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基于精确Zoeppritz方程三变量柯西分布先验约束的广义线性AVO反演

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Generalized linear AVO inversion with the priori constraint of trivariate cauchy distribution based on Zoeppritz equation

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摘要

常规AVO三参数反演是通过Zoeppritz方程的近似公式来建立AVO正演模拟的过程,然而在P波入射角过临界角和弹性参数在纵向上变化剧烈的情况下,Zoeppritz方程近似公式精度有限.针对这种情况,可以使用精确的Zoeppritz方程来构建反演目标函数,由于精确Zoeppritz方程中P波反射系数和弹性参数之间是一种复杂的非线性关系,通常解决途径是利用非线性的优化算法来进行数值计算,但是非线性优化算法的缺点是计算量过大;另外一种途径是利用广义线性反演的方法,通过泰勒一阶展开式将P波反射振幅展开后,用线性关系近似表达非线性关系,经过几次迭代后,在理论上可以达到很高的精度,但是广义线性反演算法的核心部分——Jacobian矩阵由于矩阵条件数过大,往往会造成反演算法的不稳定,其应用范围得到了限制.贝叶斯反演方法是通过引入模型参数的先验分布结合噪声的似然函数,生成模型参数的后验分布,通过求取模型参数的最大后验概率分布来得到模型参数的反演解,由于引入模型参数的先验分布信息,可以有效的降低反演的不适定问题.本文将两种反演算法的思想相结合,利用广义线性反演算法的思想,构建AVO正演模拟的过程来提高大角度地震数据反演的精度,同时结合贝叶斯理论,通过引入模型参数的先验分布信息构建反演目标函数的正则化项,可以有效降低由于Jacob矩阵条件数过大带来的反演不适定问题,该算法假设模型参数服从三变量柯西分布.

关键词 精确Zoeppritz方程, 广义线性反演, 贝叶斯反演, 先验分布, 三变量柯西分布

Abstract:

AVO forward modeling is always constructed by the approximation of Zoeppritz equation in traditional three-term AVO inversion. But the approximation is limited in the case of critical angle and elastic parameters varying severely. Given this problem, we can use the exact Zoeppritz equation to construct the inversion objective function. Because the relationship between P wave reflection coefficient and elastic parameters is nonlinear, the common approach is to use nonlinear optimization algorithm which hasn't been widespread because of the large computation. The alternative is to use generalized linear inversion which uses the linear equation to express the nonlinear relation through the expansion of P wave reflection coefficient into a truncated Taylor series. The GLI can get high accuracy through several iterations in theory. But GLI is unstable sometimes because of the large conditional number of Jacobian matrix. Bayesian inversion combines the prior distribution of model parameters with the likelihood function of the noise to form the posterior distribution of model parameters, which transforms the minimization of objective function into the maximization of the posterior probability distribution. Because of the introduction of the prior information of model parameters, the ill-posed problem can be reduced dramatically. This article combines the ideas of the two methodologies, which uses the idea of GLI to construct AVO forward modeling for improving the accuracy of inverting the large incident angle seismic data and uses Bayesian theory to

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introduce the model parameters prior information to construct the regularization of inversion objective function for reducing the ill-posed problem of inversion. This algorithm assumes that the prior distribution of the model parameters honors trivariate Cauchy distribution.

Keywords Accurate Zoeppritz equation, Generalized linear inversion, Bayesian inversion, Constraint of prior distribution, Trivariate Cauchy distribution

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