The 3rd East Asia Section of IPIA Young Scholars Symposium

March 17-18, 2018

Hong Kong Baptist University

http://www.math.hkbu.edu.hk/~hongyuliu/IPIAsymposium/index.html

Organization

Objectives:

This series of symposia aims to promote young scholars working on inverse problems in the East Asia region. The symposia also provide a platform for active young researchers to exchange ideas and research results with their peers as well as leading experts from the East Asia region and to explore opportunities for research collaborations.

Organizing Committee:

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Hong Kong Research Grants Council

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Quick Information

Conference Venue:

Room: **WLB205** (Saturday) & **WLB207** (Sunday)

Building: The Wing Lung Bank Building for Business Studies (WLB)

永隆銀行商學大樓

Shaw Campus (SC) 逸夫校園

Registration:

08:30-08:50, March 17 (Saturday), at WLB205

Accommodation:

Harbour Plaza Metropolis Hotel (都會海逸酒店)

Address: 7 Metropolis Drive, Hung Hom, Kowloon (九龍紅磡都會道7號)

http://www.harbour-plaza.com/metropolis/Index-en.htm

Banquet:

18:30-22:00 March 17 (Saturday)

Venue: Salon 1, 7/F, Harbour Plaza Metropolis

Lunch and Dinner:

12:30-14:00 March 17 (Saturday) Lunch

12:00-14:00 March 18 (Sunday) Lunch

18:30-20:00 March 18 (Sunday) Dinner

All at Renfrew Restaurant (聯福樓).

Attachments:

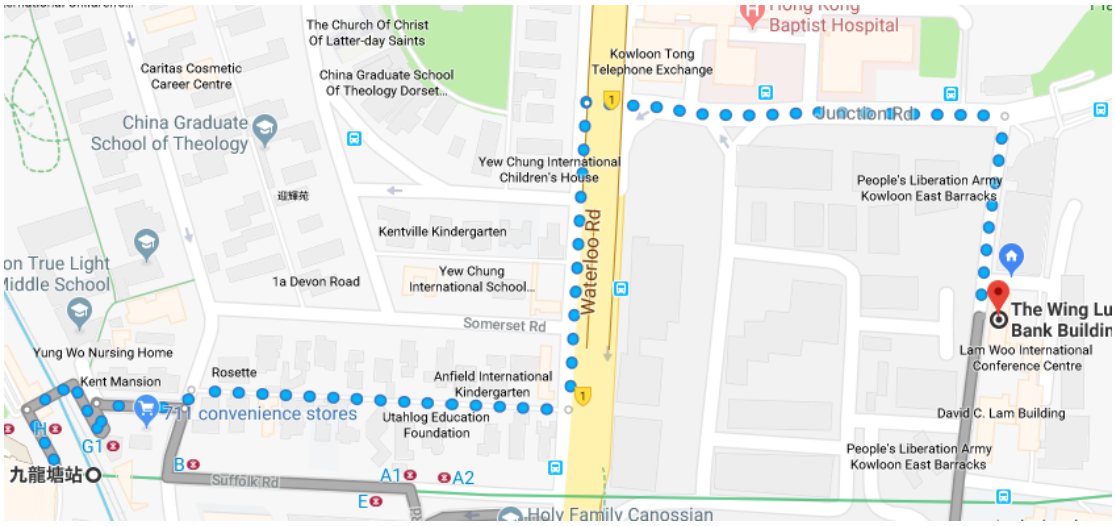
1. Addresses of the hotel and the conference venue in both Chinese and English.
2. Transportation guide provided by the hotel (Airport → Hotel).
3. Campus map.

Transportation

1. **Airport (HK) → Hotel:**
    - **Taxi:** 30-50 min, 250-300 Hong Kong Dollars (The name and address of the hotel with larger font in both English and Chinese is attached at the end.)
    - **Metro:** MTR **Hung Hom** Station (紅磡), **Exit C2** (Walk About 4 min, 270 m, to the hotel)

      Route: *Airport Express* to **Tsing Yi** Station (青衣), *Tung Chung Line* to **Nam Cheong** Station (南昌), *West Rail Line* to **Hung Hom** Station (紅磡)
    - **Bus** provided by the hotel. Please see the attachment for more details.
2. **Shen Zhen → Hotel:** To across the port first. Then,
    - **Metro:** MTR **Hung Hom** Station (紅磡), **Exit C2** (Walk About 4 min, 270 m, to the hotel)

      Route: *East Rail Line* (from the first stop to the terminal)
3. **Hotel → Conference Venue:**
    - **Taxi:** around 7min (The name and address of the hotel with larger font in both English and Chinese is attached at the end.)
    - **Metro:** MTR **Kowloon Tong** Station (九龍塘), **Exit G or E**
      Then either walk to WLB 201 (about 15min),
      or take minibus 25M/25M(S), and **let the driver know** that you are going to "HKBU Baptist University Rd Campus (浸會大學浸會大學道校園)" station.



Schedule

Day 1 (WLB 205): Saturday, March 17, 2018	
08:30-08:50	**Registration**
08:50-09:00	**Opening speeches**
Morning Session Chair: Jun Zou	
09:00-10:00	Bo Zhang (Chinese Academy of Sciences & University of Chinese Academy of Sciences) Inverse Scattering Problems：Theory and Computation
10:00-10:35	Haiwen Zhang (Chinese Academy of Sciences) Uniqueness in inverse scattering problems with phaseless far-field data at a fixed frequency
10:35-11:00	**Tea break (WLB 201) and group photo taking**
11:00-11:35	Junqing Chen (Tsinghua University) Reverse time migration method for inverse electromagnetic scattering problems
11:35-12:10	Eemeli Blåsten (Hong Kong University of Science and Technology) Inverse backscattering with point-source waves
12:30-14:00	**Lunch at Renfrew Restaurant**
Afternoon Session Chair: Bo Zhang	
14:00-14:35	Jingzhi Li (Southern University of Science and Technology) A time domain sampling method for inverse acoustic scattering problems
14:35-15:10	Keji Liu (Shanghai University of Finance and Economics) The application of multilevel sampling method in the inverse scattering problems
15:10-15:45	Xia Ji (Chinese Academy of Science) Direct sampling methods for inverse elastic scattering
15:45-16:00	**Tea break (WLB 201)**
16:00-16:35	Catalin Carstea (Hong Kong University of Science and Technology) Size estimates of inclusions for the 3d complex conductivity equation from three boundary measurements
16:35-17:10	Daisuke Kawagoe (Kyoto University) Propagation of boundary-induced discontinuity in stationary radiative transfer and its application to the optical tomography
17:10-17:45	Tracey Balehowsky (University of Helsinki) Recovering a Riemannian metric from least-area data
18:30-20:30	**Banquet**

Day 2 (WLB 207): Sunday, March 18, 2018	
Morning Session Chair: Xia Ji	
09:00-09:35	Tiexiang Li (Southeast University) On the transmission eigenvalue problem for the acoustic equation with a negative index of refraction and a practical numerical reconstruction method
09:35-10:10	Kazunori Ando (Ehime University) Spectral analysis of the elastic Neumann-Poincaré operator and cloaking by anomalous localized resonance
10:10-10:40	**Tea break (WLB 201)**
10:40-11:15	Atsuhide Ishida (Tokyo University of Science) Propagation property and inverse scattering for fractional powers of the negative Laplacian
11:15-11:50	Haibing Wang (Southeast University) Inverse boundary value problems for the heat equation with unknown inclusions
12:00-14:00	**Lunch at Renfrew Restaurant**
Afternoon Session Chair: Hongyu Liu	
14:00-14:35	Rongfang Gong (Nanjing University of Aeronautics and Astronautics) A dynamical regularization algorithm for solving inverse source problems of elliptic PDEs
14:35-15:10	Xiaodong Liu (Chinese Academy of Science) Fast acoustic source imaging using multi-frequency sparse data
15:10-15:45	Yukun Guo (Harbin Institute of Technology) Fourier method for the multi-frequency electromagnetic inverse source problem
15:45-16:00	**Tea break (WLB 201)**
16:00-16:35	Sombuddha Bhattacharyya (HKUST) Inverse problems for polyharmonic operators with an-isotropic second order perturbations
16:35-17:10	Yi-Hsuan Lin (Hong Kong University of Science and Technology) On localizing and concentrating electromagnetic fields
17:10-17:45	Youjun Deng (Central South University) On identifying magnetized anomalies using geomagnetic monitoring
18:30-20:00	**Dinner at Renfrew Restaurant**

Abstracts

Day 1, Morning Session:

Inverse Scattering Problems：Theory and Computation

Bo Zhang

Institute of Applied Mathematics, AMSS, Chinese Academy of Sciences
and School of Mathematical Sciences, University of Chinese Academy of Sciences

Abstract: Inverse scattering problems arise in diverse areas of applications, such as radar and sonar detection, nondestructive testing, medical imaging and geophysical prospection. A model scattering problem is concerned with a given wave incident on a medium enclosed by a bounded domain. The direct problem is to determine the scattered field for the known scatterer, whilst the inverse problem is to determine the scatterer from the boundary measurements of the scattered fields or the scattered far-field measurements. Mathematical issues and numerical solution of the inverse problem are challenging due to the strong nonlinearity and ill-posedness of the problem. In this talk, we will first introduce several inverse scattering problems of broad interest and then discuss briefly certain recent developments in the mathematical and computational studies of inverse scattering problems, including the recent results obtained in our group.

Uniqueness in inverse scattering problems with phaseless far-field data at a fixed frequency

Haiwen Zhang

Institute of Applied Mathematics, AMSS, Chinese Academy of Sciences

Abstract: This talk is concerned with uniqueness in inverse acoustic scattering with phaseless far-field data at a fixed frequency. The main difficulty of this problem is the so-called translation invariance property of the modulus of the far-field pattern generated by one plane wave as the incident field. Based on our previous work (J. Comput. Phys. 345 (2017), 58-73), the translation invariance property of the phaseless far-field pattern can be broken by using infinitely many sets of superpositions of two plane waves as the incident fields at a fixed frequency.

In this paper, we prove that the obstacle and the index of refraction of an inhomogeneous medium can be uniquely determined by the phaseless far-field patterns generated by infinitely many sets of superpositions of two plane waves with different directions at a fixed frequency under the condition that the obstacle is a priori known to be a sound-soft or non-absorbing impedance obstacle and the ndex of refraction n of the inhomogeneous medium is real-valued and satisfies that either $n-1\geq c_1$ or $n-1\leq -c_1$ in the support of $n-1$ for some positive constant c_1.

Reverse time migration method for inverse electromagnetic scattering problems

Junqing Chen

Department of Mathematical Sciences, Tsinghua University

Abstract: I will talk about the reverse time migration method we proposed recently. The method does not depend on the physical properties of the scatterer and is easy to implement. The imaging functional of the method is the cross-correlation of the incoming and back propagating waves. With the help of Helmholtz-Kirchhoff theory, we prove that the imaging functional is always positive and we also give the resolution. I will show some numerical results to illustrate the efficiency of the method.

Inverse backscattering with point-source waves

Eemeli Blåsten

IAS, Hong Kong University of Science and Technology

Abstract: A short review of inverse scattering problems will be given after which I will describe what's known about inverse backscattering problems. I will define the point-source problem and prove stability estimates for the inverse problem under the condition of having an angularly controlled potential. This is an improvement to recent work by Rakesh and Uhlmann.

Day 1, Afternoon Session:

A time domain sampling method for inverse acoustic scattering problems

Jingzhi Li

Department of Mathematics, Southern University of Science and Technology, China

Abstract: This talk concerns the inverse scattering problems of imaging unknown/inaccessible scatterers by transient acoustic near-field measurements. Based on the analysis of the migration method, we propose efficient and effective sampling schemes for imaging small and extended scatterers from knowledge of time-dependent scattered data due to incident impulsive point sources. Though the inverse scattering problems are known to be nonlinear and ill-posed, the proposed imaging algorithms are totally "direct" involving only integral calculations on the measurement surface. Theoretical justifications are presented and numerical experiments are conducted to demonstrate the effectiveness and robustness of our methods. In particular, the proposed static imaging functionals enhance the performance of the total focusing method (TFM) and the dynamic imaging functionals show analogous behavior to the time reversal inversion but without solving time-dependent wave equations.

The application of multilevel sampling method in the inverse scattering problems

Keji Liu

Shanghai key Lab of Finance Information Technology, Shanghai University of Finance and Economics

Abstract: The multilevel sampling method can be viewed as a direct sampling method, since it only involves matrix–vector operations and does not need to solve any large-scale ill-posed linear systems or any optimization process. Moreover, it is easy to implement, highly tolerant to noise and computationally very cheap. Furthermore, it can easily separate multiple disjoint medium components, usually with just a few iterations to provide a satisfactory initial position of each object. And the technique also works for the multiscale scatterers. With an effective initial location of each obstacle, any existing efficient but computationally more demanding methods can be applied for the further refinement of the estimated shape of each medium component as well as for the recovery of the contrast profiles of different media.

Direct sampling methods for inverse elastic scattering

Xia Ji

Institute of Computational Mathematics, AMSS, Chinese Academy of Science

Abstract: We consider the inverse elastic scattering of incident plane compressional and shear waves from the knowledge of the far field patterns. Specifically, three direct sampling methods for location and shape reconstruction are proposed using the different component of the far field patterns. Only inner products are involved in the computation, thus the novel sampling methods are very simple and fast to be implemented. With the help of the factorization of the far field operator, we give a lower bound of the proposed indicator functionals for sampling points inside the scatterers. While for the sampling points outside the scatterers, we show that the indicator functionals decay like the Bessel functions as the sampling point goes away from the boundary of the scatterers. We also show that the proposed indicator functionals continuously dependent on the far field patterns, which further implies that the novel sampling methods are extremely stable with respect to data error. For the case when the observation directions are restricted into the limited aperture, we firstly introduce some data retrieval techniques to obtain those data that cannot be measured directly and then use the proposed direct sampling methods for location and shape reconstructions. Finally, some numerical simulations in two dimensions are conducted with noisy data, and the results further verify the effectiveness and robustness of the proposed sampling methods, even for multiple multiscale cases and limited-aperture problems.

Size estimates of inclusions for the 3d complex conductivity equation from three boundary measurements

Catalin Carstea

IAS, Hong Kong University of Science and Technology

Abstract: In this talk I will consider a the conductivity equation with complex conductivity for a three dimensional object which consists of two homogeneous phases. Using a variational method (the ”translation method”) I will show how one may obtain lower and upper bounds for the relative volume of one of the phases from three boundary measurements.

Propagation of boundary-induced discontinuity in stationary radiative transfer and its application to the optical tomography

Daisuke Kawagoe

Graduate School of Informatics, Kyoto University

Abstract: We consider a boundary value problem of the stationary transport equation with the incoming boundary condition in two or three dimensional bounded convex domains and we discuss discontinuity of the solution to the boundary value problem arising from the incoming boundary data, which we call boundary-induced discontinuity. In particular, we show with two kinds of the incoming boundary data that boundary-induced discontinuity propagates along a positive characteristic line starting from a discontinuous point of the incoming boundary data and decays exponentially as it propagates, which is made use of to solve an inverse problem to determine a coefficient in the stationary transport equation from boundary data.

Recovering a Riemannian metric from least-area data

Tracey Balehowsky

University of Helsinki

Abstract: In this talk, we address the following question: Given any simple closed curve γ on the boundary of a Riemannian 3-manifold (M,g), suppose the area of the least-area surfaces bounded by γ are known. From this data may we uniquely recover g?

In several settings, we show the the answer is yes. In fact, we prove both global and local uniqueness results given least-area data for a much smaller class of curves on the boundary. We demonstrate uniqueness for g by reformulating parts of the problem as a 2-dimensional inverse problem on an area-minimizing surface. In particular, we relate our least-area information to knowledge of the Dirichlet-to-Neumann map for the stability operator on a minimal surface.

Broadly speaking, the question we address is a dimension 2 version of the classical boundary rigidity problem for simply connected, Riemannian 3-manifolds with boundary, in which one seeks to determine g given the distance between any two points on the boundary. We will also briefly review this problem of boundary rigidity as it relates to aspects of our question of recovering g from knowledge of areas.

This is joint work with S. Alexakis and A. Nachman.

Day 2, Morning Session:

On the transmission eigenvalue problem for the acoustic equation a negative index of refraction and a practical numerical reconstruction method

Tiexiang Li

Department of Mathematics, Southeast University, China

Abstract: In this work, we consider the two-dimensional Maxwell's equations with the TM mode in pseudo-chiral media. The system can be reduced to the acoustic equation with a negative index of refraction. We first study the transmission eigenvalue problem (TEP) for this equation. By the continuous finite element method, we discretize the reduced equation and transform the study of TEP to a quadratic eigenvalue problem by deflating all nonphysical zeros.

We then estimate half of the eigenvalues are negative and the other half of eigenvalues are positive. Then we present a practical numerical method to reconstruct the support of the inhomogeneity by the near-field measurements, i.e., Cauchy data. Based on the linear sampling method, we propose the truncated singular value decomposition to solve the ill-posed near-field integral equation, at one wave number which is not a transmission eigenvalue. By carefully chosen an indicator function, this method produce different jumps for the sampling points inside and outside the support. Numerical results show that our method is able to reconstruct the support reliably.

Spectral analysis of the elastic Neumann-Poincaré operator and cloaking by anomalous localized resonance

Kazunori Ando

Graduate School of Science and Engineering, Ehime University

Abstract: We study the spectrum of the Neumann-Poincaré operator for elastostatic system on two- and three-dimensional bounded domains with smooth boundary. We find that the spectrum consists of discrete eigenvalues with finite multiplicities which accumulate at the points determined by the Lamé parameters and dimensions. Using the spectral analysis of the NP operator, we show that the cloaking by anomalous localized resonance on ellipse and annuli in two dimensions.

Propagation property and inverse scattering for fractional powers of the negative Laplacian

Atsuhide Ishida

Department of Liberal Arts, Faculty of Engineering, Tokyo University of Science

Abstract: We define the fractional power of the negative Laplacian as the selfadjoint operator acting on $\mathrm{L}^2(\mathrm{R}^n)$:

$$H_{0,\rho} = \frac{(-\Delta)^\rho}{2\rho}$$

for $1/2 \le \rho \le 1$ where $\Delta = \sum_{j=1}^{n} \partial_{x_j}^2$. If $\rho = 1$, $H_{0,1}$ denotes the free Schrödinger operator $H_{0,1} = -\Delta/2$. On the other hand, if $\rho = 1/2$, then $H_{0,1/2}$ denotes the massless relativistic Schrödinger operator $H_{0,1/2} = \sqrt{-\Delta}$. We study one of the propagation estimates (Enss-type estimate) for the free dynamics $e^{-itH_{0,\rho}}$ and try to apply this estimate to inverse scattering for $\rho > 1/2$ by using the Enss-Weder time-dependent method. We report that the high velocity limit of the scattering operator uniquely determines the short-range interactions.

Acknowledgments. This work was partially supported by the Grant-in-Aid for Young Scientists (B) #16K17633 from JSPS.

Inverse boundary value problems for the heat equation with unknown inclusions

Haibing Wang

Department of Mathematics, Southeast University, China

Abstract: Consider the problem of reconstructing unknown inclusions inside a thermal conductor from boundary measurements, which arises from active thermography and is formulated as an inverse boundary value problem for the heat equation. We propose a sampling-type method for reconstructing the boundary of the unknown inclusion, which is based on the characterization of the solution to the so-called Neumann-to-Dirichlet map gap equation. We will analyze the solvability of the Neumann-to-Dirichlet map gap equation and establish a relation of its solution to the Green function of an interior transmission problem for the inclusion. This naturally provides a way of computing this Green function from the Neumann-to-Dirichlet map. Our new findings reveal the essence of the reconstruction method. A convergence result for noisy measurement data is also proved. Second, based on the heat layer potential argument, we perform a numerical implementation of the reconstruction method for the homogeneous inclusion case. Numerical results are presented to show the efficiency and stability of the proposed method.

Day 2, Afternoon Session:

A dynamical regularization algorithm for solving inverse source problems of elliptic PDEs

Rongfang Gong

Department of Mathematics, Nanjing University of Aeronautics and Astronautics

Abstract: This talk considers the inverse source problem for elliptic partial differential equations with both Dirichlet and Neumann boundary data. The unknown source term is to be determined by additional boundary conditions. Unlike the existing methods found in the literature, which usually employ the first-order in time gradient-like system (such as the steepest descent methods) for numerically solving the regularized optimization problem with a fixed regularization parameter, we propose a novel method with a second-order in time dissipative gradient-like system and a dynamical selected regularization parameter.
A modified symplectic scheme is proposed for the numerical solution. Theoretical analysis is given for both the continuous model and the numerical algorithm. Several numerical examples are provided to show the robustness of the proposed algorithm.

Fast acoustic source imaging using multi-frequency sparse data

Xiaodong Liu

Institute of Applied Mathematics, AMSS, Chinese Academy of Science

Abstract: We consider the acoustic source imaging problems using multiple frequency data. Using the data of one observation direction/point, we prove that some information (size and location) of the source support can be recovered. A non-iterative method is then proposed to image the source for the Helmholtz equation using multiple frequency far field data of one or several observation directions. The method is simple to implement and extremely fast since it only computes an indicator function on the interested domain using only matrix vector multiplications. Numerical examples are presented to validate the effectiveness of the method.

Fourier method for the multi-frequency electromagnetic inverse source problem

Yukun Guo

Department of Mathematics, Harbin Institute of Technology

Abstract: This talk is concerned with the inverse problem of identifying the current source distribution of the time-harmonic Maxwell's equations from multi-frequency measurements. Motivated by the Fourier method for the scalar Helmholtz equation and the polarization vector decomposition, we propose a novel method for determining the source function in the full vector Maxwell's system. Rigorous mathematical justifications of the method will be given. Numerical examples will be also provided to demonstrate the feasibility and effectiveness of the method.

Inverse problems for polyharmonic operators with an-isotropic second order perturbations

Sombuddha Bhattacharyya

IAS, Hong Kong University of Science and Technology

Abstract: In this talk I will present a joint work with my colleague Dr. Tuhin Ghosh. In this work we consider Calderón type inverse problems for polyharmonic operators defined on a bounded domain Ω in R^n . We consider the operator L on Ω, which is defined as:

$$\mathrm{L}u = (-\Delta)^m u + \sum_{j,k=1}^{n} A_{jk}(x)\partial_{x_j}\partial_{x_k}u + \sum_{j=1}^{n} B_j(x)\partial_{x_j}u + q(x)u, \quad m > 2,$$

where $A = A_{jk}$ is a symmetric matrix. We consider the Dirichlet to Neumann map corresponding to the operator L on $\partial\Omega$ and prove uniqueness of A, B and q in Ω. I will also discuss about the case when $m = 2$ in L and show that the uniqueness result holds with additional assumptions on the matrix A.

On localizing and concentrating electromagnetic fields

Yi-Hsuan Lin

IAS, Hong Kong University of Science and Technology

Abstract: We consider field localizing and concentration of electromagnetic waves governed by the time-harmonic anisotropic Maxwell system in a bounded domain. It is shown that there always exist certain boundary inputs which can generate electromagnetic fields with energy localized/concentrated in a given subdomain while nearly vanishing in another given subdomain. The theoretical results may have potential applications in telecommunication, inductive charging and medical therapy. We also provide a procedure via the Runge approximation to construct the boundary inputs that can generate the desired localizing/concentrated fields.
This is a joint work with Bastian Harrach and Hongyu Liu.

On identifying magnetized anomalies using geomagnetic monitoring

Youjun Deng

School of Mathematics and Statistics, Central South University, China

Abstract: We consider the inverse problem of identifying magnetized anomalies beneath the Earth using the geomagnetic monitoring. Suppose a collection of magnetized anomalies presented in the shell of the Earth. The presence of the anomalies interrupts the magnetic field of the Earth, monitored above the Earth. Using the difference of the magnetic fields before and after the presence of the magnetized anomalies, we show that one can uniquely recover the locations as well as their material parameters of the anomalies. To our best knowledge, the unique recovery result is the first one of its type in the literature, and this provides a rigorous mathematical theory to the geomagnetic detection technology that has been used in practice.

Participants

Kazunori Ando (Ehime University)

Eemeli Blåsten (Hong Kong University of Science and Technology)

Sombuddha Bhattacharyya (Hong Kong University of Science and Technology)

Tracey Balehowsky (University of Helsinki)

Xinlin Cao (Hong Kong Baptist University)

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Youjun Deng (Central South University)

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Xia Ji (Chinese Academy of Science)

Daisuke Kawagoe (Kyoto University)

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Hongjie Li (Hong Kong Baptist University)

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Wing Yan Tsui (Hong Kong Baptist University)

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Haibing Wang (Southeast University)

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Jingni Xiao (Hong Kong Baptist University)

Bo Zhang (Chinese Academy of Sciences & University of Chinese Academy of Sciences)

Hai Zhang (Hong Kong University of Science and Technology)

Haiwen Zhang (Chinese Academy of Sciences)

Jun Zou (The Chinese University of Hong Kong)

Please take me to:

Harbour Plaza Metropolis Hotel,

7 Metropolis Drive, Hunghom, Kowloon

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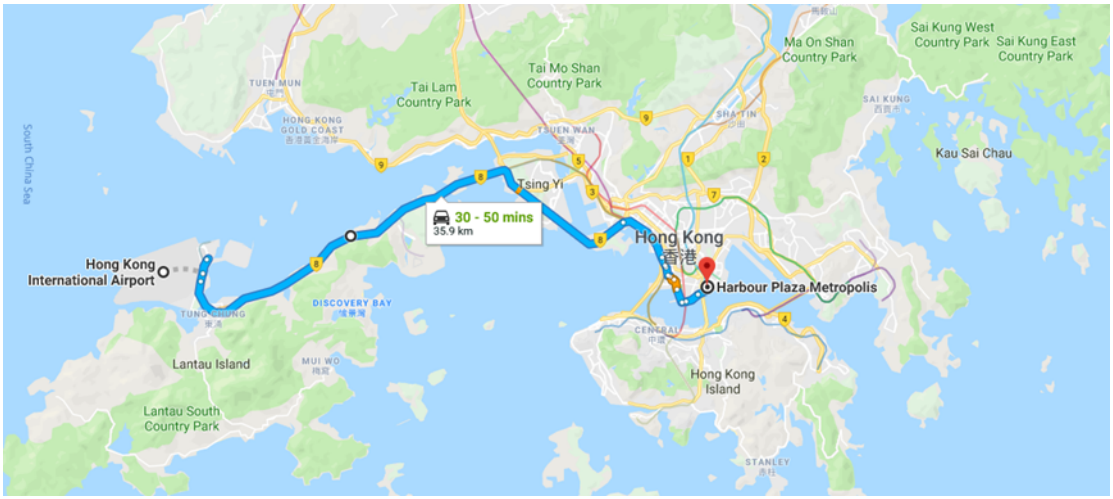

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