory B.V. https://fsquaredquant.nl/ [↑](#footnote-ref-2)