深地科学论坛（第八十三讲）

Geophysical Inversion Using Finite Element Methods

（有限元方法在地球物理反演中的应用）

报告人：澳大利亚昆士兰大学 Lutz Gross 教授

时　间： 2024 年 11 月 1 日 15：00、2024 年 11 月 6 日 15：00

地　点： 深地 411 会议室

邀请人： 方金伟 樊亚楠

报告人简介：

Lutz Gross is an Associate Professor in the School of Mathematics and Physics at The University of Queensland, Australia. His research interests are large-scale geophysical data inversion, numerical methods and mathematical modelling. Since 2003, he has been the project leader for the development of Python-based scientific software within the Australian National Collaboration Research Infrastructure Strategy for Earth Sciences. Lutz was awarded a PhD in Mathematics by the Karlsruhe Institute of Technology in 1997. Before joining The University of Queensland, he held positions at the Australian National University, Massey University in New Zealand and the Commonwealth Scientific and Industrial Research Organization in Australia.

报告摘要：

Inversion is the process of creating 3D images of physical properties by utilizing low-dimensional observational data. This can be framed as an optimization problem, where the goal is to minimize the discrepancy between the observed data and the predicted data derived from a property distribution. The forward model, which predicts data based on a given property distribution, typically involves solving one or more partial differential equations (PDEs). This solution is usually carried out numerically using the finite element method (FEM), which represents the primary computational cost of the inversion process.

The presentation will introduce the solution of geophysical inversion problems suitable for using finite element methods (FEM) on large-scale unstructured meshes and will be divided into two parts. In the first part we will begin by discussing the conventional approach, which involves first spatially discretizing the targeted physical properties. This process translates the inversion problem into an algebraic optimization problem, which can then be solved using the Gauss-Newton scheme. To address the limitations of this conventional approach, particularly when applied to large-scale unstructured FEM meshes, we propose avoiding early discretization. Instead, we will formulate the inversion as a continuous PDE-constrained optimization problem. This can be formally solved within the framework of the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm, where the necessary gradient calculations require solving adjoint forward modeling PDEs. The use of FEM allows us to implement this using computationally scalable techniques. This method will be discussed in the context of Electrical Resistivity Tomography (ERT).

In the second, more techical part of the presentation, we will extend this approach to the inversion of magnetotellurics data, focusing on the isotropic 2D case. Additionally, we will discuss more general high-order regularization techniques and examine appropriate implementations using low-order FEMs on unstructured meshes.