The 9th International Conference on Numerical Optimization and Numerical Linear Algebra

September 12-15, 2013

Changchun, Jilin, China

http://lsec.cc.ac.cn/~icnonla13

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Information for Participants

Conference Hotel and Conference Venue

Hotel:	Peony Wanpeng Hotel 厦门牡丹万鹏宾馆
Address:	No.17-19, Huyuan Road, Siming District, Xiamen 厦门市思明区虎园路17-19号
Venue:	Conference Room No. 1, Science & Art Center, Xiamen University 厦门大学科学艺术中心一号会议室
Address:	No. 422, Siming South Road, Siming District, Xiamen 厦门市思明区思明南路422号

Arrival

By air: The distance between Xiamen International Airport and the conference hotel is about 14.2 km. It will cost you about 40 RMB (6.5 USD c.a.) to take a taxi. For the invited speakers, you will be picked up at the airport, if you have sent your arrival information to the organizing committee.

By train: There is about 3.8 km from Xiamen railway station to the conference hotel. The taxi fare is about 12 RMB (2 USD c.a.).

Xiamen North railway station is 30.3 km away from the conference hotel. Participants who arrive there are suggested to take an intercity high speed train to Xiamen railway station first (22 min., 9 RMB).

On-site Registration

On-site registration will take place at the **lobby of Peony Wanpeng Hotel** on **November 6** from **9:00** to **21:00**. If you want to register at other time, please contact our conference secretary Ms. Jiping Wu.

Currency

Chinese currency is RMB. The current rate is about 6.34 RMB for 1 US dollar. The exchange of foreign currency can be done at the airport or the conference hotel. Please keep the receipt of the exchange so that you can change back to your own currency if you have RMB left before you leave China. Please notice that some additional processing fee will be charged if you exchange currency in China.

Transportation to Conference Venue

For participants accommodated at our conference hotel (Peony Wanpeng Hotel), in each morning and evening of November

7-9, there will be conference shuttle buses transferring between our conference hotel and conference venue at Xiamen University. The detailed schedule is as follows:

- Start at **07:40** from **Hotel Lobby** to **Science & Art Center**
- Start at **18:10** for **Science & Art Center** to **Hotel Lobby**

In the evening of Nov 9, the schedule will be slightly changed due to the conference banquet, but the shuttle buses will still send all the participants stayed at our conference hotel back.

For participants who don't stay at our conference hotel or miss the time, we are not responsible for your transportation cost.

Contact Information

If you need any help, please feel free to contact

- Dr. Xin Liu: +86-138-1000-2122
- Ms. Jiping Wu: +86-136-9106-6084 (in Chinese)

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Conference Schedule

<u>September 12, Thursday</u>

08:00-08:30 Opening Ceremony

- **08:00-08:10 Welcome Address**
- **08:10-08:30 Group Photo**

08:30-10:00 Invited Talks V1
Chair: Y.X. Yuan

- **08:30-09:15 Liqun Qi**, Symmetric tensors
- **09:15-10:00 Gianni Di Pillo**, A derivative-free approach to constrained global optimization based on non-differentiable exact penalty functions

10:00-10:20 Coffee Break

10:20-11:50 Invited Talks V2
Chair: Liqun Qi

- **10:20-11:05 Hulin Wu**, Nonlinear high-dimensional optimization problems in reverse engineering of biological systems
- **11:05-11:50 Wotao Yin**, Distributed sparse optimization

11:50-12:30 Penal Discussion P1
Chair: Wotao Yin

- **11:50-12:30 All participants**, Open to all workshop related topics

12:30-13:30 Lunch

13:30-14:50 Contributed Talks C1
Chair: Takashi Tsuchiya

13:30-13:50 **S. Jimenez**, A Quadratic Iterative Method to Compute Eigenvectors

13:50-14:10 **Wei Bian**, Complexity Analysis of Interior Point Algorithms for Non-Lipschitz and Nonconvex Minimization

14:10-14:30 **Lijun Liu**, Dual Purpose Subspace Tracking on Noncompact Stiefel Manifold

14:30-14:50 **Cong Sun**, Sum Rate Maximization Algorithms for MIMO Relay Networks in Wireless Communications

13:30-14:50 Contributed Talks C2
Chair: Hulin Wu

14:50-15:10 **Mehiddin Al-Baali**, Reducing the number of updates for the limited memory quasi-Newton methods

15:10-15:30 **Zhouhong Wang**, On the Convergence Order of the Central Path for Second Order Cone Optimization

15:30-15:50 **Zhi-Feng Pang**, Data Clustering Based On The Total Variation Energy Functional

15:50-16:10 Coffee Break

16:10-17:30 Contributed Talks C3
Chair: Yangfeng Su

16:10-16:30 **Yong Xia**, On Minimizing the Ratio of Quadratic Functions over an Ellipsoid

16:30-16:50 **Shaohua Pan**, Multi-stage Convex Relaxation Approach for PS-D Structured Low-rank Optimization Problems

16:50-17:10 **Hailin Sun**, Regularized Mathematical Programs with Stochastic Equilibrium Constraints: Estimating Structural Demand Models

17:10-17:30 **Yanfang Zhang**, Regularizations for Stochastic Linear Variational Inequalities

17:30-18:50 Contributed Talks C4
Chair: Xin Liu

17:30-17:50 **Zaikun Zhang**, A Subspace Decomposition Framework for Nonlinear Optimization

17:50-18:10 **Shujun Bi**, Multi-stage Convex Relaxation for Rank Regularized Minimization Problem

18:10-18:30 **Tianxiang Liu**, A Node-based SDP Relaxation Approach for Sensor Network Localization

18:30-18:50 **Qian Dong**, TBA

18:50 **Dinner**

September 13, Friday

08:00-10:15 Invited Talks V3

Chair: Yuhong Dai

08:00-08:45 **Zhaojun Bai**, Recent advances in variational principles and the steepest descent type methods for matrix eigenvalue problems

08:45-09:30 **Andreas Griewank**, Representation and analysis of continuous piecewise linear functions in abs-normal form

09:30-10:15 **Zaiwen Wen**, Algorithms for eigenvalue optimization

10:15-10:30 Coffee Break

10:30-11:50 Contributed Talks C5

Chair: Zhaojun Bai

10:30-11:50 **Wenwen Zhou**, A modified Primal-dual Augmented Lagrangian Method for Large Scale Nonlinear Optimization

10:50-11:10 **Yilun Wang**, SOARS: Statistical and Optimization Analysis and Response Surfaces for Computationally Expensive Models

11:10-11:30 **Yuan Shen**, Partial Convolution for Total Variation Problem by Augmented Lagrangian-based Proximal Point Descent Algorithm

11:30-11:50 **Xin Liu**, Symmetric Low-Rank Product Matrix Approximation and Gauss Newton Method

11:50-12:30 Penal Discussion P1

Chair: Zaiwen Wen

11:50-12:30 **All participants**, Open to all workshop related topics

12:30-13:30 Lunch

13:30-15:00 Invited Talks V4

Chair: Gianni Di Pillo

13:30-14:15 **Xiaoling Sun**, Optimization with semi-continuous variables

14:15-15:00 **Chao Yang**, Numerical algorithms for energy minimization in electronic structure calculation

15:00-16:00 Contributed Talks C6

Chair: Xiaoling Sun

15:00-15:20 **Zi Xu**, Joint User Grouping and Linear Virtual Beamforming: Complexity, Algorithms and Approximation Bounds

15:20-15:40 **Geovani Nunes Grapiglia**, A Derivative-Free Trust-Region Algorithm for Composite Nonsmooth Optimization

15:40-16:00 **Shuxiong Wang**, Feasible Method for Semi-Infinite Programming

16:00-16:20 Coffee Break

16:20-17:40 Contributed Talks C7
Chair: Chao Yang

16:20-16:40 **Shenglong Zhou**, New RIC Bounds vea l_q-minimization with $0 < q \leq 1$ in Compressed Sensing

16:40-17:00 **Ning Zheng**, Accelerated Modulus-based Matrix Splitting Iteration Methods for Linear Complementarity Problem

17:00-17:20 **Ya-Feng Liu**, Non-Convex L_q Minimization: Complexity Analysis and A Potential Reduction Algorithm

17:20-17:40 **Fangfang Xu**, Covariance Matrix Estimation Using Factor Models from Incomplete Information

17:40-18:40 Contributed Talks C8
Chair: Yafeng Liu

17:40-18:00 **Xiaochao Xiu**, Rank-one and Sparse Nonnegative Matrix Decomposition for Surveillance Video

18:00-18:20 **Chunfeng Cui**, Computing k Largest Eigenvalues of Supersymmetric Tensors

18:20-18:40 **Zhenli Sheng**, TBA

18:40-21:00 Conference Banquet (Restaurant, Peony Wanpeng Hotel)

September 14, Saturday

08:00-9:30 Invited Talks V5

Chair: Andreas Griewank

08:00-08:45 **Takashi Tsuchiya**, A structural geometrical analysis of ill-conditioned semidefinite programs

08:45-09:30 **Yangfeng Su**, Numerical methods for quadratic eigenvalue problems

9:30-9:55 Coffee Break

Excursion

10:00, Leave for Changbai Mountain

(Estimated time of return Changchun: 21:00, September 15)

Abstracts

Part I

Invited Talks

Recent Advances in Variational Principles and The Steepest Descent Type Methods for Matrix Eigenvalue Problems

Zhaojun Bai

The variational principles, such as minimax principle andtrace min principle, are of great importance in theoryand computation of Hermitian eigenvalue problem. In this talk,we begin with recent results on the extension of theseprinciples beyond Hermitian eigenvalue problem. Thenwe focus on the application of newly established principlesin the development of the s-teepest descent and conjugate gradienttype methods for ill-conditioned generalized Hermitian eigenvalueproblems, and linear response eigenvalue problems arisingfrom the density functional theory (DFT) and time-dependent DFTin computational material science.

This is a joint work with Yunfeng Cai, Ren-cang Li,Dario Rocca and Giulia Galli.

A derivative-free approach to constrained global optimization based on non-differentiable exact penalty functions

Gianni Di Pillo

In the field of global optimization many efforts have been devoted to globally solving bound constrained optimization problems $\{\min f(x),\ l \leq x \leq u,\ x, l, u \in \Re^n,\ f : \Re^n \to \Re\}$ without using the derivatives of f. In this talk we show how derivative-free bound constrained global optimization methods can be used for globally solving optimization problems where also general constraints $\{g(x) \leq 0, g : \Re^n \to \Re^p\}$ are present, without using neither the derivatives of f nor the derivatives of g. This is of great practical importance in many real-world problems where only problem functions values are available. To our aim we make use of a non-differentiable exact penalty function $P_q(x; \varepsilon)$. We exploit the property that, under weak assumptions, there exists a threshold value $\bar{\varepsilon} > 0$ of the penalty parameter ε such that, for any $\varepsilon \in (0, \bar{\varepsilon}]$, any unconstrained global minimizer of P_q is a global solution of the related constrained problem and conversely. On these bases, we describe an algorithm that combines a derivative-free bound constrained global minimization technique for minimizing P_q for given values of ε and a derivative-free automatic rule for updating ε that acts only a finite number of times. We prove that the algorithm produces a sequence $\{x_k\}$ such that any limit point of the sequence is a global solution of the general constrained problem. In the algorithm any efficient derivative-free bound constrained global minimization technique can be used. In particular, we adopt an improved version of the DIRECT algorithm. In addition, to improve the performance, the approach is enriched by resorting to local searches, in a multistart framework, based on the proof that for every global minimum point there exists a neighborhood of attraction for the local search. Some numerical experimentation confirms the effectiveness of the approach.

Joint work with Stefano Lucidi, Francesco Rinaldi.

Representation and Analysis of Continuous Piecewise Linear Functions in Abs-normal Form

Andreas Griewank

It follows from the well known min/max representation given by Scholtes in his recent Springer book, that all piecewise linear continuous functions $y = F(x) : \mathbb{R}^n \to \mathbb{R}^m$ can be written in a so-called abs-normal Form.

This means in particular, that all nonsmoothness is encapsulated in s absolute value functions that are applied to intermediate switching variables z_i for $i = 1 \ldots s$. The relation between the vectors $x, z, andy$ is described by four matrices Y, L, J, and Z, s.t.

$$\begin{pmatrix} z \\ y \end{pmatrix} = \begin{pmatrix} b \\ c \end{pmatrix} + \begin{pmatrix} Z & L \\ J & Y \end{pmatrix} \begin{pmatrix} x \\ |z| \end{pmatrix}$$

which can be generated by ADOL-C or other Automatic Differentation Tools. Hence L is a lower triangular matrix, and therefor z_i can be computed successive from previous results. We show that in the square case n=m the system of equations F(x) = 0 can be rewritten in terms of the variable vector z as a linear complementarity problem. The transformation itself and the properties of the LCP depend on the Schur complement $S = L - ZJ^{-1}Y$. We discuss associated linear algebra computations and highlight various theoretical and numerical effects via examples.

Theory of Tensors (Hypermatrices)

Liqun Qi

A matrix is an $m \times n$ array of real or complex numbers. The study of matrices has long been a fundamental tool in mathematical disciplines and many application fields. A tensor (hypermatrix) is an $n_1 \times ... \times n_m$ array of real or complex numbers. In the recent years, several important concepts of matrices, such as eigenvalues, eigenvectors, tensors (hypermatrices) and studied extensively. They have been applied or linked to some related areas such as tensor approximation, tensor decomposition, higher order tensor magnetic resonance imaging and spectral hypergraph theory, blind source separation, tensor principal component analysis, etc. It is now a time to make tensor (hypermatrix) theory a mathematical discipline, a useful tool for the above mentioned areas, and a base of tensor theory. Here, the last term tensor" is in the sense of geometry or physics.

Some important concepts of matrices, such as the inverse, can be extended to even-order tensors (hypermatrices), when the tensors (hypermatrices) are treated as matrices. On the other hand, some concepts of matrices, can have more than one natural extensions in tensors (hypermatrices), such as eigenvalues can be extended to eigenvalues or E-eigenvalues, irreducible matrices can be extended to irreducible ten- sors or weakly irreducible tensors, symmetric matrices can be extended to symmetric tensors or strongly symmetric tensors, etc. Thus, tensor (hypermatrix) theory is rich to be studied and explored.

In this talk, I intend to review these issues and the scope of the theory of tensors (hypermatrices).

Numerical Methods for Quadratic Eigenvalue Problems

Yangfeng Su

Quadratic eigenvalue problems (QEPs) appear in almost all vibration analysis of systems, such as buildings, circuits, acoustic structures, and so on. Conventional numerical method for QEPs is to linearize a QEP as a doublly-sized generalized eigenvalue problem (GEP), then call a linear eigen-solver to solve the GEP, e.g. the QZ algorithm for dense GEP, the IRA (implicitly restarted Arnoldi method) for sparseGEP. This method may encounter two difficulties. The first one is that although the linear eigen-solver is good, the eigen-solutions for the original QEP may be bad, in sense of condition number and backward error. The second is that the linearized GEP has its own structure, and the structure is not explorered in a general linear eigen-solver.

In this talk, we will review recent advances of numerical methods for QEPs.

Optimization with Semi-Continuous Variables

Xiaoling Sun

In many real-world applications of optimization models, the decision variables often have to take certain minimum positive values if they are nonzero, due to managerial and technological considerations. Such variables are called semi-continuous variables. For instance, in the production planning problems, the semi-continuous variables can be used to describe the state of a production process that is either turned off (inactive), hence nothing is produced, or turned on (active) such that the amount of the production has to lie in certain interval. Optimization problems with semi-continuous variables can be modeled as mixed-integer programs with special structures and are in general NP-hard.

In this talk, we discuss some recent developments for this class of challenging optimization problems. Our focuses are on efficient MIQP reformulations using SDP and SOCP techniques. In particular, we discuss the relations between perspective reformations and Lagrangian decomposition of the problems. A new lift-and-convexification approach will be also presented. We also report some computational results for different convex reformulations for test problems from portfolio selection, subset selection and compressed sensing.

A structural geometrical analysis of ill-conditioned semidefinite programs

Takashi Tsuchiya

While linear programming and semidefinite programing have many nice propertiesin common, they can be quite different in the absence of interior-feasibility. In particular, the existence of weak infeasibility and finite duality gap is oneof the major difficulties in semidefinite programming.In this talk, we develop a geometrical analysis of ill-conditioned semidefinite programs to shed new light on their common structures.

This is a joint work with Bruno F. Lourenço of Tokyo Institute of Technology and Masakazu Muramatsu of the University of Electro-Communications.

Algorithms for Eigenvalue Optimization

Zaiwen Wen

Eigenvalue computation has been a fundamental algorithmic component for solving semidefinite programming, low-rank matrix optimization, sparse principal component analysis, sparse inverse covariance matrix estimation, the total energy minimization in electronic structure calculation, and many other data-intensive applications in science andengineering. This talk will present a few recent advance on both linear and nonlinear eigenvalue optimization.

Nonlinear High-Dimensional Optimization Problems in Reverse Engineering of Biological Systems

Hulin Wu

The cutting-edge and innovative biomedical technologies now are available to produce huge amount of high-throughput and high-resolution complex data to gain insight of a biological system. Recently many new quantitative and computational sciences such as bioinformatics, systems biology and Big Data science have evolved from various disciplines to become major tools to deal with the complex data in biomedical research. A great challenge is to integrate the multi-scale and multi-level high-dimensional data to understand the biological systems and their interactions in a quantitative and dynamic way. In order to quantify a biological system, it is necessary to reverse engineer a mathematical model such as differential equation models based on the high-dimensional and complex experimental data, which usually requires to optimize a nonlinear high-dimensional objective function derived from statistical concepts and methods. This is very challenging from both computational and theoretical perspectives. Computationally it is not an easy task to optimize a nonlinear objective function of a high-dimensional matrix (model parameters) with complex constraints. Theoretically it is not easy to establish the algorithm convergence results since it requires to consider numerical error (deterministic), model approximation error (deterministic), and data noise (random). I will use gene regulatory network modeling as an example to propose these complex optimization problems and issues. Some initial ideas will be proposed to potentially address these problems.

Numerical Algorithms for Energy Minimization in Electronic Structure Calculation

Chao Yang

In Kohn-Sham density functional theory based electronic structure calculation, the ground-state energy of a multi-electron system can be obtained by minimizing the Kohn-Sham total energy functional over a manifold of orthonormal single-particle wavefunctions. One may solve the constrained minimization problem directly, or seek a solution that satisfies the first order necessary condition, which defines a set of nonlinear eigenvalue problems and a fixed point mapthat takes the ground-state electron density to itself. For metallic systems at a non-zero temperature, the Mermin free energy functional is a more suitable objective function to minimize.This functional contains an extra entropy term. As a result, its first order necessary condition contains an additional equation that defines the chemical potential and occupation numbers for all eigenstates. For this type of problem, the widely used self-consistent field (SCF) iteration seeks the solution to two sets of equations in an alternating fashion. However, it is not clear yet whether an alternating direction method is effective when we try to minimize the Mermin free energy directly. We will examine this problem in detail.

Distributed Sparse Optimization

Wotao Yin

Sparse optimization has found interesting applications in many data-processing areas such as compressed sensing, machine learning, signal processing, medical imaging, finance, etc. After reviewing compressed sensing and sparse optimization, this talk then introduces novel algorithms tailored for very large scale sparse optimization problems with very big data. Besides the typical complexity analysis, we analyze the overhead due to parallel and distributed computing. Numerical results are presented to demonstrate the scalability of the parallel codes for handling problems with hundreds of gigabytes of data under 2 minutes on the Amazon EC2 cloud computer.

The work is joint with Zhimin Peng and Ming Yan.

Part II

Contributed Talks

Reducing The Number of Updates for The Limited Memory Quasi-Newton Methods

Mehiddin Al-Baali

The limited-memory L-BFGS method of Nocedal for large-scale unconstrained optimization will be considered. On each iteration of this method a fixed number, say m, of updates is usually employed. Since the number of function and gradient evaluations required to solve an optimization problem is usually decreased, while the cost of updates is increased, as m increased, the choice of m plays an important role in practice. The possibility of defining m sufficiently large and employing a small number of updates in certain cases will be proposed on the basis of certain simple measures for Hessian approximations. We will focus on our recent damped technique, in modified quasi-Newton methods for unconstrained optimization, which extends that of Powell (1978) in the damped BFGS method for constrained optimization that uses Lagrange functions. Some numerical results will be described to show, in particular, that the proposed measures improve the performance of the L-BFGS method substantially when applied to certain unconstrained optimization problems. Since the damped technique enforces safely the positive definiteness property of any quasi-Newton update, other results will be presented.

Keywords: Large-Scale Optimization, L-BFGS Method, Damped-Technique, Line Search Framework.

Multi-stage Convex Relaxation for Rank Regularized Minimization Problem

Shujun Bi

In this talk, we introduce a multi-stage convex relaxation approach to the rank regularized problem with a certain ball constraint. Specifically, we first reformulate this nonconvex and nonsmooth problem as an equivalent continuous augmented optimization problem with a semi-bilinear equality constraint by a variational characterization of rank function, and then show that the penalty problem yielded by adding the semi-bilinear constraint to the objective is exact in the sense that it has the same global optimal solution set as the equivalent continuous augmented optimization problem. By solving the penalty problem in an alternating way, we propose a framework to design the multi-stage convex relaxation approach for the rank regularized problem. This class of approaches consist of solving a sequence of semi-nuclear norm convex regularized problems, and particularly includes the adaptive semi-nuclear norm method with a truncated technique（see Miao, Pan and Sun, 2013）. We apply the multi-stage convex relaxation approach to the rank regularized least square problem, and establish the error bound of the optimal solution of the k-th stage to the global optimal solution under some condition weaker than the RIP, which reveals that the proposed multi-stage convex relaxation approach is superior to the nuclear norm convex relaxation. Finally, numerical results are reported to illustrate the efficiency of the proposed method.

Keywords: rank regularized problem; exact penalty; multi-stage convex relaxation; rank regularized least square.

Complexity Analysis of Interior Point Algorithms for Non-Lipschitz and Nonconvex Minimization

Wei Bian

We propose a first order interior point algorithm for a class of non-Lipschitz and nonconvex minimization problems with box constraints, which arise from applications in variable selection and regularized optimization. The objective functions of these problems are continuously differentiable typically at interior points of the feasible set. Our first order algorithm is easy to implement and the objective function value is reduced monotonically along the iteration points. We show that the worst-case iteration complexity for finding an ϵ scaled first order stationary point is $O(\epsilon^{-2})$. Furthermore, we develop a second order interior point algorithm using the Hessian matrix, and solve a quadratic program with a ball constraint at each iteration. Although the second order interior point algorithm costs more computational time than that of the first order algorithm in each iteration, its worst-case iteration complexity for finding an ϵ scaled second order stationary point is reduced to $O(\epsilon^{-\frac{3}{2}})$. Note that an ϵ scaled second order stationary point must also be an ϵ scaled first order stationary point.

This is a join work with Xiaojun Chen and Yinyu Ye.

Computing k Largest Eigenvalues of Supersymmetric Tensors

Chunfeng Cui

A tensor is a multidimensional array. Computing the largest eigenvalue of super-symmetric tensors is equivalent to solving a constrained homogenous polynomial optimization problem. We put forward a new model for computing the k largest eigenvalues based on the exact Jacobian relaxation. Furthermore, it is well-known in numerical algebra that the k-largest eigenvectors and the best rank-k approximation of symmetric matrices are equivalent, yet it is not true for supersymmetric tensors. We will analysis different formulations in the tensor case. Some preliminary numerical results will be presented.

This work is joint with Prof. Yu-Hong Dai and Prof. Jiawang Nie.

A Derivative-Free Trust-Region Algorithm for Composite Nonsmooth Optimization

Geovani Nunes Grapiglia

A derivative-free trust-region algorithm is proposed for minimizing the nonsmooth composite function $F(x) = h(f(x))$, where f is smooth and h is convex. This formulation includes problems of finding feasible points of nonlinear systems of inequalities (where $h(f) \equiv \|f^+\|_p$, with $f_i^+ = \max\{f_i, 0\}$ and $1 \leq p \leq +\infty$), finite minimax problems (where $h(f) \equiv \max_{1 \leq i \leq m} f_i$), and best L_1, L_2 and L_∞ approximation problems (where $h(f) \equiv \|f\|_p$, $p = 1, 2, \infty$). The algorithm combine ideas from Powell (1983), Yuan (1985) and Conn, Scheinberg and Vicente (2009). Under some conditions, global convergence results are given. Preliminary numerical tests indicate that the algorithm is promising.

A Quadratic Iterative Method to Compute Eigenvectors

S. Jimenez

We combine two iterative methods, a first one with linear convergence as a primer and a second one with quadratic convergence, and obtain an effectively quadratic iterative method that converges towards an eigenvector of a square matrix that corresponds to the eigenvalue with greater real part. The method can also be adjusted to converge towards eigenvectors of other eigenvalues.

This is a joint work with L. Vazquez.

Dual Purpose Subspace Tracking on Noncompact Stiefel Manifold

Lijun Liu

Fast estimation and tracking of the principal or minor subspace of a sequence of random vectors is a major problem in many applications. Due to the numerical complexity of the task, eigenvalue decomposition (EVD) cannot be directly performed at every time step. This observation motivates research to find a way to recursively compute the subspace basis, which are usually formulated as optimization problems with orthogonality constraints. However, it is generally difficult to solve such optimization problems since the constraints can lead to many local minimizers and, in particular, several of these problems in special forms are NP-hard. Moreover, even generating a sequence of feasible points is not easy since preserving the orthogonality constraints can be numerically expensive.

In this talk, we address the problem of subspace tracking for the principal subspace as well as the minor subspace in a dual learning style utilizing the geometric structure of Grassmann manifold. We restate the subspace tracking problem as an optimization of an extended Rayleigh Quotient on the noncompact Stiefel manifold. A dual purpose gradient procedure for the extended Rayleigh Quotient is obtained by introducing a Riemannian metric on the noncompact Stiefel manifold. Compared to the other subspace tracking algorithms, the proposed algorithm has demonstrated an increased stability, a low complexity and good performances.

A Node-based SDP Relaxation Approach for Sensor Network Localization

Tianxiang Liu

In this report we propose a new model to solve the sensor network localization problem. This method is based on the semidefinite programming (SDP) relaxation, which is actually a further relaxation of the node-based SDP, called RNSDP. To reduce problem scale, in the precondition, we use a trick of edge sparsification. After RNSDP, we use a gradient search method to refine the solution. Numerical results show the efficiency of this method for random produced medium-sized localization problems.

Symmetric Low-Rank Product Matrix Approximation and Gauss Newton Method

Xin Liu

We consider computing an eigenspace of an n by n symmetric matrix A corresponding to a set of k largest positive eigenvalues. We derive an efficient formula for applying the Gauss-Newton method to this problem, formulated as minimizing the Frobenius norm of A-XX' where X is n by k and XX' is called a symmetric low-rank product (SLRP). Preliminary numerical results are presented to demonstrate the potential of the algorithm in suitable applications.

Non-Convex L_q Minimization: Complexity Analysis and A Potential Reduction Algorithm

Ya-Feng Liu

We consider the L_q minimization problem: finding a minimizer of $\| \max\{b - Ax, 0\} \|_q^q + c^T x$ subject to $l \le x \le u$ for given $A \in \mathcal{R}^{m \times n}, b \in \mathcal{R}^m, c, l, u \in \mathcal{R}^n$ and the parameter $q \in (0, 1)$. This problem can be regarded as a non-convex approximation of the sparse L_0 minimization problem, which finds a large number of applications such as wireless communications, signal processing, discriminant analysis, and machine learning. In this talk, we shall first give some exact recovery results, i.e., under which conditions, the solution of the L_q minimization problem will be the global minimizer of its corresponding sparse L_0 minimization problem. We shall also show that, the L_q minimization problem is strongly NP-hard for any given $q \in (0, 1)$, including its smoothed version. Finally, we shall extend the interior-point potential reduction algorithm to solve the L_q minimization problem. The potential reduction algorithm is guaranteed to return an ϵ-KKT solution of the L_q minimization problem in polynomial time.

This is a joint work with Shiqian Ma, Yu-Hong Dai, and Shuzhong Zhang.

Multi-stage Convex Relaxation Approach for PSD Structured Low-rank Optimization Problems

Shaohua Pan

This paper is concerned with positive semidefinite (PSD) structured low-rank matrix optimization problems. For this class of NP-hard problems, we use a family of spectral functions to reformulate it as a mathematical program with PSD equilibrium constraints (MPSDEC for short), and show that the penalty problem of this MPSDEC, yielded by adding the equilibrium constraints to the objective, is exact in the sense that it has the same global optimal solution set as the MPSDEC problem when the penalty parameter is over a certain threshold. Then, by solving the exact penalty problem of the MPSDEC in an alternating way, we propose a unified framework to design the multi-stage convex relaxation approach for the PSD structured low-rank optimization problem, which consists of solving a sequence of weighted trace-norm minimization problems. This framework particularly includes the reweighted trace-norm minimization method with a truncated technique (see Mohan 2010 and Miao 2013). For the proposed multi-stage convex relaxation approach, we establish the error bound between the optimal solution of the k-th stage and the global optimal solution under a weaker condition than the RIP. Numerical results are also reported for several classes low-rank structured matrix recovery, including the low-rank covariance matrix recovery, the low-rank correlation matrix recovery, the low-rank density matrix recovery, and the low-rank Toeplitz matrix recovery, which verify the efficiency of the proposed approach. Keywords: Multi-stage convex relaxation; structure; low-rank matrix recovery; mathematical program with PSD equilibrium constraints.

Data Clustering Based On The Total Variation Energy Functional

Zhi-Feng Pang

The performance of the data clustering highly relies on the proposed model and the numerical algorithms. Following from the extension of the total variation functional in the spatially continuous setting, in this report we propose some efficient numerical methods to solve it based on the alternating direction method of multipliers(ADMM) and the primal-dual method(PDM). We show the convergence of proposed numerical methods under the framework of variational inequalities. Some numerical examples are arranged for solving the balanced clustering problem and the unbalanced clustering problem to illustrate the efficiency of our proposed methods.

Partial Convolution for Total Variation Problem by Augmented Lagrangian-based Proximal Point Descent Algorithm

Yuan Shen

In the field of image processing field, recovering an image from its blurry and noisy observation is a classic problem. A new dedicated alternating minimization method (ADM) arises from a new structured total variation (TV) regularization-based optimization problem has been proposed and intensively studied. This algorithm is called "Fast Total Variation Deconvolution" (FTVD), and its per-iteration computational cost is dominated by only several fast Fourier transforms (FFT) and convolution operations which are cheap to compute, so they are practical methods. However, this algorithm is only applicable to full convolution model, hence they can not handle more difficult problems. In this paper, we propose a partial convolution model as well as a dedicated algorithm which is based on the idea of Ye and Yuan's ADM. Extensive numerical results show that our algorithm can produce result with much better quality while its speed performance is still comparable with several state-of-the-art algorithms.

Sum Rate Maximization Algorithms for MIMO Relay Networks in Wireless Communications

Cong Sun

Sum rate maximization problem is always of great interests in the field of wireless communications. For MIMO relay networks, we propose a new approach to approximate sum rate maximization, and prove it is a lower bound of achievable sum rate. To solve the nonlinear nonconvex optimization problem, we first change the fraction function into a non-fraction function in the objective function, and show that the optimization problems share the same stationary points. By applying the alternating minimization method, we decompose the complex problem into several subproblems that are easier handled with. Moreover, we prove that the proposed models always lead to rank one solutions. From practical demand, we also add orthogonal constraints and solve the corresponding problem.

Regularized Mathematical Programs with Stochastic Equilibrium Constraints: Estimating Structural Demand Models

Hailin Sun

The article considers a particular class of optimization problems involving set-valued stochastic equilibrium constraints. A solution procedure is developed by relying on an approximation scheme for the equilibrium constraints, based on regularization, that replaces them by equilibrium constraints involving only single-valued Lipschitz continuous functions. In addition, sampling has the further effect of replacing the 'simplified' equilibrium constraints by more manageable ones obtained by implicitly discretizing the (given) probability measure so as to render the problem computationally tractable. Convergence is obtained by relying, in particular, on the graphical convergence of the approximated equilibrium constraints. The problem of estimating the characteristics of a demand model, a widely studied problem in micro-economics, serves both as motivation and illustration of the regularization and sampling procedure.

SOARS: Statistical and Optimization Analysis and Response Surfaces for Computationally Expensive Models

Yilun Wang

We are developing a new framework of Statistical and Optimization Analysis and Response Surfaces (SOARS, for short) for Computationally Expensive Objective Functions. The objective functions are computationally expensive often because they are either involving large scale complex computational simulations or complicated data processing procedure. An important application is parameter calibration of large scale complex model, where the objective function is a distance between the measured data and model output. Unlike most of parameter estimation methods, we are not only searching a single optimal solution, but also calculate its probability distribution and perform related sensitivity analysis. In brief, (global) optimization, sensitivity analysis and uncertainty analysis are the research tasks. One of our innovations is to build the framework "SOARS" to integrate them together via the adoption of response surface (also called surrogate, emulator, or metamodel), and make SOARS suitable for relatively high dimensional problems. In addition, for each of its component (optimization, sensitivity analysis and uncertainty analysis), we have proposed new efficient algorithms, especially for relatively high dimensional cases.

On the Convergence Order of the Central Path for Second Order Cone Optimization

Zhouhong Wang

In this talk, we will discuss the possible convergence order of the central path of Second Order Cone Optimization (SOCO) based upon the optimal partition for SOCO proposed by Bonnans and Ramírez (2005). First we will show that the optimal partition for SOCO can be identified along the central path when the barrier parameter μ is small enough. Then Some examples are presented to illustrate the possible convergence order of the central path of SOCO.

Key words: Second Order Cone Optimization; Optimal Partition; Convergence Order of Central Path.

On Minimizing the Ratio of Quadratic Functions over an Ellipsoid

Yong Xia

In this talk, we study the optimization problem (RQ) of minimizing the ratio of two quadratic functions over a possibly degenerate ellipsoid. The well-definition of problem (RQ) is fully characterized. We show any well-defined (RQ) admits a semi-definite programming reformulation (SDP) without any assumption. Moreover, the minimum of (RQ) is attained if and only if (SDP) has a unique solution. We finally make some extensions.

Rank-one and Sparse Nonnegative Matrix Decomposition for Surveillance Video

Xiaochao Xiu

This paper presents rank-one and sparse nonnegative matrix decomposition model for surveillance video. Based on its convex relaxation, we establish the alternating direction methods of multipliers. We also introduce a statistical approach to solve the original model with the help of its special properties. Numerical experiments are given to illustrate the efficiency of our algorithms.

Covariance Matrix Estimation Using Factor Models from Incomplete Information

Fangfang Xu

Covariance matrix estimation plays an important role in risk management, asset pricing, and portfolio allocation. This task becomes very challenging when the dimensionality is comparable or much larger than the sample size. A widely used approach for reducing dimensionality is a multi-factor model. Although it has been well studied and quite successful in many applications, the quality of the estimated covariance matrix is often degraded due to a nontrivial amount of missing data in the factor matrix for both technical and cost reasons. Since the factor matrix is only approximately low rank or even has full rank, existing matrix completion algorithms are not applicable. In this paper, we consider a new matrix completion model based on the factor model directly and apply the alternating direction method of multiplier for the recovery. Numerical experiments show that our proposed models and algorithms are helpful.

Joint User Grouping and Linear Virtual Beamforming: Complexity, Algorithms and Approximation Bounds

Zi Xu

In this work, we consider the problem of properly selecting a subset of users to form the virtual multi-antenna system, while at the same time designing their joint transmission strategies. In the aim of designing practical algorithms with provable theoretical performance, we focus on a class of simple yet important scenarios in which either multiple transmitters cooperatively transmit to a receiver, or a single transmitter transmits to the receiver with the help of a set of cooperative relays. We formulate the joint problems in different settings as cardinality constrained programs that contain both discrete and continuous variables. We then leverage the technique of semi-definite relaxation to obtain approximated solutions for them. The effectiveness of the proposed algorithms is evaluated via both theoretical analysis as well as extensive numerical experiments. We expect that our approach can be applied to solve cross-layer resource allocation problems in many other wireless communication systems as well.

Regularizations for Stochastic Linear Variational Inequalities

Yanfang Zhang

This paper applies the Moreau-Yosida regularization to a convex expected residual minimization formulation for a class of stochastic linear variational inequalities. To have the convexity of the corresponding sample average approximation problem , we adopt the Tikhonov regularization. We show that any cluster point of minimizers of the Tikhonov regularization for the sample average approximation problem is a minimizer of the expected residual minimization formulation with probability one as the sample size goes to infinity and the Tikhonov regularization parameter goes to zero. Moreover, we prove that the minimizer is the least l2-norm solution of the expected residual minimization formulation. We also prove the semismoothness of the gradient of the Moreau-Yosida and Tikhonov regularizations for the sample average approximation problem.

A Subspace Decomposition Framework for Nonlinear Optimization

Zaikun Zhang

We discuss a general subspace decomposition framework for optimization (for the moment without constraints). Two versions of the framework are presented, namely a Levenberg-Marquardt version and a trust-region one. We establish global (asymptotic) convergence and derive global rates for both of them. We also discuss how to exploit the framework to design parallel and multilevel derivative-free algorithms for large-scale problems.

This is a joint work with S. Gratton (ENSEEIHT-INT and CERFACS, France) and L. N. Vicente (University of Coimbra, Portugal).

Accelerated Modulus-based Matrix Splitting Iteration Methods for Linear Complementarity Problem

Ning Zheng

For the large sparse linear complementarity problem, a class of accelerated modulusbased matrix splitting iteration methods is established by reformulating it as a general implicit fixed-point equation, which covers the known modulus-based matrix splitting iteration methods. The convergence conditions are presented when the system matrix is either a positive definite matrix or an H+-matrix, and the optimal iteration parameters in accelerated modulus-based AOR method are determined by minimizing the spectral radius of the iteration matrix. Numerical experiments further show that the proposed methods are efficient and accelerate the convergence performance of the modulus-based matrix splitting iteration methods with less iteration steps and CPU time.

New RIC Bounds vea l_q-minimization with $0 < q \leq 1$ in Compressed Sensing

Shenglong Zhou

The restricted isometry constants (RICs) play an important role in exact recovery theory of sparse signals via $l_q(0 < q \leq 1)$ relaxations in compressed sensing. Recently, Cai and Zhang have achieved a sharp bound $\delta_{tk} < \sqrt{1-1/t}$ for $t \geq \frac{4}{3}$ to guarantee the exact recovery of k sparse signals through the l_1 minimization. This paper aims to establish new RICs bounds via $l_q(0 < q \leq 1)$ relaxation. Based on a key inequality on l_q norm, we show that (i) the exact recovery can be succeeded via $l_{1/2}$ and l_1 minimization if $\delta_{tk} < \sqrt{1-1/t}$ for $t \geq 1$, (ii) several sufficient conditions can be derived, such as for any $q \in (0, \frac{1}{2})$, $\delta_{2k} < 0.5547$ when $k \geq 2$, for any $q \in (\frac{1}{2})$, $\delta_{2k} < 0.6782$ when $k \geq 1$, (iii) the bound on δ_k is given as well as for any $0 < q \leq 1$, especially for $q = \frac{1}{2}, 1$, we obtain $\delta_k < \frac{1}{3}$ when $k(\geq 2)$ is even or $\delta_k < 0.3203$ when is $k(\geq 3)$ odd.

Keywords: compressed sensing, bound, restricted isometry constant, l_q minimization, exact recovery.

A Modified Primal-dual Augmented Lagrangian Method for Large Scale Nonlinear Optimization

Wenwen Zhou

The Primal Dual Augmented Lagrangian approach [1] has been proposed for large-scale nonconvex optimization. This approach has a number of promising features including a natural extension to a matrix-free environment. Our numerical experience indicates that the algorithm can have difficulty when the problem is locally infeasible or badly scaled. The addition of a modified version of the feasibility restoration phase[2] typically used in filter methods is proposed with the added goal of improving Lagrange multiplier estimates when the problem is feasible.

Hybrid Divide-and-Conquer Methods for Solving Polynomial Systems

Bo Yu

In this talk, a brief introduction of some hybrid divide-and-conquer methods for solving polynomial systems will be given. At first, for polynomial systems derived from mixed trigonometric polynomial systems, a hybrid homotopy and its improved symmetric version will be introduced, and the sketch of a hybrid divide-and-conquer method for this special class of polynomial systems will be formulated. Then, a framework of a general-purpose hybrid divide-and-conquer method for solving deficient polynomial systems will be given. Some numerical results will also be given to show the efficiency of the proposed algorithm.

Analysis of Conjugate Gradient for Nonsmooth Problems

Gonglin Yuan

The conjugate gradient (CG) method is one of the most popular methods for solving smooth unconstrained optimization problems due to its simplicity and low memory requirement. However, the usage of CG methods are mainly restricted in solving smooth optimization problems so far. The purpose of this report is to present efficient conjugate gradient-type methods to solve nonsmooth optimization problems. By using the Moreau-Yosida regulation (smoothing) approach, we propose a modified Polak-Ribière-Polyak (PRP) CG algorithm for solving a nonsmooth unconstrained convex minimization problem. Our algorithm possesses the following three desired properties. (i) The search direction satisfies the sufficiently descent property and belongs to a trust region automatically; (ii) The search direction makes use of not only gradient information but also function information; (iii) The algorithm inherits an important property of the well-known PRP method: the tendency to turn towards the steepest descent direction if a small step is generated away from the solution, preventing a sequence of tiny steps from happening. Under standard conditions, we show that the algorithm converges globally to an optimal solution. Numerical experiment shows that our algorithm is effective and suitable for solving large-scale nonsmooth unconstrained convex optimization problems.

This is a joint work with Zengxin Wei and Guoyin Li.

A Novel Filled Function Method for Nonlinear Equations

Liuyang Yuan

In this paper a novel filled function method is suggested for solving box-constrained systems of nonlinear equations. Firstly, the original problem is converted into an equivalent global optimization problem. Subsequently, a novel filled function with one parameter is proposed for solving the converted global optimization problem. Some properties of the filled function are studied and discussed. Finally, an algorithm based on the proposed novel filled function for solving systems of nonlinear equations is presented. The objective function value can be reduced by quarter in each iteration of our algorithm. The implementation of the algorithm on several test problems is reported with satisfactory numerical results.

Nonconvex ℓ_p-Regularization and Box Constrained Model for Image Restoration

Chao Zhang

Nonsmooth nonconvex regularization has remarkable advantages for the restoration of piecewise constant images. Constrained optimization can improve the image reconstruction using a priori information. In this paper, we study regularized nonsmooth nonconvex minimization with box constraints for image restoration. We present a computable positive constant θ for using nonconvex nonsmooth regularization, and show that the difference between each pixel and its four adjacent neighbors is either 0 or larger than θ in the recovered image. Moreover, we give an explicit form of θ for the box constrained image restoration model with the non-Lipschitz nonconvex ℓ_p-norm ($0 < p < 1$) regularization. Our theoretical results show that any local minimizer of this imaging restoration problem is composed of constant regions surrounded by closed contours and edges. Numerical examples are presented to validate the theoretical results and show that the proposed model can recover image restoration results very well.

This is a joint work with Xiaojun Chen and Michael K. Ng.

On the Second-order Directional Derivatives of Singular Values of Matrices and Symmetric Matrix-valued Functions

Liwei Zhang

The (parabolic) second-order directional derivatives of singular values of matrices and symmetric matrix-valued functions induced by real-valued functions play important roles in studying second-order optimality conditions for different types of matrix cone optimization problems. We propose a direct way to derive the formula for the second-order directional derivative of any eigenvalue of a symmetric matrix in Torki (2001), from which a formula for the second-order directional derivative of any singular value of a matrix is established. We demonstrate a formula for the second-order directional derivative of the symmetric matrix-valued function. As applications, the second-order derivative for the projection operator over the SDP cone is derived and used to get the second-order tangent set of the SDP cone in Bonnans and Shapiro (2000), and the tangent cone and the second-order tangent set of the epigraph of the nuclear norm are given as well.

Stochastic Variational Inequalities: Residual Minimization Smoothing/Sample Average Approximations

Yanfang Zhang

The stochastic variational inequality (SVI) has been used widely, in engineering and economics, as an effective mathematical model for a number of equilibrium problems involving uncertain data. This paper presents a new expected residual minimization (ERM) formulation for a class of SVI. The objective of the ERM-formulation is Lipschitz continuous and semismooth which helps us guarantee the existence of a solution and convergence of approximation methods. We propose, a globally convergent (a.s.) smoothing sample average approximation (SSAA) method to minimize the residual function; this minimization problem is convex for linear SVI if the expected matrix is positive semi-definite. We show that the ERM problem and its SSAA problems have minimizers in a compact set and any cluster point of minimizers and stationary points of the SSAA problems is a minimizer and a stationary point of the ERM problem (a.s.). Our examples come from applications involving traffic flow problems. We show that the conditions we impose are satisfied and that the solutions, efficiently generated by the SSAA-procedure, have desirable properties.

This is a joint work with Xiaojun Chen and Roger J-B Wets.

Computing Dominant SVD of Large and Unstructured Matrices

Yin Zhang

Singular value decompositions (SVD) is a fundamental computational tool in many data-intensive applications where usually a dominant part of SVD is computed such as in principal component analysis. Various algorithms have been developed for efficiently computing dominant SVD of large sparse matrices, but they may not be the most suitable for large and unstructured matrices. We propose a limited memory Krylov subspace optimization scheme to significantly accelerate the simple subspace iteration scheme. Theoretical and extensive numerical results will be presented showing a superior performance of the proposed algorithm over a wide range of unstructured matrices.

Joint work with Xin Liu and Zaiwen Wen.

Sobolev Seminorm of Quadratic Functions with Applications to Derivative-Free Optimization

Zaikun Zhang

In this talk, we inspect the classical H^1 Sobolev seminorm of quadratic functions over balls of $\mathbb{R}^n$. We express the seminorm explicitly in terms of the coefficients of the quadratic function under consideration. The seminorm gives some new insights into the least-norm interpolation widely used in derivative-free optimization. It shows the geometrical/analytical essence of the least-norm interpolation and explains why it is successful. We finally present some numerical results to show that H^1 seminorm is helpful to the model selection of derivative-free optimization.

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Excursion Information

Fujian Tulou[1]

Fujian Tulou (Chinese: 福建土楼; pinyin: Fú Jiàn Tǔ Lóu, literally, "Fujian earthen structures") is a type of Chinese rural dwellings of the Hakka and others in the mountainous areas in southeastern Fujian, China. They were mostly built between the 12th and the 20th centuries.

A tulou is usually a large, enclosed and fortified earth building, rectangular or circular in configuration, with very thick load-bearing rammed earth walls between three and five storeys high and housing up to 80 families. Smaller interior buildings are often enclosed by these huge peripheral walls which can contain halls, storehouses, wells and living areas, the whole structure resembling a small fortified city.

The fortified outer structures are formed by compacting earth, mixed with stone, bamboo, wood and other readily available materials, to form walls up to 6 feet (1.8 m) thick. Branches, strips of wood and bamboo chips are often laid in the wall as additional reinforcement. The end result is a well-lit, well-ventilated, windproof and earthquake-proof building that is warm in winter and cool in summer.Tulous usually have only one main gate, guarded by 4 – 5-inch-thick (100 – 130 mm) wooden doors reinforced with an outer shell of iron plate. The top level of these earth buildings has gun holes for defensive purposes.

A total of 46 Fujian Tulou sites, including Chuxi tulou cluster, Tianluokeng tulou cluster, Hekeng tulou cluster, Gaobei tulou cluster, Dadi tulou cluster, Hongkeng tulou cluster, Yangxian lou, Huiyuan lou, Zhengfu lou and Hegui lou, have been inscribed in 2008 by UNESCO as World Heritage Site, as "exceptional examples of a building tradition and function exemplifying a particular type of communal living and defensive organization in a harmonious relationship with their environment".

[1]from Wikipedia: http://en.wikipedia.org/wiki/Fujian_Tulou.

Gulangyu Island[1]

Gulangyu (Chinese: 鼓浪屿; pinyin: Gǔ Làng Yǔ, literally, "Drum Wave Islet") is a car free island off the coast of Xiamen, Fujian province in southern China, about 2 square kilometres (0.77 sq mi) in area. It is home to about 20,000 people and is a very popular tourist destination. Visitors can reach it by ferry from Xiamen Island in about 5 minutes. Gulangyu Island is renowned for its beaches and winding lanes and its varied architecture. The island is on China's list of National Scenic Spots and also ranks at the top of the list of the ten most-scenic areas in Fujian Province.

Xiamen (formerly known as Amoy) became a treaty port resulting from China's loss in the First Opium War and the Treaty of Nanking in 1842, hence the predominantly Victorian-era style architecture throughout Gulangyu Island, where 13 countries including Great Britain, France and Japan established consulates, churches, and hospitals. Gulangyu was officially designated an International Settlement in 1903. Japanese occupation of the island began in 1942, and lasted until the end of World War II. The Amoy dialect of Hokkien is spoken on the island.

As a place of residence for Westerners during Xiamen's colonial past, Gulangyu is famous for its architecture and for hosting China's only piano museum, giving it the nickname of "Piano Island" or "The Town of Pianos" or "The Island of Music". There are over 200 pianos on this island. The Chinese name also has musical roots, as "Gu Lang" means drum waves so-called because of the sound generated by the ocean waves hitting the reefs. Yu means "islet".

In addition, on the west beach of the island you can rent pedal boats and jet skis. There's a garden of 12 grottos to represent each of the animals on the zodiac. Built into the hillside, its a maze of caves and tunnels to find all twelve (and the exit). There are many boutique hotels to stay in as well. The island of Gulangyu is a pedestrian only destination, where the only vehicles on the islands are several fire trucks and electric tourist buggies. The narrow streets on the island, together with the architecture of various styles around the world, give the island a unique appearance.

[1] from Wikipedia: http://en.wikipedia.org/wiki/Gulangyu_Island.

The organizing committee wishes you a pleasant stay in Xiamen!