# Contents

# Introduction

Inverse Problems has become a very active, interdisciplinary and well-established research area over the past two decades, the same as Optimal Control. Both areas are closely related to each other and have found wide applications in engineering, industry, medicine, as well as life and earth sciences.

This international conference aims to provide a forum for researchers from the world to present and exchange their latest research achievements on Inverse Problems and Optimal Control, as well as their applications. It also aims to promote collaborative research on Inverse Problems and Optimal Control between China and the rest of the world. This conference will encourage international collaboration and interactive activities on inverse problems and optimal control and provide an opportunity for young researchers to learn the current state of the art in the fields and present their recent research results as well.

Professor Kazufumi Ito has been well recognized as one of the most active and productive mathematicians in the areas of inverse problems and optimal control. He has made tremendous contributions to both fields throughout his career. For this reason, two special mini-symposia are organized in this conference to honor Professor Ito at his $60^{th}$ birthday for his contributions to inverse problems and optimal control.

# Scientific Committee

| | |
|---|---|
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| Thomas BANKS, | North Carolina State University, USA |
| Tatsien LI, | Fudan University, China |
| Peter MAASS, | University of Bremen, Germany |
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| Masahiro YAMAMOTO, | The University of Tokyo, Japan |
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# Plenary Speakers

| | |
|---|---|
| Habib AMMARI, | Ecole Normale Superieure, France |
| Guillaume BAL, | Columbia University, USA |
| Thomas BANKS, | North Carolina State University, USA |
| Gang BAO, | Zhejiang University, China |
| Tony F CHAN, | The Hong Kong University of Science and Technology, Hong Kong |
| Zhiming CHEN, | Chinese Academy of Sciences, China |
| Qiang DU, | Computational Science Research Center, Beijing, China |
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| Michael HINTERMULLER, | Humboldt-University of Berlin, Germany |
| Kazufumi ITO, | North Carolina State University, USA |
| Bangti JIN, | University College London, UK |
| Michael KLIBANOV, | University of North Carolina at Charlotte, USA |
| Tatsien LI, | Fudan University, China |
| Hongyu LIU, | Hong Kong Baptist University, Hong Kong |
| Peter MAASS, | University of Bremen, Germany |
| Lassi PÄIVÄRINTA, | University of Helsinki, Finland |
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| | University of Washington, USA |
| Yanfei WANG, | Chinese Academy of Sciences, China |
| Masahiro YAMAMOTO, | The University of Tokyo, Japan |
| Hongkai ZHAO, | Peking University, China |
| | University of California, Irvine, USA |

# Schedule Overview

*Thursday, December 4, 2014*

| | Mong Man Wai Building (MMW), LT2 |
|---|---|
| 8:30am | Registration |
| 9:10am | Opening |
| 9:15am | Heinz Engl |
| 9:50am | Qiang Du |
| 10:25am | Photo-taking & Coffee break |
| 10:50am | Tony F Chan |
| 11:25am | Hongkai Zhao |
| 12:00noon | Lunch |
| 1:30pm | Thomas Banks |
| 2:05pm | Zhiming Chen |
| 2:40pm | Yanfei Wang |
| 3:15pm | Coffee break |
| 3:35pm | William Rundell |
| 4:10pm | Hongyu Liu |
| 4:45pm | Lassi Päivärinta |

*Friday, December 5, 2014* *(*All contributed talks (CT) will be held at MMW 705)*

| | MMW, LT2 | *MMW, 705 |
|---|---|---|
| 9:00am | Gunther Uhlmann | |
| 9:35am | Guillaume Bal | |
| 10:10am | Peter Maass | |
| 10:45am | Coffee break | |
| 11:05am | Yalchin Efendiev | |
| 11:40am | Habib Ammari | |
| 12:15pm | Lunch | |
| 1:45pm | Kazufumi Ito | |
| 2:20pm | Jingzhi Li (MS-1) | Eldad Haber (CT-1) |
| 2:45pm | Yifeng Xu (MS-2) | Quy Muoi Pham (CT-2) |
| 3:10pm | Xiliang Lu (MS-3) | Alexander Litvinenko (CT-3) |
| 3:35pm | Coffee break | |
| 3:55pm | Daijun Jiang (MS-4) | Fang Zeng (CT-4) |
| 4:20pm | Yat-Tin Chow (MS-5) | Xiaomao Deng (CT-5) |
| 4:45pm | Youjun Deng (MS-6) | Ruanui Nicholson (CT-6) |
| 5:10pm | Peijun Li (MS-7) | |
| 6:00pm | Banquet | |

## *Saturday, December 6, 2014*

| | Mong Man Wai Building (MMW), LT2 |
|---|---|
| 9:00am | Tatsien Li |
| 9:35am | Michael Hintermuller |
| 10:10am | Gang Bao |
| 10:45am | Coffee break |
| 11:05am | Michael Klibanov |
| 11:40am | Bangti Jin |
| 12:15pm | Lunch |
| 1:45pm | Masahiro Yamamoto |
| 2:20pm | Franz Kappel (MS-8) |
| 2:45pm | Zhilin Li (MS-9) |
| 3:10pm | Christian Clason (MS-10) |
| 3:35pm | Coffee break |
| 3:55pm | Yao Lu (MS-11) |
| 4:20pm | Marius Tucsnak (MS-12) |
| 4:45pm | Jari Toivanen (MS-13) |
| 5:10pm | Carlos Rautenberg (MS-14) |

# Schedule with Titles of Talks

*Thursday, December 4, 2014*

| | Mong Man Wai Building (MMW), LT2 |
|---|---|
| 8:30am | Registration |
| 9:10am | Opening |
| **Chair** | **Jun Zou** |
| 9:15am | Heinz Engl<br>*Industrial mathematics and nonlinear inverse problems* |
| 9:50am | Qiang Du<br>*Optimization problems related to nonlocal models* |
| 10:25am | Photo-taking & Coffee break |
| **Chair** | **Heinz Engl** |
| 10:50am | Tony F Chan<br>*Four color theorem for image segmentation* |
| 11:25am | Hongkai Zhao<br>*Approximate separability of Green's function for Helmholtz equation in the high frequency limit* |
| 12:00noon | Lunch |
| **Chair** | **William Rundell** |
| 1:30pm | Thomas Banks<br>*Estimation of distributed parameters in composite dielectric materials using reflectance data* |
| 2:05pm | Zhiming Chen<br>*Reverse time migration for inverse scattering problems* |
| 2:40pm | Yanfei Wang<br>*Data regularization and imaging using sparse optimization* |
| 3:15pm | Coffee break |
| **Chair** | **Gunther Uhlmann** |
| 3:35pm | William Rundell<br>*Inverse problems for fractional diffusion; some things we know and many more we don't* |
| 4:10pm | Hongyu Liu<br>*Recovery by a single far-field measurement* |
| 4:45pm | Lassi Päivärinta<br>*Scattering by corners* |

## *Friday, December 5, 2014*

| | MMW, LT2 | MMW, 705 |
|---|---|---|
| **Chair** | **Habib Ammari** | |
| 9:00am | Gunther Uhlmann<br>*Seeing through space time* | |
| 9:35am | Guillaume Bal<br>*Some mathematical problems in elastography* | |
| 10:10am | Peter Maass<br>*Inverse problems with sparsity constraints: application in image processing and digital pathology* | |
| 10:45am | Coffee break | |
| **Chair** | **Zhiming Chen** | |
| 11:05am | Yalchin Efendiev<br>*Uncertainty quantification in inverse problems with multilevel approaches* | |
| 11:40am | Habib Ammari<br>*Bio-inspired imaging* | |
| 12:15pm | Lunch | |
| **Chair** | **Masahiro Yamamoto** | |
| 1:45pm | Kazufumi Ito<br>*Direct sampling method for inverse medium problem* | |
| **Chair** | **Bangti Jin** | **Eric Chung** |
| 2:20pm | Jingzhi Li (MS-1)<br>*Numerical reconstruction for distributed fluxes by an adaptive finite element method* | Eldad Haber (CT-1)<br>*Stochastic optimization techniques for large scale & data rich inverse problems* |
| 2:45pm | Yifeng Xu (MS-2)<br>*An adaptive finite element method for reconstruction of the Robin coefficient* | Quy Muoi Pham (CT-2)<br>*Non-smooth minimization problems of matrix variable and applications* |
| 3:10pm | Xiliang Lu (MS-3)<br>*A primal dual active set algorithm for sparse optimization problems* | Alexander Litvinenko (CT-3)<br>*Inverse problems & uncertainty quantification* |
| 3:35pm | Coffee break | |
| **Chair** | **Masahiro Yamamoto** | **Eric Chung** |
| 3:55pm | Daijun Jiang (MS-4)<br>*Levenberg-Marquardt Method for Robin inverse problem in an elliptic system* | Fang Zeng (CT-4)<br>*A reciprocity gap method for an interior inverse scattering problem* |
| 4:20pm | Yat-Tin Chow (MS-5)<br>*Direct sampling method for electrical impedance tomography and diffusive optical tomography* | Xiaomao Deng (CT-5)<br>*Reduced & full space methods for unsteady point source inversion problems* |
| 4:45pm | Youjun Deng (MS-6)<br>*Reconstruction of inhomogeneous conductivity from generalized polarization tensors* | Ruanui Nicholson (CT-6)<br>*Multiscale finite element methods applied to electrical impedence tomography* |
| 5:10pm | Peijun Li (MS-7)<br>*Inverse elastic surface scattering with near-field data* | |
| 6:00pm | Banquet | |

## *Saturday, December 6, 2014*

| | Mong Man Wai Building (MMW), LT2 |
|---|---|
| **Chair** | **Qiang Du** |
| 9:00am | Tatsien Li<br>*Criteria of Kalman's type to the approximate controllability and the approximate synchronization for a coupled system of wave equations with dirichlet boundary controls* |
| 9:35am | *Michael Hintermuller*<br>*Generalized nash equilibrium problems in banach spaces* |
| 10:10am | Gang Bao<br>*Inverse problems in wave propagation* |
| 10:45am | Coffee break |
| **Chair** | **Gang Bao** |
| 11:05am | Michael Klibanov<br>*Global convergence for inverse problems and phaseless inverse problems* |
| 11:40am | Bangti Jin<br>*Numerical methods for fractional elliptic problems, with an application to inverse eigenvalue problems* |
| 12:15pm | Lunch |
| **Chair** | **Thomas Banks** |
| 1:45pm | Masahiro Yamamoto<br>*Inverse problems for fractional diffusion equations* |
| **Chair** | **Michael Hintermuller** |
| 2:20pm | Franz Kappel (MS-8)<br>*Control of the cardiovascular-respiratory system under time varying workloads* |
| 2:45pm | Zhilin Li (MS-9)<br>*Immersed finite elements for optimal control problems of elliptic PDEs with interfaces* |
| 3:10pm | Christian Clason (MS-10)<br>*A convex analysis approach to switching control of PDEs* |
| 3:35pm | Coffee break |
| **Chair** | **Christian Clason** |
| 3:55pm | Yao Lu (MS-11)<br>*Fast collocation method for model-based image restoration* |
| 4:20pm | Marius Tucsnak (MS-12)<br>*Estimatability and observers for a model of population dynamics with diffusion and age dependence* |
| 4:45pm | Jari Toivanen (MS-13)<br>*Active noise control in stochastic domains* |
| 5:10pm | Carlos Rautenberg (MS-14)<br>*On a shape optimization problem for navier-Stokes applied to flow in a duct* |

# Titles and Abstracts

# Plenary Talks

# Bio-inspired Imaging


## Habib Ammari

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### Abstract


In this talk, we will discuss bio-inspired imaging. We will present results for shape identification in electrosensing using pulse form and waveform signals. We will also introduce efficient and novel approach for shape classification in echolocation.


# Some Mathematical Problems in Elastography


## Guillaume Bal

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### Abstract


Elastography is a medical imaging modality aiming to reconstruct the elastic properties of tissues. In ultrasound elastography, the displacements generated by propagating shear waves are measured by ultrasound. A first inverse problem consists of reconstructing such displacement maps from the ultrasound echos. I will present a mathematical modeling and theoretical and numerical results for such a problem. Once displacements are obtained, a second inverse problem consists of reconstructing quantitative estimates of the elastic properties of tissues. I will present a general mathematical framework for such an inverse problem and related hybrid inverse problem.

# Estimation of Distributed Parameters in Composite Dielectric Materials Using Reflectance Data


## Thomas Banks

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### Abstract

We summarize the computational and theoretical framework, the Prohorov Metric Framework, developed by our group in the past two decades for nonparametric estimation of probability measures using a least-squares and/or generalized least-squares method. We illustrate theory and computational ideas in the context of quantifying properties of a composite dielectric material through the reflectance, where the permittivity is described by the Lorentz model in which an unknown probability measure is placed on the model parameters. We demonstrate the feasibility of our proposed methods by numerical results obtained for both simulated data and experimental data for inorganic glass when considering the resonance wavenumber as a distributed parameter. Finally, in the case where the distributed parameter is taken as the relaxation time, we show how the addition of derivative measurements improves the accuracy of the method.

This research represents joint efforts with colleagues at NCSU (Jared Catenacci and Dr. Shuhua Hu) and collaborative research efforts of our group with scientists at AFRL (Materials State Awareness and Supportability Branch, Air Force Research Lab, WPAFB 45433, USA) led by Amanda K. Criner and Adam T. Cooney. In these efforts, the goal is to develop a noninvasive technique to characterize the degradation of a complex nonmagnetic dielectric material (e.g., ceramic matrix composites, which are used in a wide range of applications such as high temperature engines) by assessing the small physical and chemical changes in the material using reflectance spectroscopy. This involves determining the components of the permittivity of the composite dielectric medium using the measured spectral responses.


# Inverse Problems in Wave Propagation


## Gang Bao

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College of Science

Zhejiang University

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### Abstract

Recent progress will be reported on the inverse problems. Particular emphasis will be given to ongoing and open research topics.

# Four Color Theorem for Image Segmentation


## Tony F Chan

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## Abstract

Image segmentation is an essential problem in imaging science. One of the most successful segmentation models is the piecewise constant Mumford-Shah minimization model. This minimization problem is however difficult to carry out, mainly due to the non-convexity of the energy. Recent advances based on convex relaxation methods are capable of estimating almost perfectly the geometry of the regions to be segmented when the mean intensity and the number of segmented regions are known a priori. The next important challenge is to provide a tight approximation of the optimal geometry, mean intensity and the number of regions simultaneously while keeping the computational time and memory usage reasonable.

In this work, we propose a new algorithm that combines convex relaxation methods with the four color theorem to deal with the unsupervised segmentation problem. The proposed algorithm can segment any a priori unknown number of regions with only four intensity functions and four indicator (labeling) functions. The number of regions in our segmentation model is decided by one parameter that controls the regularization strength of the geometry, i.e., the total length of the boundary of all the regions. The segmented image function can take as many constant values as needed. We will present the detail about the new model as well the numerical techniques used to solve it. This talk is based on joint works with: Xavier Bresson (EPFL), Xue-Cheng Tai (Univ. of Bergen) and Ruiliang Zhang (HKUST).

# Reverse Time Migration for Inverse Scattering Problems


## Zhiming Chen

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Academy of Mathematics and Systems Science

Chinese Academy of Sciences

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### Abstract

Inverse scattering problems which aim to find the support of an unknown obstacle embedded in a known background medium from a knowledge of scattered waves measured on a given acquisition surface are of tremendous application interests. Reverse time migration methods that are widely used in geophysics do not require any a priori information of the physical properties of the obstacle such as penetrable or non-penetrable, and for non-penetrable obstacles, the type of boundary conditions on the boundary of the obstacle. In this talk we report our recent efforts in new mathematical understanding of the RTM method for imaging extended obstacles without resorting to the geometric optics or small inclusion assumption previously made in the literature. This new understanding leads to new imaging algorithms and new physical interpretation of the imaging results. The focus of the talk will be on reconstructing extended obstacles in the half space with finite aperture data using acoustic waves at a fixed frequency. Numerical experiments are included to illustrate the powerful imaging quality and to confirm our resolution results. This talk is a joint work with Guanghui Huang.


# Optimization Problems Related to Nonlocal Models


## Qiang Du

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### Abstract

We will discuss a few optimization problems related to nonlocal diffusion and nonlocal peridynamic models such as nonlocal variational problems and their local limits, variational coupling of local and nonlocal models, and inverse problems for identifying nonlocal interaction kernels.

# Uncertainty Quantification in Inverse Problems with Multilevel Approaches


## Yalchin Efendiev

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### Abstract

In this talk, we discuss a framework for the uncertainty quantification in inverse problems. It is based on the generalized multiscale finite element method (GMsFEM) and multilevel Monte Carlo (MLMC). The former provides a hierarchy of approximations of different resolution, whereas the latter gives an efficient way to estimate quantities of interest using samples on different levels. The number of basis functions in the online GMsFEM stage can be varied to determine the solution resolution and the computational cost, and to efficiently generate samples at different levels. In particular, it is cheap to generate samples on coarse grids but with low resolution, and it is expensive to generate samples on fine grids with high accuracy. By suitably choosing the number of samples at different levels, one can leverage the expensive computation in larger fine-grid spaces toward smaller coarse-grid spaces, while retaining the accuracy of the final Monte Carlo estimate. We describe a multilevel Markov chain Monte Carlo method, which sequentially screens the proposal with different levels of approximations and reduces the number of evaluations required on fine grids, while combining the samples at different levels to arrive at an accurate estimate. Numerical results will be presented.


# Industrial Mathematics & Nonlinear Inverse Problems


## Heinz Engl

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### Abstract

The scientific core of this talk is the functional analytic theory of nonlinear inverse problems, starting from convergence (rate) analysis of Tikhonov regularization via iterative regularization methods to more recent results about sparsity enforcing regularization. This theory is of core importance in several application areas which are described in some detail:

- inverse problems in connection with modelling the blast furnace process for iron making -identification problems in computational finance -qualitative inverse problems in systems biology in connection with modelling the HPA
- axis -a recently patented learning algorithm for blood glucose prediction
- calibration of surrogate models in automotive simulation -adaptive optics for the ESO Extremely Large Telescope.

Emphasis will be more on the theory-based use of regularization in real world application than on new theory. The projects described were guided by A.Binder, P.Kügler, S.Pereverzyev, and R.Ramlau.

# Generalized Nash Equilibrium Problems in Banach Spaces

**Michael Hintermuller**

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## Abstract

A class of non-cooperative Nash equilibrium problems is presented, in which the feasible set of each player is perturbed by the decisions of their competitors via a convex constraint. In addition, for every vector of decisions, a common ``state" variable is given by the solution of an affine linear equation. Due to the presence of an additional constraint on the state, the problem cannot be reduced to the classical setting as considered in work by Nash. The resulting problem is therefore a generalized Nash equilibrium problem (GNEP). The existence of an equilibrium for this problem is demonstrated and first order optimality conditions are derived under a constraint qualification. An approximation scheme is proposed, which involves the solution of a parameter-dependent sequence of standard Nash equilibrium problems. This leads to the need for a new type of path-following strategy, which uses a value function based in part on the Nikaido-Isoda function. Function-space-based numerics for parabolic GNEPs and a spot-market model are developed, and numerical results are presented.

# Direct Sampling Method for Inverse Medium Problem

**Kazufumi Ito**

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## Abstract

The direct sampling method for inverse medium problems is presented. Applications of the method include the inverse scattering, the electrical impedance tomography (EIT) and the diffusive optical tomography (DOT). The tomography problems are very important in bio-medical imaging and material sciences. Especially for the EIT and DOT owing to its diffusive nature of the forward problem, it is a severely ill-posed problem and it always hard to obtain high quality reconstruction from a limited number of Cauchy data. Similarly for the scattering problems, it is harder to to obtain an image from one incident field with limited aperture cases, In the direct sampling method, we define a set of probing functions and an index function based on the dipole solutions. It is also necessary to modify the index functions by normalization weighting. The proposed probing index estimates the distribution of the unknown medium very well. The method is tested numerically and the verification and justification of the proposed probing function is discussed.

# Numerical Methods for Fractional Elliptic Problems, with an Application to Inverse Eigenvalue Problems

**Bangti Jin**

Department of Computer Science

University College London

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## Abstract

In this talk, we discuss the eigenvalue problems with a fractional derivative in the leading term, and the related inverse problems. Numerically, we illustrate the behavior of the eigenvalues and eigenfunctions. The numerical analysis of the source problem will be discussed.

# Global Convergence for Inverse Problems and Phaseless Inverse Problems

**Michael Klibanov**

Mathematics and Statistics

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## Abstract

In this talk three topics will be discussed. Corresponding papers were published in 2008-2014, also see www.arxiv.org. These topic are:

1. A globally convergent numerical method of the first type for coefficient inverse problems with single measurement data. Both the theory and numerical results will be presented. Numerical results will be focused on the most challenging case of blind backscattering experimental data for buried targets.

2. A globally convergent numerical method of the second type type for coefficient inverse problems will be presented. This method is based on the construction of a globally strictly convex cost functional. The key element of this functional is the Carleman Weight Function.

3. The first solution of a long standing problem (since 1977). This is uniqueness of the 3-d coefficient inverse scattering problem in the case when only the modulus of the complex valued scattering wave field is measured, whereas the phase is unknown. In quantum inverse scattering only the differential cross-section is measured, which means the modulus. On the other hand, the entire theory of quantum inverse scattering is constructed for the case when both the modulus and phase of the scattering wave field are measured.

# Criteria of Kalman's Type to the Approximate Controllability and the Approximate Synchronization for a Coupled System of Wave Equations with Dirichlet Boundary Controls

**Tatsien Li**

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## Abstract

In this talk, necessary conditions, presented as criteria of Kalman's type, are obtained to the approximate null controllability, the approsimate synchronization and the approximate synchronization by groups, respectively, for a coupled system of wave equations with Dirichlet boundary controls. The sifficiency of these conditions is also studied for some special kinds of systems.

# Recovery by a Single Far-field Measurement

**Hongyu Liu**

Department of Mathematics

Hong Kong Baptist University

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## Abstract

In this talk, the speaker shall discuss the recent progress on the uniqueness, stability and reconstruction schemes by a single far-eld pattern for inverse scattering problems. The discussion is mainly based the acoustic scattering problems. Extensions to electromagnetic scattering problems shall be briey described.

# Inverse Problems with Sparsity Constraints: Application in Image Processing and Digital Pathology

**Peter Maass**

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## Abstract

The talk consists of two parts.

The first part addresses the notion of sparse structures, which was introduced as a concept in image processing about ten years ago and which has attracted growing interest in the inverse problems community since the pioneering papers by Daubechies, Defrise, DeMol and S. Osher, M. Burger in 2004. First of all, we introduce the basic concept of sparse structures, which refers to objects which can be well approximated with very few components in an appropriate basis. Then, we review the present state of research concerning the regularization theory of inverse problems with sparsity constraints and sketch some recent results on parameter identification problems for partial differential equations.

The second part is devoted to discussing some applications in more detail. First we introduce the problem of image sequence interpolation, i.e. how to feed additional frames into a movie sequence, as a parameter identification problem for a parabolic PDE. We introduce sparsity constraints for this task and discuss results from real data.

We then mote to applications of MALDI imaging (matrix assisted laser di-ionization) in digital pathology. Sparsity concepts allow to develop so-called staining tests, which have the potential of aiding pathological diagnosis or even for replacing conventional immunohistochemical staining tests.

The results shown in this presentation partially originate from industrial collaborations. We gratefully acknowledge the support of Bruker Daltonik GmbH, Hoffmann-LaRoche AG and Micronas AG.

# Scattering by Corners

**Lassi Päivärinta**

Department of Mathematics and Statistics/Rolf Nevanlinna Institute

University of Helsinki

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## Abstract

Recently we showed with E. Blåsten and J. Sylvester that domains having rectangular corners always scatter. Together with M.Salo and E. Vesalainen we have extend this result to other corners in dimensions two and three, as well. In the talk we discus results of both papers.

# Inverse Problems for Fractional Diffusion; Some Things We Know and Many More We Don't


## William Rundell

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Texas A&M University

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### Abstract

The field of anomalous diffusion has been widely accepted as providing an alternative model to the more classical Brownian motion based on a Gaussian process. There has been extensive study into the mathematics behind the forward problem models, but much less work done on the associated inverse problems. Yet there is reason to believe that these can, under certain circumstances - for example, "the backwards heat problem", lead to a drastic change in the degree of ill-conditioning and thus exhibit very different physics. We will study a few examples to show that both uniqueness questions and, in particular, ill-conditioning can be quite complex in the fractional case and can be both less and more than the classical situation depending on changes in data.


# Seeing Through Space Time


## Gunther Uhlmann

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### Abstract

We consider inverse problems for the Einstein equation with atime-depending metric on a 4-dimensional globally hyperbolic Lorentzian manifold. We formulate the concept of active measurements for relativistic models. We do this by coupling Einstein equations with equations for scalar fields. The inverse problem we study is the question, do the observations of the solutions of the coupled system in an open subset U of the space-time with the sources supported in U determine the properties of the metric in a larger domain? To study this problem we define the concept of light observation sets and show that these sets determine the conformal class of the metric. This corresponds to passive observations from a distant area of space which is filled by light sources. We will start by considering inverse problems for scalar non-linear hyperbolic equations to explain our method.

This is joint work with Y. Kurylev and M. Lassas

# Data Regularization and Imaging Using Sparse Optimization


## Yanfei Wang

Institute of Geology and Geophysics

Chinese Academy of Sciences

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### Abstract

Using the observations to infer the unknowns (layer reflectivity, impedance, density, velocity, data completion, etc.) is called geophysical inversion. In this report, we focus on data completion and data imaging problems. In seismic acquisition, because of the influence of obstacles at land surface, rivers, bad receivers, noise, acquisition aperture, restriction of topography and investment, the observed data usually do not satisfy the sampling theorem. A direct effect of the limitations of acquisition is the sub-sampled data will generate aliasing in the frequency domain; therefore, it may affect the subsequent processing such as filtering, de-noising, AVO (amplitude versus offset) analysis, multiple eliminating and migration imaging. In our recent work, we develop some sparse optimization methods for the wavefield reconstruction problem. We consider sparse Gaussian beams decomposition methods and solve the corresponding norm-constrained minimization problem by sparse optimization methods. In addition, seismic migration imaging using sparse Gaussian beams for both 2d and 3d problems is addressed. Numerical experiments for both synthetic and field data are performed for solving the ill-posed data regularization problem and the related Gaussian beams migration.


# Inverse Problems for Fractional Diffusion Equations


## Masahiro Yamamoto

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### Abstract

Recently the fractional diffusion equation has called attention related with applications such as modelling anomalous diffusion in soil. The author and his group have studied also the well-posedness for initial-boundary value problems and other qualitative properties for fractional diffusion equations with Caputo time derivatives. Here I survey them and show some new results on the uniqueness and the stability for inverse problems of determining coefficient, source terms and orders of fractional derivatives.

# Approximate Separability of Green's Function for Helmholtz Equation in the High Frequency Limit

**Hongkai Zhao**

Department of Mathematics

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zhao@math.uci.edu

## Abstract

Approximate separable representations of Green's functions for differential operators is a basic and important question in analysis of differential equations and development of efficient numerical algorithms. It also reveals the intrinsic complexity or degrees of freedom of the problem. Being able to approximate a Green's function as a sum with few separable terms is equivalent to the existence of low rank approximation of the corresponding discretized operators which can be explored for matrix compression and fast solution techniques. Green's function for coercive elliptic differential operator has been shown to be highly separable. However, the case of Helmholtz equation in the high frequency limit is more challenging both mathematically and numerically. We develop a new approach to study approximate separability for the Green's function of Helmholtz equation in the high frequency limit based on an explicit characterization of the relation between two Green's functions and a tight dimension estimate for the best linear subspace approximating a set of almost orthogonal vectors. We derive both lower bounds and upper bounds and show their sharpness and implications for computation setups that are commonly used in practice. This is a joint work with Bjorn Engquist.

# Titles and Abstracts

# Mini-Symposium Talks

# Mini-symposium on inverse problems in honor of Professor Kazufumi Ito at his 60th birthday

Organizers:

Bangti Jin, University College London, UK
Masahiro Yamamoto, The University of Tokyo, Japan

# Direct Sampling Method for Electrical Impedance Tomography and Diffusive Optical Tomography


## Yat-Tin Chow

Chinese University of Hong Kong

ytchow@math.cuhk.edu.hk



### Abstract

In this talk, we are concerned with the electrical impedance tomography (EIT) and the diffusive optical tomography (DOT) in the case when only one or two pairs of Cauchy data are available, which are known to be very difficult in achieving high reconstruction quality owing to their severely ill-posed nature. We propose simple and efficient direct sampling methods (DSM) to locate inhomogeneities inside a homogeneous background and attempt the two tomographies in both full and limited aperture cases. Following the pioneering works of proposing the DSM by Ito, Jin and Zou, we have now extended this method, which is originally only applicable to the inverse acoustic medium scattering problem, to a much wider class of severely ill-posed inverse problems, e.g. DOT and EIT. In each of the aforementioned tomography, a new family of probing functions is introduced to construct an indicator function for imgaging the inclusions, which is defined as a dual product between the observed data and the probing functions under an appropriate choice of Sobolev scale. The newly proposed DSMs are easy to implement and computationally cheap. Numerical experiments are presented to illustrate its robustness against noise in the data, and its extremely effective in locating small abnormalities. This provides a new promising numerical strategy for solving the various problems in the inverse problem community.


# Reconstruction of Inhomogeneous Conductivity from Generalized Polarization Tensors


## Youjun Deng

School of mathematics and statistics,

Central South University,

dengyijun_001@163.com



### Abstract

In this talk we present a new method in reconstruction of inhomogeneous conductivities by using generalized polarization tensors. The concept of generalized polarization tensors (GPTs), which was previously defined for inclusions with homogeneous conductivities. We begin by giving two slightly different but equivalent definitions of the GPTs for inhomogeneous inclusions. We then show that, as in the homogeneous case, the GPTs are the basic building blocks for the far-field expansion of the voltage in the presence of the conductivity inclusion. Relating the GPTs to the Neumann-to-Dirichlet (NtD) map, it follows that the full knowledge of the GPTs allows unique determination of the conductivity distribution. We demonstrate the viability of the proposed algorithm by preforming a sensitivity analysis and giving some numerical examples.

# Levenberg-Marquardt Method for Robin Inverse Problem in An Elliptic System

**Daijun Jiang**

School of Mathematics and Statistics,

Central China Normal University,

jiangdaijun@mail.ccnu.edu.cn

## Abstract

We shall study the Levenberg-Marquardt (L-M) iterative method for solving the nonlinear inverse problem of identifying the Robin coefficients in an elliptic system.The uniqueness of the Robin inverse problem is justified. The highly ill-posed Robin inverse problem is formulated into output least-squares nonlinear and non-convex minimization with Tikhonov regularization. By applying the L-M iterative method, we transform the non-convex minimization into convex minimization. The quadratic convergence of L-M method is demonstrated and the surrogate functional method is used to solve the convex minimization at each L-M iteration, which leads to get the explicit expression of the minimizer. Numerical experiments are provided to demonstrate the accuracy and efficiency of the methods.

(This is a joint work with Prof. Jun Zou and Hui Feng)

# Numerical Reconstruction for Distributed Fluxes by an Adaptive Finite Element Method

**Jingzhi Li**

Financial Math&Engineering Department

South University of Science and Technology of China

li.jz@sustc.edu.cn

## Abstract

Based on a posteriori error estimates, we propose an adaptive finite element method for a distributed flux reconstruction in a diffusion system, recovering the unknown distributed flux on some inaccessible boundary using partial measurement data on part of the accessible boundary. A posteriori error estimates are first derived, and the efficiency of the error estimator is addressed by showing that the error estimator provides upper and lower bounds on the discretization errors of quantities of interest. Numerical experiments are presented to show the applicability and efficiency of the proposed adaptive method based on the derived error estimator, which provides a robust guidance for the adaptive refining of meshes to locate the singularities of the fluxes.

# Inverse Elastic Surface Scattering with Near-Field Data


## Peijun Li

Department of Mathematics

Purdue University

lipeijun@math.purdue.edu



### Abstract

Consider the scattering of a time-harmonic plane wave by a one-dimensional periodic surface. A novel computational method is proposed for solving the inverse elastic surface scattering problem by using the near-field data. Above the surface, the space is filled with a homogeneous and isotropic elastic medium, while the space below the surface is assumed to be elastically rigid. Given an incident field, the inverse problem is to reconstruct the surface from the displacement of the wave field at a horizontal line above the surface. Based on the Helmholtz decomposition, the wave field is decomposed into its compressional and shear parts by using two scalar potential functions. The transformed field expansion is then applied to each component and a coupled recurrence relation is obtained for their power series expansions. By solving the coupled system in the frequency domain, simple and explicit reconstruction formulas are derived for two types of measurement data. The method requires only a single illumination with a fixed frequency and incident angle. Numerical experiments will be shown that it is capable of reconstructing the scattering surfaces with subwavelength resolution.


# A Primal Dual Active Set Algorithm for Sparse Optimization Problems


## Xiliang Lu

School of Mathematics and Statistics,

Wuhan university

xllv.math@whu.edu.cn



### Abstract

In this talk, we consider the problem of recovering a sparse vector from noisy measurement data. An algorithm of primal-dual active set type for a class of convex/nonconvex sparsity-promoting penalties is proposed. A novel necessary optimality condition for the global minimizer using the associated thresholding operator is derived. Upon introducing the dual variable, the active set can be determined from the primal and dual variables. This relation lends itself to an iterative algorithm of active set type which at each step involves updating the primal variable only on the active set and then updating the dual variable explicitly. Numerical experiments demonstrate its efficiency and accuracy.

# Fast Collocation Method for Model-based Image Restoration

**Yao Lu**

School of Mathematics and Computational Science

Sun Yat-sen University

luyao23@mail.sysu.edu.cn

## Abstract

The discrete system model was consistently used in practice for image restoration, which has unavoidable approximate error from the true physical model. This approximate error degraded the resolution of the reconstructed images. The issue that limits the use of integral equation model in practice is the huge computational cost to solve the integral equations arising from image blurring. We propose to use directly the physical model of image blurring, exploit the multiscale structure of images, and develop fast multiscale collocation method for image restoration, reducing the computational complexity. Numerical experiments show that the method based on the continuous model performs better than those based on discrete models, in terms of PSNR values and visual quality of the reconstructed images.

# An Adaptive Finite Element Method for Reconstruction of the Robin Coefficient

**Yifeng Xu**

Department of Mathematics,

Shanghai Normal University,

yfxu@shnu.edu.cn

## Abstract

In this talk, I introduce an adaptive finite element method to recover the Robin coefficient involved in a diffusion system from some boundary measurement. Unlike the standard approach for direct problems, the relevant a posteriori error estimator is derived from convergence analysis of the adaptive algorithm. It is proved that the adaptive algorithm guarantees a convergent subsequence of discrete solutions in an energy norm to some exact triplet (the Robin coefficient, state and costate variables) satisfying the optimality system of the least-squares formulation with Tikhonov regularization for the concerned inverse problem. Finally, two numerical examples are reported to illustrate the performance of the algorithm. This is a joint work with Prof. Jun Zou at The Chinese University of Hong Kong

# Mini-symposium
# on optimal control problems
# in honor of Professor Kazufumi Ito
# at his 60th birthday

Organizers:

Christian Clason, University Duisburg-Essen, Germany.
Michael Hintermuller, Humboldt-University of Berlin, Germany

# A Convex Analysis Approach to Switching Control of PDEs


## Christian Clason

Faculty of Mathematics

University Duisburg-Essen

christian.clason@uni-due.de



### Abstract

This talk is concerned with convex relaxation of binary-continuous optimization problems and their numerical solution by semi-smooth Newton methods are discussed. The proposed framework is especially suited for optimal control problems governed by partial differential equations subject to a switching constraint, which is illustrated with numerical examples.


# Control of the Cardiovascular-respiratory System under Time Varying Workloads


## Franz Kappel

Institute for Mathematics and Scientific Computing

University of Graz

franz.kappel@uni-graz.at



### Abstract

Modeling the control processes acting in the combined cardiovascular-respiratory system in response to an ergonometric workload has been topic for intensive research in the past. Most approaches to construct an appropriate feedback law for the controls were based on two ideas: a) Determine the feedback law explicitly using sigmoid functions; b) Use results from optimal control theory. Up to now, in case of the second approach it was always assumed that the system tends to an equilibrium state, which for instance had the consequence that the imposed ergonometric workload had to be constant. Another restriction of this approach was that the equilibrium state to which the system had to be controlled had to be determined from the measurements of state variables (usually the heart rate or the systemic arterial pressure). In order to avoid these problems one needs a quantity which is controlled to a fixed a priori known value under a wide range of perturbations acting on the system. In the cardiovascular system there is no such quantity. However, in the combined cardiovascular-respiratory system the partial pressure of CO2 in arterial blood is usually regulated to 40 mmHg. We present results obtained by using the Euler-Lagrange formulation of the optimal control problem.

# Immersed Finite Elements for Optimal Control Problems of Elliptic PDEs with Interfaces


## Zhilin Li

Department of Mathematics

North Carolina State University

zhilin@math.ncsu.edu



### Abstract

This talk presents a numerical method, based on the variational discretization concept, for optimal control problems governed by elliptic PDEs with interfaces. This method uses a simple uniform mesh which is independent of the interface. Due to discontinuous coefficients, which often represent different conductivities, densities, or permeability of distinct materials separated by the interface, the standard linear finite element method can not achieve optimal convergence when the uniform mesh used. Therefore the immersed finite element method (IFEM) is used to discretize the state equation required in the variational discretization approach. Optimal error estimates for the control, state and adjoint state are derived. Numerical examples are provided to confirm the efficiency of the method and the theoretical results.

This is a joint research with Kazifumi Ito (NCSU), Zhiyue Zhang (NNU), and Qian Zhang (NNU)


# On a Shape Optimization Problem for Navier-Stokes Applied to Flow in a Duct


## Carlos Rautenberg

Institute for Mathematics

Humboldt-University Berlin

carlos.rautenberg@math.hu-berlin.de



### Abstract

A shape optimization problem of a duct for the stationary Navier-Stokes equations with mixed boundary conditions is considered. The problem arises (in part) from the need to obtain an almost-uniform outflow in a duct when the velocity profile in the inlet is given. Such a formulation determines a Navier-Stokes system of equations with non-homogeneous Dirichlet boundary conditions on one part of the boundary and “do nothing” conditions on another part. As shapes of the duct are limited by maximal bounded geometries, additional geometrical constraints are imposed. The well-posedness of the optimization problem and existence of solutions to the Navier-Stokes system are studied and a continuous approach to the derivation of the shape gradient is presented. Numerical tests in 2D and 3D are also provided.

# Active Noise Control in Stochastic Domains

**Jari Toivanen**

Institute for Computational and Mathematical Engineering

Stanford University

toivanen@stanford.edu

## Abstract

A new optimal feed-forward local active noise control (ANC) method is proposed for stochastic environments. The method is based on frequency domain finite element acoustical models. Stochastic domains and noise sources are considered. Measurements from an array of microphones are mapped to secondary loudspeakers, by an offline optimized linear mapping minimizing the expected value of a noise functional. The presented ANC method gives robust and efficient noise attenuation. A numerical study demonstrates it in a passenger car cabin.

# Estimatability and Observers for a Model of Population Dynamics with Diffusion and Age Dependence

**Marius Tucsnak**

Institut Élie Cartan de Lorraine

Université de Lorraine

Marius.Tucsnak@inria.fr

## Abstract

We consider a model of McKendrick type for population dynamics with age dependence and diffusion. We prove that, using various observation operators, we obtain an infinite system which is estimatable (detectable). This information is used to construct observers able to reconstruct population dynamics in the whole spatial domain from measures in an arbitrarily small spatial and age domain.

# Titles and Abstracts

# Contributed Talks

# Reduced and Full Space Methods for Unsteady Point Source Inversion Problems


## Xiaomao Deng

Laboratory for Engineering and Scientific Computing

Shenzhen Institutes of Advanced Technology

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### Abstract


In this talk we present some recent work on the topic of inverse unsteady point source identification problems. Linear elements are least expensive finite elements for simultaneously recovering the source location and intensity in a general convection-diffusion process. However, the derivatives of the least-squares objective functional with Tikhonov regularizations are not well-defined when linear finite elements are used. We propose a reduced space method with some effective techniques to overcome the un-definedness that may occur in inversion process. As the number of processor cores on supercomputers becomes larger and larger, algorithms with high degree of parallelism attract more attention. However the sequential steps within the reduced space method are quite challenging for parallelization. We develop a space-time parallel domain decomposition preconditioning technique for the induced Karush-Kuhn-Tucker (KKT) system and solve the fully-coupled KKT system all-at-once. Numerical experiments validate that both approaches are effective and robust for recovering single and multiple unsteady point sources, and the preconditioned full space method is scalable on a supercomputer with over 103 processors.


# Stochastic Optimization Techniques for Large Scale and Data Rich Inverse Problems


## Eldad Haber

Dept of Mathematics, Earth and Ocean Science

Earth and Ocean Science, UBC

haber@math.ubc.ca


### Abstract


In recent years, many geophysical inverse problems are characterized by enormous number of data that needs to be fitted. Standard optimization techniques are inefficient for the solution of such problems. In this talk, we will explore the application of Monte-Carlo methods for the solution of the optimization problems and show that by semi-random sampling we can dramatically reduce the computational complexity of such problems.

# Inverse Problems and Uncertainty Quantification


## Alexander Litvinenko

Center for Uncertainty Quantification in Computational Science & Engineering

King Abdullah University of Science and Technology

alexander.litvinenko@kaust.edu.sa



## Abstract

In a Bayesian setting, inverse problems and uncertainty quantification (UQ) - the propagation of uncertainty through a computational (forward) model - are strongly connected. In the form of conditional expectation the Bayesian update becomes computationally attractive. This is especially the case as together with a functional or spectral approach for the forward UQ there is no need for time-consuming and slowly convergent Monte Carlo sampling. The developed sampling-free non-linear Bayesian update is derived from the variational problem associated with conditional expectation. This formulation in general calls for further discretisation to make the computation possible, and we choose a polynomial approximation. After giving details on the actual computation in the framework of functional or spectral approximations, we demonstrate the workings of the algorithm on a number of examples of increasing complexity. At last, we compare the linear and quadratic Bayesian update on the small but taxing example of the chaotic Lorenz 84 model, where we experiment with the influence of different observation or measurement operators on the update.

# Multiscale Finite Element Methods Applied to Electrical Impedence Tomography

**Ruanui Nicholson**

Department of Mathematics

The University of Auckland

rnic052@aucklanduni.ac.nz

## Abstract

We investigate the multiscale electrical impedance tomography (MsEIT) problem of reconstructing the multiscaled conductivity distribution, !"(x), of a two dimensional object. The multiscaled conductivity is characterised by the hallmark !"(x) = O(1) while r!"(x) = O(1"), where 0 < " ☒ 1. For simplicity we address the continuuum model for this proof of concept, as the extension to complete electrode model for example, will follow naturally. Traditional electrical impedance tomography (EIT) is used successfully in a variety of geological, medical and industrial imaging applications. Standard methods for recovering the conductivity are impeded by the dimensionality of the problem. Numerically computing the solution to the associated forward problem requires a fine resolution, furthermore, the use of iterative processes to identify the conductivity can exaggerate this drawback to the point of infeasible. Several novel multiscale numerical methods have been developed to overcome these barriers. We investigate the use of multiscale finite element methods (MsFEM) a method based largely on the standard FEM [Efendiev and Hou, 2009] .This method was adapted to finite volume elements methods (FVE) by Efendiev and Hou to investigate multiscale inverse problems associated with porous media flows [Efendiev and Hou, 2007]. We investigate the possible coupling of further model reduction techniques along with a basic, non-oversampled, MsFEM. However, the simplification of MsFEM and the scaling down of the problem lead to a more approximative model. We are thus faced with a dichotomy: on the one hand, maintaining a more accurate model increases the computationally complexity of the inverse problem. While on the other hand applying the simpler forward model may become inaccurate. To overcome this dichotomy we propose the use of the Bayesian approximation error (BAE) approach [Kaipio and Somersalo, 2005]. In this approach we represent this model contrast as a random variable, we can thus ascertain the probability distribution random variable and consequently treat it as noise.

# Non-smooth Minimization Problems of Matrix Variable and Applications


## Quy Muoi Pham

Division of Mathematical Sciences,

School of Physical & Mathematical Sciences,

Nanyang Technological University

phamquymuoi@gmail.com



### Abstract

In this talk, we propose algorithms for both constrained and non-smooth unconstrained minimization problems of matrix variables. For unconstrained minimization problems, we give a fixed point iteration and an alternative iteration, and then prove the convergence of the iterations under mild conditions on step sizes. After that we first present and prove the convergence of the penalty method for the constrained minimization problem and then give a modified penalty method. The fast convergence of the modified method is confirmed by a numerical example. The algorithms are analyzed and illustrated in numerical examples.


# A Reciprocity Gap Method for an Interior Inverse Scattering Problem


## Fang Zeng

College of Optoelectronic Engineering

Chongqing University

fangzeng1985@gmail.com



### Abstract

We consider an interior inverse scattering problem of reconstructing the shape of a cavity. The measurements of scattered fields and point sources are distributed on a curve inside the cavity. We employ the Reciprocity Gap method to reconstruct the shape of the cavity. Preliminary numerical examples are provided to show the viability of the method.

# Accommodation & Transportation Directions

## A. Between Airport and Accommodation

### 1) Royal Park Hotel (帝都酒店)

Address: 8 Pak Hok Ting Street, Sha Tin, New Territories, Hong Kong

香港新界沙田白鶴汀街八號

Telephone: +852- 2601 2111

Website: http://www.royalpark.com.hk/hongkong/eng/index.html

**By Public Airport Bus**

*(Not recommended for guests who have bulky luggage)*

Public Airport Bus No. A41 goes from the airport to Royal Park Hotel bus stop (帝都酒店巴士站), for HK$22.3 per person. It runs from 05:30 to 23:30 and departs every 25 min at Airport Bus Terminus. The journey takes approx. 60 min.

Details of Airport Bus No. A41:http://m.kmb.hk/en/result.html?busno=a41#desDetail

**By Taxi**

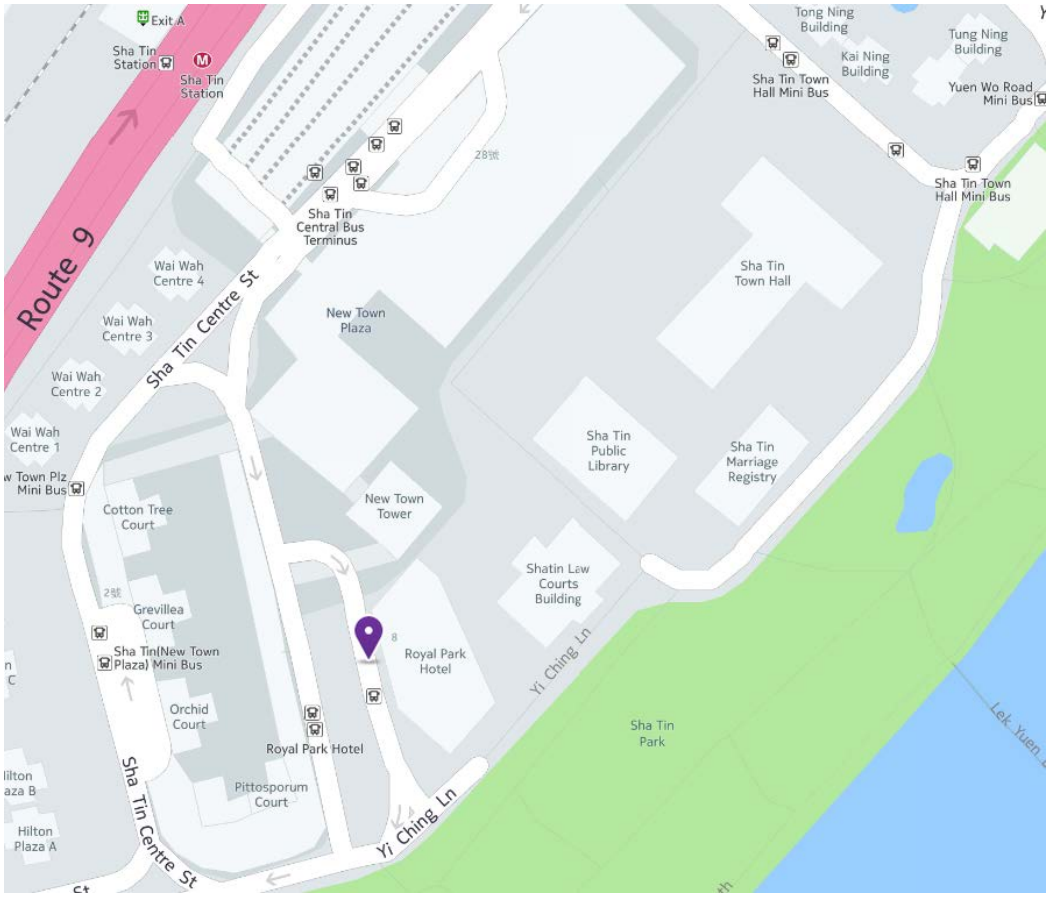
A direct taxi ride from the airport to the hotel would cost about HK$300 per car (max 5 persons each), depending on the traffic.

*For your easy communication with taxi driver, you may show the following Chinese note card:

請送我到 (Please drive me to):

新界沙田白鶴汀街八號帝都酒店

**Royal Park Hotel,**
**8 Pak Hok Ting Street, Sha Tin, N.T.**



# 2) Hyatt Regency Hong Kong, Sha Tin (沙田凱悅酒店)

Address: 18 Chak Cheung Street, Sha Tin, New Territories, Hong Kong

香港新界沙田澤祥街 18 號

Telephone: +852- 3723 1234

Website: http://www.hongkong.shatin.hyatt.com/en/hotel/home.html

## By Public Airport Bus interchange with MTR Rail

*(Not recommended for guests who have bulky luggage)*

Public Airport Bus No. A41 goes from the airport to Sha Tin Central Bus Terminus stop (沙田市中心巴士總站), for HK$22.3 per person. It runs from 05:30 to 23:30 and departs every 25 min at Airport Bus Terminus. The journey takes approx. 60 min. Subsequent interchange with MTR rail would be required.

Then, take escalator to upstairs New Town Plaza for MTR rail station entrance. The MTR ride from Sha Tin station to University station, Exit B (East Rail Line, towards Lo Wu direction) would take about 10 min and costs HK$4 per person.

## By Public Airport Bus interchange with Taxi

*(Not recommended for guests who have bulky luggage)*

Public Airport Bus No. A41 goes from the airport to Sha Tin Central Bus Terminus stop (沙田市中心巴士總站), for HK$22.3 per person. It departs every 25 min at the Airport Bus Terminus, and the journey takes approx. 60 min. Subsequent interchange with Taxi would be required.

Taxi ride to Hyatt Regency Hong Kong, Sha Tin directly would cost around HK$60 to HK$80 per car (max 5 persons each), depending on the traffic.

Details of Airport Bus No. A41:http://m.kmb.hk/en/result.html?busno=a41#desDetail

## By Taxi

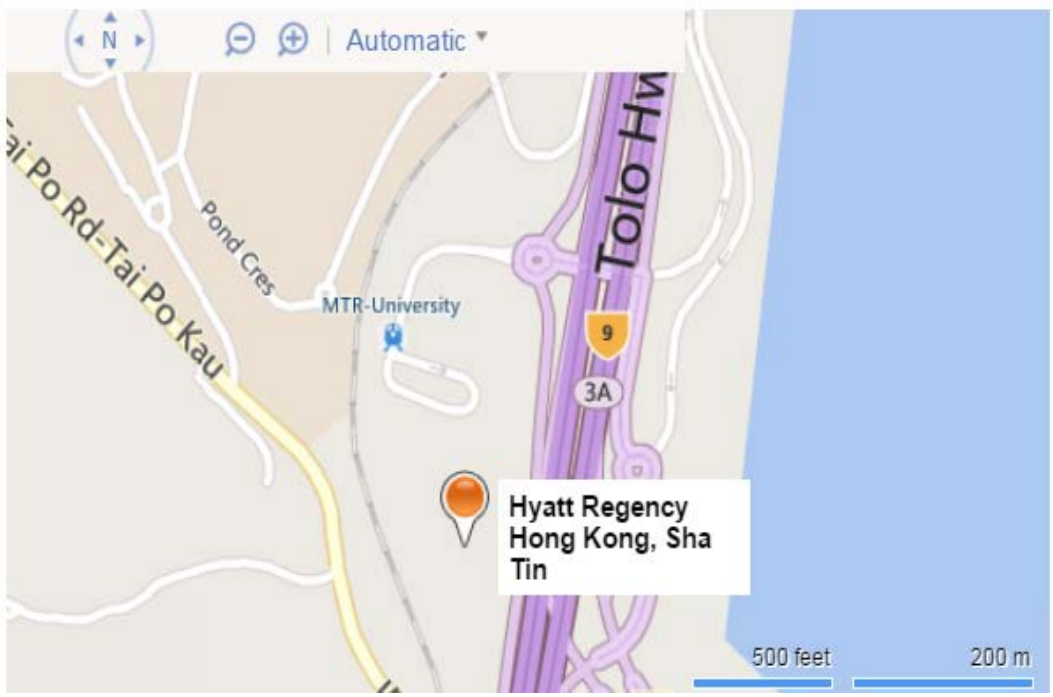
A direct taxi ride from the airport to the hotel would cost about HK$300 per car (max 5 persons each), depending on the traffic.

*For your easy communication with taxi driver, you may show the following Chinese note card:

請送我到 (Please drive me to):

新界沙田澤祥街 18 號沙田凱悅酒店

**Hyatt Regency Hong Kong, Sha Tin,**
**18 Chak Cheung Street, Sha Tin, N.T.**



# 3) Yali Guest House (雅禮賓館)

Address: Yali Guest House, Clinic Road, The Chinese University of Hong Kong Sha Tin, New Territories, Hong Kong

香港新界沙田香港中文大學, 保健路, 雅禮賓館

Telephone: +852-2603 6411

Website: http://www.cuhk.edu.hk/ugh/08other/aboutus.html

## By Public Airport Bus interchange with Taxi

*(Not recommended for guests who have bulky luggage)*

Public Airport Bus No. A41 goes from the airport to Sha Tin Central Bus Terminus stop (沙田市中心巴士總站), for HK$22.3 per person. It runs from 05:30 to 23:30 and departs every 25 min at Airport Bus Terminus. The journey takes approx. 60 min. Subsequent interchange with Taxi would be required.

Taxi ride to from Sha Tin Station to University directly would cost around HK$60 to HK$80 per car (max 5 persons each), depending on the traffic.

Details of Airport Bus No. A41:http://m.kmb.hk/en/result.html?busno=a41#desDetail

## By Taxi

A direct taxi ride from the airport to Yali Guest House would cost about HK$300 per car (max 5 persons each), depending on the traffic.

*For your easy communication with taxi driver, you may show the following Chinese note card:

請送我到 (Please drive me to):

**香港新界沙田，香港中文大學**

**雅禮賓館 (保健路)**

**Yali Guest House (Clinic Road)**

**The Chinese University of Hong Kong**

**Sha Tin, New Territories, Hong Kong**

請於大學門口向保安人員查詢詳細位置

Please check up the location with security guard (at entrance of University)

# 4) Friendship Lodge, New Asia College (新亞書院會友樓)

## By Public Airport Bus interchange with MTR Rail & School Shuttle

*(Not recommended for guests who have bulky luggage)*

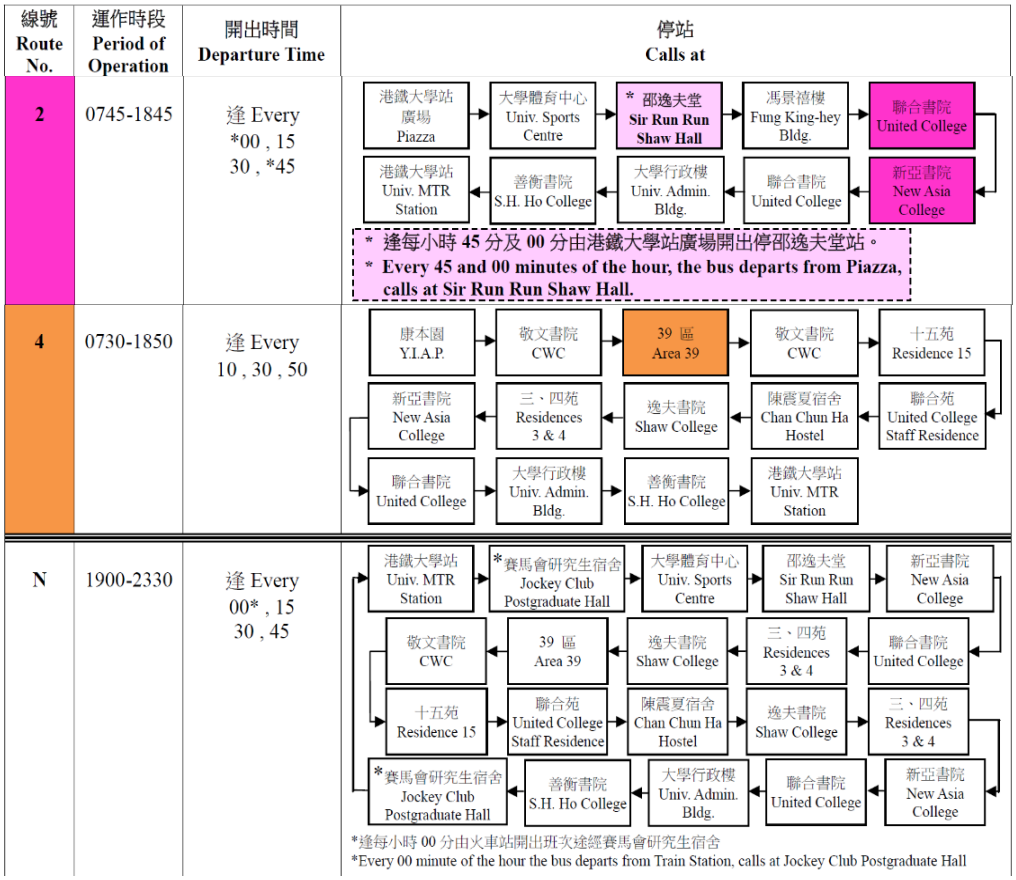
** ONLY IF you arrive Sha Tin Central Bus Terminus at 05:35 – 23:00

Public Airport Bus No. A41 goes from the airport to Sha Tin Central Bus Terminus stop (沙田市中心巴士總站), for HK$22.3 per person. It runs from 05:30 to 23:30 and departs every 25 min at Airport Bus Terminus. The journey takes approx. 60 min. Subsequent interchange with MTR rail would be required.

Details of Airport Bus No. A41:http://m.kmb.hk/en/result.html?busno=a41#desDetail

Take escalator within Sha Tin Central Bus Terminus stop to upstairs New Town Plaza for MTR rail station entrance. The MTR ride from Sha Tin station to University station, Exit A (East Rail Line, towards Lo Wu direction) would take about 10 min and costs HK$4 per person.

When you arrive University MTR Station, Exit A, turn right and walk to school shuttle bus stop. Take school shuttle bus No. 2 or 4 before 18:50 or No. N from 18:50–23:30 to the stop at New Asia College bus stop.



## By Public Airport Bus interchange with Taxi

Public Airport Bus No. A41 goes from the airport to Sha Tin Central Bus Terminus stop (沙田市中心巴士總站), for HK$22.3 per person. It runs from 05:30 to 23:30 and departs every 25 min at Airport Bus Terminus. The journey takes approx. 60 min. Subsequent interchange with Taxi would be required.

Taxi ride to Friendship Lodge, New Asia College directly would cost around HK$60 to HK$80 per car (max 5 persons each), depending on the traffic.

Details of Airport Bus No. A41:http://m.kmb.hk/en/result.html?busno=a41#desDetail

## By Taxi

A direct taxi ride from the airport to Friendship Lodge, New Asia College would cost about HK$300 per car (max 5 persons each), depending on the traffic.

*For your easy communication with taxi driver, you may show the following Chinese note card:

請送我到(Please drive me to):

香港新界沙田，香港中文大學

新亞書院會友樓

**Friendship Lodge, New Asia College**

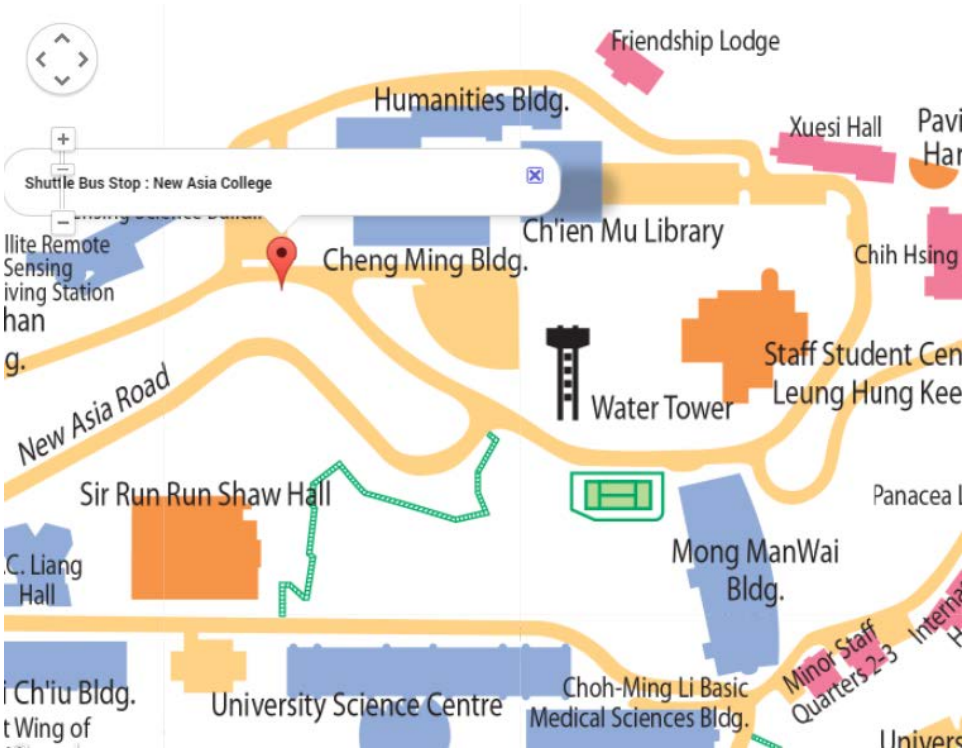
**The Chinese University of Hong Kong**

**Sha Tin, New Territories, Hong Kong**

請於大學門口向保安人員查詢詳細位置

Please check up the location with security guard

(at entrance of University)


Friendship Lodge
Humanities Bldg.
Xuesi Hall
Shuttle Bus Stop : New Asia College
Ch'ien Mu Library
Cheng Ming Bldg.
Chih Hsing
Staff Student Cen
Leung Hung Kee
Water Tower
New Asia Road
Sir Run Run Shaw Hall
Panacea
Mong ManWai
Bldg.
Hall
Ch'iu Bldg.
University Science Centre
Choh-Ming Li Basic
Medical Sciences Bldg.
Minor Staff
Quarters 2-3

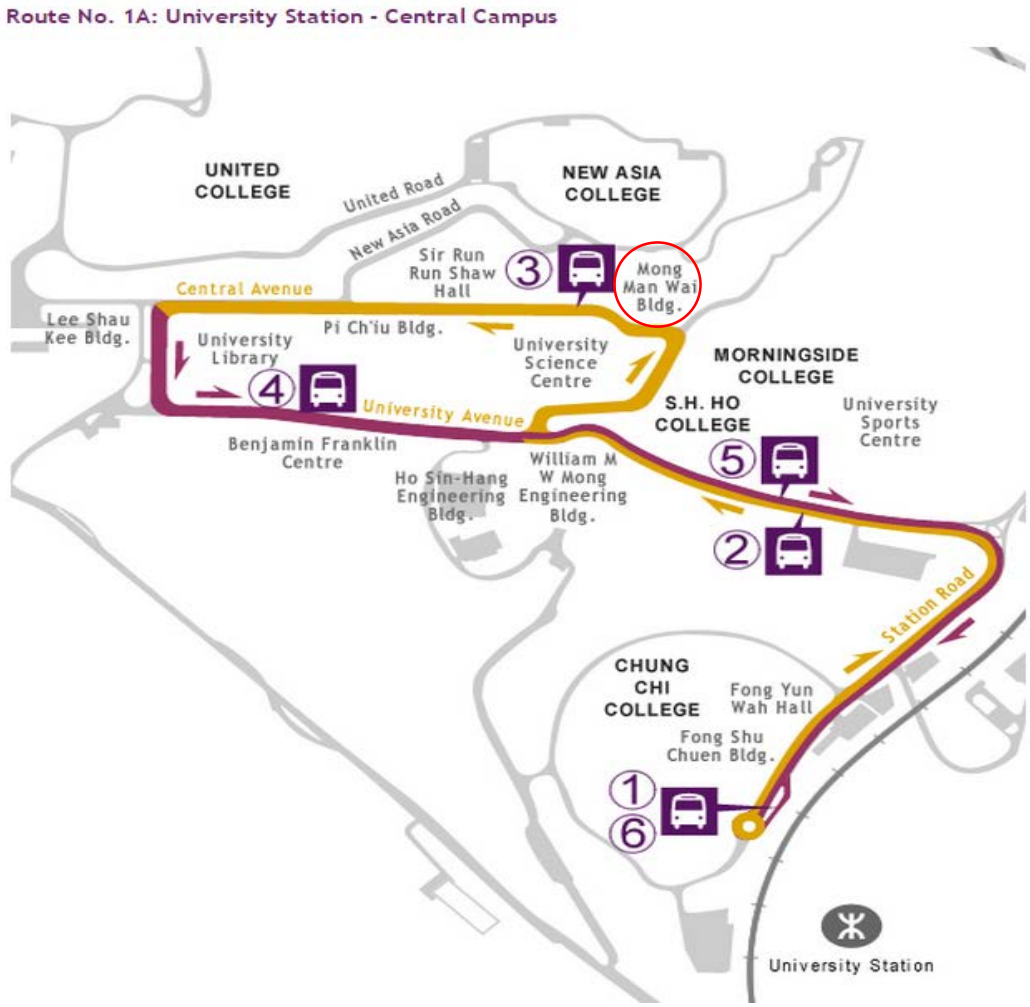
# B.Between Accommodation & Conference Venue

## 1) Royal Park

A shuttle bus will be arranged at 8:15am on 4 - 6 Dec, from Royal Park Hotel to Man Man Wai Building directly.

## 2) Hyatt hotel

Take school shuttle bus No.1A at University station, exit A. Get off from the shuttle and walk backward from bus stop to Man Man Wai Building.




## 3) Yali Guest House

Our guide will wait at 8:30am on 4 - 6 Dec in Yali Guest House lobby. He will to lead you to Man Man Wai Building directly.

## 4) Friendship Lodge, New Asia College

Our guide will wait at 8:30am on 4 - 6 Dec in Friendship Lodge lobby. He will to lead you to Man Man Wai Building directly.

# Banquet and Meals

## Banquet

Venue: Chung Chi College Staff Club

Date: 5 Dec 2014

Time: Start from 6:00pm

## Lunch

Venue: New Asia College Staff Canteen

Date: 4-6 Dec 2014

Time: Lunch Time

# Useful Information

1. Contact Persons

Prof. Eric Chung: 9385 9985 (mobile)

Ms Konnie Pak : 9145 5427 (mobile)

Ms Maggie Lam: 9852 9404 (mobile)

2. Travel Card

Octopus Card, an electronic fare card that is accepted by almost all forms of public transport, and at many fast food chains and stores. It's convenient and eliminates the need for small change.

Add money to it whenever you need to, and any unspent value in On-Loan Octopus is refundable along with the HKD50 deposit at any MTR Station.

*minus HKD7 handling fee for cards returned within three months

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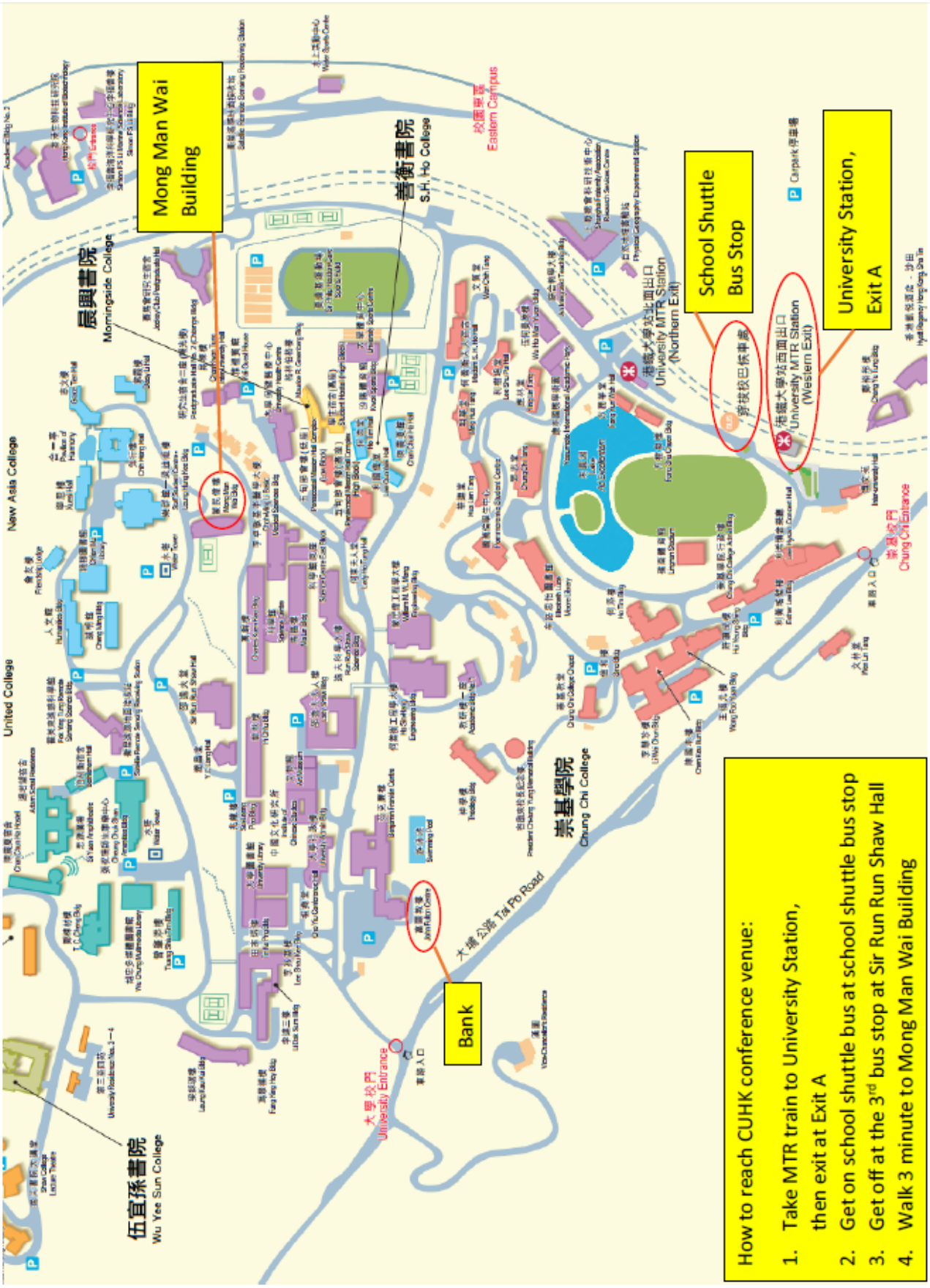
3. Emergency Numbers

For any kind of emergency, please contact the Security Unit

Telephone: 3943 7999

Email: security_unit@cuhk.edu.hk

# CUHK Campus Map



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