地下系成立60周年系列活动之一

学术报告

Seismic Reconnaissance in a Tunnel Environment using Full Waveform Inversion

报 告 人：Prof. Klaus Hackl(高端外国专家)

时　　间：2018年7月27号（周五）下午14:00

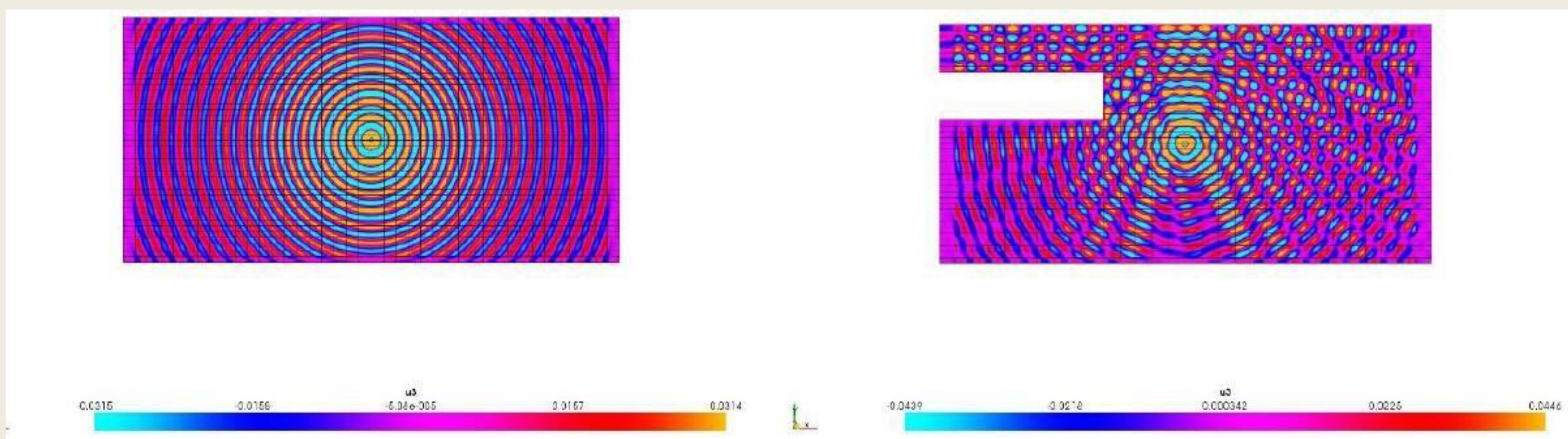
地　　点：同济大学岩土楼201室

邀 请 人：朱合华教授

Abstract

Waveform inversion is a highly demanding field in geophysics. This methodology was successfully applied to predict the inner structure of the earth or to find energy resources in the ground. In tunneling applications, it hasn't been frequently used. However, with the help of this methodology the structure of the ground in front of the tunneling machine can be estimated and an improved geological model can be acquired. A better model will lead to more realistic simulations, and undisturbed excavation and construction stages with more information about the ground available.

The aim of the waveform inversion is to find an optimal velocity field model whose response is consistent with the seismic data. In this study, a high-order finite element method is utilized to solve forward problems in the frequency domain and a gradient-based approach is used to optimize the model. Perfectly Matched Layers (PML) are implemented in order to absorb waves on the fictitious boundaries of the considered geometry. Two examples demonstrating the PML boundaries are shown in Figure 1. Figure 1A shows the pressure field of a rectangular acoustic model surrounded with perfectly matched layers, thus preventing reflections on all edges. Figure 1b represents the pressure field of an acoustic model with free surface on top and at the inner tunnel surface, and PMLs elsewhere. There are some reflections occurring due to the free surfaces.



a) domain surrounded with absorbing boundaries　　b) free surface on top and inner tunnel surface

Figure 1: Forward Calculations with PMLs

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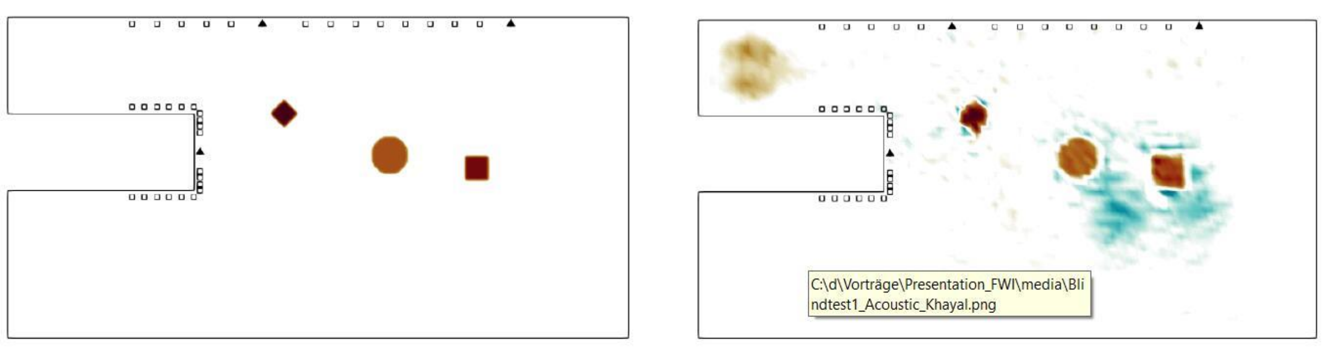
Abstract（2）

The model is inverted only over a limited number of frequencies reducing the nonlinearity of the inverse problem. In such problems, the number of design variables is very high which makes the calculation of the gradient vector very expensive with straightforward methods. Fortunately, the adjoint method eases the computational struggle by reducing the number of forward simulations tremendously. This method requires only two forward simulations per source point in order to calculate the gradient of a defined objective function. Every model is unique and has to be closely investigated before being inverted: appropriate boundaries, setting of source and receiver points, and an initial model close to the real model are crucial points to be considered separately and carefully.

It was possible to verify the methods with high confidence by using different approaches (time versus frequency domain) and different FE-approximations for the forward and inverse problem. Sample results for various scenarios will be given. The result of a typical inversion problem is shown in Figure 2.



a) initial velocity distribution　　b) result of inversion

Figure 2: Full Waveform Inversion, velocity distribution (triangle = sender, square = receiver)

Introduction of Prof. Klaus Hackl

Klaus Hackl，工学博士，教授，从事材料理论、数值计算和结构力学领域的科研和教学工作。1980年德国卡尔斯鲁厄大学/海德堡大学物理学士毕业，1985年德国海德堡大学数学硕士毕业，1988年获德国亚琛工业大学博士学位，1997年被奥地利格拉茨技术大学授予教授特许任教资格。历任德国亚琛工业大学助理研究员，德国格拉茨技术大学材料强度研究所助理教授、副教授，1989-1992年在美国特拉华大学数学系荣获德国洪堡基金会佛欧多尔・吕南奖，1999年至今担任德国鲁尔-波鸿大学材料与力学理论研究所所长。他是德国德意志研究委员会重大科研项目SFB的首席科学家，是德国应用数学和力学学会委员会成员及学会下设微观力学分委会主任。

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