第五届反演问题计算方法及其应用国际会议
会议指南

The Fifth International Workshop on Computational Inverse Problems and Applications

主办单位：中国科学院地质与地球物理研究所

Institute of Geology and Geophysics,

Chinese Academy of Sciences

承办单位：龙岩学院

Longyan University

协办单位：莫斯科国立大学

LomonosovMoscow State University

福建·龙岩

Longyan, Fujian, China

25-29, July, 2019

Contents

1. Organizations and Instructions

Chairman

YanfeiWang
(Institute of Geology and Geophysics, Chinese Academy of Sciences(CAS))

Scientific Committee

Chairman:

YaxiangYuan(Academy of Mathematics and Systems Science, CAS)

Committee members：

Jin Cheng (Fudan University)

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Sergey Pereverzyev (Austrian Academy of Sciences)

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Organizing Committee

Director：

Yanfei Wang(Institute of Geology and Geophysics, CAS)

Members：

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Ling Zhang (Longyan University)

Yusen Guo (Longyan University)

MingjieLin(Longyan University)

ChaofanWu(Longyan University)

Zhijie Wu(Longyan University)

Scope of the conference

The inverse problem has always been a focus of attention in many fields of scientific research. The inverse problem is usually ill-posed. In recent years, different inverse problems have arisen in the frontier of science. The conventional method for solving inverse problems is regularization method. Optimizing methods are widely applied in big data, artificial intelligence, geophysics, medicine, transportation, image processing and other scientific and technological fields.

We sincerely welcome experts, professors and students from all over the world to participate in theFifth International Workshop on Computational Inverse Problems and Applications held at Longyan University. Let's exchange and cooperate to promote the further development of inverse problems and their applications.

The conference includes but not limited to the following topics

- Research on inverse problems
- Regularization methods
- Optimization methods
- Non-standard regularization methods
- Inverse problems in Geophysics
- Big data and artificial intelligence
- More cutting-edge scientific issues

Invited speakers(Alphabetic order)

- **L. V. Gelius**(Professor,University of Oslo, Norway)
- **Qinian Jin** (Professor, Australian National University, Australia)
- **S. I. Kabanikhin**(Professor, Russian Academy of Sciences, Russia)
- **G. M. Kuramshina** (Professor, Lomonosov Moscow State University, Russia)
- **Gongsheng Li**(Professor, Shandong University of Technology, China)
- **Peijun Li**(Professor, Purdue University, USA)
- **Gen Nakamura** (Professor, Hokkaido University, Japan)
- **M. Shishelenin**(Professor,Russian Academy of Sciences, Russia)
- **Zewen Wang**(Professor, East China University of Technology, China)
- **Ting Wei**(Professor, Lanzhou University, China)
- **Dinghua Xu**(Professor, Zhejiang Sci-Tech University, China)
- **Yuesheng Xu** (Professor, Old Dominion University, USA)
- **A.G.Yagola**(Professor, Lomonosov Moscow State University, Russia)
- **M. Yammamoto**(Professor,University of Tokyo, Japan)
- **Guozheng Yan** (Professor,Central China Normal University, China)
- **Hongqi Yang** (Professor, Sun Yat-sen University, China)
- **Yaxiang Yuan**(Professor, Academy of Mathematics and System Sciences, CAS, China)

- **Bo Zhang**(Professor, Academy of Mathematics and System Sciences, CAS, China)
- **Hai Zhang** (Professor, Hong Kong University of Science and Technology, HK)
- **Ran Zhang** (Professor, Jilin University, China)
- **Wensheng Zhang** (Professor, Academy of Mathematics and System Sciences, Chinese Academy of Sciences, China)
- **Haoming Zhou** (Professor, Georgia Institute of Technology, USA)
- **Jun Zou**(Professor, Chinese University of Hong Kong, HK)

Daily Schedule

Date	Event
25th, July	Registration
26th-29th, July	Lectures

Registration fees

For the regular attendees:150 US dollars (RMB:1000Yuan),for students:100 US dollars (RMB:800Yuan).

Accommodation

Please bear the expenses all by oneself, but we can provide reservation service.Forstandard room:350 RMB/day, for advanced suite:500-800 RMB/day. There are different advanced suites. For details, please consult the Conference Secretariat.

Apply for a visa

Please contact Prof.Yanfei Wang (yfwang@mail.iggcas.ac.cn)forthe invitation letters and other information (Dr. Wenquan Liang, onethink2002@foxmail.com).

Contact

Conference affairs:

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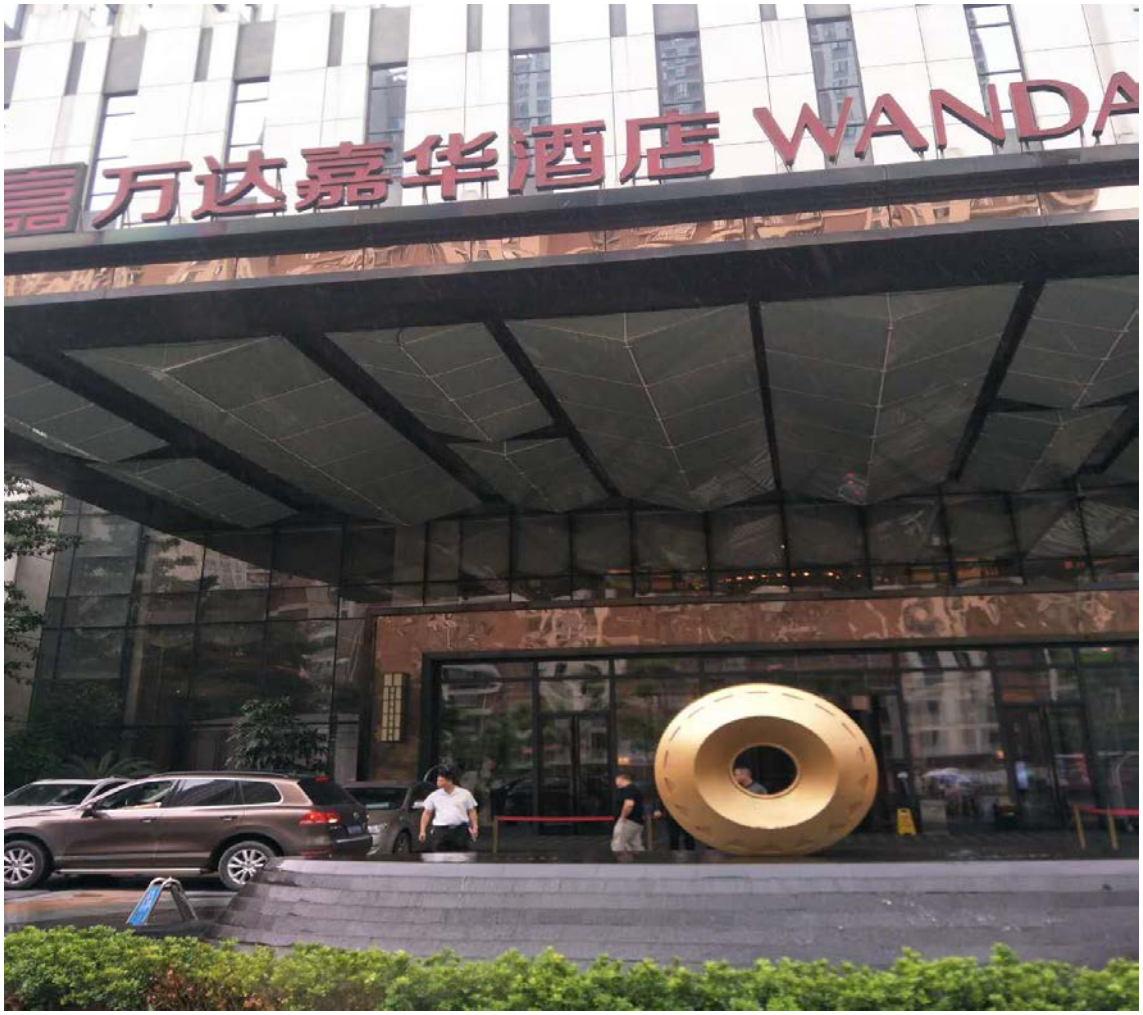
QQ Group:

Name:反演问题计算方法及其应用

Group Num.:717622504

QR code:as shown in the Fig.

Meeting-place:Demo Hall, library



Wanda Realm Hotel

From Longyan Railway Station to Wanda Realm Hotel

From Wanda Realm Hotelto Longyan University

2. Conference Agenda

Thursday, 25th July, 2019			
Time	Event	Location	Personnel
9:00 - 22:00	Register	Wanda Realm Hotel (龙岩万达嘉华酒店)	Attendees
18:30 - 21:00	Icebreak	Wanda Realm Hotel	Attendees
Friday, 26th July, 2019			
Time	Event	Location	Personnel
07:00 - 08:00	Breakfast	Wanda Realm Hotel	Attendees
08:10	Pick up to the meeting room	Wanda Realm Hotel	Wenquan Liang/attendees
08:30 - 09:00	The opening ceremony Welcome speech by the vice president of Longyan University & Conference Chair	Demo Hall (演播厅)	Yanfei Wang
09:00 - 9:30	Group photo	Demo HallEntrance	
09:40 - 10:10	Ill-posed problems with a posteriori error estimation in applications (Speaker: A. G. Yagola, Lomonosov Moscow State University)	Demo Hall	
10:10 - 10:40	Inverse scattering problems with phaseless data (Speaker: Bo Zhang， AMSS, China Academy of Sciences)	Demo Hall	
10:40 - 10:55	Break	Demo Hall	Wenquan Liang/attendees
10:55 - 11:25	Mathematical analysis for vibroseis reflection exploration （Speaker: G. Nakamura, Hokkaido University）	Demo Hall	Bo Zhang
11:25 - 11:55	ECT Medical Image Reconstruction: Sparse Modeling and Algorithms （Speaker: Yuesheng Xu, Old Dominion University）	Demo Hall	

12:00	Pick up to the hotel	Demo Hall Entrance	Wenquan Liang/attendees
12:30 - 13:40	Lunch& break	Wanda Realm Hotel	Wenquan Liang/attendees
13:50	Pick up to the meeting room	Wanda Realm Hotel Entrance	Wenquan Liang/attendees
14:10 - 14:40	Regularized quantum mechanical molecular force fields: application to melatonine and vitamin B6 metabolites （Speaker: G. M. Kuramshina, Lomonosov Moscow State University）	Demo Hall	G. Nakamura
14:40 - 15:10	Direct inversion algorithm for inverse coefficient problems in the diffusion equations based on the variational adjoint method (Speaker: Gongsheng Li, Shandong University of Technology)	Demo Hall	
15:10 - 15:40	Practical inverse problems from industry and environmental engineering:numerics and the construction of mathematical theories (Speaker: M. Yamamoto, University of Tokyo)	Demo Hall	
15:40 - 16：00	Break	Demo Hall	Wenquan Liang/attendees
16:00 - 16:30	Super resolution using sub wavelength resonators （Speaker: Hai Zhang, Hong Kong University of Science and Technology）	Demo Hall	L.J. Gelius
16:30 - 17:00	The factorization method for inhomogeneous medium with an impenetrable obstacle （Speaker: Guozheng Yan, Central China Normal University）	Demo Hall	

17:00 - 17:30	A non-iterative method for recovering the space-dependent source and the initial value simultaneously in a parabolic equation （Speaker: Zewen Wang, East China Institute of Technology）	Demo Hall	
17:45	Pick up to the hotel	Demo HallEntrance	Wenquan Liang/attendees
18:30 - 21:00	Banquet	Wanda Realm Hotel	attendees
Saturday, 27th July, 2019			
Time	Event	Location	Personnel
07:00 - 08:00	Breakfast	Wanda Realm Hotel	Attendees
08:10	Pick up to the meeting room	Wanda Realm Hotel Entrance	Wenquan Liang/attendees
08:30 - 09:00	Machine learning and convolutional neural networks – example of applications to seismic field data （Speaker: L. J. Gelius，University of Oslo）	Demo Hall	A. G. Yagola
09:00~09:30	Landweber iteration and its acceleration （Speaker: QinianJin,Australian National University）	Demo Hall	
09:30~10:00	Inverse source scattering problems （Speaker: Peijun Li, Purdue University）	Demo Hall	
10:00~10:15	Break	Demo Hall	Wenquan Liang/attendees
10:15 - 10:45	Elastic full waveform inversion in the frequency domain with the Green function method (Speaker: Wensheng Zhang, China Academy of Sciences)	Demo Hall	Guozhen Yan

10:45 - 11:15	A weak Galerkin finite element scheme for the Cahn-Hilliard equation （Speaker: Ran Zhang/Qilong Zhai, Jilin University）	Demo Hall	
11：15 - 11：45	A new class of accelerated regularization methods for ill-posed inverse problems(Speaker: Ye Zhang, Örebro University)	Demo Hall	
11:50	Pick up to the hotel	Demo Hall Entrance	Wenquan Liang/attendees
12：30 - 13：40	Lunch& break	Wanda Realm Hotel	Wenquan Liang/attendees
13:50	Pick up to the meeting room	Wanda Realm Hotel Entrance	Wenquan Liang/attendees
14：10 - 14：40	Coefficient inverse problems for parabolic equations: application to medicine and finance （Speaker: M. Shishlenin, Institute of Computational Mathematics and Mathematical Geophysics）	Demo Hall	Dinghua Xu
14：40 - 15：10	Inverse problems for the time-fractional diffusion-wave equations (Speaker: Ting Wei, Lanzhou University, China)	Demo Hall	
15：10 - 15：40	Stable methods for numerical differentiation based on ordinary differential equations （Speaker: Hongqi Yang, Sun Yat-sen University）	Demo Hall	
15：40 - 16： 00	Break	Demo Hall	Wenquan Liang/attendees
16：00 - 16：25	An accelerated sequential subspace optimization method based on homopoty perturbation for nonlinear ill-posed problems （Speaker: Shanshan Tong, Shaanxi Normal University）	Demo Hall	Ting Wei
16：25 - 16：50	PP-PS joint sparse inversion with lateral constraint （Speaker： Jing Tang, Southwest Petroleum University）	Demo Hall	

16:50 - 17:15	Non-balanced staggered-grid finite-difference scheme for seismic wave-equation modeling (Speaker: Wenquan Liang, Longyan University)	Demo Hall	
17:45	Pick up to the hotel	Demo Hall Entrance	Wenquan Liang/attendees
18:30 - 20:30	Dinner	Wanda Realm Hotel	Attendees
Sunday, 28th July, 2019			
Time	Event	Location	Personnel
07:00 - 08:00	Breakfast	Wanda Realm Hotel	Attendees
08:10	Pick up to the meeting room	Wanda Realm Hotel Entrance	Wenquan Liang/attendees
08:30 - 09:00	Discrete optimal transport and inverse optimal transport with application in matching （Speaker: Haomin Zhou, Georgia Institute of Technology）	Conference Room on the 5th Floor of the Library	Jijun Liu
09:00~09:30	Data modeling in functional clothing design：forward and inverse problems approaches (Speaker:Dinghua Xu, Shanghai University of Finance and Economics)	Conference Room on the 5th Floor of the Library	
09:30~09:45	Break	Conference Room on the 5th Floor of the Library	Wenquan Liang/attendees
09:45 - 10:25	Efficient optimization algorithms for large scale data analysis (Speaker: Yaxiang Yuan, Chinese Academy of Sciences)	Demo Hall	Yuesheng Xu
10:25 - 11:20	Visiting the school history exhibition hall of Longyan University	2nd Floor of the Attached Building of the Administration Building (行政楼附楼二楼)	University leaders/attendees
11:20	Pick up to the hotel	Administration Building Entrance	Wenquan Liang/attendees

11:30 - 12:30	Lunch	Wanda Realm Hotel	Attendees
13:00 - 17:30	Panel discussion/Cultural exchange	Wanda Realm Hotel	Attendees
18:00 - 20:30	Dinner	Wanda Realm Hotel	Attendees
Friday, 26th July, 2019			
16:00 - 16:25	XCT image reconstruction by a modified superiorized iteration and theoretical analysis (Speaker: Shousheng Luo, Henan University)	Conference Room on the 5th Floor of the Library	Peijun Li
16:25 - 16:50	The adjoint-state method for computing the gradient of trust region inversion in TEM (Speaker: Xiaomeng Sun，China Academy of Sciences)	Conference Room on the 5th Floor of the Library	
16:50 - 17:15	A new Kaczmarz-type method and its acceleration for nonlinear ill-posed problems (Speaker: Haie Long,Harbin Institute of Technology)	Conference Room on the 5th Floor of the Library	Wensheng Zhang
17:15 - 17:40	Simultaneous-source seismic data deblending based on sparse inversion and curvelet domain thresholding （Speaker:Jingjie Cao, Hebei University of Geology）	Conference Room on the 5th Floor of the Library	
17:45	Pick up to the hotel	The Library Entrance	Attendees
18:30 - 21:00	Banquet	Wanda Realm Hotel	Attendees
Saturday, 27th July, 2019			
16:00 - 16:25	Some numerical features of the magnetic parameters inversion method with full tensor gradient data（Speaker: D. Lukyanenko, Lomonosov Moscow State University）	Conference Room on the 5th Floor of the Library	Gongsheng Li

16:25 - 16:50	Variational Bayes' approach for functions and applications to some inverse problems (Speaker: JunxiongJia, Xi'an Jiaotong University)	Conference Room on the 5th Floor of the Library	
16:50 - 17:15	A 3D marine MT inversion method with considering the seafloor topography (Speaker: Pengfei Liang,University of Chinese Academy of Sciences)	Conference Room on the 5th Floor of the Library	Jingjie Cao
17:15 - 17:40	A novel Kaczmarz type method for nonlinear ill-posed problems in Banach spaces with uniformly convex penalty terms (Speaker: RuixueGu, Harbin Institute of Technology)	Conference Room on the 5th Floor of the Library	
17:45	Pick up to the hotel	The Library Entrance	Attendees
18:30- 20:30	Dinner	Wanda Realm Hotel	Attendees

3. CIPA2019 Presentations

Part I Plenary Talks

Efficient optimization algorithms for large scale data analysis

Yaxiang Yuan

Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences

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In this talk, two classes of problems in large scale data analysis and their optimization algorithmswill be discussed. The first class focuses on composite convex program problems, where I introducealgorithms including a regularized semi-smooth Newton method, a stochastic semi-smooth Newton methodand a parallel subspace correction method.The second class is on optimization with orthogonalityconstraints, particularly on parallelizable approaches for linear eigenvalue problems and nonlinear reigenvalue problems, and quasi-Newton type methods. Numerical results of applications, e.g., electronicstructure calculations, l_1-regularized logistic regression problems, Lasso problems and Hartree-Focktotal energy minimization problems, will be highlighted.

Ill-posed problems with a posteriori error estimation in applications

Anatoly Yagola

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In order to calculate a priori or a posteriori error estimates for solutions of an ill-posed operator equation with an injective operator we need to describe a set of approximate solutions that contains an exact solution. After that we have to calculate a diameter of this set or maximal distance from a fixed approximate solution to any element of this set. I will describe three approaches for constructing error estimates and also their practical applications in solving the inverse elastography problem and the inverse problem of microtomography.

This work was supported by the RFBR grant 17-01-00159 and the RFBR-NSCF grant 19-51-53005.

Inverse scattering problems with phaseless data

Bo Zhang

Institute of Applied Mathematics, AMSS, Chinese Academy of Sciences

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In this talk, we give a brief review on uniqueness results and numerical methods for inverse scattering problems with phaseless data, obtained recently in our group. This talk is based on joint works with X Ji, X Liu, X Xu and H Zhang.

Mathematical analysis for vibroseis reflection exploration

Gen Nakamura

Hokkaido University

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In this talk we will give some method how to propagate the local Neumann-Dirichlet map or the local Dirichlet to Neumann map for dynamical anisotropic elastic system of equations. Based on this we will apply this result to the vibroseis reflection exploration where the local Neumann-Dirichlet map can be used to model its measurement. Here we model the underground structure as a piecewise homogeneous anisotropic elastic medium with piecewise homogeneous density. By assuming some curvature condition on the interfaces, we will give a uniqueness of identifying the elasticity tensors and density in a domain of interest within a time as small as possible.

ECT medical image reconstruction:sparse modeling and algorithms

Yuesheng Xu

Old Dominion University

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We will present recent development in sparse methods for ECT medical image reconstruction. Several crucial issues including integral equation models, sparse regularization, and fast fixed-point algorithms in the development will be discussed. Numerical examples will be presented to illustrate the proposed ideas.

Regularized quantum mechanical molecular force fields: application to melatonine and vitamin b6 metabolites

Gulnara Kuramshina

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The rotation of one molecular fragment relatively another observed in organic molecules can result in significant changes in molecular geometry, force field parameters and vibrational spectra of different molecular conformations. The knowledge of peculiarities for different conformers force fields is necessary for the construction of force constant matrices of complicated biomolecules. The force constant matrices can be considered within different models varying from the complete identical to the quite different matrices for different conformers. The construction of sufficiently simple and adequate physical model that can be applied to a wide range of compounds with hindered internal rotation is very complicated problem due to a limited number of experimental data directly related to the force field parameters of different conformers. Determination of force constants from experimental data requires a solving of the so-called inverse vibrational problem related to the ill-posed problems and characterized by non-uniqueness and instability of its solution as well as by possible incompatibility within harmonic model of experimental data available [1]. These difficulties of solving the inverse vibrational problem are overcome by using stable numerical methods for the joint treatment of experimental and quantum mechanical data [1] when ab initio or DFT data serve as a stabilizer of a solution. It allows us to narrow the class of possible solutions and obtain the so-called regularized quantum mechanical force field (expressed in terms of any system of generalized coordinates. Additionally, the quantum mechanical calculations are served as the basic guide for describing the conformational dependence of conformer vibrational spectrum and force field. Theoretical results on structure-property properties of the key (model) molecules are useful for the testing the correlations between molecular structure and its force field parameters which should be taken into account on composing force field databases. Here we present results of force field models analysis for some molecules of biological interest such as melatonin and vitamin B6 derivatives (metabolites). Theoretical force field parameters of investigated molecules are compared with a goal to find the specific peculiarities of conformer force field parameters and the

trends in force constants of different molecular conformations, and formulation of a priori limitations on force constant values of considered molecules which can serve as the stabilizers for the calculation of optimized force field parameters within different approaches.

This work was supported in part by the RFBR grant No 18-03-00412.

Direct inversion algorithm for inverse coefficient problems in the diffusion equations based on the variational adjoint method

Gongsheng Li

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In this talk, we consider some inverse problems for diffusion equations in bounded domain. Several inverse problems, such as determining the diffusion coefficient, the reaction coefficient, the linear source term are discussed with suitable additional information, and conditional uniqueness is proved by using the variational adjoint method. Furthermore, a direct inversion algorithm based on the variational equation with regularization is set forth to perform numerical inversions for the corresponding inverse problems. Numerical examples, including for the factional diffusion equation and the system of diffusion equations, are presented.

Data modeling in functional clothing design：forward and inverse problems approaches

Dinghua Xu

Shanghai Univerisity of Finance and Economics& Zhejiang Sci-Tech University

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Textile material design is of paramount important in the study offunctional clothing design. The experimental data shows that there are great challenges in Intelligent Manufacturing in Clothing Industry, such as Thermal Comfort Clothing (TCC) and Thermal Protective Clothing (TPC). The experimental Data varies from the data on clothing parameters, environmental situation, human body comfort Index and skin Injury. Therefore the data modelling of functional clothing design will based on physical model of heat and moisture transfer. The advantages of the data modelling may reduce the design cost and experimental risk.

We focus on revealing heatand moisture transfer characteristics in the system of humanbody-clothing-environment, which directly determinethermalcomfort/safety level of human body. Based on the parabolic model ofdynamic heat and moisture transfer, we present inverseproblems of textile parameters determination (IPTPD), including thickness, thermal conductivity and porosity determination. Moreover we mathematically formulate a new space-fractional parabolic model of heat transfer within thermal protective clothing under high environmental temperature- humidity, and the corresponding inverse problems of textile material design are put forward. Some numerical algorithms are presented by the regularization approaches. Theoretical study and numerical simulation results validatethe formulation of the IPTPD and demonstrate effectiveness ofthe proposed numericalalgorithms.

Machine learning and convolutional neural networks – example of applications to seismic field data

Leiv-J. Gelius

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The recent availability of powerful GPUs and open source software have enabled artificial neural networks (ANNs) to be applied to a number of practical and industrial scale problems. The level of adoption of this technology within the field of O&G exploration is well illustrated by the number of abstracts related to ANNs that are submitted to the annual EAGE and SEG conferences. Since 2001, there have typically been one or two papers per year discussing ANNs. In 2018 the level rose significantly to between 50 and 100 papers. In seismic processing, ANNs have the potential to be applied to many of the key processing steps which today involve significant testing time and computational power. Once trained, ANNs are computationally very light and potentially adaptable to varied datasets. Their use could therefore significantly cut processing times and, in the long term, impact the whole business sector. In this work we will consider a special type of ANN which is the Convolutional Neural Networks (CNNs). CNNs are neural networks consisting of at least one convolutional layer. Convolutional layers differ from other types of layers in that they employ convolutions over subsets of the data, rather than a general matrix multiplication. This makes CNNs well suited for 2D images where neighboring pixels are connected in a larger pattern. Seismic field data examples will be presented employing CNNs within both classification (salt detection) and regression (denoising of various types of seismic noise).

Landweber iteration and its acceleration

QinianJin

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We will revisit the Landweber iteration for solving inverse problems in Banach spaces by providing new results which allow the forward operator to be nonsmooth and the image space to be arbitrary Banach space. We will also discuss the acceleration of Landweber iteration by adapting the Nesterov's acceleration strategy and by considering two-point gradient methods.

Inverse source scattering problems

Peijun Li

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The inverse source scattering problems, as an important research subject in inverse scattering theory, have significant applications in diverse scientific and industrial areas such as antenna design and synthesis, medical imaging, and optical tomography. Although they have been extensively studied, some of the fundamental questions, such as uniqueness, stability, and uncertainty quantification, still remain to be answered.

In this talk, our recent studies will be discussed on the inverse source problems for acoustic, elastic, and electromagnetic waves. The stability will be addressed for the inverse source scattering problems. I will also highlight some ongoing projects on the stochastic inverse source problems.

Elastic full waveform inversion in the frequency domain with the green function method

Wensheng Zhang

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The elastic fullwaveform inversion in the frequency domain basedon the Green tensor function is investigated. The method allows to image media velocities ofcompressional wave and shear wave by using vertical and horizontal of wavefiled components. Theforward problem is solved by the finite difference scheme with the perfectly matched layerabsorbing boundary condition in the frequency domain. The inversion is an optimizationiterative process to minimize the residual between the synthetic data and the observeddata. A gradient method is used to find the optimization direction, preconditioned withthe diagonal part of the inverse Hessian matrix. The gradient is constructed based on theGreen tensor function, which allows to compute the gradient of the objective function withrespect to model parameters effectively. The inversion is completed from low frequencyto high frequency so that smaller wavelengths are progressively introduced in inversion.Numerical computations both for a typical model and a benchmark model demonstrate the method can inverse the media parameters accurately.

A weak galerkin finite element scheme for the cahn-hilliard equation

Ran Zhang

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This talk presents a weak Galerkin (WG) finite element method for the Cahn- Hilliard equation. The WG method makes use of piecewise polynomials as approximating functions, with weakly partial derivatives (first and second order) computed locally by using the information in the interior and on the boundary of each element. A stabilizer is constructed and added to the numerical scheme for the purpose of providing certain weak continuities for the approximating function. A mathematical convergence theory is developed for the corresponding numerical solutions, and optimal order of error estimates are derived. Some numerical results are presented to illustrate the efficiency and accuracy of the method.

Resonance analysis of electromagnetic metasurfaces

Jun Zou

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In this talk we report some recent resonance analysis of electromagnetic metasurfaces. We consider the anomalous electromagnetic scattering by periodically distributed sub-wavelength plasmonic nanoparticles, and establish some quantitative representation of the field enhancement due to mixed collective plasmon resonances, which can be characterized by the spectra of periodic Neumann-Poincare type operators. Based on the far field analysis, we demonstrate the optical effect of the electromagnetic metasurface can be effectively approximated by a Leontovich boundary condition. These results confirm essential physical changes of metasurface at resonances mathematically.

Coefficient inverse problems for parabolic equations:application to medicine and finance

Maxim Shishlenin

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Many papers have been published devoted to the problem of the recovering the coefficients of parabolic equations when the data of the inverse problem are specified as nonlocal information (integral over time or space). Inverse problems with non-local conditions arise in heat transfer, thermoelasticity, non-destructive testing, chemical kinetics, medicine, economics, sociology, etc. We propose algorithms for solving the coefficient inverse problems of parabolic equations by nonlocal additional information of integral type.The nonlinear inverse problem is formulated as the problem of minimizing the misfit functional. The gradient method is applied to minimize the functional.

Inverse problems for the time-fractional diffusion-wave equations

Ting Wei

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In this paper, we propose and analyse a novel Kaczmarz type method for solving nonlinear ill-posed problems which can be written as systems of nonlinear equations in Banach spaces. The proposed method uses the homotopy perturbation iteration with uniformly convex penalty to cyclically solve each nonlinear equation. The penalty term is allowed to be non-smooth, including the L^1 and the total variation-like penalty functionals, to reconstruct special features of the solutions such as sparsity and piecewise constancy in practical applications. Under certain assumptions, we establish the convergence result of the proposed method in the noise-free case. For the data containing noise, together with a suitable stopping rule, we analyse the stability and regularization property of the method. Finally, some numerical experiments for parameter identification problems with multiple interior sources are presented to validate the effectiveness of the proposed method.

Stable methods for numerical differentiation based on ordinary differential equations

Hongqi Yang

School of Data and Computer Science, Sun Yat-sen University

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In this talk, we propose stable methods for numerical differentiation of non-exact functions based on first order and second order ordinary differential equations with small parameters. We take the derivative of the solution of ordinary differential equation as an approximation to the original derivative which needs to be computed, and proved convergence and convergence rate under certain conditions. Numerical examples show the efficiency and the accuracy of the proposed methods.

Discrete optimal transport and inverse optimal transport with application in matching

Haomin Zhou

Georgia Institute of Technology

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In this presentation, I will briefly review the discrete optimal transport theory, and introduce the inverse optimal transport and its application in data matching problem. We propose a unified data-driven framework that can learn adaptive, nonlinear interaction cost function from noisy and incomplete empirical matching matrix and predict new matching in various matching contexts. The proposed method uses properties of optimal transport distance to solve a bi-level optimization problem. This is based on joint work with Ruilin Li (GT Math), Xiaojing Ye (GSU, Math) and HongyuanZha (GT, CSE).

Practical inverse problems from industry and environmental engineering: numerics and the construction of mathematical theories

M. Yamamoto

University of Tokyo

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Many problems from the real-world such as industry, can be considered as inverse problems.We present case studies of such inverse problems with some numerical approaches.Moreover, motivated by anomalous diffusions, for the time fractional partial differentialequations we discuss the theoretical foundation.

Part II Invited Talks

Super resolution using sub wavelength resonators

Hai Zhang

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Wave imaging techniques such as optical microscopy play an important role in our understanding of the microscopic world. Because of Abbe's diffraction limit, their resolution is usually limited by half the wavelength of the radiating waves. In this talk, we develop a mathematical theory to demonstrate how subwavelength resonances can be used to break the diffraction limit to achieve super-resolution. The theory also sheds light on the mechanism of meta-materials.

The factorization method for inhomogeneous medium with an impenetrable obstacle

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This paper is concerned with the inverse problem of scattering of time-harmonic acoustic waves by a mixed-type scatterer. Such a scatterer is given as the union of an inhomogeneous medium with unknown buried objects inside and an impenetrable obstacle. Having established the well-posedness of the direct problem by the variational method, we study the factorization method for recovering the support of the inhomogeneous medium and the shape of the impenetrable obstacle simultaneously. Finally, some numerical examples are provided to illustrate the feasibility and effectiveness of the inverse algorithm.

A non-iterative method for recovering the space-dependent source and the initial value simultaneously in a parabolic equation

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This talk is concerned with the inverse problem for determining the space-dependent source and the initial value simultaneously in a parabolic equation from two over-specified measurements. By transforming information of the initial value into the source term and obtaining a combined source term, the parabolic equation problem is converted into a parabolic problem with homogeneous boundary conditions. Then the considered inverse problem is formulated into a regularized minimization problem, which is implemented by the finite element method based on solving a sequence of well-posed direct problems. The uniqueness of inverse solutions are proved by the solvability of the corresponding variational problem, and the conditional stability as well as the convergence rate of regularized solutions are also provided. Then, the error estimate of approximate regularization solutions is presented in the finite dimensional space. The proposed method is a very fast non-iterative algorithm, and it can successfully solve the multi-dimensional inverse problem for recovering the space-dependent source and the initial value simultaneously. Numerical results of five examples including one- and two-dimensional cases show that the proposed method is efficient and robust with respect to data noise.

An accelerated sequential subspace optimization method based on homopoty perturbation for nonlinear ill-posed problems

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Homotopy perturbation iteration is an effective and fast method for solving nonlinear ill-posed problems. It only needs approximately half the computation time of Landweber iteration to reach the similar recovery precision. In this paper, a Nesterov-type accelerated sequential subspace optimization method based on homotopy perturbation iteration is proposed for solving nonlinear problems. The convergence analysis is provided under the general assumptions for iterative regularization methods. The numerical experiments on inverse potential problem and diffuse optical tomography (DOT) indicate that the proposed method has obvious effects on reducing the total number of iteration and time consumption to obtain satisfying approximations, especially for the issues with costly solution of forward problem.

PP-PS joint sparse inversion with lateral constraint

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With the seismic target changing from structural reservoir to lithologic reservoir, it requires more reliable attribute information with clear geological meaning from seismic data to identify lithology or lithofacies of the reservoir. The AVO inversion technique can be used to estimate the properties of rock and fluid through P-wave velocity, S-wave velocity, density information and other elastic parameters extracting from the amplitude variations with offset. However, the AVO inversion is ill-posed in nature. The seismic P-wave reflection coefficient is not sensitive to the shear wave velocity and density, which will lead to large errors in the inversion results. With the development of seismic data acquisition and data processing technology, more and more scholars begin to study the PP-PS joint inversion and apply it to the actual field data. The joint inversion can improve the inversion accuracy and to some extent reduce the instability of the inversion. However, in the case of low signal-to-noise ratio situation, we cannot obtain good results from the joint inversion, and we put forward the l1 norm constrained sparse optimization method with the initial model generated from particle filtering, and also apply the Kalman filtering to the joint inversion to enhance the lateral's continuality.

Non-balanced staggered-grid finite-difference scheme for seismic wave-equation modeling

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Wave equation extrapolation is the basis for reverse time migration and full waveform inversion, which are the hot topics of the recent seismic exploration geophysics. Finite difference methods are the most popular wave equation extrapolation method. Staggered-grid finite-difference methods are one of most widely finite difference methods. However, compared with the normal-grid finite-difference，staggered-grid finite-difference method is more time consuming. We proposed a non-balanced staggered-grid finite-difference scheme for wave equation modeling, which uses different finite-difference operators for different first-order spatial derivatives in the first-order wave-equation. The non-balanced staggered-grid finite-difference scheme could benefit reverse time migration and full waveform inversion.

A new class of accelerated regularization methods for ill-posed inverse problems

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In this talk I will introduce a new class of iterative regularization methods for solving ill-posed linear operator equations. The prototype of these iterative regularization methods is in the form of second order evolution equation with a linear vanishing damping term, which can be viewed not only as an extension of the asymptotical regularization, but also as a continuous analog of the Nesterov's acceleration scheme. New iterative regularization methods are derived from this continuous model in combination with damped symplectic numerical schemes. The regularization property as well as convergence rates and acceleration effects under the conventional source conditions of both continuous and discretized methods are proven.

The second part of my talk is concerned with the application of the newly developed accelerated iterative regularization methods with a posteriori stopping rule to the diffusion-based bioluminescence tomography, which is modeled as an inverse source problem in elliptic partial differential equations with both Dirichlet and Neumann boundary data.

XCT image reconstruction by a modified superiorized iteration and theoretical analysis

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In this paper, we propose an improved iteration superiorization method for X-ray computed tomography image reconstruction. We simplify the classic superiorized iteration by removing two constraints imposed on the perturbation. A novel method is proposed to determine the perturbation amount and direction for the superiorized iteration simultaneously. Some theoretical properties (convergence for instance) of the superiorized iteration sequence with the proposed perturbation are analysed. We present a general proof for the convergence of ART-like iterations with summable perturbations. In addition, we prove the convergence of simultaneous iterations without the summable perturbation assumption. Experiments on simulated and real data not only verify the theoretical result but also show that the proposed algorithm is superior to the classic superiorized iteration and can reconstruct desirable images.

The adjoint-state method for computing the gradient of trust region inversion in TEM

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In the inversion problem of geophysics, we generally obtain the parameters results by minimizing the error function. In the process, we always need to compute the gradient of the measured data with respect to the model parameters. The traditional method is that solving the minimizing objective function by a series of linear problems with Jacobian matrix, which is expensive. Therefore, we urgently need an efficient method to reduce computation and memories. In this paper, we study the transient electromagnetic response abnormal response for difference forms of geology by trust region method, which have been widely used for solving non-linear problems, and provide globally convergent solutions. In the process, we provide an adjoint-state formulation for computing the gradient instead of Jacobian matrix. Numerical experimentation suggest that the adjoint-based method allow to more rapidly acquire accurate gradient and results than by traditional methods.

A new Kaczmarz-type method and its acceleration for nonlinear ill-posed problems

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In this paper, we first introduce a new Kaczmarz-type method for solving inverse problems that can be written as a system of a finite number of nonlinear equations. The proposed homotopy perturbation Kaczmarz (HPK) iteration is seen as a hybrid method between the homotopy perturbation iteration and the Kaczmarz strategy. Furthermore, an accelerated homotopy perturbation Kaczmarz (AHPK) method is presented based on the general case of Nesterov's acceleration scheme. Under the classical assumptions for iterative regularization methods, we provide the corresponding convergence analysis for HPK and AHPK, respectively. The HPK iteration is shown to have faster calculation speed and less time consumption than the Landweber-Kaczmarz iteration through some numerical experiments on inverse potential problem. Besides, the significantly reduced computation cost and much better reconstruction quality indicate a remarkable acceleration effect for AHPK.

Simultaneous-source seismic data deblending based on sparse inversion and curvelet domain thresholding

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The simultaneous-source technology has become popular since it can reduce the acquisition period and increase spatial sampling for seismic exploration. However, blending noise is produced in the simultaneous-source data, which should be removed for the following seismic signal processing. Removing blending noise in the common-source domain is a tough task since they are correlative in the common-source domain. Fortunately, they are randomly distributed as pulses in the common-receiver domain after pseudo-deblending, thus they can be removed by using sparse inversion. In this paper, we remove the blending noise in the common-receiver domain based on L1 norm based iterative inversion method. The curvelet transform was chosen as the sparse transform. Different from the traditional sparse inversion method, we did not directly use threshold denoising for the pseudo-separated data. At each iteration, the residual between the pseudo-deblending data and the cumulative useful signals in the common-receiver domain should be calculated at first, then we use the threshold denoising for the residual data to get useful signals. In the next, the obtained useful signals should be added to the previous cumulative useful signals to update cumulative useful signals. Numerical experiments demonstrate that the proposed method has higher signal-noise-ratio and better fitting with the original data in the processing of the boundary of seismic wave events compared with the multilevel median filtering method.

Some numerical features of the magnetic parameters inversion method with full tensor gradient data

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Retrieval of magnetization parameters using magnetic tensor gradient measurements receives attention in recent years. Determination of subsurface properties from the observed potential field measurements is referred to as inversion. Traditional magnetic inversion is based on the total magnetic intensity data and solving the corresponding mathematical physical model. In recent years, with the development of the advanced technology, acquisition of the full tensor gradient magnetic data becomes available. Some unobvious features of numerical solution of this inversion problem using the full tensor magnetic gradient data will be described.

Variational Bayes' approach for functions and applications to some inverse problems

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Bayesian approach as a useful tool for quantifying uncertainties has been widely used for solving inverse problems of partial differential equations (IPPDE). One of the key difficulties for employing Bayesian approach is how to extract information from the posterior probability measure. Variational Bayes' method (VBM) is one of the most activate research topics in the field of machine learning, which has the ability to extract posterior information approximately by using much lower computational resources compared with the sampling type method. In this talk, we generalize the usual finite-dimensional VBM to infinite-dimensional space, which makes the usage of VBM for IPPDE rigorously. General infinite-dimensional mean-field approximation theory has been established, and has been applied to abstract linear inverse problems with Gaussian and Laplace noise assumption. Finally, two numerical examples are given which illustrate the effectiveness of the proposed approach.

A 3D marine MT inversion method with considering the seafloor topography

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Inversion of magnetotelluric (MT) responses has been used to explore the electrical conductivity distribution of the Earth's interior. In 3-D inversions, it is significant to use a good initial model, because final model obtained by most 3-D inversion methods is influenced by the initial model. Although uniform initial models are widely used in 3-D inversions, one-dimensional (1-D) initial models are alternatives, which could more appropriately represent the actual conductivity variations in the Earth's interior. This paper presents a two-step 3-D inversion method, especially for marine cases. This inversion method first concentrates on obtaining a 1-D initial model and then inverts for 3-D conductivity structures with it, in both of which the 3-D topography is carefully taken into consideration. This method was tested by synthetic models of different topography variations (depression-shaped, smoothly varying, channel-shaped and square-shaped plateau topography) and of heterogeneous layers with different checkerboard-type anomalies (sharp or smooth lateral conductivity variations) embedded in 1-D model of depth-dependent conductivity. The comparisons were done about obtaining an initial model by the proposed method and that inverted from the corrected responses. The results of 3-D inversions by using the method of this study were also compared to that with different uniform initial models. Results of synthetic tests and comparisons were discussed by using directional information of newly introduced model-vector parameters. This paper has indicated performance and validity of this method. We have also revealed that some of the newly introduced model-vector parameters could be used to show the convergence of inversions and help to select inverse model.

A novel Kaczmarz type method for nonlinear ill-posed problems in Banach spaces with uniformly convex penalty terms

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In this paper, we propose and analyse a novel Kaczmarz type method for solving nonlinear ill-posed problems which can be written as systems of nonlinear equations in Banach spaces. The proposed method uses the homotopy perturbation iteration with uniformly convex penalty to cyclically solve each nonlinear equation. The penalty term is allowed to be non-smooth, including the L^1 and the total variation-like penalty functionals, to reconstruct special features of the solutions such as sparsity and piecewise constancy in practical applications. Under certain assumptions, we establish the convergence result of the proposed method in the noise-free case. For the data containing noise, together with a suitable stopping rule, we analyse the stability and regularization property of the method. Finally, some numerical experiments for parameter identification problems with multiple interior sources are presented to validate the effectiveness of the proposed method.

The Kirchhoff-Helmholtz transform pair:Geometrical concepts for seismic imaging

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Seismic reflection surveys are carried out by sources and receivers deployed at preassigned locations (e.g., at land or sea surface) and a given recording time duration. Mechanical waves emitted by the sources propagate into the earth subsurface, reflect and scatter at geological structures, and are registered by the receivers. The resulting data consists of a collection of seismic traces, each of them containing the registers of the earth's response at a given receiver due to a given source. In other words, for each source-receiver pair, the corresponding seismic trace consists of sampled travel time arrivals of the energy emitted by that source and registered at that receiver. Meaningful subsurface geological features (such as, e.g., layer interfaces and point diffractions) appear as coherent data-sample alignments, referred to as travel time events. Under these conditions, a fundamental task of seismic processing is to transform the original, time-domain acquired data set into a corresponding depth domain image data set. The latter is supposed to display, as depth events, the geological features (e.g., structural interfaces, diffraction points). In the seismic literature, the above transformation is called depth migration, or, more simply, migration. Also important in seismic processing is demigration, namely the inverse transformation of migration. Demigration transforms a (depth) migrated data set into its corresponding (time) un-migrated data set. Migration and demigration constitute a so-called imaging transform pair. In this talk, we provide an introductory, geometrical description of the migration and demigration transformations. That description is elegantly formulated as a Kirchhoff-Helmholtz transform pair. Even though the underlying basic concepts of migration and demigration are well established in the literature, constant theoretical and practical demands, in particular in seismic processing and imaging, make the subject an ever active topic of research.

4. Introduction to Longyan University

Longyan University is situated in the well-known former Revolutionary Base and the world-famous Hakka ancestral land-----Longyan City, Fujian Province.

This university is originated from Longyan Teachers College established in 1958, merged with Fujian Resource Industry School in 2001, and officially renamed as Longyan University in 2004. Since 2007 the university has been an Authorized Institution of Granting Bachelor's Degree and in 2012 it passed the Teaching Qualification Assessment by the Ministry of Education with a good mark. In 2018 the university is selected as one of the Provincial-level Exemplary Application-oriented Universities and one of the Provincial Construction Universities of Granting Master's Degree in Fujian.

The university is consisted of 14 colleges and 2 special institutes, i.e. Institute of Central Soviet Area Research, Institute of Fujian-Taiwan Hakka Research. There are now 40 specialties in the university covering all the 8 major disciplines, which are entitled to enroll students all over the country. Currently the university has nearly 12,000 students and over 900 members of staff, including 288 professors or associate professors, 598 teachers of doctor’s or master’s degrees as well as 6 national-level talents, 27 provincial-level talents and 10 provincial-level distinguished teachers.

The university is now implementing a strategy of strengthening itself with talents and attaching importance to teacher education, which has established a Provincial-level Academician and Expert Workstation. The university also pays attention to its connotative development, which has been equipped with 1 National-level Specialty of Characteristic Construction, 1 National-level Pilot Project of Comprehensive Specialty Reform, 6 Provincial-level Key Disciplines, 1 Provincial-level Key Laboratories and 4 Provincial-level Applied Disciplines. The Journal of Longyan University has been awarded as the National-level Excellent Periodical in Local Universities, whose column of “Hakka Research” has been awarded as the National-level Characteristic Column in Local University Journals. The College of Special Mechanical Equipment of the university has been awarded as the Provincial-level Exemplary Industrial College while the practice base of mechanical and electrical engineering has been awarded as the Provincial-level Exemplary Practice Base for Vocational Education Co-constructed by University and Enterprise. The university teachers have won 1 Second Prize and 3 Third Prizes of the Provincial-level Science and Technology Awards as well as 1 Second Prize, 4 Third Prizes of the Provincial-level Outstanding Achievements in Social Sciences and 1 Youth Masterpiece Award in their research achievements.

Longyan University, sticking to the motto of being “Rooted in the Red Land, Devoted to Application, manifesting through Characteristics and Serving Local Development”, with the goal of “Footholds in Longyan, Service on West Coast, Orientation at Basic Level and Connection

with Industry”, is now working hard to reconstruct itself into an exemplary high-standard and application-oriented university.

The Introduction of the School of Resource Engineering

The School of Resource Engineering is a secondary college cultivating professionally technical talents of advanced applied engineering. It has a history of more than 60 years. There are 47 faculty members, including 5 professors, 12 associate professors and 12 doctors. Among these faculty team, there are 6 excellent teachers or prestigious teachers.

The college has a series of key disciplines on deferent levels, including a provincial key discipline, a provincial applied discipline of Geological Engineering, a university-level key discipline of Surveying and Mapping Engineering, and a featured discipline of Mining Engineering in Fujian Province. As for the laboratories, we have a university key laboratory of Safe Mining of Mineral Resources in Fujian Province, a university engineering research center of Engineering Quality Inspection and Safety Assessment in Fujian Province, a virtual simulation teaching and experiment center of Safe Mining of Mineral Resources in Fujian Province, an engineering research center of Mining Safety in Longyan City and three university-level research institutes. In recent years, the school made an outstanding achievement in teaching and research, undertaking more than 20 projects above provincial-ministerial-level, including the national natural and science foundation, provincial natural and science foundation and other projects. Currently, there are 835 undergraduate students majoring in Mining Engineering, Surveying and Mapping Engineering, Geological Engineering and Civil Engineering.

The School of Resource Engineering has been attaching great importance to domestic and international cooperation. We jointly cultivate undergraduates with China University of Mining and Technology by selecting several outstanding students and recommending them to study at the target University. And the students majoring in Civil Engineering also have the chance to study at Taiwan Chung-Hua University. The college put great attention to the cultivation of students’ practical skills and innovation ability. Meanwhile, we adhere to the path of integrating production, learning and research. Our students have won numerous awards in Mining Engineering student practical works competition, Building Information Modeling (BIM) Application Competition, national college students’ geological skills competition and other competitions at all levels. 116 person-times have won 30 awards in national and provincial competitions. Our graduates are mainly engaged in geotechnical engineering, underground engineering, construction engineering, space information engineering, precise surveying and mapping engineering, resource survey, engineering survey and geological disaster control, etc. The employment rate of graduates in recent three years has reached above 96%, among which 20% of graduates are working in government departments and public institutions. In the past three years, more than 40 students have been admitted to masters’ degree programs. Some of them have obtained doctorate degrees from top universities such as the University of Chinese Academy of sciences and Tongji University. Our graduates are highly complimented by employers.

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