Review of: "Annealed Stein Variational Gradient Descent for Improved Uncertainty Estimation in Full-Waveform Inversion"

Shih-Lin Lin[1]

1 Graduate Institute of Vehicle Engineering, National Changhua University of Education, Taiwan, Province of China

Potential competing interests: No potential competing interests to declare.

The study introduces a novel approach called Annealed Stein Variational Gradient Descent (ASVGD) for uncertainty quantification in Full-Waveform Inversion (FWI). ASVGD leverages the strengths of Stein Variational Gradient Descent (SVGD) and Annealed Importance Sampling (AIS) to enhance the accuracy of uncertainty estimation in FWI. The authors' findings indicate that ASVGD offers superior parameter estimation and uncertainty quantification, especially in complex geological structures, outperforming traditional methods. While the research demonstrates innovation, several areas could be improved to enhance the quality and impact of the study:

1. The study's use of an idealized geological model does not adequately reflect real-world complexities. This limitation may reduce the applicability of ASVGD in practical scenarios, potentially hindering its performance in realistic settings.
2. The convergence speed and stability of ASVGD are highly sensitive to parameter choices in the annealing process. However, the study lacks a thorough discussion or theoretical basis for these choices, relying heavily on empirical adjustments. This dependence may affect the reproducibility of the results.
3. The paper primarily compares ASVGD with the standard SVGD method, without exploring its advantages and disadvantages against other advanced uncertainty quantification techniques. This omission fails to fully demonstrate the relative strengths of ASVGD.
4. The study relies predominantly on experimental validation, with insufficient theoretical analysis or proof of the convergence properties and mathematical characteristics of ASVGD. This shortcoming may weaken the method's theoretical credibility, particularly for high-dimensional, nonlinear problems.

Overall, while the proposed ASVGD algorithm shows innovation, there is room for improvement in experimental design, theoretical analysis, parameter selection strategy, and the breadth of applications. Addressing these suggestions could significantly enhance the academic impact and practical value of the research.