The Good, the Bad, and the Ugly with AI in Geosciences

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Abstract

Artificial Intelligence (AI) is rapidly transforming geosciences, from seismic interpretation and reservoir characterization to mineral exploration and climate modeling. This presentation examines some of the promises and pitfalls of AI in geosciences through a balanced lens: the good, the bad, and the ugly.

The good highlights AI's capacity to extract subtle patterns from high-dimensional geophysical data, accelerate interpretation workflows, improve fault and horizon detection, enhance AVO classification, rapidly create geoscience labs (see Figure 1) and learning materials, and enable real-time decision-making. Machine learning models, particularly deep neural networks, can outperform traditional deterministic methods when trained on large, well-curated datasets, offering increased efficiency and reproducibility. I show how physics-informed machine learning, such as autoencoder wave-equation inversion or principal-component wave-equation inversion (see Figure 2), can outperform some early-arrival wave-equation inversion methods.

The bad is that AI methods can fall victim to overfitting, data bias, lack of uncertainty quantification, and the misuse of black-box models without physical constraints. Many AI models produce impressive predictions but fail when applied outside their training distribution. Poor validation practices, data leakage, and unbalanced training datasets can lead to overconfident results.

The ugly confronts deeper issues: interpretability challenges, ethical concerns, reproducibility gaps, and the erosion of physical intuition when models are used as substitutes rather than complements to geologic reasoning. Without integration of rock physics, wave propagation physics, and domain expertise, AI risks becoming a sophisticated curve-fitting tool rather than a scientific advancement. Perhaps the most concern of some is that important aspects of, e.g., interpreters, project/strategy planning, or code generation, can be more efficiently accomplished by large language models. Thus, many professional jobs will be replaced by AI, and there will be fewer professionals to oversee the final product.

The talk provides examples of the good, bad, and ugly with AI adoption in geosciences—emphasizing physics-informed machine learning, examples of significant improvement in geoscience education, rigorous validation, uncertainty quantification, and integration with established geophysical theory. When grounded in domain knowledge, AI becomes not a replacement for geoscientists but a powerful amplifier of their expertise. For some geoscience educators, AI is becoming a Renaissance in training the next generation of geoscientists.

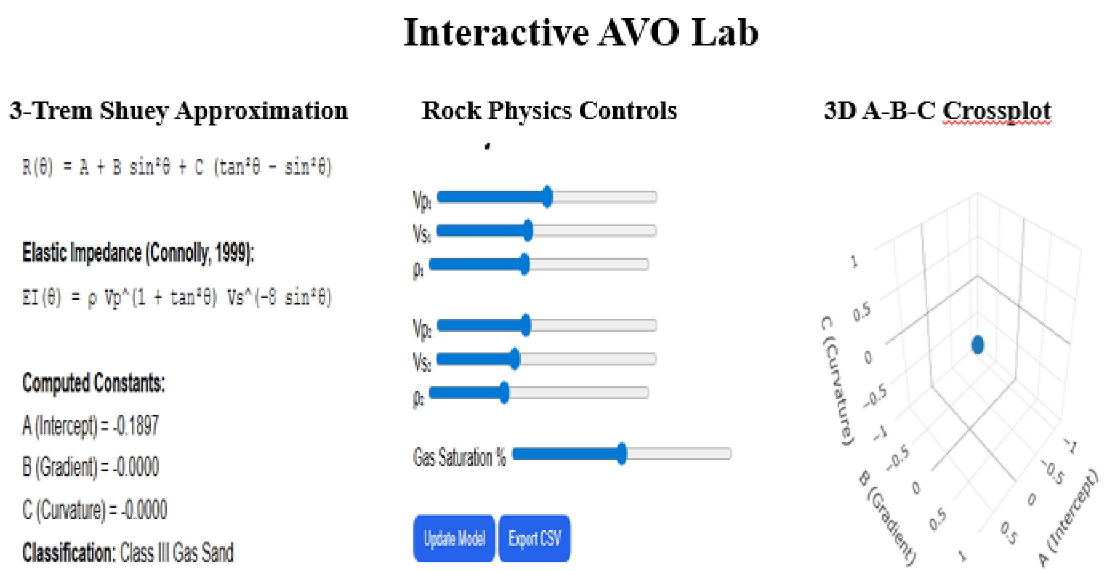

Figure 1. Example of an interactive AVO lab written in Javascript by ChatGPT.

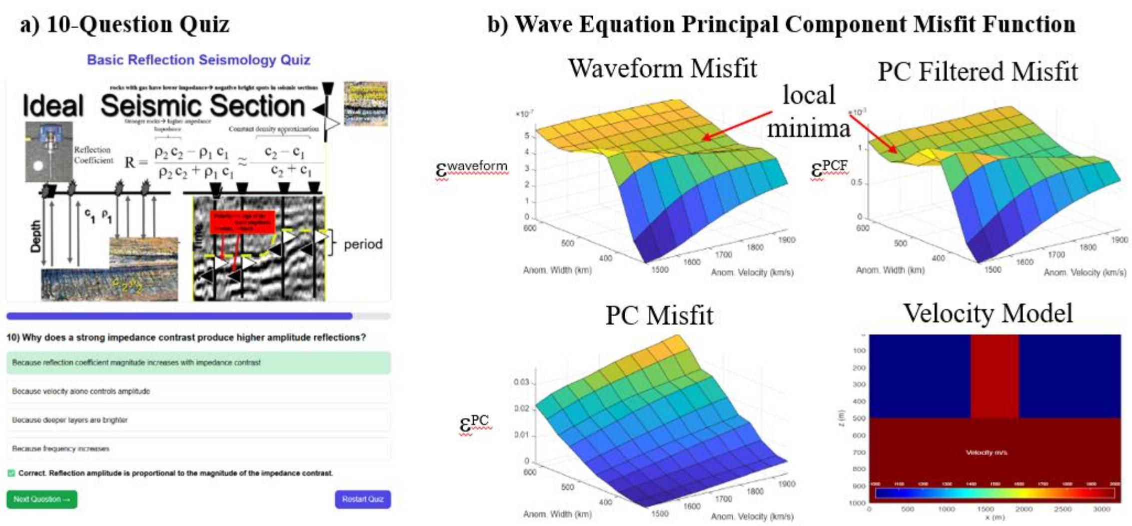

Figure 2. a) Portion of 10 questions written in Javascript by ChatGPT for a Basic Seismology course. b) is a display of results testing the robustness of Principal Component inversion of seismic data in avoiding local minima. The code was partly written by ChatGPT and demonstrates that a misfit function with Principal Components avoids local minima compared to waveform misfit functions for the depicted velocity model.